CURRENT TRENDS AND RESEARCH IN MEDICAL NUTRITION THERAPY TO CONTROL DISEASES

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PREFACE

This book, Current Trends and Research in Medical Nutrition Therapy to Control Diseases, is an essential part of everyday life. It has an impact on our health and can be used to prevent and treat disease. Substantial interventions in dietary intake and lifestyle changes have been shown to reduce disease risk in both the general population and patients suffering from various diseases. Traditional plant-based diets and medicines have received a lot of attention as an alternative to modern science-based drugs, while recent technological advancements in bioinformatics, genomics, and proteomics have provided a better understanding of plant-based drugs, improved quality assurance, and allowed clinical trials to be accelerated to bridge the gap with Western medicine. Furthermore, research in nutrigenomics and epigenomics has increased understanding of the relationship between nutrition and disease. The book addresses concerns about our planet's future well-being, the health of the global human population as a result of the worldwide obesity epidemic, issues concerning sustainable food production, and the need for a shift to a healthier, more plant-based diet.

This advanced nutrition therapy book will cover topics such as the cause, diagnosis, and reversal of lifestyle diseases such as diabetes and hypertension. Simple and illustrative examples are provided for communicating complex topics. The simplified explanations of topics can benefit anyone with no prior knowledge of medical science, nutrition, or diet. This book focuses solely on a plant-based diet rich in raw fruits and vegetables to reverse diseases labelled as irreversible or incurable by a modern-day medical industry driven by profits and greed rather than compassion and healing. You will be able to maintain a healthy body weight, reverse chronic lifestyle diseases, get rid of harmful drugs and medications, teach healthy eating habits to your friends and family, and become an asset to society and community after reading this book.

Upper division undergraduates and graduate students in nutrition and dietetics, as well as professional nutritionists, dieticians, epidemiologists, general practitioners, nurse practitioners, and family medicine physicians, will benefit from this book.

CONTENT

Current Trends and Research in Medical Nutrition Therapy to Control Diseases *https://www.kdpublications.in*

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1. Prebiotics and Probiotics in Health

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Abstract:

A complex microbiome develops colonised the human gastrointestinal tract. In virtue to being commensal, intestinal bacteria co-evolve with their host in a technique labelled as synbiotic co-evolution. Beneficial intestinal bacteria accomplish a variety of essential key activities for their host, including trying to make various nutrients, preventing infections driven on by intestinal pathogens, and directing a healthy immune response. Therefore, changing the intestinal microbiota to achieve, restore, and maintain a favourable ecosystem balance as well as the activity of microorganisms present in the gastrointestinal tract are essential for the host's improved health. The intestinal microbiota profits from the insertion of probiotics, prebiotics, or synbiotics to the human diet. They can be eaten as raw fruits and vegetables, pickles that have survived fermentation, or dairy products. Pharmaceutical dosage formulations and functional foods could be another resource. This essay reviews the information that is now accessible and summarises what is known about how probiotics, prebiotics, and synbiotics affect human health. The mechanism of such substances' beneficial effect is discussed, and confirmed study findings demonstrating their effectiveness in human nutrition are discussed.

1.1 Introduction:

The problem of food poisoning, obesity, allergies, cardiovascular illnesses, and cancer—the disease of the twenty-first century—make food quality crucial. Scientific studies support the use of probiotics and prebiotics in human diet as having positive effects on health. Greek is the origin of the word "probiotic," which means "for life." By contrasting the negative effects of antibiotics and other antibacterial drugs on the intestinal microbiota with the positive effects ("probiotika") of some helpful bacteria, Ferdinand Vergin most likely coined the word "probiotic" in his 1954 article "Anti-und Probiotika." [1]. Probiotics have undergone extensive modification and change. According to Fuller (1989), probiotics must have living microorganisms and have a positive impact on their host in order to emphasise their microbial origin [2]. Probiotics are explained primarily as "live strains of strictly selected microorganisms that, when administered in adequate amounts, confer a health benefit on the host" according to the definition formed in 2002 by experts from the FAO (Food and Agriculture Organization of the United Nations) and WHO (World Health Organization) working group [3]. In 2013, the International Scientific Association for Probiotics and Prebiotics (ISAPP) maintained the definition [4]. By stimulating the growth and/or activity of a single type or a small number of bacteria existing in the gastrointestinal

system, prebiotics were described by Gibson and Roberfroid in 1995 as non-digested food components that enhance the health of a host [5]. Prebiotics are components that have been selectively fermented to allow for certain changes in the composition and/or activity of bacteria in the gastrointestinal system, changes that are advantageous to the host's health and welfare. This definition was modified in 2004 [6]. Prebiotics are a nonviable dietary component that offers health benefits on the host related with regulation of the microbiota, according to FAO/WHO scientists in 2007 [7]. In the last few decades, a lot of study has been done on the health benefits that probiotics, prebiotics, and synbiotics confer. Functional foods are food supplements that have been shown to change, adapt, and restore the body's natural gut flora. They also support the intestinal environment's efficient operations. The probiotic strains Bifidobacterium, Lactobacilli, S. boulardii, and B. coagulans that are most frequently utilised [7]. The most widely utilised prebiotics include fructans, inulin, GOS, and XOS. These fibres are known as synbiotics when they are combined with probiotics to increase the viability of the probiotics. We will now learn more particularly about prebiotics and probiotics.

1.2 Definition of Prebiotics:

Glenn Gibson and Marcel Roberfroid [5] initially introduced the idea of prebiotics in 1995. According to definitions, prebiotics are "a non-digestible food element that advantageously impacts the host by selectively encouraging the growth and/or activity of one or a restricted number of bacteria in the colon, and so enhances host health." For more than 15 years, this definition remained largely constant. Only a small number of molecules belonging to the carbohydrate class, including lactulose, GOS, and short and long chain fructans [FOS and inulin], can be categorised as prebiotics by this criterion "Dietary prebiotics" are defined as "selectively fermented ingredients that result in specific changes in the composition and/or activity of the gastrointestinal microbiota, thus conferring benefit(s) upon host health" in 2008 at the 6th Meeting of the International Scientific Association of Probiotics and Prebiotics (ISAPP).

1.2.1 Prebiotics in Human Health:

Prebiotics are crucial for maintaining human health. Asparagus, sugar beet, garlic, chicory, onion, Jerusalem artichoke, wheat, honey, banana, barley, tomato, rye, soybean, human and cow's milk, peas, beans, etc., as well as, more recently, seaweeds and microalgae, naturally occur in various nutritional food products. They are produced on an industrial basis due to their low concentration in foods. The basic materials lactose, sucrose, and starch are used to make some prebiotics. Since the majority of prebiotics fall under the GOS and FOS categories on an industrial scale [8].

1.2.2 Action of Prebiotics:

The vast genetic potential of the gut microbiota population, which is engaged in numerous metabolic processes, can be modulated to benefit the host's health. Prebiotics, which are short-chain carbohydrates with a degree of polymerization between two and sixty and are indigestible by human or animal digestive enzymes, can be used to modulate this process. The ability to selectively utilise prebiotics sets them apart from other undigested dietary

components and compounds, such antibiotics, minerals, and vitamins, since prebiotics are not the only substances having the capacity to modify the gut environment. Prebiotics, which are typically present in fruits and vegetables, may have a number of positive health effects when included in the diet. Among the benefits of those prebiotics, it is important to emphasise the decrease in blood density lipoprotein levels, the stimulation of the immune system, the enhanced calcium absorbability, the maintenance of the proper intestinal pH value, and the low caloric value [9].

Studies have suggested that the microbial metabolic products, including SCFAs, the promotion of ion and trace element absorption, such as that of calcium, iron, and magnesium, and the regulation of the immune system, increasing IgA production and modulating cytokine production, are the mechanisms by which prebiotics confer benefits to the host. Prebiotics, which are typically present in fruits and vegetables, may have a number of positive health effects when included in the diet. Among the benefits of those prebiotics, it is important to mention the decrease in blood low density lipoprotein levels, activation of the immune system, higher calcium absorbability, preservation of the proper intestinal pH value, and low calorie value [10].

1.2.3 Beneficiary Prebiotics:

Prebiotics have an extraordinary impact on human health, making them tempting and desirable treatments for cancer, vascular disease, obesity, and mental problems. There is numerous research on the beneficial benefits of prebiotics on human health; however, to substantiate the health claims, carefully planned long-term clinical trials and genomics studies are required. In order to improve human health, scientists will be able to create better food supplements by figuring out the basic workings of prebiotics. Prebiotic food components have the potential to normalise the makeup of the gut microbiota, which is an appealing method in the management and recovery of several serious illnesses [11].

1.3 Definition of Probiotics:

The word "probiotics," generally refers to live, non-pathogenic organisms and their potential benefits on hosts, is derived from a Greek word that indicates "for life." Vergin initially used the word "probiotics" when he was investigating the harmful effects of antibiotics and other microbial agents on the population of bacteria in the gut.

Probiotika, he saw, was beneficial to the gut flora. After that, Lilly and Stillwell [10] redefined probiotic as "A substance produced by one microbe encouraging the growth of another microorganism. Eventually, the concept was further defined by Fuller as Non-pathogenic microorganisms that, when consumed, have a positive influence on the host's health or physiology [12]. According to the most recent definition proposed jointly by FDA and WHO, living microorganisms when given to a host in adequate amounts improve their health. The following actions must be taken in accordance with the rules:

- Recognition of the strain.
- The strain(s) functional characterization for probiotic benefits and safety.
- Human investigations that verify the health benefits.

- Labelling of efficacy claims and content that is truthful and not deceptive throughout the whole shelf life.

1.3.1 Food Products in Probiotic:

The variety of dietary items that involve probiotic strains is substantial and continues to expand. Dairy-based goods such as fermented milks, cheese, ice cream, buttermilk, milk powder, and yoghurt make up the majority of the market's offerings. Yogurt sales account for the greatest percentage of total sales. Soy-based goods, nutrition bars, cereals, and a range of juices are examples of non-dairy food applications that are appropriate for providing probiotics to customers [13].

1.3.2 Types of Microorganisms in Probiotics:

A number of bacteria may be present in probiotics. Bacteria from the families Lactobacillus and Bifidobacterium are the most prevalent. As probiotics, other bacteria as well as yeasts such Saccharomyces boulardii may be employed.

Microorganisms considered as probiotics Lactobacillus species, Bifidobacterium species, L. acidophilus, B. adolescentis, L. casei, B. animalis, L. crispatus, B. breve, L. *g*allinarum, B. *l*actis, L. gasseri, B. longum, L. johnsonii, B. bifidum, L. paracasei, B. infantis, L. plantarum, L. reuteri, L. rhamnosus, Other lactic acid bacteria Non-lactic acid bacteria Enterococcus aecium, Escherichia coli, strain nissle Streptococcus thermophilus, Saccharomyces cerevisiae, Lactococcus *l*actis, S. boulardii [14].

1.3.3 Beneficiary Probiotics:

The assertions that probiotics have positive effects, such as improving intestinal health, enhancing the immune system, lowering blood cholesterol, and preventing cancer, are being supported by more and more research. These strain-specific health characteristics are influenced by the numerous processes discussed above. Although some of the medical advantages have a strong body of evidence, others need more research to be confirmed. Probiotics have been shown to be effective in treating acute diarrheal illnesses, preventing antibiotic-associated diarrhoea, and improving lactose metabolism, but there is not enough data to support its use in treating other clinical problems [15].

Prebiotics encourage the development and spread of healthy bacteria in the gastrointestinal tract. Live microorganisms that, when given in sufficient quantities, boost the host's health are known as probiotics. Prebiotics, as opposed to probiotics, which are living organisms, are parts of food that are ordinarily difficult for humans to digest. They effectively act as food for the good bacteria in your stomach [16].

1.4 Types of Prebiotics:

Anything that contains sugar qualifies as a prebiotic. Inulin About 36,000 different plants contain inulin, including:

- Chicory root, burdock root, and dandelion root are examples of herbs.
- Apples and bananas are examples of fruits.
- Mother's milk for infants
- sweet vegetables including onions, garlic, asparagus, leeks, and Jerusalem artichokes; raw apple cider vinegar
- Eco Bloom, a prebiotic dietary fibre supplement from Body Ecology
- Fructooligosaccharides (FOS), a subgroup of inulin, is also a prebiotic and is often added to dairy foods and baked goods. It improves the taste and stimulates the growth of the beneficial bacteria, bifidobacterial

1.4.1 Heart Health:

Prebiotics have been found to reduce triglyceride and cholesterol levels, two markers of heart disease. One study specifically demonstrates that inulin can prevent artery hardening, or artherosclerosis, by 30%. New techniques to therapy and treatment that do not use pharmaceuticals are showing to be beneficial as heart disease grows more common among both men and women. They also have the extra advantage of being side impact free, unless you regard enhanced health as a negative effect [17].

1.4.2 Immunity:

Prebiotics appear to increase white blood cells and killer T cells and may even enhance the immune system's response to vaccinations, according to early study. Children in one study who consumed yoghurt with inulin missed fewer days of daycare, went to the doctor less frequently, and required fewer antibiotics [18].

1.4.3 Chronic Illness and Digestion:

Prebiotics have a significant impact on the pathogens and harmful bacteria in the system that can lead to disease. They act in the human intestines. Prebiotics are used to treat Crohn's disease and irritable bowel syndrome, and they may also be effective in the treatment of cancer, osteoporosis, and diabetes [18].

1.5 Probiotics in Health:

Probiotics are food items or nutritional supplements that contain friendly, helpful, and good microbes or yeasts that are typically found in the human body.

1.5.1 Benefits of Probiotics:

A. Immune System:

- Continue to live a healthy and happy life.
- Give your body a natural defence or immune system.
- Stop the spread of dangerous microorganisms.
- Boost your immune system's resistance to autoimmune illnesses and allergies.

- Assist the body in producing vitamins.

B. Digestion System:

- Encourage sound digestion.
- Increase bowel movements and decrease constipation.
- Assist in keeping the germs that cause disease in your intestines under control.
- Lessen the consequences of a Candida infection.
- Help those individuals who are lactose intolerant better digest lactose.
- Decreased cholesterol levels.
- Blood pressure reduction.
- Increasing your body's capacity to absorb nutrients, particularly calcium.
- Reducing oral bacteria that cause dental caries.

C. Probiotics to Prevent Disease:

- Treat yeast infections in the vagina.
- Infections of the urinary tract.
- Prevent diarrhoea following the administration of specific medications.
- Prevent Salmonella- or virus-induced diarrhoea
- Irritable bowel syndrome symptoms and signs should be managed (IBS).
- Boost immunological function to fight off allergies and other immune-related illnesses.
- Reduce the quantity of chemicals in your intestine that cause cancer.
- Diminish a Candida infection's negative effects.
- Eliminate or lessen colon cancer.
- Stop the kids from developing allergies.
- Lower inflammation and infections.
- Combating eczema

1.5.2 Probiotics Products:

Miso, cheese, and kefir are all well-known dairy products that have undergone fermentation and are loaded with health advantages. One of them is a probiotic.

Sauerkraut; pickles; chocolate; tofu; and tempeh, an Indonesian fermented soybean snack with a nutty flavour that has gained popularity as a probiotic food source.

Probiotics have a solid body of research supporting their use in the treatment and treatment of gastrointestinal illnesses such traveler's diarrhoea, diarrhoea brought on by antibiotic use, and diarrhoea due to Clostridium difficile. With less evidence of efficacy in Crohn's disease, other bowel disorders where they have a visible clinical impact comprise ulcerative colitis, particularly in relapse rather than maintenance. Additionally, they have been reported to help with some IBS, lactose intolerance, and constipation symptoms. Probiotics, whether consumed by the pregnant or nursing mother or the child, have also been shown to be effective in avoiding eczema in kids [19]. Prebiotics have been demonstrated to be good for the wellness of the gastrointestinal system, suppressing infections and boosting immune function, despite the fact that their impacts on health are still being studied. With data from

RCTs and systematic reviews indicating benefits in dementia, depression, Parkinson's disease, cardiometabolic health and obesity, as well as in lung diseases, reducing the risk of upper respiratory tract infection, asthma, bronchitis, and chronic obstructive pulmonary disease, there is growing evidence that probiotics have a positive impact on brain health [20].

Probiotics may be taken into consideration for the purpose of preserving a healthy gut microbiota in individuals with gut dysbiosis who have acquired COVID-19 since they appear to be at an increased risk of more serious illness and mortality. This interaction between the gut microbiota and these organs via immune cells, proinflammatory mediators, neurotransmitters, and hormones is what causes these impacts on distant organs. These results offer promising prospects for the future of both probiotics and prebiotics, even if much more research is need to determine the effects on human health.

1.6 Reference:

1. Vergin, F. Anti-und Probiotica. Hipokrates 1954, 25, 116–119.
2. Fuller, R. Probiotics in man and animals. J. Appl. Microbiol. 1989, 66, 365–378.
3. Food and Agriculture Organization (FAO). Guidelines for the Evaluation of Probiotics in Food; Report of a Joint FAO/WHO Working Group on Drafting Guidelines for the Evaluation of Probiotics in Food; FAO: London, ON, Canada, 30 April–1 May 2002.
4. Hill, C.; Guarner, F.; Reid, G.; Gibson, G.R.; Merenstein, D.J.; Pot, B.; Morelli, L.; Canani, R.B.; Flint, H.J.; Salminen, S.; et al. Expert consensus document: The International Scientific Association for Probiotics and Prebiotics consensus statement on the scope and appropriate use of the term probiotic. Nat. Rev. Gastroenterol. Hepatol. 2014, 11, 506–514. [CrossRef] [PubMed]
5. Gibson, R.G.; Roberfroid, M.B. Dietary modulation of the human colonic microbiota: Introducing the concept of prebiotics. J. Nutr. 1995, 125, 1401–1412. [PubMed]
6. Gibson, G.R.; Probert, H.M.; van Loo, J.; Rastall, R.A.; Roberfroid, M. Dietary modulation of the human colonic microbiota: Updating the concept of the prebiotics. Nutr. Res. Rev. 2004, 17, 259–275. [CrossRef] [PubMed]
7. Food and Agriculture Organization. FAO Technical Meeting on Prebiotics: Food Quality and Standards Service (AGNS), Food and Agriculture Organization of the United Nations (FAO); FAO Technical Meeting Report; FAO: Rome, Italy, 15–16 September 2007.
8. European Food Safety Authority (EFSA). Scientific opinion on the maintenance of the list of QPS biological agents intentionally added to food and feed (2013 update). EFSA J. 2013, 15, 1–108.
9. European Food Safety Authority (EFSA). Scientific Opinion on the update of the list of QPS-recommended biological agents intentionally added to food or feed as notified to EFSA (2017 update). EFSA J. 2017, 15, 1–177.
10. Lilly, D. M., & Stillwell, R. H. (1965). Probiotics: growth-promoting factors produced by microorganisms. *Science*, *147*(3659), 747-748.
11. Fuller, R. (1989). Probiotics in man and animals. *The Journal of applied bacteriology*, *66*(5), 365-378.
12. Thomas, D.W.; Greer, F. Probiotics and prebiotics in pediatrics. Pediatrics 2010, 126, 1217–1231.

13. Kumar, S.; Bansal, A.; Chakrabarti, A.; Singhi, S. Evaluation of efficacy of probiotics in prevention of Candida colonization in a PICU—A randomized controlled trial. Crit. Care Med. 2013, 41, 565–572.
14. Marteau, P.; Shanahan, F. Basic aspects and pharmacology of probiotics: An overview of pharmacokinetics, mechanisms of action and side-effects. Best Pract. Res. Clin. Gastroenterol. 2003, 17, 725–740.
15. Elli, M.; Zink, R.; Rytz, A.; Reniero, R.; Morelli, L. Iron requirement of Lactobacillus spp. in completely chemically defined growth media. J. Appl. Microbiol. 2000, 88, 695–703. [CrossRef] [PubMed]
16. Anukam, K.C.; Osazuwa, E.; Osemene, G.I.; Ehigiagbe, F.; Bruce, A.W.; Reid, G. Clinical study comparing probiotic Lactobacillus GR-1 and RC-14 with metronidazole vaginal gel to treat symptomatic bacterial vaginosis. Microbes Infect. 2006, 8, 2772–2776. [CrossRef] [PubMed]
17. Billoo, A.G.; Memon, M.A.; Khaskheli, S.A.; Murtaza, G.; Iqbal, K.; Saeed Shekhani, M.; Siddiqi, A.Q. Role of a probiotic (Saccharomyces boulardii) in management and prevention of diarrhoea. World J. Gastroenterol. 2006, 12, 4557–4560. [CrossRef] [PubMed]
18. Gøbel, R.J.; Larsen, N.; Jakobsen, M.; Mølgaard, C.; Michaelsen, K.F. Probiotics to adolescents with obesity: Effects on inflammation and metabolic syndrome. J. Pediatr. Gastroenterol. Nutr. 2012, 55, 673–678. [CrossRef] [PubMed]
19. The Weight Watchers Research Department, (2009, Sept. 24). In Probiotics and Prebiotics. Retrieved June 1, 2010, from http://www. weightwatchers.com/util/art/index_art.aspx? tabnum=1&art_id=35481&sc=805
20. American Dietetic Association, (2010). Retrieved June 1, 2010, from http://eatright.org

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2. Benefits of Probiotics and Prebiotics to Control Diseases

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Abstract:

Probiotics are beneficial bacteria, and Prebiotics provide nourishment to these bacteria. Consuming both in foods or supplements can assist in balancing your intestinal flora. In recent years and in the forthcoming decades, significant advancements in technologies and related approaches will continue to play a crucial role in the prebiotic and probiotic fields. This review provides current perspective on the probiotics and prebiotics concept, sources of probiotics and prebiotics, as well as the current insight into their effect on human health. The mechanism of beneficial effects is described, and proven study findings demonstrating their efficiency in human nutrition are discussed.

Keywords:

Probiotics, Prebiotics, Bacteria, Health, Supplements, Beneficial.

2.1 Introduction:

According to the World Health Organization (WHO), probiotics are defined as the live microorganisms that "when administered in adequate amounts, confer a health benefit on the host" [1]. Most common species of probiotics belong in the families of Lactobacillus, Bifidobacterium and Streptococcus [2] with the first two families being mostly used in studies related to human health [3]. As these microorganisms are naturally found in the gut microbiota, most studies are focused on their effects in the context of the natural function in the gut and as preventive or therapeutic agents against disease development [4–11]. They play an important role in creating a healthier gut environment by inhibiting undesirable microbes and by crossfeeding other beneficial gut microbes, resulting in production of butyrate, which fuels intestinal epithelial cells [12]. Thus, organic acids commonly produced by many different probiotic strains and species contribute to general gut health benefits [13]. Thus, probiotics have been used for the study and treatment of intestinal diseases such as gastroenteritis [14], intestinal hyperpermeability [15], urinary tract infection [16], intestinal dysbiosis [17], irritable bowel syndrome [18], Crohn's disease [19], colon cancer [20,21], ulcerative colitis [22,23] and peptic ulcer [18]. Identifying and establishing precise mechanisms responsible for any given health benefit remain active areas of research. Probiotics are poised as a valuable means of influencing the function of the gut ecosystem to improve nutritional status and health. [24]

On the other hand, Prebiotics are the substances which reach the colon in the intact form are given to the animals and beneficial for microbial growth in the intestine and normal digestion process. They act as fertilizer for probiotics for example: insulin, fructooligosaccharides. [26] Gibson and Roberfroid [27] in 1995 defined prebiotics as "a non-digestive food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon that can improve the host health." Later, these authors revised the concept and proposed a new definition for prebiotic as "a selectively fermented ingredient that allows specific changes; both in the composition and/or activity in the gastrointestinal microbiota that beneficially affects the host health." [27,28]. The Food and Agriculture Organization of the United Nations defines prebiotics as "a nonviable food component that confers a health benefit on the host associated with modulation of the microbiota." [29]

2.2 Probiotics:

The word probiotics derives from the Latin word pro means for and the Greek bios means life. Probiotics are the community of microbes living in our intestines and are considered a metabolic 'organ' due to their positive impact on human wellbeing, including our metabolism and immune function. Our gut microbiome has actually evolved as humans have undergone evolution and have shaped and interacted with our body over thousands of years, influencing our physiology [30].

2.2.1 Common Microbes Used as Probiotics:

Human microbiota is composed of different types of bacteria, yeasts, fungi used as probiotics. New studies indicate that our microbiome can change incredibly fast in the human gut—within three or four days of a big shift in what we eat. Eating a mainly plant based diet supports health giving probiotics [31]. Specific probiotic strains have mostly been shown to provide health advantages.

- **Bacterial microbes**: (i) Lactobacillus Species: acidophilus, sporogenes, plantarum, delbrueck, reuteri, brevis, fermentum, lactus, cellobiosus, , casei, farciminis, rhamnosum paracasei, gasseri, crispatus; (ii) Bifidobacterium Species: bifidum, adolescentis, longum, thermophilum, infantis, breve, lactis, animalis;(iii) Streptococcus: lactis, cremoris, alivarius, thermophilis, intermedius, diacetylactis; (iv) Leuconostoc mesenteroides; (v) Enterococcus; (vi) Propionibacterium; (vii) Bacillus; (viii) Pediococcus; (ix) Enterococcus faecium
- **Yeast and molds:** Saccharomyces bourlardii, Saccharomyces cerevisiae, Candida pintolopesii, Aspergillus niger, Aspergillus oryzue, Sacaromyces boulardii
- **Viruses:** Our guts are home to several plant-derived viruses, and it has been hypothesised that these viruses may alter the local bacterial flora. [32,33]

2.2.2 Characteristics of A Good Probiotics [34-36]:

- The probiotic ought to have a beneficial effect on the host. It ought to be resistant to bile, acid, and at least 30 109 CFU per Gram.
- The probiotic must have a high survival rate and rapidly multiply.
- The probiotic's adhesive ability must be firm and swift.

- Reduce or eliminate pathogenic adhesion.
- Make acids, peroxide, and bacteriocins that stop pathogens from growing.
- Safe, non-invasive, non-pathogenic, and free of cancer
- Collect into a normal, well-balanced flora.
- In order to reach the intestine alive, probiotics need to be durable enough to withstand commercial manufacturing, processing, packaging, and distribution.

2.2.3 Mechanism of Action:

The following are some suggested ways that probiotic microorganisms may exert their beneficial effects on health: **[37-42]**

a. Production of inhibitory agents that prevent pathogenic bacteria from adhering to the intestinal epithelium;
b. Suppression of pathogenic bacteria's growth by directly binding to gram-negative bacteria
c. Maintenance of normal levels of short-chain fatty acids (SCFAs)
d. Suppression of intestinal pro-inflammatory cytokine production.
e. Regulate lipid metabolism.
f. Enhance the intestinal immune response
g. Repair of intestinal permeability by colonocyte multiplication
h. Inhibits the growth of pathogenic enteric bacteria by decreasing luminal pH
i. intestinal electrolyte absorption is increased
j. Improves the barrier function and changes the form and function of the intestinal epithelium.

2.2.4 Sources of Probiotics:

Probiotics supplements are not necessary for normal, healthy individuals. For healthy adults, daily consumption of probiotics-rich foods, like yoghurt and cultured milk drinks, and fiber rich diets (prebiotics) should adequately supply the amount of probiotics required to maintain a healthy digestive system and overall wellbeing [43].

Probiotics in our Diet: The bacteria in fermented foods increase its levels of vitamins B, C, and K, deactivate harmful nutrients such as the protein inhibitors and phytic acid, and release nutrients from food that would otherwise have passed through the intestines undigested.

Yogurt is a dairy product made from milk that has undergone bacterial fermentation. Streptococcus salivarius subsp. and Lactobacillus bulgaricus are used in the culture used to make dairy yoghurt.

Live cheeses contain probiotics such as Live Active natural cheese snacks and yogurt Cheese (prepared with the probiotic live cultures Lactobacillus acidophilus and bifidobacterium).

Buttermilk Commercial cultured buttermilk is produced from cow's milk using either Streptococcus lactis or Lactobacillus bulgaricus.

Kefir is a fermented milk beverage that also contains yeasts such Candida humilis, Kazachstania unispora, and Kluyveromyces lactis as well as bacteria like Lactobacillus acidophilus, brevis, casei, and delbrueckii subsp. Bulgaricus.

Kombucha is a Chinese tangy/sweet "mushroom tea." The yeast component of kombucha may contain Saccharomyces cerevisiae, Brettanomyces bruxellensis, or Candida stellata.

Sauerkraut, Tempeh, Miso, Soya sauce, Natto are some other sources of probiotics

Probiotic supplements: They come in tablet, powder, capsule, and liquid forms. They do not provide the nutrition like probiotic foods, but they are an option to promote healthy gut bacteria. [44]

2.2.5 Probiotics Effects on Human Health:

A. Irritable Bowel Syndrome and Probiotics

Probiotics were somewhat effective in children and adults with irritable bowel syndrome (IBS) and in children with functional abdominal pain, in clinical trials.

Pain and flatulence in patients with irritable bowel syndrome is decreased by administration of a L plantarum strain in a double blind clinical trial. [45]

B. Allergy and Probiotics

Probiotics associated with disappearance of food allergy manifestation with decrease in concentration of IgE in the serum and with a lower frequency of allergies was reported by Loskutova et al and Trapp et al in two different studies [46,47].

C. Skin and Probiotics:

Lactobacilli and Bifidobacterium are the most commonly used probiotics and thought to mediate skin inflammation, treat atopic dermatitis (AD) and prevent allergic contact dermatitis (ACD). [48]

D. Oral Health and Probiotics:

Probiotics can help to destroy the harmful microbes in the oral cavity by fighting against them and helps in maintaining healthy gums and teeth. Since probiotics is an all-natural treatment it should not have any side effects [49,50].

Both *lactobacillus acidophilus* and *bifidobacterium lactis* have well known antifungal property [51].

Table 2.1: Role of Probiotics in Health Improvement and Disease Treatment

Disease	Probiotic Strains	References
Atopic eczema	Escherichia coli Bifidobacterium bifidum Bifidobacterium lactis	[52,53]
Food allergy	Escherichia coli	[54]
Immunity Modulation	Bacillus circulans PB7 Lactobacillus plantarum DSMZ 12028	[55,56]
Removal of Antibiotic effect	Enterococcus mundtii ST4SA Lactobacillus plantarum 423 Lactobacillus brevis KB290 Lactobacillus strains Bifidobacterium strains	[57,58,59]
Gastroenteritis	Lactobacillus casei	**[60]**
Intestinal hyperpermeability	Lactobacillus plantarum species 299 (LP299)	**[61,62,63]**
Vaginal candidiasis	Lactobacillus rhamnosus GR-1 Lactobacillus reuteri RC-14	**[64]**
Urinary tract infection	Lactobacillus rhamnosus GR-1 Lactobacillus reuteri RC-14	**[65]**
Lactose intolerance	Lactobacillus acidophulus	**[66]**
Non-steroidal anti-inflammatory drug	Escherichia coli strain Nissle 1917	**[67]**
Intestinal dysbiosis	Lactobacillus johnsonii La1 Lactobacillus strain	**[66,68,69]**

Disease	Probiotic Strains	References
	Lactobacillus GG	
Irritable bowel syndrome	Bifidobacterium infantis 35624 Escherichia coli DSM17252 Bifidobacterium infantis 35624	**[70-72]**
Traveler's diarrhea	Lactobacillus GG Lactobacillus plantarum	**[66,73]**
Crohn's disease	Escherichia coli strain Nissle 1917	**[74]**
Prevention of colon cancer	Enterococcus faecium M-74 lactic acid bacteria	**[75,76]**
Ulcerative colitis	Lactobacillus acidophilus Escherichia coli Nissle 1917 Bifidobacterium	**[77-79]**
Peptic ulcer disease	Lactobacillus acidophulus	**[80]**
Hypercholesterolemia and cardiovascular diseases	Enterococcus faecium M-74 Lactobacillus plantarum Propionibacterium freudenreichii Lactobacillus plantarum PH04	**[81,82]**
Oral Health and dental caries	Actobacillus acidophilus Bifidobacterium lactis	**[83]**
Caries gingivitis	Lactobacillus reuteri	**[84]**

2.3 Prebiotics:

Prebiotics are "a nonviable food component that imparts a health benefit on the host associated with regulation of the microbiota," according to the Food and Agriculture Organization of the United Nations [85]. Prebiotics promote particular microbial genera and species' growth or activities in the gut microbiota in order to boost the host's health.

Table 2.2: Criteria for Characterization of an Ingredient as A Prebiotic [87]

Characterization of Prebiotics
• Counteract gastric acidity, hydrolysis by mammalian enzymes, and absorption in the upper GI tract • Fermented by the intestinal microbiota • Selectively promotes the growth and/or activity of intestinal bacteria potentially associated with health and well-being

2.3.1 Sources of Prebiotics:

Prebiotics	Source	References
Inulin	Present in a range of natural foods, including chicory, onion, garlic, Jerusalem artichokes, tomatoes, and bananas	[87]
Fructooligosaccharides (FOS)	Occur naturally in fruits and vegetables (asparagus, endive, sugar beet, garlic, chicory, onion, Jerusalem artichokes, bananas, tomatoes). FOS is prepared commercially from chicory in a hydrolysis reaction using inulinase and may also be derived in an enzymatic synthetic reaction via transfer of fructosyl units from sucrose molecules. Other sources: cereals, wheat, barley, rye, and honey	[88-90]
Galactooligosaccharides	Legumes, nuts, soy beans and soy products, peas, rapeseed meal, lentils, Chickpeas/hummus, green peas, lima beans, kidney beans	[91,92]
Fructans	Naturally occurring oligosaccharides found in onions, bananas, wheat, artichokes, garlic, and other whole foods. They are also extracted from chicory or manufactured from sucrose for use in the food industry	[93,94]
Resistant starch granules	Raw potatoes, bananas	[95]
Pectins	Apple, sugar beet pulp	[95]
β-Glucans	Oats and barley	[96,97]
Psyllium	Psyllium husk (plant)	[97]
Isomaltooligosaccharides	Produced commercially from the enzymatic action of α-amylase, pullulanase, and α-glucosidase on cornstarch	[98]
Lactulose	Galactofructose isomerization product derived from lactose	[99,100]

Prebiotics	Source	References
Milk oligosaccharides	Human and cow's milk. They may also produce synthetically from lactose syrup using β-galactosidase	[101-103]

2.3.2 Mechanism of Action of Prebiotics:

The molecular structure of prebiotics determines their physiological effects and the types of microorganisms that are able to use them as a source of carbon and energy in the bowel [103].

The mechanism of a beneficial effect of prebiotics on immunological functions remains unclear. Several possible models have been proposed [104, 105]:

a. Prebiotics are able to regulate the action of hepatic lipogenic enzymes by influencing the increased production of short-chain fatty acids (SCFAs), such as propionic acid.
b. The production of SCFAs (especially of butyric acid) as a result of fermentation was identified as a modulator of histone acetylation, thus increasing the availability of numerous genes for transcription factors.
c. The modulation of mucin production.
d. It was demonstrated that FOS and several other prebiotics cause an increased count of lymphocytes and/or leukocytes in gut-associated lymphoid tissues (GALTs) and in peripheral blood.
e. The increased secretion of IgA by GALTs may stimulate the phagocytic function of
f. intra-inflammatory macrophages.

The main aim of prebiotics is to stimulate the growth and activity of beneficial bacteria in the gastrointestinal tract, which confers a health benefit on the host.

Through mechanisms including antagonism (the production of antimicrobial substances) and competition for epithelial adhesion and for nutrients, the intestinal microbiota acts as a barrier for pathogens.

2.3.3 Prebiotics Mechanisms for Health Maintenance and Protection against Disorders:

A. Irritable Bowel Syndrome and Crohn's Disease:

IBS is a gastrointestinal syndrome characterized by chronic abdominal pain and altered bowel habits in the absence of any organic cause. IBDs like Crohn's disease, which can affect any portion of the digestive system from the mouth to the anus, are chronic, relapsing conditions. According to reports, the populations of Bifidobacteria and Faecalibacterium prausnitzii as well as the Bacteroides to Firmicutes ratio were lower in people with IBS and Crohn's disease [106, 107]. It has been reported that supplementation with 15 g/day FOS for 3 weeks elevated Bifidobacteria population in the feces and improved Crohn's disease [108].

B. Colorectal Cancer:

Normal cell replication is aided by butyrate, which also has an anticarcinogenic effect by reducing altered or mutant cells through apoptosis.109]. Butyrate also functions as an HDAC inhibitor, which increases the accessibility of transcriptional factors to nucleosomal DNA and modifies the expression of oncogenes by hyperacetylating histones. Butyrate's capacity to regulate cell cycle and gene expression is due to these outcomes. Butyrate enhances the activity of glutathione S-transferase, an enzyme that detoxifies xenobiotics, according to studies on colonic cancer cells. Butyrate has the ability to mediate the growth and proliferation of tumour cells by blocking the decay-accelerating factor. [110]

C. Necrotizing Enterocolitis:

Necrotizing enterocolitis (NEC) is a gastrointestinal emergency disorder which is most common in premature neonates, causes portions of the bowel undergo necrosis. It can lead to high morbidity and mortality rates [111]. Prebiotics like FOS and GOS, which can increase the proliferation of gut microbiota (such Bifidobacteria) and decrease pathogenic bacteria in preterm newborns, are thought to be able to prevent NEC [112-114].

D. Cardiovascular Disease:

Unhealthy diets that are low in complex carbohydrates, fruits, and vegetables and heavy in fats, salt, and free sugar can raise the risk of CVDs. Low-density lipoprotein (LDL) levels have been closely linked to the risk of CVD. The microbial population in the gut uses prebiotics to make SCFAs (acetate, butyrate, and propionate), which may lower the risk of CVDs and enhance lipid profiles. [115-117]

E. Type II Diabetes and Glycemic Control (T2D):

By 2030, diabetes will, unfortunately, rank as the sixth largest cause of mortality. [118] T2D prevention and management depend on understanding how food affects the regulation of glycemia and metabolic diseases. According to some reports, consuming fibre regularly may decrease the pace at which glucose is absorbed, prevent weight gain, raise levels of healthy nutrients and antioxidants, and so aid in the prevention of diabetes. [119]. People who ingested more than 15 g of fibre per day had a considerably decreased probability of developing diabetes, indicating an antagonistic link between dietary fibre intake and the onset of T2D. [120]

F. Weight Management:

By altering the GI tract, gut microbiota is crucial in the regulation of weight. The effects of FOS supplementation on body weight were assessed in overweight and obese people during a 12-week, randomised, double-blind, placebo-controlled experiment. According to the study's findings, FOS caused a decrease in body weight, whereas the control groups had an increase. [119]

G. Immune Function:

It is possible to stimulate the immune system by enhancing gastrointestinal microbiota, increasing the growth of probiotics, and/or limiting the growth of harmful microbes. [121]. This can be accomplished by regularly consuming specific prebiotic kinds that support gut-associated modulation of immune and microbial activity.

H. Prebiotics and The Nervous System:

For instance, prebiotics are given to piglets to reduce grey matter and enhance neural pruning [122]. Prebiotics' effects on human brain regulation, however, are still not well understood. There are three ways that the gut microbiota might affect the brain: neurological, endocrine, and immunological pathways. Prebiotics like FOS and GOS can regulate synaptic proteins including synaptophysin and N-Methyl-D-aspartate or NMDA receptor subunits as well as brain-derived neurotrophic factors, neurotransmitters, and d-serine [123,124].

Mood: Stress hormones have the power to influence behaviours linked to anxiety [125,126]. Adrenocorticotropic hormone (ACTH) and corticosterone levels were shown to rise in germ-free mice after exposure to controlled stress, according to research. Corticosterone and ACTH levels returned to normal after taking Bifidobacterium infantis [127].

Learning, focus, and memory The relationship between memory and the administration of fermentable chemicals in both animals and humans has recently been demonstrated in a number of studies [128]. Prebiotics that can improve general cognition and slow the formation of dementia-related glial fibrillary acidic protein in mice include arabinoxylan and arabinose [129].

Hepatic encephalopathy: When the liver is not functioning properly, it can cause hepatic encephalopathy. The main cause of hepatic encephalopathy is a rise in blood ammonia levels. It was established in 1966 that lactulose might successfully cure hepatic encephalopathy by lowering the amount of ammonia in the gut. People with hepatic encephalopathy can live better lives because to lactulose. [130-132]

I. Prebiotics and Skin:

Prebiotics (such fructo-oligosaccharides, galacto-oligosaccharides, and konjac glucomannan hydrolysates) help probiotics proliferate, which helps treat disorders like atopic dermatitis, acne, and photo ageing. [48]

2.4 Conclusion:

Throughout the coming decades, the use of probiotics and prebiotics in food and medicine will grow significantly. Medical practitioners should take into account their use in the prevention and treatment of various illnesses, and the food sector should promote it. Before being marketed, newly created probiotic strains should undergo a rigorous safety assessment.

Although there is still much to understand about the ways in which probiotic strains work and how best to administer them, it is obvious that different strains can have very diverse impacts. Additionally, their impacts may differ in terms of health and disease, as well as in different disease states and age groups. To better understand mechanistic difficulties and interactions, more research is required. Clinicians need to be aware of the dangers and advantages of these treatments given the growing use of probiotics and prebiotics as dietary supplements and medicinal agents.

2.5 References:

1. Report of a Joint FAO/WHO Working Group on Drafting Guidelines for the Evaluation of Probiotics in Food; Guidelines for the Evaluation of Probiotics in Food: London, ON, Canada, 2002; pp. 1–11. Fijan, S. (2014).
2. Gasbarrini, G.; Bonvicini, F.; Gramenzi, A. Probiotics History. J. Clin. Gastroenterol. 2016, 50, S116–S119.
3. Ouwehand, A.C.; Salminen, S.; Isolauri, E. Probiotics: An overview of beneficial e_ect. Antonie Van Leeuwenhoek. 2002, 82, 279–289
4. Britti, M.S.; Roselli, M.; Finamore, A.; Merendino, N.; Mengheri, E. Regulation of immune response at intestinal and peripheral sites by probiotics. Biologia (Bratislava) 2006, 61, 735–740.
5. Chen, C.C.; Allan Walker, W. Probiotics and the mechanism of necrotizing enterocolitis. Semin. Pediatr. Surg. 2013, 22, 94–100.
6. Bansal, S.; Mangal, M.; Sharma, S.K.; Gupta, R.K. Non-dairy Based Probiotics: A Healthy Treat for Intestine. Crit. Rev. Food Sci. Nutr. 2016, 56, 1856–1867.
7. Wang, X.; Farnell, Y.Z.; Peebles, E.D.; Kiess, A.S.; Wamsley, K.G.; Zhai,W. E_ects of prebiotics, probiotics,and their combination on growth performance, small intestine morphology, and resident Lactobacillus of male broilers. Poult. Sci. 2016, 95, 1332–1340.
8. Sánchez, B.; Delgado, S.; Blanco-Míguez, A.; Lourenço, A.; Gueimonde, M.; Margolles, A. Probiotics, gut microbiota, and their influence on host health and disease. Mol. Nutr. Food Res. 2017, 61, 1–15.
9. Friedrich, A.D.; Paz, M.L.; Leoni, J.; Maglio, D.H. Message in a bottle: Dialog between intestine and skin modulated by probiotics. Int. J. Mol. Sci. 2017, 18, 1067.
10. Thomas, C.M.; Versalovic, J. Probiotics-host communication. Gut Microbes 2010, 1, 148–163.
11. Mori, N.; Kano, M.; Masuoka, N.; Konno, T.; Suzuki, Y.; Miyazaki, K.; Ueki, Y. E_ect of probiotic and prebiotic fermented milk on skin and intestinal conditions in healthy young female students. Biosci. Microbiota Food Health 2016, 35, 105–112.
12. Topping DL & Clifton PM (2001) Short-chain fatty acids and human colonic function: roles of resistant starch and nonstarch polysaccharides. Physiological Reviews 81: 1031–64.
13. Ritchie ML & Romanuk TN (2012) A meta-analysis of probiotic efficacy for gastrointestinal diseases. PLoS ONE 7: e34938.
14. Yamada, T.; Nagata, S.; Kondo, S.; Bian, L.; Wang, C.; Asahara, T.; Ohta, T.; Nomoto, K.; Yamashiro, Y.; Effect of Continuous Fermented Milk Intake Containing Lactobacillus casei Strain Shirota on Fever in Mass Infectious Gastroenteritis Rest Home Outbreak; Kansenshogaku Zasshi 2009, 83, 31–35.

15. White, J.S.; Hoper, M.; Parks, R.W.; Clements, W.D.; Diamond, T.; Bengmark, S. The probiotic bacterium Lactobacillus plantarum species 299 reduces intestinal permeability in experimental biliary obstruction. Lett. Appl. Microbiol. 2006, 42, 19–23.
16. Anukam, K.C.; Hayes, K.; Summers, K.; Reid, G. Probiotic Lactobacillus rhamnosus GR-1 and Lactobacillus reuteri RC-14 may help downregulate TNF-alpha, IL-6, IL-8, IL-10 and IL-12 (p70) in the neurogenic bladder of spinal cord injured patient with urinary tract infections: A two-case study. Adv. Urol. 2009, 680363.
17. Bennett, R.G.; Gorbach, S.L.; Greenough, W.B.; Bartlett, J.G. Treatment of Relapsing Clostridium di_cile Diarrhea with Lactobacillus GG. Nutr. Today Suppl. 1996, 31, 35–38.
18. Amara, A.A.; Shibl, A. Role of Probiotics in health improvement, infection control and disease treatment and management. Saudi Pharm. J. 2015, 23, 107–114.
19. Boudeau, J.; Glasser, A.L.; Julien, S.; Colombel, J.F.; Darfeuille-Michaud, A. Inhibitory e_ect of probiotic Escherichia coli strain Nissle 1917 on adhesion to and invasion of intestinal epithelial cells by adherent-invasive E. coli strains isolated from patients with Crohn's disease. Aliment. Pharm. Ther. 2003, 18, 45–56.
20. Mego, M.; Májek, J.; Koncˇeková, R.; Ebringer, L.; Cˇ ierniková, S.; Rauko, P.; Kovac, M.; Trupl, J.; Slezak, P.; Zajac, V. Intramucosal bacteria in colon cancer and their elimination by probiotic strain Enterococcus faecium M-74 with organic selenium. Folia Microbiol. 2005, 50, 443–447.
21. Thirabunyanon, M.; Boonprasom, P.; Niamsup, P. Probiotic potential of lactic acid bacteria isolated from fermented dairy milks on antiproliferation of colon cancer cells. Biotechnol. Lett. 2009, 31, 571–576.
22. Abdin, A.A.; Saeid, E.M. An experimental study on ulcerative colitis as a potential target for probiotic therapy by Lactobacillus acidophilus with or without "olsalazine". J. Crohn's Colitis 2008, 2, 296–303.
23. Imaoka, A.; Shima, T.; Kato, K.; Mizuno, S.; Uehara, T.; Matsumoto, S.; Setoyama, H.; Hara, T.; Umesaki, Y. Anti-inflammatory activity of probiotic Bifidobacterium: Enhancement of IL-10 production in peripheral blood mononuclear cells from ulcerative colitis patients and inhibition of IL-8 secretion in HT-29 cells. World J. Gastroenterol. 2008, 14, 2511–2516.
24. Versalovic J (2013) The human microbiome and probiotics: implications for pediatrics. Annals of Nutrition & Metabolism 63(Suppl 2): 42–52.
25. Gibson GR, Roberfroid MB. Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics. J Nutr 1995; 125:1401.
26. Sameer Singh Faujdar*, Priya Mehrishi, Surabhi Bishnoi and Amisha Sharma; Role of Probiotics in human health and disease: An update; Int.J.Curr.Microbiol.App.Sci (2016) 5(3): 328-344; http://dx.doi.org/10.20546/ijcmas.2016.503.040
27. Gibson GR, Probert HM, Van Loo J, Rastall RA, Roberfroid MB. Dietary modulation of the human colonic microbiota: updating the concept of prebiotics. Nutr Res Rev 2004; 17:259–75.
28. Roberfroid M. Prebiotics: the concept revisited. J Nutr 2007;137: 830S–7S.
29. Pineiro M, Asp N-G, Reid G, et al. FAO Technical meeting on prebiotics. J Clin Gastroenterol 2008;42: S156–9.
30. Ley, R., Peterson, D., & Gordon, J. (2006). Ecological and Evolutionary Forces Shaping Microbial Diversity in the Human Intestine. *Cell*, 124(4), pp. 837-848. doi: 10.1016/j.cell.2006.02.017

31. Scarpellini, E., Ianiro, G., Attili, F., Bassanelli, C., De Santis, A., & Gasbarrini, A. (2015). The human gut microbiota and virome: Potential therapeutic implications. *Digestive and Liver Disease*, 47(12), pp. 1007-1012. doi: 10.1016/j.dld.2015.07.008
32. Madhumita Sen; *Role of Probiotics in Health and Disease – A Review; Int J Adv Life Sci Res. Volume 2(2)1-11*
33. A.A. Amara, A. Shibl; Role of Probiotics in health improvement, infection control and disease treatment and Management; Saudi Pharmaceutical Journal (2013); http://dx.doi.org/10.1016/j.jsps.2013.07.001
34. *Abatenh E, Gizaw B, Tsegay Z, et al. Health benefits of probiotics. J Bacteriol Infec Dis. 2018;2(1):8-27(PRO66)*
35. Azizpour K, Bahrambeygi S, Azizpour A (2009). History and Basic of Probiotics. Res J boil sci; 4:409-426.
36. Behnsen J, Deriu E, Sassone-Corsi M, Raffatellu M 2013. Probiotics: properties, examples, and specific applications. Cold Spring Harb Perspect Med 3: a010074. doi:.10.1101/cshperspect. a010074
37. Narwal A, Shashi Bala (2011). Probiotics in Dentistry – A Review. J Nutr Food Sci 1:114. doi:10.4172/2155-9600.1000114
38. Tiwari G, Tiwari R, Pandey S, Pandey P (2012). Promising future of probiotics for human health: Current scenario. Chron Young Sci; 3:17-28.
39. Cremonini F, Di Caro S, Nista EC, *et al.,* (2002). Meta-analysis: the effect of probiotic administration on antibiotic-associated diarrhoea. Aliment Pharmacol Ther; 16:1461–7.
40. Kumar A, Vandana (2013). Probiotics: Nature's medicine. Int J Nutr Pharmacol Neurol Dis; 3:219-28
41. Rastogi P, Saini H, Dixit J, Singhal R (2011). Probiotics and oral health. Natl J Maxillofac Surg; 2:6-9
42. Probio
43. Wilkins, T., & Sequoia, J. (2017). Probiotics for Gastrointestinal Conditions: A Summary of the Evidence. *American Family Physician*, 96(3), pp. 170-178.
44. Melissa Conrad Stoppler, M. (2017). Digestive Health: 10 Probiotic Foods That Help Digestion. Retrieved from https://www.onhealth.com/content/1/probiotic_foods
45. Nobaek S, Johansson ML, Molin G *et al.,* (2000). Alteration of intestinal microflora is associated with reduction in abdominal bloating and pain in patients with irritable bowel syndrome. Am J Gastroenterol; 95:1231–8.
46. Loskutova IE (1985). Effectiveness of using maluitka and Malysh adapted propronic acidophilus mixtures in the combined treatment of congenital hypertrophy. *Vopr Pitan*; 17-20.
47. Trapp CL, Charg CC, Halpern GM *et al.,* (1993). The influence of chronic yogurt consumption on population of young and elderly adults. *Int J Imunother*; 9: 53-64.
48. Vasiliki Lolou and Mihalis I. Panayiotidis; Fermentation 2019, 5, 41; doi:10.3390/fermentation5020041
49. Chitra N. Bactermia associated with probiotic use in medicine and dentistry. IJIRSET. 2013;2(12):7322-25.
50. Dhawan R, Dhawan S. Role of probiotics on oral health: A randomized, double-blind, placebo-controlled study. J Interdiscip Dentistry. 2016; 3:71-8.
51. Lesan S, Hajifattahi F, Rahbar M, et al. The effect of probiotic yoghurt on the frequency of salivary candida. J Res Dentomaxillofac Sci. 2017;2(2):1-7.

52. Yesilova Y, Calka O, Akdeniz N, et al. Effect of probiotics on the treatment of children with atopic dermatitis. Ann Dermatol. 2012;24(2):189–93.
53. Doege K, Grajecki D, Zyriax BC, et al. Impact of maternal supplementation with probiotics during pregnancy on atopic eczema in childhood–a meta-analysis. Br J Nutr. 2012; 107:1-6.
54. Lodinova-Zadnikova, R., Cukrowska, B., Tlaskalova-Hogenova, H., 2003. Oral administration of Probiotic Escherichia coli after birth reduces frequency of allergies and repeated infections later in life (after 10 and 20 years). Int. Arch. Allergy Immunol. 131, 209–211.
55. Bandyopadhyay, P., Das Mohapatra, P.K., 2009. Effect of a Probiotic Bacterium Bacillus circulans PB7 in the formulated diets: on growth, nutritional quality and immunity of Catla catla (Ham.). Fish Physiol. Biochem. 35, 467–478
56. Cammarota, M., De Rosa, M., Stellavato, A., Lamberti, M., Marzaioli, I., Giuliano, M., 2009. In vitro evaluation of Lactobacillus plantarum DSMZ 12028 as a probiotic: emphasis on innate immunity. Int. J. Food Microbiol. 135, 90–98.
57. Botes, M., Loos, B., van Reenen, C.A., Dicks, L.M., 2008. Adhesion of the probiotic strains Enterococcus mundtii ST4SA and Lactobacillus plantarum 423 to Caco-2 cells under conditions simulating the intestinal tract, and in the presence of antibiotics and anti-inflammatory medicaments. Arch. Microbiol. 190, 573–584.
58. Fukao, M., Tomita, H., Yakabe, T., Nomura, T., Ike, Y., Yajima, N., 2009. Assessment of antibiotic resistance in probiotic strain Lactobacillus brevis KB290. J. Food Prot. 72, 1923–1929.
59. Zhou, J.S., Pillidge, C.J., Gopal, P.K., Gill, H.S., 2005. Antibiotic susceptibility profiles of new probiotic Lactobacillus and Bifidobacterium strains. Int. J. Food Microbiol. 98, 211–217.
60. Yamada, T., Nagata, S., Kondo, S., Bian, L., Wang, C., Asahara, T., Ohta, T., Nomoto, K., Yamashiro, Y., 2009. Effect of continuous probiotic fermented milk intake containing Lactobacillus casei strain Shirota on fever in mass infectious gastroenteritis rest home outbreak. Kansenshogaku Zasshi 83, 31–35.
61. Kennedy, R.J., Hoper, M., Deodhar, K., Kirk, S.J., Gardiner, K.R., 2000. Probiotic therapy fails to improve gut permeability in a hapten model of colitis. Scand. J. Gastroenterol. 35, 1266–1271.
62. Strowski, M.Z., Wiedenmann, B., 2009. Probiotic carbohydrates reduce intestinal permeability and inflammation in metabolic diseases. Gut 58, 1044–1045.
63. White, J.S., Hoper, M., Parks, R.W., Clements, W.D., Diamond, T., Bengmark, S., 2006. The probiotic bacterium Lactobacillus plantarum species 299 reduces intestinal permeability in experimental biliary obstruction. Lett. Appl. Microbiol. 42, 19–23.
64. Martinez, R.C., Franceschini, S.A., Patta, M.C., Quintana, S.M., Candido, R.C., Ferreira, J.C., De Martinis, E.C., Reid, G., 2009. Improved treatment of vulvovaginal candidiasis with fluconazole plus probiotic Lactobacillus rhamnosus GR-1 and Lactobacillus reuteri RC-14. Lett. Appl. Microbiol. 48, 269–274.
65. Anukam, K.C., Hayes, K., Summers, K., Reid, G., 2009. Probiotic Lactobacillus rhamnosus GR-1 and Lactobacillus reuteri RC-14 may help downregulate TNF-Alpha, IL-6, IL-8, IL-10 and IL-12 (p70) in the neurogenic bladder of spinal cord injured patient with urinary tract infections: a two-case study. Adv. Urol., 680363.
66. Hawrelak, J., 2003. Probiotics: choosing the right one for your needs. J. Aust. Traditional-Med. Soc. 9 (2), 67–75.

67. Ukena, S.N., Westendorf, A.M., Hansen, W., Rohde, M., Geffers, R., Coldewey, S., Suerbaum, S., Buer, J., Gunzer, F., 2005. The host response to the probiotic Escherichia coli strain Nissle 1917: specific up-regulation of the proinflammatory chemokine MCP-1. BMC Med. Genet. 6, 43.
68. Silva, M., Jacobs, N.V., Deneke, C., Gorbach, S.L., 1987. Antimicrobial substance from a human Lactobacillus strain. Antimicrob. Agents Chemother. 31, 1231–1233.
69. Bennett, R.G., Gorbach, S.L., Goldin, B.R., Chang, T., Laughon, B.E., Greenough, W.B., Bartlett, J.G., 1996. Treatment of relapsing Clostridium difficile
70. Brenner, D.M., Chey, W.D., 2009. Bifidobacterium infantis 35624: a novel probiotic for the treatment of irritable bowel syndrome. Rev. Gastroenterol. Disord. 9, 7–15. diarrhea with Lactobacillus GG. Nutr. Today 31, 35S–39S.
71. Enck, P., Zimmermann, K., Menke, G., Klosterhalfen, S., 2009. Randomized controlled treatment trial of irritable bowel syndrome with a probiotic E. coli preparation (DSM17252) compared to placebo. Z. Gastroenterol. 47, 209–214.
72. Whorwell, P.J., Altringer, L., Morel, J., Bond, Y., Charbonneau, D., O'Mahony, L., Kiely, B., Shanahan, F., Quigley, E.M., 2006. Efficacy of an encapsulated probiotic Bifidobacterium infantis 35624 in women with irritable bowel syndrome. Am. J. Gastroenterol. 101, 1581–1590.
73. Michail, S., Abernathy, F., 2002. Lactobacillus plantarum reduces the in vitro secretory response of intestinal epithelial cells to enteropatho- genic Escherichia coli infection. J. Pediatr. Gastroenterol. Nutr. 35 (3), 350–355.
74. Boudeau, J., Glasser, A.L., Julien, S., Colombel, J.F., Darfeuille- Michaud, A., 2003. Inhibitory effect of probiotic Escherichia coli strain Nissle 1917 on adhesion to and invasion of intestinal epithelial cells by adherent-invasive E. coli strains isolated from patients with Crohn's disease. Aliment. Pharmacol. Ther. 18, 45–56.
75. Mego, M., Majek, J., Koncekova, R., Ebringer, L., Ciernikova, S., Rauko, P., Kovac, M., Trupl, J., Slezak, P., Zajac, V., 2005. Intramucosal bacteria in colon cancer and their elimination by probiotic strain Enterococcus faecium M-74 with organic selenium. Folia Microbiol. (Praha) 50, 443–447.
76. Thirabunyanon, M., Boonprasom, P., Niamsup, P., 2009. Probiotic potential of lactic acid bacteria isolated from fermented dairy milks on antiproliferation of colon cancer cells. Biotechnol. Lett. 31, 571– 576.
77. Abdin, A.A., Saeid, E.M., 2008. An experimental study on ulcerative colitis as a potential target for probiotic therapy by Lactobacillus acidophilus with or without ''olsalazine''. J. Crohns. Colitis. 2, 296– 303.
78. Adam, B., Liebregts, T., Holtmann, G., 2006. Maintaining remission of ulcerative colitis with the probiotic Escherichia coli Nissle 1917 is as effective as with standard mesalazine. Z. Gastroenterol. 44, 267– 269.
79. Imaoka, A., Shima, T., Kato, K., Mizuno, S., Uehara, T., Matsumoto, S., Setoyama, H., Hara, T., Umesaki, Y., 2008. Anti-inflammatory activity of probiotic Bifidobacterium: enhancement of IL-10 production in peripheral blood mononuclear cells from ulcerative colitis patients and inhibition of IL-8 secretion in HT-29 cells. World J. Gastroenterol. 14, 2511–2516.
80. Iarovenko, I.I., Golofeevskii, V., Sitkin, S.I., 2007. The new possibilities for improving peptic ulcer therapy with the use of probiotic drugs. Voen. Med. Zh. 328, 17–22
81. Hlivak, P., Odraska, J., Ferencik, M., Ebringer, L., Jahnova, E., Mikes, Z., 2005. One-year application of probiotic strain Enterococcus faecium M-74 decreases serum cholesterol levels. Bratisl. Lek. Listy 106, 67–72.

82. Kiatpapan, P., Yamashita, M., Kawaraichi, N., Yasuda, T., Murooka, Y., 2001. Heterologous expression of a gene encoding cholesterol oxidase in probiotic strains of Lactobacillus plantarum and Propionibacterium freudenreichii under the control of native promoters. J. Biosci. Bioeng. 92, 459–465.
83. Lesan S, Hajifattahi F, Rahbar M, et al. The effect of probiotic yoghurt on the frequency of salivary candida. J Res Dentomaxillofac Sci. 2017;2(2):1-7.
84. Ravinder Nagpal1, Ashwani Kumar2, Manoj Kumar3, Pradip V. Behare4, Shalini Jain5 & Hariom Yadav; Probiotics, their health benefits and applications for developing healthier foods: a review; FEMS Microbiol Lett 334 (2012) 1–15; DOI: 10.1111/j.1574-6968.2012. 02593.x
85. Pineiro M, Asp N-G, Reid G, et al. FAO Technical meeting on prebiotics. J Clin Gastroenterol 2008;42: S156–9.
86. Amy M. Brownawell,3 Wim Caers,4 Glenn R. Gibson,5 Cyril W. C. Kendall,6 Kara D. Lewis,3* Yehuda Ringel,7 and Joanne L. Slavin8; Prebiotics and the Health Benefits of Fiber: Current Regulatory Status, Future Research, and Goals; J. Nutr. 142: 962–974, 2012.
87. Crittenden R, Playne MJ. Production, properties and applications of food-grade oligosaccharides. *Trends Food Sci Technol* 1996; 7:353–61.
88. Bird AR, Brown IL, Topping DL. Starches, resistant starches, the gut microflora and human health. *Curr Issues Intest Microbiol* 2000; 1:25–37.
89. Crittenden RG. Prebiotics. In: Tannock GW, editor. *Probiotics: a critical review*. Wymondham (England): Horizon Scientific Press; 1999. p. 141–56.
90. Sangeetha P, Ramesh M, Prapulla S. Recent trends in the microbial production, analysis and application of fructooligosaccharides. *Trends Food Sci Technol* 2005; 16:442–57.
91. Niba AT, Beal JD, Kudi AC, Brooks PH. Bacterial fermentation in the gastrointestinal tract of non-ruminants: influence of fermented feeds and fermentable carbohydrates. *Tropical animal health and production* 2009;41(7):1393.
92. Iacovou M, Tan V, Muir JG, Gibson PR. The Low FODMAP diet and its application in east and Southeast Asia. *J Neurogastroenterol Motil* 2015; 21:459.
93. Chow J. Probiotics and prebiotics: a brief overview. *J Ren Nutr* 2002; 12:76–86.
94. Anadón A, Martínez-Larrañaga MR, Caballero V, Castellano V. Assessment of prebiotics and probiotics: an overview. In: Watson RR, Preedy VR, editors. *Bioactive foods in promoting health: probiotics and prebiotics*. San Diego (CA): Academic Press; 2010. p. 19–41.
95. Niba AT, Beal JD, Kudi AC, Brooks PH. Bacterial fermentation in the gastrointestinal tract of non-ruminants: influence of fermented feeds and fermentable carbohydrates. *Tropical animal health and production* 2009;41(7):1393.
96. Arena MP, Russo P, Capozzi V, et al. Combinations of cereal β-glucans and probiotics can enhance the anti-inflammatory activity on host cells by a synergistic effect. *J Funct Foods* 2016; 23:12–23.
97. Shigwedha N, Hiwilepo-Van Hal P, Jia L, Sichel L, Zhang S. Prebiotics: metabolism and symbiotic synergy with probiotics in promoting health. In: Rao V, Rao LG, editors. *Probiotics and prebiotics in human nutrition and health*. InTech; 2016.
98. Kohmoto T, Kukui F, Takaku H, Machida Y, Arai M, Mitsuoka T. Effect of isomalto-oligosaccharides on human fecal flora. *Bifidobact Microflora* 1988; 7:61–9.
99. Conway PL. Prebiotics and human health: the state-of-the-art and future perspectives. *Näringsforskning* 2001; 45:13–21.

100. Saunders D, Wiggins H. Conservation of mannitol, lactulose, and raffinose by the human colon. *Am J Physiol Gastrointest Liver Physiol* 1981;241: G397–402.
101. Crittenden RG. Prebiotics. In: Tannock GW, editor. *Probiotics: a critical review*. Wymondham (England): Horizon Scientific Press; 1999. p. 141–56.
102. Venema K. Intestinal fermentation of lactose and prebiotic lactose derivatives, including human milk oligosaccharides. *Int Dairy J* 2012; 22:123–40.
103. Crittenden, R.; Playne, M.J. Prebiotics. In Handbook of Probiotics and Prebiotics; Lee, Y.K., Salminen, S., Eds.; John Wiley & Sons Inc.: Hoboken, NJ, USA, 2009; pp. 535–561.
104. Schley, P.D.; Field, C.J. The immune-enhancing effects of dietary fibres and prebiotics. Br. J. Nutr. 2002, 87, S221–S230.
105. Paulina Markowiak, Katarzyn Sli˙zewska; Effects of Probiotics, Prebiotics, and Synbiotics on Human Health; Nutrients 2017, 9, 1021; doi:10.3390/nu9091021
106. Whelan, K. Mechanisms and effectiveness of prebiotics in modifying the gastrointestinal microbiota for the management of digestive disorders. Proc. Nutr. Soc. 2013, 72, 288–298
107. Wilson, B.; Whelan, K. Prebiotic inulin-type fructans and galacto-oligosaccharides: Definition, specificity, function, and application in gastrointestinal disorders. J. Gastroenterol. Hepatol. 2017, 32, 64–68.
108. Lindsay, J.O.; Whelan, K.; Stagg, A.J.; Gobin, P.; Al-Hassi, H.O.; Rayment, N.; Kamm, M.; Knight, S.C.; Forbes, A. Clinical, microbiological, and immunological effects of fructo-oligosaccharide in patients with crohn's disease. Gut 2006, 55, 348–355.
109. Wollowski I, Rechkemmer G, Pool-Zobel BL. Protective role of probiotics and prebiotics in colon cancer. *Am J Clin Nutr* 2001;73. 451s-455s.
110. Hamer HM, Jonkers D, Venema K, Vanhoutvin S, Troost F, Brummer RJ. The role of butyrate on colonic function. *Aliment Pharmacol Ther; 2008*; 27:104–19.
111. Patel, R.M.; Denning, P.W. Therapeutic use of prebiotics, probiotics, and postbiotics to prevent necrotizing enterocolitis: What is the current evidence? Clin. Perinatol. 2013, 40, 11–25.
112. Knol, J.; Boehm, G.; Lidestri, M.; Negretti, F.; Jelinek, J.; Agosti, M.; Stahl, B.; Marini, A.; Mosca, F. Increase of faecal bifidobacteria due to dietary oligosaccharides induces a reduction of clinically relevant pathogen germs in the faeces of formula-fed preterm infants. Acta Paediatr. 2005, 94, 31–33.
113. Boehm, G.; Lidestri, M.; Casetta, P.; Jelinek, J.; Negretti, F.; Stahl, B.; Marini, A. Supplementation of a bovine milk formula with an oligosaccharide mixture increases counts of faecal bifidobacteria in preterm infants. Arch. Dis. Childhood-Fetal Neonatal Ed. 2002, 86, F178–F181.
114. Kapiki, A.; Costalos, C.; Oikonomidou, C.; Triantafyllidou, A.; Loukatou, E.; Pertrohilou, V. The effect of a fructo-oligosaccharide supplemented formula on gut flora of preterm infants. Early Hum. Dev. 2007, 83, 335–339.
115. Ooi L-G, Liong M-T. Cholesterol-lowering effects of probiotics and prebiotics: a review of in vivo and in vitro findings. *Int J Mol Sci* 2010; 11:2499–522.
116. Gyawali R, Ibrahim SA. Impact of plant derivatives on the growth of foodborne pathogens and the functionality of probiotics. *Appl Microbiol Biotechnol* 2012; 95:29–45.
117. Conlon MA, Bird AR. The impact of diet and lifestyle on gut microbiota and human health. *Nutrients* 2014; 7:17–44.

118. 118. WHO. Global report on diabetes. October 9, 2017. Retrieved from: http://www.who.int/diabetes/global-report/en/.
119. Slavin J. Fiber and prebiotics: mechanisms and health benefits. Nutrients 2013; 5:1417–35.
120. Hopping BN, Erber E, Grandinetti A, Verheus M, Kolonel LN, Maskarinec G. Dietary fiber, magnesium, and glycemic load alter risk of type 2 diabetes in a multiethnic cohort in Hawaii. J Nutr 2010; 140:68–74.
121. Shigwedha N, Hiwilepo-Van Hal P, Jia L, Sichel L, Zhang S. Prebiotics: metabolism and symbiotic synergy with probiotics in promoting health. In: Rao V, Rao LG, editors. Probiotics and prebiotics in human nutrition and health. InTech; 2016.
122. Mudd, A.T.; Alexander, L.S.; Berding, K.; Waworuntu, R.V.; Berg, B.M.; Donovan, S.M.; Dilger, R.N. Dietary prebiotics, milk fat globule membrane, and lactoferrin affects structural neurodevelopment in the young piglet. Front. Pediatr. 2016, 4, 4.
123. Savignac, H.M.; Corona, G.; Mills, H.; Chen, L.; Spencer, J.P.; Tzortzis, G.; Burnet, P.W. Prebiotic feeding elevates central brain derived neurotrophic factor, n-methyl-d-aspartate receptor subunits and d-serine. Neurochem. Int. 2013, 63, 756–764.
124. Williams, S.; Chen, L.; Savignac, H.M.; Tzortzis, G.; Anthony, D.C.; Burnet, P.W. Neonatal prebiotic (bgos) supplementation increases the levels of synaptophysin, glun2a-subunits and bdnf proteins in the adult rat hippocampus. Synapse 2016, 70, 121–124
125. Heijtz, R.D.; Wang, S.; Anuar, F.; Qian, Y.; Björkholm, B.; Samuelsson, A.; Hibberd, M.L.; Forssberg, H.; Pettersson, S. Normal gut microbiota modulates brain development and behavior. Proc. Natl. Acad. Sci. USA 2011, 108, 3047–3052.
126. Neufeld, K.; Kang, N.; Bienenstock, J.; Foster, J. Reduced anxiety-like behavior and central neurochemical change in germ-free mice. Neurogastroenterol. Motil. 2011, 23, 255-e119
127. Sudo, N.; Chida, Y.; Aiba, Y.; Sonoda, J.; Oyama, N.; Yu, X.N.; Kubo, C.; Koga, Y. Postnatal microbial colonization programs the hypothalamic–pituitary–adrenal system for stress response in mice. J. Physiol. 2004, 558, 263–275.
128. Nelson, E.D.; Ramberg, J.E.; Best, T.; Sinnott, R.A. Neurologic effects of exogenous saccharides: A review of controlled human, animal, and in vitro studies. Nutr. Neurosci. 2012, 15, 149–162.
129. Han, H.S.; Jang, J.-H.; Jang, J.H.; Choi, J.S.; Kim, Y.J.; Lee, C.; Lim, S.H.; Lee, H.-K.; Lee, Water extract of triticum aestivum l. And its components demonstrate protective effect in a model of vascular dementia. J. Med. Food 2010, 13, 572–578.
130. Müller, J.B.; Guggenheim, P.; Haemmerli, U. Treatment of chronic portal-systemic encephalopathy with lactulose. Lancet 1966, 287, 890–893.
131. Prasad, S.; Dhiman, R.K.; Duseja, A.; Chawla, Y.K.; Sharma, A.; Agarwal, R. Lactulose improves cognitive functions and health-related quality of life in patients with cirrhosis who have minimal hepatic encephalopathy. Hepatology 2007, 45, 549–559.
132. Shukla, S.; Shukla, A.; Mehboob, S.; Guha, S. Meta-analysis: The effects of gut flora modulation using prebiotics, probiotics and synbiotics on minimal hepatic encephalopathy. Aliment. Pharmacol. Ther. 2011, 33,662–671.;

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3. Nutrition Treatment Plan

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3.1 Introduction:

Nutrition plays a crucial role in maintaining good health and preventing disease. It is important for individuals to have a balanced and varied diet that includes all essential nutrients. However, for individuals with specific medical conditions, a specialized nutrition treatment plan may be necessary to manage their condition and improve their overall health. A nutrition treatment plan is a personalized plan that is developed by a registered dietitian or nutritionist in collaboration with other healthcare professionals, such as a physician or nurse. The plan takes into account the individual's medical history, current health status, and personal preferences. The goal of the nutrition treatment plan is to provide the individual with the necessary nutrients to support their health and manage their condition.

3.2 Nutrition Treatment Steps:

The first step in developing a nutrition treatment plan is to conduct a comprehensive nutrition assessment. This assessment includes a thorough evaluation of the individual's dietary intake, anthropometric measurements, and laboratory data. The registered dietitian or nutritionist will use this information to identify any nutrient deficiencies or imbalances and to determine the individual's calorie and nutrient needs.

The next step is to set realistic and specific goals for the individual. These goals should be tailored to the individual's specific needs and should be achievable within a reasonable time frame. The registered dietitian or nutritionist will then develop a personalized meal plan for the individual that includes a variety of foods that meet their calorie and nutrient needs. The meal plan should also take into account the individual's preferences and cultural background. It is also important to monitor the individual's progress and make adjustments to the nutrition treatment plan as needed. The registered dietitian or nutritionist should schedule regular follow-up appointments to review the individual's progress and make any necessary adjustments to the plan.

A nutrition treatment plan is a personalized plan that is developed by a registered dietitian or nutritionist in collaboration with other healthcare professionals. It takes into account the individual's medical history, current health status, and personal preferences and aims to provide the individual with the necessary nutrients to support their health and manage their condition. It is important to conduct regular follow-up appointments to review the individual's progress and make any necessary adjustments to the plan.

3.3 Principles of Nutritional Treatment Plan:

In addition to the general aspects of nutrition treatment, there are specific medical conditions that require specialized nutrition plans. For example, individuals with diabetes may require a meal plan that is high in fiber and low in carbohydrates to manage their blood sugar levels.

Individuals with heart disease may require a meal plan that is low in saturated and trans-fats, cholesterol, and salt to reduce their risk of cardiovascular disease. Individuals with food allergies or intolerances may require a meal plan that eliminates certain foods or ingredients.

Nutrition treatment plans for weight management are also important for individuals who are overweight or obese. The registered dietitian or nutritionist will develop a calorie-controlled meal plan that promotes weight loss while providing all essential nutrients. Physical activity and behavior modification strategies are also often incorporated into weight management nutrition treatment plans.

It's also important to note that some medical conditions may require enteral or parenteral nutrition. Enteral nutrition refers to the delivery of nutrition via the gastrointestinal tract, while parenteral nutrition refers to the delivery of nutrition via an intravenous line. These specialized nutrition plans are typically used for individuals who are unable to maintain adequate nutrition through oral intake alone, such as those with severe malabsorption or who are critically ill.

Overall, a nutrition treatment plan is a critical component of managing and improving health for individuals with specific medical conditions. Registered dietitians and nutritionists play a vital role in developing and implementing these plans, working in collaboration with other healthcare professionals to ensure optimal health outcomes.

3.4 Basic Ideas for Nutrition Treatment Plan:

It is also worth mentioning that a nutrition treatment plan should also consider any supplements or vitamins the individual may be taking. It is important to ensure that any supplements or vitamins are appropriate for the individual's specific medical condition and that they do not interact with any medications the individual may be taking.

Another important aspect of nutrition treatment plan is the education of the individual and their caregivers. The registered dietitian or nutritionist should provide the individual and their caregivers with the necessary information and resources to understand and implement the nutrition treatment plan. This may include information on how to read food labels, how to prepare healthy meals, and how to make healthy food choices when eating out.

It is also important to consider the psychological and social aspects of nutrition and eating. Registered dietitians and nutritionists should be aware of the potential emotional and social barriers to adherence to the nutrition treatment plan. They should address these barriers through counseling, support groups, and other interventions as necessary.

In summary, a nutrition treatment plan is a personalized plan that takes into account an individual's medical history, current health status, and personal preferences. It should be developed by a registered dietitian or nutritionist in collaboration with other healthcare professionals and should include regular follow-up appointments to monitor progress.

The plan should be tailored to the individual's specific medical condition, consider any supplements or vitamins the individual may be taking, provide education and resources to understand and implement the plan, and address any emotional or social barriers to adherence.

3.5 Factors That Affected Nutrition Treatment Plan:

A nutrition treatment plan will vary depending on the individual's specific medical condition, dietary needs, and personal preferences. Below is an example of a nutrition treatment plan for an individual with type 2 diabetes:

A. Assessment:

- The individual is a 60-year-old male with a history of type 2 diabetes, hypertension, and hyperlipidemia.
- The individual's anthropometric measurements show a BMI of 30 kg/m2, indicating obesity.
- Laboratory data shows that the individual's hemoglobin A1c is 7.5%, indicating poor glucose control.
- The individual's dietary intake assessment reveals that he consumes a diet high in refined carbohydrates and saturated fat, and low in fiber.

B. Goals:

- Improve glucose control by decreasing hemoglobin A1c to 7% or lower
- Reduce total and LDL cholesterol levels
- Achieve and maintain a healthy body weight (BMI <25 kg/m2)

C. Intervention:

- Develop a calorie-controlled meal plan that provides 1200-1400 calories per day, with 45-50% of calories from carbohydrates, 20-25% of calories from protein, and 25-30% of calories from fat.
- Include at least 3 servings of whole grains, 3 servings of fruits, and 4 servings of vegetables daily
- Include lean protein sources such as fish, poultry, and legumes
- Limit saturated fat and cholesterol intake by choosing low-fat dairy products, lean meats, and plant-based protein sources
- Provide education on carbohydrate counting and the importance of consistent meal timing

D. Monitoring:

- Schedule follow-up appointments every 2-3 months to review the individual's progress and make any necessary adjustments to the meal plan
- Monitor the individual's hemoglobin A1c, lipid profile, and weight at each follow-up appointment

It's worth noting that this is an example, and the specific plan will vary depending on the individual's needs, preferences and other factors, but the approach is similar.

3.6 There are Several Factors that can Affect the Success of a Nutrition Treatment Plan. These Include:

- Medical condition: The specific medical condition of the individual will determine the types of foods and nutrients that are necessary for the treatment plan. For example, a nutrition treatment plan for an individual with diabetes will be different from a plan for an individual with celiac disease.
- Food preferences and cultural background: An individual's food preferences and cultural background can play a significant role in the development of a nutrition treatment plan. The plan should take into account the individual's likes and dislikes as well as their cultural and religious beliefs.
- Medications: The individual's medication regimen can affect their nutrient needs and can also interact with certain foods. It's important to consider any medications the individual is taking when developing the nutrition treatment plan.
- Social and psychological factors: Social and psychological factors, such as stress, depression, and social support, can affect an individual's ability to adhere to a nutrition treatment plan. Registered dietitians and nutritionists should be aware of these factors and provide counseling and support as needed.
- Access to healthy foods: Access to healthy foods can be a barrier to adherence to a nutrition treatment plan. Individuals living in food deserts or with limited financial resources may have difficulty accessing fresh fruits and vegetables, lean proteins, and whole grains.
- Physical ability: Physical ability can also be a factor that affects the success of a nutrition treatment plan. Individuals with physical disabilities or mobility issues may have difficulty preparing meals or accessing healthy foods.
- Compliance: Compliance is a key factor in the success of a nutrition treatment plan. Individuals should be provided with the necessary education and resources to understand and implement the plan, and regular follow-up appointments should be scheduled to monitor progress and address any barriers to adherence.
- Follow up and monitoring: Regular monitoring and follow-up of the individual's progress is crucial to ensure the success of the nutrition treatment plan. The registered dietitian or nutritionist should schedule regular follow-up appointments to review the individual's progress and make any necessary adjustments to the plan.

3.7 The Variations of Food and Environment Can Have a Significant Impact on the Success of a Nutrition Treatment Plan:

A. Variation of Food:

The availability of certain foods can vary depending on the season, geographical location, and cultural background.

For example, an individual living in a rural area may have limited access to fresh fruits and vegetables, while an individual living in an urban area may have access to a wide variety of foods. This can make it difficult to adhere to a nutrition treatment plan that includes specific foods that may not be readily available.

B. Food Insecurity:

Food insecurity, or the lack of consistent access to enough food for an active, healthy life, can also impact the success of a nutrition treatment plan. Individuals experiencing food insecurity may not have the resources to purchase healthy foods or may resort to cheaper, less nutritious options.

C. Cultural and Religious Beliefs:

Cultural and religious beliefs can also affect an individual's food choices and ability to adhere to a nutrition treatment plan. For example, certain religious groups may prohibit the consumption of certain foods, such as pork or shellfish, which may need to be taken into consideration when developing a nutrition treatment plan.

D. Food Preparation:

The environment and the available resources for food preparation can also affect the success of a nutrition treatment plan. Individuals living in areas with limited access to cooking equipment or in temporary housing may have difficulty preparing meals or may resort to fast food or pre-packaged meals, which are often high in calories and unhealthy fats.

E. Food Environment:

The food environment, including the availability of healthy food options in the immediate area and the presence of fast food restaurants or convenience stores, can also impact an individual's food choices and ability to adhere to a nutrition treatment plan.

It is important for healthcare professionals to take these variations and factors into account when developing a nutrition treatment plan for an individual.

They should work with the individual to identify any potential barriers and to find solutions that will enable the individual to adhere to the plan despite these variations.

3.8 The Relationship Between Nutrionists and Physicians and Coordination of Nutrition Treatment Plan?

Nutritionists and physicians play important roles in the coordination of nutrition treatment plans.

A. Nutritionists:

Registered dietitians and nutritionists are experts in the field of nutrition and are responsible for conducting nutrition assessments, developing nutrition treatment plans, and providing education and counseling to individuals. They work closely with individuals to understand their medical history, dietary needs, and personal preferences, and use this information to create a personalized nutrition treatment plan.

B. Physicians:

Physicians, such as family doctors or specialists, are responsible for the overall medical care of an individual. They are responsible for diagnosing medical conditions and prescribing medications, and they also provide referrals to registered dietitians or nutritionists for nutrition treatment plans.

C. Coordination:

Nutritionists and physicians work together to coordinate the care of individuals with specific medical conditions. The nutritionist will provide the physician with updates on the individual's progress and any necessary adjustments to the nutrition treatment plan, and the physician will provide updates on the individual's medical status and any changes to the medication regimen.

D. Communication:

Effective communication between nutritionists and physicians is critical for ensuring that the individual receives the best possible care. Regular meetings and case conferences can help to ensure that all healthcare professionals are aware of the individual's progress and any changes that need to be made to the nutrition treatment plan.

E. Teamwork:

Nutritionists and physicians work together as a team to provide comprehensive care for the individual. They use their respective areas of expertise to provide the best possible care for the individual and work together to achieve the best possible health outcomes.

In conclusion, the relationship between nutritionists and physicians is important for the coordination of nutrition treatment plans. They both play a vital role in providing comprehensive care for individuals with specific medical conditions and work together to achieve optimal health outcomes.

3.9 Here Is an Example of a Nutrition Treatment Plan for an Individual with Type 2 Diabetes:

A. Assessment:

- The individual is a 65-year-old female with a history of type 2 diabetes, hypertension, and hyperlipidemia.
- The individual's anthropometric measurements show a BMI of 32 kg/m2, indicating obesity.
- Laboratory data shows that the individual's hemoglobin A1c is 8%, indicating poor glucose control.
- The individual's dietary intake assessment reveals that she consumes a diet high in refined carbohydrates and saturated fat, and low in fiber.

B. Goals:

- Improve glucose control by decreasing hemoglobin A1c to 7% or lower
- Reduce total and LDL cholesterol levels
- Achieve and maintain a healthy body weight (BMI <25 kg/m2)

C. Intervention:

- Develop a calorie-controlled meal plan that provides 1200-1400 calories per day, with 45-50% of calories from carbohydrates, 20-25% of calories from protein, and 25-30% of calories from fat.
- Include at least 3 servings of whole grains, 3 servings of fruits, and 4 servings of vegetables daily
- Include lean protein sources such as fish, poultry, and legumes
- Limit saturated fat and cholesterol intake by choosing low-fat dairy products, lean meats, and plant-based protein sources
- Provide education on carbohydrate counting and the importance of consistent meal timing
- Suggest her to do physical activity for at least 30 minutes per day, 5 days a week

D. Monitoring:

- Schedule follow-up appointments every 2-3 months to review the individual's progress and make any necessary adjustments to the meal plan
- Monitor the individual's hemoglobin A1c, lipid profile, and weight at each follow-up appointment
- Monitor her physical activity level and progress.

Note that this is an example, and the specific plan will vary depending on the individual's needs, preferences and other factors.

This plan is tailored to this specific individual and may not be appropriate for everyone with type 2 diabetes.

It's also important to consult a registered dietitian or a physician before starting any new diet or treatment plan.

3.10 Example of Parental and Enternal Feeding in Hospital?

Parental and enteral feeding are specialized forms of nutrition support that are used in the hospital setting for individuals who are unable to maintain adequate nutrition through oral intake alone.

A. Parental nutrition: Parental nutrition refers to the delivery of nutrients via an intravenous line (IV) directly into the bloodstream. This method is used for individuals who are critically ill or who have severe malabsorption and are unable to absorb nutrients from the gastrointestinal tract. Parental nutrition is typically administered through a central venous catheter (CVC) or a peripheral IV line.
B. Enteral nutrition: Enteral nutrition refers to the delivery of nutrients via a tube that is placed directly into the stomach or small intestine. This method is used for individuals who are unable to eat or swallow due to a medical condition or surgical procedure. Enteral nutrition is typically administered through a nasogastric (NG) tube, nasojejunal (NJ) tube, or a gastrostomy (G) tube.
C. Coordination: The coordination of parental and enteral feeding in the hospital setting involves a team of healthcare professionals, including physicians, nurses, dietitians, and pharmacists. The team works together to determine the appropriate method of nutrition support, monitor the individual's progress, and make any necessary adjustments to the nutrition plan.
D. Monitoring: Monitoring is an essential part of parental and enteral feeding in the hospital setting. The healthcare team closely monitors the individual's vital signs, laboratory values, and response to the nutrition support. They also monitor for any complications such as infections, blood clots, and blockages in the tubes.
E. Education: Education is also a critical aspect of parental and enteral feeding in the hospital setting. The healthcare team provides education to the individual, their caregivers, and their family members on the proper care and maintenance of the nutrition support equipment, as well as the importance of proper hygiene to prevent infection.
F. Transitioning: Once the individual's condition improves, they will be transitioned back to oral intake as soon as possible. The healthcare team works closely with the individual and their family to ensure a smooth transition back to oral nutrition.
G. example of parental and enteral feeding in the hospital setting. It is important to note that the specific treatment plan for an individual will vary depending on their specific medical condition, nutritional needs, and other factors. The healthcare team will work closely with the individual and their family to determine the most appropriate form of nutrition support and to monitor progress throughout the course of treatment. Additionally, parental and enteral feeding should be administered under the supervision of a physician or a nurse practitioner, and the healthcare team should be aware of the potential risks and side effects associated with these forms of nutrition support.

3.11 Nutrition therapist role in treatment of obesity in children and adults?

Nutrition therapists play an important role in the treatment of obesity in both children and adults. The role of nutrition therapy in treating obesity includes:

A. Conducting a thorough nutrition assessment: This includes taking a detailed dietary history, measuring anthropometric indicators such as body weight, height, and body mass index (BMI) and assessing the individual's current dietary habits and physical activity level.
B. Developing a personalized nutrition treatment plan: Based on the results of the nutrition assessment, the therapist will develop an individualized plan that includes specific goals and strategies for achieving a healthy body weight. This may include recommendations for calorie-controlled meals, nutrient-dense foods, and physical activity.
C. Providing education and counseling: Nutrition therapists will provide education on the importance of healthy eating, physical activity, and behavior modification techniques to help individuals achieve their weight loss goals. They will also provide counseling and support to help individuals overcome emotional and psychological barriers to weight loss.
D. Monitoring progress: The nutrition therapist will regularly monitor the individual's progress, including changes in body weight, BMI, and other anthropometric indicators, and make any necessary adjustments to the nutrition treatment plan.
E. Collaboration with other healthcare professionals: Nutrition therapists often work as part of a multidisciplinary team of healthcare professionals, including physicians, nurses, and exercise physiologists, to provide comprehensive care for individuals with obesity.
F. Specialized programs: Nutrition therapists may also be involved in the development and implementation of specialized programs such as weight management program, bariatric surgery pre-and post-surgery nutrition program, and lifestyle modification programs.

In summary, nutrition therapists play a crucial role in the treatment of obesity in both children and adults. They use their expertise in nutrition and behavior change to develop personalized nutrition treatment plans, provide education and counseling, and monitor progress to help individuals achieve a healthy body weight.

3.12 References:

1. American Dietetic Association. (2016). Nutrition Care Manual.
2. National Institute of Diabetes and Digestive and Kidney Diseases. (2017). Nutrition Therapy for Diabetes.
3. American Academy of Pediatrics. (2018). Nutrition in Pediatrics: Basic Science and Clinical Applications.
4. World Health Organization. (2020). Nutrition.
5. American College of Sports Medicine. (2021). Nutrition and Athletic Performance.
6. American Diabetes Association. (2019). Standards
7. American Heart Association. (2018). Diet and Lifestyle Recommendations.
8. National Institute of Allergy and Infectious Diseases. (2019). Food Allergy: A Guide for Families.

9. American Medical Association. (2020). Obesity: Assessment and Management.
10. American Society for Parenteral and Enteral Nutrition. (2021). Clinical Guide to Parenteral and Enteral Nutrition.
11. American Dietetic Association. (2018). Position of the American Dietetic Association: Supplementation of Vitamins and Minerals.
12. American Psychological Association. (2019). Psychological Aspects of Eating and Nutrition.
13. American Nurses Association. (2020). Social and Psychological Factors in Nutrition.
14. American Medical Association. (2013). Policy on Childhood Obesity.
15. American Dietetic Association. (2011). Position of the American Dietetic Association: Nutrition Intervention in the Treatment of Anorexia Nervosa, Bulimia Nervosa, and Other Eating Disorders.
16. American Academy of Pediatrics. (2015). Bright Futures: Nutrition.
17. American Psychological Association. (2016). Understanding and Treating Obesity as a Behavioral Disorder.
18. World Health Organization. (2020). Obesity and Overweight.
19. International Association for the Study of Obesity. (2018). Clinical Guidelines for the Management of Adult Obesity.
20. Academy of Nutrition and Dietetics. (2016). Nutrition Care for Adults with Obesity.
21. These references may provide more detailed information on the topics discussed in my previous answers, such as the role of nutrition therapy in treating obesity, the importance of regular monitoring, the importance of a multidisciplinary team approach, and the importance of education and counseling.

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4. Alternative Proteins - Food and Feed for The Future

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Abstract:

The population boom and rising incomes will increase the global demand for meat in the near future. Sustainable alternative proteins could be a solution to reduce the protein gap i.e., the gap between the protein demand and protein supply. Alternative proteins are proteins sourced from plants, insects, fungi or through tissue culture to replace conventional animal based sources. The different types of alternative proteins are single cell proteins, food analogues, protein isolates, leaf protein concentrate, insect proteins and mushrooms. Single cell protein (SCP) is a generic term for crude or refined sources of protein obtained from unicellular or multicellular microorganisms such as yeast, bacteria, algae and fungi. Food analogue is a manufactured food product, designed to imitate a given food, possessing characteristics equal or superior to that of food. In vitro meat production is an emerging technology where cell culture and tissue engineering are involved to produce animal muscle in a laboratory. Isolates are the most refined form of protein products containing concentrated form of protein. Leaf protein concentrate is a nutritious protein source made by mechanically separating indigestible fibre and soluble anti-nutrients from fresh green leaves of plant. Consumption of insects or entomophagy is another area that needs to be explored. Mushrooms have a protein content ranging from 19.68 per cent to 36.96 per cent of dry weight. Hence, to meet the protein needs of the projected population of 10 billion by 2050, a change in food system with alternative proteins is necessary, which thereby helps to create a sustainable and healthy future with diminished environmental and health impacts.

Keywords:

Alternative proteins, Food analogues, Insect proteins, In vitro meat, Leaf protein concentrate, Mushrooms, Protein isolates, Single cell proteins

4.1 Introduction:

Today, due to population boom and rise in incomes there is an increase in the global demand for animal based proteins. Hence, one of the main concerns about world food supply is the production of proteins. Protein deficiency is one of the major nutritional problems in the world. In developing countries, the prevalence is 12.9 per cent and of developed countries is less than 5 per cent. This problem is not only the result of insufficient food production and inadequate distribution, but also the financial inability of the poor to purchase good quality animal protein. It is a global challenge to address food security and preserve land and water resources due to climate change, population growth and changing diets. Accordingly, interest in sustainable and biodiverse food systems is also on the rise. From a consumer's perspective, purchasing habits that can improve the environment are gaining prominence. Consumers are seeking transparency and sustainability in their food supply. Accordingly, food industries are interested in commercializing products formulated with ingredients derived from environmentally sustainable crops or process.

It is estimated that the livestock production does have an impact on environment, as there is emission of greenhouse gases such as methane and immense deforestation is taking place in the name of livestock production farms. To combat global protein deficiencies and to ensure the future of global food security it is required to make changes in the way we produce our food as well as in what we eat. Thus, food industrialists aim cheaper, high bioavailable and more convenient food products leading to development of novel protein sources. These sustainable alternative proteins could be a solution to reduce the protein gap i.e., the gap between the protein demand and protein supply.

4.2 Proteins:

The term protein is derived from a Greek word "*proteins"* meaning holding the first place. The term was coined by Jons Jacob Berzelius in 1838. Proteins are composed of amino acids and the main functions of protein in our body are body building and as an energy source providing 4 Kcal of energy per gram of protein.

Protein requirements vary with age, physiological status and stress. More proteins are required by growing infants and children, pregnant women and individuals during infections and illness or stress. Animal foods like milk, meat, fish and eggs, and plant foods such as pulses and legumes are rich sources of proteins.

4.3 Types of proteins:

Some of the types of proteins based on biological function other than body building and providing energy are:

- **Structural proteins:** Collagen / fibrous protein present in skin and bone. Also known as fibrous proteins, structural proteins are necessary components of your body. They include collagen, keratin and elastin. Collagen forms the connective framework of our muscles, bones, tendons, skin and cartilage. Keratin is the main structural component in hair, nails, teeth and skin.

- **Defensive protein:** Proteins in the form of clotting factors prevent the loss of blood and proteins in the form of immunoglobulins protect body from infections. Antibodies, or immunoglobulin, are a core part of immune system, keeping diseases at bay. Antibodies are formed in the white blood cells and attack bacteria, viruses and other harmful microorganisms, rendering them inactive.
- **Storage proteins:** Myoglobin is the protein that stores oxygen in muscles. Storage proteins store mineral ions in body. Iron, for example, is an ion required for the formation of hemoglobin, the main structural component of red blood cells. Ferritin - a storage protein - regulates and guards against the adverse effects of excess iron in your body. Ovalbumin is a storage proteins found in breast milk that play a huge role in embryonic development.
- **Receptor proteins:** Proteins responsible for transmitting nerve impulses. Located on the outer part of the cells, receptor proteins control the substances that enter and leave the cells, including water and nutrients. Some receptors activate enzymes, while others stimulate endocrine glands to secrete epinephrine and insulin to regulate blood sugar levels.
- **Hormonal and genetic regulatory proteins:** Coordinates the activities of different cells and genetic material. Hormones are protein-based chemicals secreted by the cells of the endocrine glands. Usually transported through the blood, hormones act as chemical messengers that transmit signals from one cell to another. Each hormone affects certain cells in your body, known as target cells. Such cells have specific receptors on which the hormone attaches itself to transmit the signals. An example of a hormonal protein is insulin, which is secreted by the pancreas to regulate the levels of blood sugar in your body.
- **Enzymes:** These are the proteins that catalyse chemical reactions in the body. Enzymatic proteins accelerate metabolic processes in cells, including liver functions, stomach digestion, blood clotting and converting glycogen to glucose. An example is digestive enzymes that break down food into simpler forms that your body can easily absorb.
- **Transport proteins:** These are the proteins such as albumin, heamoglobin that transport oxygen and iron through blood. Transport proteins carry vital materials to the cells e.g. hemoglobin, carries oxygen to body tissues from the lungs. Serum albumin carries fats in your bloodstream, while myoglobin absorbs oxygen from hemoglobin and then releases it to the muscles.

4.4 Alternative Proteins:

Alternative proteins are proteins sourced from plants, insects, fungi or through tissue culture to replace conventional animal based sources. These provide a substantial amount of protein, but requires less natural inputs (e.g. water) to produce, compared to the most common and conventional protein sources (i.e. meat and fish).

The advantages or rather need for alternative proteins is that a more sustainable alternative protein would help in diminishing environmental health impacts. Also, a thought to alternative proteins would help in developing products that are similar in sensorial characteristics to that of meat products. Most importantly it helps to reduce the protein gap.

4.5 Types of Alternative Proteins:

A. Single cell proteins
B. Food analogues
C. Protein isolates
D. Leaf protein concentrates
E. Insect proteins
F. Mushrooms

4.5.1 Single Cell Proteins (SCP):

Single cell protein is a generic term for crude or refined sources of protein whose origin is unicellular or multicellular microorganisms[1]. The term single cell proteins were coined by Carroll L. Wilson in 1966.

The advantages of single cell proteins are:

- Fast growth rate
- High yield of production
- Independent of seasons

There are different types of single cell proteins as shown in the Figure 4.1.

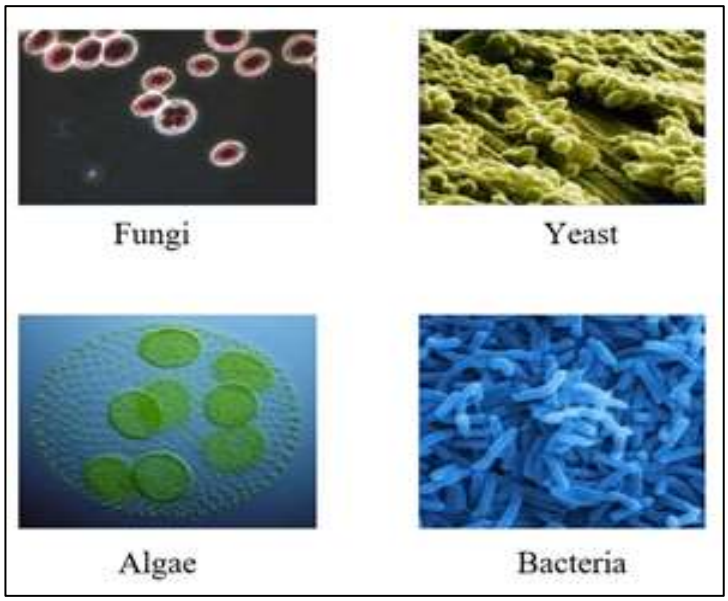

Figure 4.1: Types of SCP

Microorganisms can grow on a wide range of raw materials like low value wastes, cellulose, molasses, raffinose, whey *etc.* Different substrates used for SCP production are detailed in Table 4.1.

Table 4.1: Substrates used for SCP Production

Source	Example
Energy sources	Methanol, methane, ethanol, starch, glucose, maltose and lactose
Waste products	Molasses, raffinose, whey, cellulose, lignin, hemicellulose
Petroleum by-products	Natural gas and CO_2

A. Production of SCP:

The basic requirements for SCP production include pure culture of microorganism, a fermenter, bioreactor, thermostat, cooling device and an equipment for moisture removal.

The general protocol for SCP production is the addition of inoculum and the subsequent substrate along with the nutrients into the fermenter which is then aerated. When the microorganism is grown up to the required extent it is filtered which is then dried producing SCP.

The comparative evaluation of amino acids in SCP and egg reveals that leucine is the amino acid present in highest amount and methionine is the limiting amino acid. In India the SCP production is taking place at National Botanical Research Institute **(NBRI),** Lucknow and at Central Food Technological Research Institute **(CFTRI),** Mysuru.

4.5.2 Food Analogues:

Food analogues are manufactured food products, designed to imitate a given food, possessing characteristics equal or superior to that of food[2]. Different types of food analogues are discussed below.

A. Meat analogue:

Meat analogue, also called a meat substitute, mock meat, faux meat or imitation meat, approximates the aesthetic qualities and/or chemical characteristics of specific types of meat[3].

B. Textured vegetable protein (TVP):

TVP is a fabricated vegetable product mostly used to replace meat. It was invented at "Archer Daniel Midland" company in 1960. The TVP name is a registered trademark of this particular company. TVP is famous for its high protein and low fat content and it resembles meat mostly in terms of chewiness and flavor. There are two different types of TVP which is used as a meat analogue which is shown in the table (Table 4.2) below.

Table 4.2: Types of TVP used as Meat Analogue

Parameters	Dry meat analogue	Wet meat analogue
Moisture content (%)	20 – 40	50 – 70
Texture	Higher in springiness	Higher in hardness and cutting strength
Structure	Sponge like	Fibrous structure like muscle meat
Cooking	Rehydration prior to cooking	Direct cooking with added flavours
Shelf life	Within 6 months	Within 2 weeks
Storage	Dry and store at room temperature	In refrigerator
	Eg. Soy chunks 	

Green gram based meat analogue with 60 per cent green gram, 30 per cent wheat and 10 per cent soyabean could be prepared[4]. The method of preparation begins with pretreatment such as roasting of green gram for 15 minutes and soaking all the grains for 12 hours. To the pretreated grains, spices are added to enhance flavour. The mixture was then ground and steamed for 40 minutes which ones cooled were cut into desired shapes and kept for drying at 65° C for 18 hours. The organoleptic evaluation revealed great acceptance especially in terms of taste, texture and flavour. The nutritional quality evaluation (Table 4.3) showed that the developed meat analogue had a protein content of 26 g.

Table 4.3: Nutritional Quality Evaluation of Green Gram Based Meat Analogue

Nutrient	Amount (in 100g)
Protein (g)	26
Fat (g)	1.23
Dietary fibre (g)	1.82

Nutrient	Amount (in 100g)
Calcium (mg)	276
Potassium (mg)	72
Iron (mg)	1.89

C. Tempeh:

Tempeh is a compact and sliceable mass of cooked particles of raw materials covered, penetrated and held together by dense non-sporulated mycelium of *Rhizopus spp*[5]. The origin of tempeh was in Indonesia and the most isolated culture from tempeh is *Rhizopus oligosporus* and the most commonly used raw material for production of tempeh is soybean. The production process of soyabean based tempeh begins with the washing of soyabeans which is then boiled for 30 minutes. After boiling the soyabeans are washed again and is kept for soaking overnight. Then the dehulling is done and its surface is dried. To this vinegar is added and the inoculation is done after which it is kept for incubation at 32 C for 48 hours finally producing tempeh[6]. Tempeh could also be developed from raw materials other than soyabean such as green gram and combinations of green gram and rice. It was observed that the *invitro* digestibility of protein was higher for tempeh prepared with 100 per cent green gram than combinations of green gram and rice as well as 100 per cent soya bean and products such as tempeh roast, tempeh chips and soup mixes could also be developed from green gram based tempeh[7].

D. Tofu:

Tofu is another meat analogue also known as bean curd is prepared by coagulating soy milk and then pressing the resulting curds into solid white blocks of varying softness. It has a subtle flavour it can also be used in savory and sweet dishes. It is even possible to produce tofu with probiotic bacteria that has acceptable sensory characteristics by inoculating *Lactobacilus casie*, incubated at 37^0C for 2 hours with $CaSO_4$ which is the recommended treatment for commercial production. The protein content in normal tofu is 45 per cent and the probiotic incorporated tofu is 48.2 per cent[8].

E. In Vitro Meat:

In vitro meat in simple terms is the process of culturing muscle like tissue in liquid medium. The application of in vitro meat has been successful on producing ground and processed foods such as hamburgers. The goal of the industries involved in production of in vitro meat is to create traditional meat pieces such as chicken wing or beef steak.

The idea of developing cultured meat was predicted by Winston Churchill in 1920. Later in 1950 a Dutch researcher, Willian Van Eelen developed the idea of using tissue culture to develop *in vitro* meat. In 1995, the US Food and Drug Administration approved the commercial production of invitro meat and in 1999 William Van Eelen received the first patent. In 2013 Mark Post presented and sampled the first lab grown hamburger which received great appreciation and critical evaluation.

For the production process, first a technician takes cells from a live animal. Then these cells are grown up in a lab to permanently establish a culture called a cell line. Once a good cell line has been established, a sample is introduced into a bioreactor which is essentially a culture medium containing all the materials the cells need to grow. The cells in the bioreactor grow and multiply exponentially and are then harvested. Once harvested, the meat cells can be formed into any number of items such as patties and sausages.

The advantages of invitro meat when compared to that of livestock production are:

- Possibility in production of exotic meat
- For the same mass of meat, the nutrients and time needed for growing *in vitro* meat is less.
- There is better control over meat composition and quality
- The water, energy and land requirement for the production of invitro meat is less which could possibly alleviate the environmental burden

The possibility of requirement of less resources and energy for the production *of in vitro* meat was proved through a study conducted at Oxford University's Wild Conservation Research Unit and the results are depicted in the figure 4.2 and it suggests that when compared to livestock production, the energy and the land required for growing *in vitro* meat are 35 - 60 per cent and 80 - 95 per cent less respectively[9].

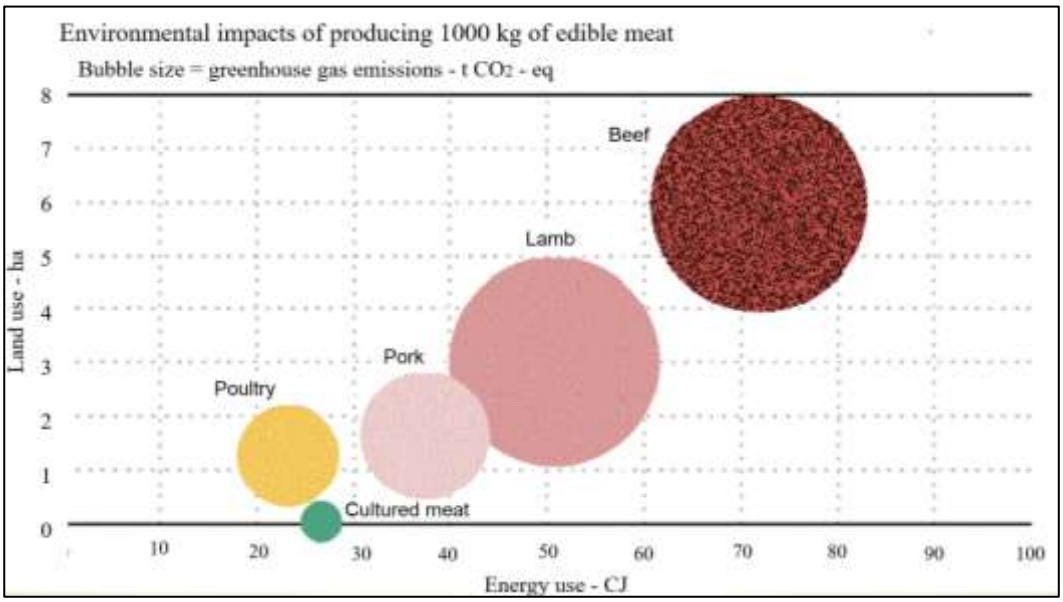

Figure 4.2: Environmental Impact of Producing Meat

The first cultured meat to get approval for sale was produced by the company "**Eat Just Inc."** under the brand name "**Good Meat**" in the year 2020 at Singapore. The product was chicken nuggets and it is sold for a price of $ 17.

Figure 4.3: In vitro meat

Figure 4.4: Chicken nuggets from cultured meat

4.6 Dairy Analogues:

Dairy analogue is an imitation product that is designed or structured to mimic or offered as an alternative/replacement to a milk or milk product by partial or full substitution with other components from non-dairy sources.

A. Cheese analogue:

Development of cheese analogues involves the use of fat and/or protein sources other than those native to milk, together with a flavor system simulating as closely as possible that of the natural product.

The major advantages of cheese analogues are that

- It helps to meet special dietary needs
- Manufacturing is simple
- Cost effective

The production of cheese analogue first the temperature of vegetable fat is raised to around 70^0 C and to this stabilizer such as sodium phosphate or sodium citrate is added forming an emulsion. Then protein, salt, acid and flavor are added and then it is refrigerated and stored. The protein content is comparable and the fat content is much less in cheese analogue when compared to that of natural cheese which makes cheese analogue a healthier alternative[10] (Table 4.4).

Table 4.4: Nutritional Qualities Comparison of Natural Cheese and Cheese Analogue

Nutrients	Natural cheese	Cheese analogue
Protein (g)	23.06	20.13
Fat (g)	24.56	15.23

Nutrients	Natural cheese	Cheese analogue
Calcium (mg)	0.62	0.39
Ash (%)	3.18	3.91

The beneficial aspect of synthetic cheese analogue is that many such products can be produced with high shelf life. Cheese analogue was functionally more stable during refrigerated storage than natural cheese. Such stability makes analogues very attractive to the food processing and service industries. They have consistent quality, without seasonal variations and they can be varied to meet desirable quality characteristics. Production can be scheduled to meet sales needs, eliminating or significantly reducing storage and refrigeration costs[11]. The different quality attributes of cheese analogue are given in table 4.5.

Table 4.5: Advantages of cheese analogue

Quality attributes	Natural cheese	Cheese analogue from soy protein
Shelf life	Low	High
Seasonality	Affects quality	Do not affect quality
Refrigerated storage	Low stability	High stability
Cost of production	High	Low
Nutritional quality variation	Can't design	Can design

B. Vegan paneer:

Vegan paneer is another dairy analogue with base ingredients soy and groundnut. The best vegan paneer is prepared with the addition of 10 per cent ground nut milk to 90 per cent soy milk due to the ability of groundnut milk to mask the bean flavor of soy. The protein content of soy-groundnut paneer is 15.5 per cent which is comparable to that of soy paneer[12].

4.7 Protein Isolates:

Isolates are the most refined form of protein products containing the concentrated form of protein but unlike flour and concentrates they contain no dietary fibre[13]. It is digestible, can be easily incorporated into different food products. Protein isolates are widely produced from cereal bran, deoiled cake of legumes, nuts and oil seeds.

For the production of protein isolates first the defatted nuts or seeds are taken along with water in the ration 1:10. Then the pH is adjusted to 9.5 and the slurry is centrifuged. The next step is precipitation after which the precipitate is taken and neutralized. It then undergoes freeze drying and is ready for storage[14].

Some of the examples of legumes, nuts and oilseeds used for protein isolation are rapeseed, groundnut, hemp seed, pea, sunflower seed, soybean *etc.* The comparison of essential amino acids of oilseeds such as chia, hemp and sesame depicts that leucine is the highest amino acid followed by valine and the methionine content is comparable to that of chicken[15] (Figure 4.5).

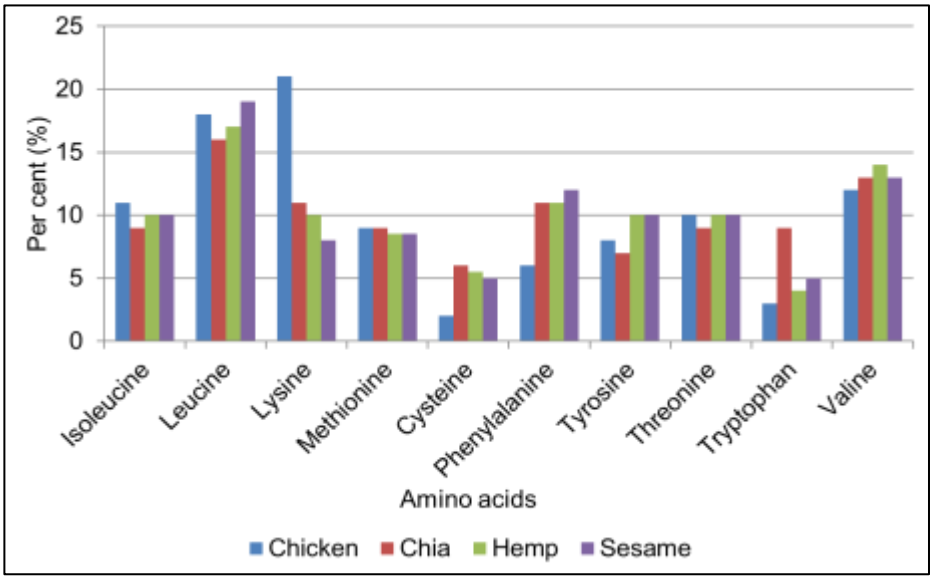

Figure 4.5: Comparison of Essential Amino Acids of Oilseeds with Chicken

The therapeutic benefits of rapeseed are due the presence of bioactive protein peptides that shows Angiotensin Converting Enzyme (ACE) inhibitory activity. This ACE is a key enzyme that regulate the blood pressure. In disease conditions the ACE increases which develops undesirable high blood pressure. Hence rapeseed could be a natural peptide that can act as an ACE inhibitor for the treatment of hypertension. Also rapeseed contains phenolic compounds such as sinapine which shows antioxidant activity[16].

Cereals are edible seeds from agricultural grasses and bran is the skin of an edible seed. Bran is obtained while dehusking and polishing whole grain in order to obtain polished grain. The different proteins form in cereal brans are albumin, globulin, prolamin and glutelin and the major sources are wheat, maize, oat and rice. Products such as rice bran based cookies is being developed from the rice variety *Rakthasali* depicting the successful incorporation of rice bran with the protein content in rice being 11.36g and in the rice bran cookies was 8.78 g/ 100 g[17].

4.8 Leaf Protein Concentrate:

Leaf protein concentrate (LPC) is a nutritious protein source made by mechanically separating indigestible fiber and soluble antinutrients from much of the protein in certain fresh green leaves of plant[18]. It is a good source of amino acids and polyphenols and the its production cost is also low.

For the production of LPC the leaves are collected and its moisture and pH are adjusted which is an important step for better protein extractability. The moisture should be greater than 95 per cent and pH should be greater than 7.5. To achieve this, the leaves are to be blended with distilled water.

The pulp is then filtered and to get maximum juice out of the cake, it is pressed further. Then the filterate is acidified with drops of HCl and heated till the protein coagulate. It is again filtered and it is then oven dried forming protein concentrate[19].

Among common plant leaves such as pumpkin, amaranth, sugar been, sweet potato, cowpea and cabbage, pumpkin leaves recorded the highest protein yield (11.75 %) followed by amaranth leaves (10.7 %). The protein from amaranth is very smooth and less fibrous. The protein contents in the leaves of sugar been, sweet potato, cowpea and cabbage were 8.85 per cent, 7.85 per cent, 6.95 per cent, and 5.60 per cent respectively[19].

4.9 Insect Proteins:

Insect consumption or entomophagy is not a new concept but has been traditionally followed in different parts of the world such as Africa, Asia and Latin America. The most widely consumed insects are caterpillars, palm weevil larvae, termites, stink bugs and grasshoppers. For the commercial production, house cricket, yellow mealworm and palm weevil are the ones mostly being used. The usual negative emotional response toward acceptability of insects as food by consumers is gradually fading away, as many insect containing food products are finding their ways into the market.

More than 1900 species have reportedly been used as food. Insects are a highly nutritious and healthy food source with high fat, protein, vitamin, fibre and mineral content. The nutritional value of edible insects is highly variable because of the wide range of edible insect species.

Even within the same group of species, nutritional value may differ depending on the habitat in which it lives, and its diet. For example, the composition of unsaturated omega-3 and six fatty acids in mealworms is comparable with that in fish (and higher than in cattle and pigs), and the protein, vitamin and mineral content of mealworms is similar to that in fish and meat. To make insects commonly used as human food, it is necessary to develop the technology which will allow large scale productions at a reasonable cost.

The processing methods that can be applied on insects for consumption are drying, pulverizing or grounding, can be converted into paste, heating methods (cooking, boiling, frying, roasting, toasting, extrusion and canning) can be used and for preservation freeze drying or vacuum packing can be done after degutting.

The incorporation of silkworm pupae and locust replacing skim milk powder in high energy biscuit is observed to have the protein content comparable to that of skim milk powder when it was replaced with 15 per cent edible insect powder. Also, vitamin c content was also very high with the incorporation of insect powders. The use of insects to replace skim milk powder would reduce the overall cost of production of high energy biscuits[20].

The protein content in different insect forms[21] are depicted in the Table 4.6 and some of the commercially available insect products are shown in Figure 4.6.

Table 4.6: Protein Content in Various Insect Forms

Insect forms	Protein (%)
Termites	23.3
Caterpillars	38.1
Adult weevils	30.3
House fly pupae	63.1
May beetle larvae	11.1
Bee	18.1
Silkworm	23.1
Grasshopper	46.1

Figure 4.6: Insect Products available in International Market

4.10 Mushrooms:

Mushrooms have a protein content ranging from 19.68 per cent to 36.96 per cent of dry weight. It contains several bioactive compounds that providing antifungal, antibacterial, antioxidant and antiviral properties in mushroom. The production of status of mushroom in India, shows that white button mushroom is cultivated highest (73 %) followed by Oyster mushroom (16 %), Paddy straw mushroom (7 %), milky mushroom (3 %). Production of all other types of mushrooms constituted to (1 %). The protein content of composite maize flour was found to increase from 6.9 g/100 g to 19.32 g/100 g when oyster mushroom was added up to 50 per cent[22].

A. Limitations:

- Less acceptance
- Allergenic factors
- Ant nutritional factors
- Lack of production and extraction process
- Toxicity testing and detailed long term studies are scanty

4.11 Conclusion:

To meet the protein, need of projected population of 10 billion by 2050 is a challenge. Change in food system could be a solution for which innovation and experimentation in food especially in alternative proteins is essential in order to meet the goal of creating a safe, sustainable, affordable and healthy future.

4.12 References:

1. Sadler, M. J. 1994. Fungal protein. In: Hudson, B. J. F. (ed.), *New and Developing Sources of Food Proteins*. Springer, Boston MA, pp. 343-362.
2. Sahurkar, M. R. and Karadbhajne, S. V. (2018). Replacement of fat, salt and sugar: Need of an hour for food industries. *Int. J. Food Sci. Nutr.* 3(4): 200-211.
3. Sadler, M. J. 2004. Diet and health symposium: emerging evidence – A multidisciplinary approach. *Br. J. Cardiology* 10(1):1-4.
4. Nisha. 2008. Standardization of green gram based meat analogues. M. Sc. (Home Science) thesis, Kerala Agricultural University, Thrissur, 62p.
5. Nout, M. J. R. and Kiers, J. L. (2005). Tempeh fermentation, innovation and functionality: update into the third millenium. *J. Appl. Microbiol.* 98(4): 789-805.
6. Jurus, M. A. and Sundberg, J. W. 1976. Penetration of *Rhizopus oligosporus* into soyabeans in Tempeh. *Appl. Envion. Microbiol*. 32(2): 284-287.
7. Lakshmy, P. S. 2011. Standardisation and quality evaluation tempeh and tempeh based instant soup mixes. Ph. D (Home Science) thesis, Kerala Agricultural University, Thrissur, 111p.
8. Zielińska, D., Kamińska, A., and Kołożyn-Krajewska, D. (2021). Development of tofu production method with probiotic bacteria addition. *J. Microbiol. Biotechnol. Food Sci.* 20(2): 485-490.
9. Tuomisto, H. L. 2011. Environmental impacts of cultured meat production. *Environ. Sci. Technol.* 45(14): 6117-6123.
10. Chavan, R. S. and Jana, A. 2007. Cheese substitutes an alternative to natural cheese-A review. *Int. Food Sci*. 2(2): 25-39.
11. Farahmandfar, R., Tehrani, M. M., Razavi, S. M. A., and Najafi, M. B. I. 2010. Effect of soy cheese and trisodium citrate on pizza cheese. *J. Food Eng.* 6(5):1-9.
12. Khodke, S., Pardhi, M., Pramodini, M., and Kakade, A. (2016). Characteristic evaluation of soy-groundnut paneer. *J Environ. Sci. Toxicol. Food Technol*. 8(2): 12-16.
13. Jay, R. and Michael, M. 2004. Functional properties of protein isolate from cowpea (*Vigna unguiculata* L. Walp.). *J. Food Sci.* 69(2): 119-121.
14. Qayyum, M. M. N., Butt, M. S., Anjum, F. M., and Nawaz, H. (2012). Composition analysis of some selected legumes for protein isolates recovery. *J. Anim. Plant Sci.* 22(4): 1156-1162.
15. Kotecka-Majchrzak, K., Sumara, A., Fornal, E., and Montowska, M. 2020. Oilseed proteins -Properties and application as a food ingredient. *Food Sci. Technol*. 87(2): 77-84.
16. Hashmi, S. I., Satwadhar, P. N., Khotpal, R. R., Deshpande, H. W., Syed, K. A., and Vibhute, B. P. 2010. Rapeseed meal nutraceuticals. *J. Oilseed Brassica*. 1(2): 43-54.

17. Aiswarya, G. 2019. Nutritional and antioxidant potential of medicinal rice variety *Rakthasali*. M. Sc. (Home Science) thesis, Kerala Agricultural University, Thrissur, 77p.
18. Edward, R. H., de Fremery, D., Mackey, B. E., and Kohler, G. O. 1977. Factors affecting juice extraction and yield of leaf protein concentrate from chopped alfalfa. *Trans. ASAE* 20(3): 423-428.
19. Ghaly, A. E. and Alkoaik, F. N. 2010. Extraction of protein from common plant leaves for use as human food. *Am. J. Agric. Biol. Sci*. **7**(3): 331-342.
20. Akande, A. O., Jolayemi, O. S., Adelugba, V. A., and Akande, S. T. 2020. Silkworm pupae and locusts as alternative protein sources for high energy biscuits. *J. Asia Pac. Entomol.* 23(1): 234-241.
21. Ghaly, A. E. and Alkoaik, F. N. 2009. The yellow meal worm as a novel source of protein. *Am. J. Agric. Biol. Sci*. 4(4): 319-331.
22. Ishara, J. R., Sila, D. N., Kenji, G. M., and Buzera, A. K. 2018. Nutritional and functional properties of mushroom (*Agaricus bisporus* and *Pleurotus ostreatus*) and their blends with maize flour. *Am. J. Food Sci. Technol.* 6(1): 33-41.

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5. Enzymes in Food Industry- Significance and Applications

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Abstract:

Enzymes have wide spread applications in food processing, because it can modify and improve the functional, nutritional and sensory properties of ingredients and products. It involves conversion of raw and perishable food materials into shelf stable and palatable food products. Enzymes are biocatalysts that speed up biochemical reactions in living organisms. They are unique processing aids in the food and beverage industry.

In food processing, enzymes are used for efficient utilization of raw materials, simplifying processing and for bringing about desirable quality attributes. Enzymes used in food processing are obtained from three primary sources, that are plants, animal tissues and microbes. Enzymes are extensively used for various food applications like brewing, baking, meat tenderization, milk coagulation, starch modification and also in coffee, tea and chocolate industries. Enzyme applications are environment friendly with lower energy consumption levels and yields biodegradable products. The potential of enzymes in efficient use of raw materials, improved product recovery and quality may lead to better applications of enzymes in the coming decades. Many of the enzymes are still unexplored and there are wider industrial applications for enzymes in food sector.

Keywords:

Enzyme, food processing, food applications

5.1 Introduction:

Enzymes are proteins that are produced by all living organisms. They speed up chemical reactions selectively as part of essential life processes such as digestion, respiration, metabolism and tissue maintenance. Enzymes find application in food, detergent, pharmaceutical and paper industries. Nowadays, the enzymatic hydrolysis and enzyme-based

processes are preferred to the chemical ones due to the environmentally friendly nature, efficient process control, high yield, low refining costs and process safety. Food processing using biological agents is historically a well-established approach. Enzymes have wide spread applications in food processing, because it can modify and improve the functional, nutritional and sensory properties of ingredients and products.

It involves conversion of raw, perishable, edible food materials into shelf stable, palatable food products and beverages. Enzymes are biocatalysts that speed up biochemical reactions in living organisms. They are unique natural processing aids in the food and beverage industry.

5.2 Enzymes:

Enzymes are biological catalysts (also known as biocatalysts) that speed up biochemical reactions in living organisms (Robinson, 2015). The term enzyme is derived from the latin word meaning "in yeast". Enzymes are proteins produced by living organisms to increase the rate of an immense and diverse set of chemical reactions required for life. In other words, they are highly specific biological catalysts. Enzymes are usually named according to the reaction they carry out. Typically, the suffix 'ase' is added to the name of the substrate (E.g. glucose-oxidase, an enzyme which oxidizes glucose) or the type of reaction (E.g. a polymerase or isomerase for a polymerization or isomerization reaction). The exceptions to this rule are some of the enzymes studies originally, such as pepsin, rennin and trypsin (Berg *et al.*, 2001).

5.3 Mechanism of Enzyme Activity:

Enzymes are protein molecules they speed up chemical reactions. An enzyme (E) molecule has a highly specific binding site or active site to which its substrate (S) bind to produce enzyme-substrate complex (ES). The reaction proceeds at the binding site to produce the products (P), which remain associated briefly with enzyme (enzyme-product complex). The product is then liberated and the molecule is then released in an active state to initiate another round of catalysis (Rabin, 1970). The affinity of binding site for the product is much lower than that for the substrate (Figure 5.1).

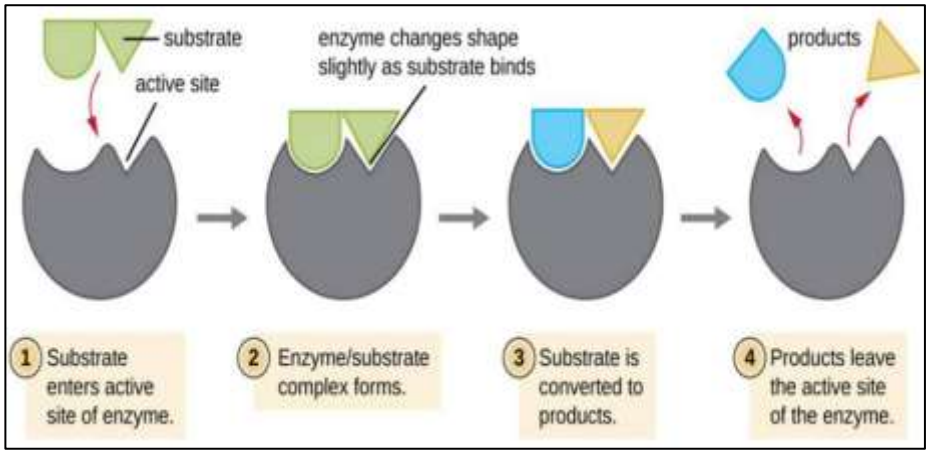

Figure 5.1: Mechanism of enzyme activity

5.4 Sources of Enzymes:

Enzymes have been used deliberately in food processing since ancient times to make a variety of food products, such as breads, fermented alcoholic beverages, fish sauces, cheeses and to produce several food ingredients. Enzymes have been traditionally produced by extraction and fermentation processes from plant and animal sources, as well as from a few cultivatable microorganisms. Industrial enzymes have traditionally been derived from plant, animal and microbial sources (Benjamin *et al*., 2012) and described in Table 5.1.

Table 5.1: Sources of Industrial Food Enzymes

Sources	Enzymes
Plants	α-amylase, β-amylase, bromelain, β-glucanase, ficin, papain, chymopapain and lipoxygenase
Animals	Trypsin, pepsin, chymotrypsin, catalase, pancreatic amylase and rennin (chymosin)
Microoraganisms	α-amylase, β-amylase, glucose isomerase, pullulanase, cellulase, catalase, lactase, pectinases, pectolyase, invertase, raffinose, microbial lipases and proteases

5.5 Enzymes Used in Food Industries:

In food processing, enzymes are used for efficient utilization of raw materials, simplifying processing and also for bringing about desirable quality attributes. Enzymes are extensively used for various food applications like brewing, baking, meat tenderization, milk coagulation, starch modification and also in coffee, tea and chocolate industries. Enzymes have always been important to food technology because of their ability to act as catalysts, transforming raw materials into improved food products. The main values of enzymes are their substrate specificity (Salim *et al*., 2017).

5.6 Dairy Industry:

Dairy enzymes are utilized for processing cheddar, yogurt, milk and milk products. The properties of these enzymes change broadly from coagulant, utilization in the making of cheese, bioprotective enzymes to improve shelf life aspects of dairy products processing. The utilization of enzymes in dairy technology and food technology is well known. Rennet (also known as rennin, which is a blend of pepsin and chymosin extracted from animals and microbiological sources) is utilized for milk curdling as the primary phase of cheese processing technology (Merheb-Dini *et al*., 2010).

Proteases of different types are utilized for speeding up cheese aging, as a functional property and changing milk protein to decrease the allergic effects of cow milk products in infant foods (Fox, 2002). Lipase is mostly used in cheese maturing for the improvement of flavours. Lactase is usually applied to hydrolyse lactose to glucose and galactose sugars and increase the solubility and sweet flavour in different dairy items.

Milk contains protein, particularly casein that preserves the liquid structure. Rennet and rennin termed as enzymes are used to coagulate the milk. Rennet is isolated from the lining of a fourth part of the calf stomach. Animal rennet (bovine chymosin) is conventionally used as a milk-clotting agent in dairy industry for the manufacture of quality cheeses with good flavour and texture (Bhoopathy, 1994). Chymosin is the widely recognized enzyme separated from rennet. Chymosin is easy to acquire from animals, microbial and vegetable sources. microbial rennet is produced from the mold - Mucor miehei. Most common vegetable rennet is thistle. It is extracted from Cirsium plant, this thistle can be used for coagulation of milk (Eva-Maria *et al*., 2017).

Lactase converts lactose into galactose and glucose sugars. Lactase can be obtained from various sources like plants, animal organs, bacteria, yeasts (intracellular enzyme) and molds. Lactase is typically obtained from Aspergillus species of fungi and Kluyveromyces species of yeasts. Lactase is mainly for people suffer from lactose intolerant who have less creation of lactase in small intestine. Lactase is utilized at a commercial level to develop products free from lactose for lactose intolerant people (Wilkinson *et al.*, 2003).

Milk contains protein, particularly casein that preserves the liquid structure. When protease enzyme is added to cheese processing, it hydrolyses casein into kappa casein, which stabilizes the micelle function preventing from coagulation in milk. Protease hydrolyses the peptide linkages of a protein. Bovine and human milk contain protease as a native ingredient. It hydrolyses the macro peptides in production of cheese. It provides flavour and desired texture to cheese (Razzaq *et al*., 2019) (Fig. 2). Catalase has limited and specific usage in cheese processing. Catalase is obtained from bovine liver or microbial sources. It is usually added to dissolve hydrogen peroxide to water and oxygen. Therefore, it is utilized in making certain cheeses instead of pasteurization (E.g., swiss cheese) in order to save regular milk proteins that provide benefits to finished product and flavour enhancement of the cheese (Silva *et al*., 2007).

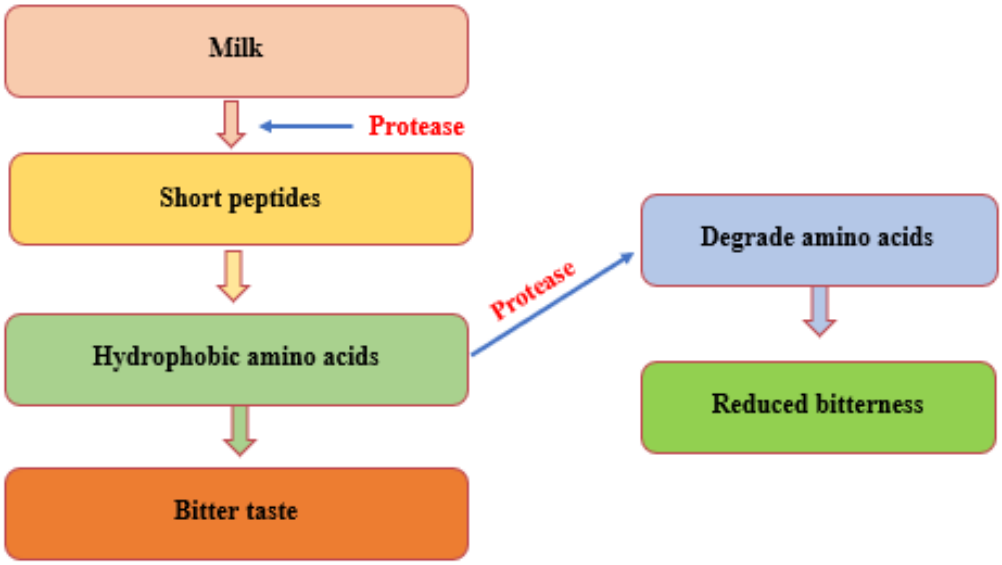

Figure 5.2: Role of Protease Enzyme in Cheese Preparation

5.7 Brewing Industry:

Beer and wine are both alcoholic beverages, produced by yeast fermentation of sugars. Beer is the world's most widely consumed alcoholic beverage (Nelson, 2005). Wine is based on grapes and beer is traditionally based on barley.

In the brewing process enzymes have an important role especially starch undergoes some transformations during the scarification process. The main enzymes used in beer brewing industry can be divided into four main processes which are germination, mashing, fermentation and clarification Some enzymes are already present in the barley (Figure 5.3), but the majority of enzymes are produced during germination. Different enzymes are used in brewing industry and described in Table 5.2.

In the final malt all the enzymes needed for the conversion of "grains" into a fermentable liquid (wort) is present.

Table 5.2: Brewing Enzymes and Their Effects

Enzyme	Sources	Function	Reference
α-amylase	Barley kernel *Bacillus licheniformis* *Bacillus subtilis*	Starch hydrolysis Improve clarification	Sammaritino (2015)
β-amylase	Barley kernel Wheat kernel *Bacillus licheniformis*	Starch hydrolysis Improve malting Improve saccharification Increase fermentation yield	Guerra *et al.* (2009)
β-glucanase	Barley kernel *Trichoderma* sp. *Orpinomyces* sp.	Improve malting Lower viscosity Aid in production of a clear wort	Tomasi *et al.* (2017)
Protease	*Aspergillus* sp. Pineapple latex	Improve fermentation Improve chilling and storage quality	Dulieu *et al.* (2000); Lei *et al.* (2013)
Amyloglucosidase	*Aspergillus niger*	Increase the amount of glucose in wort	Lei *et al.* (2013)

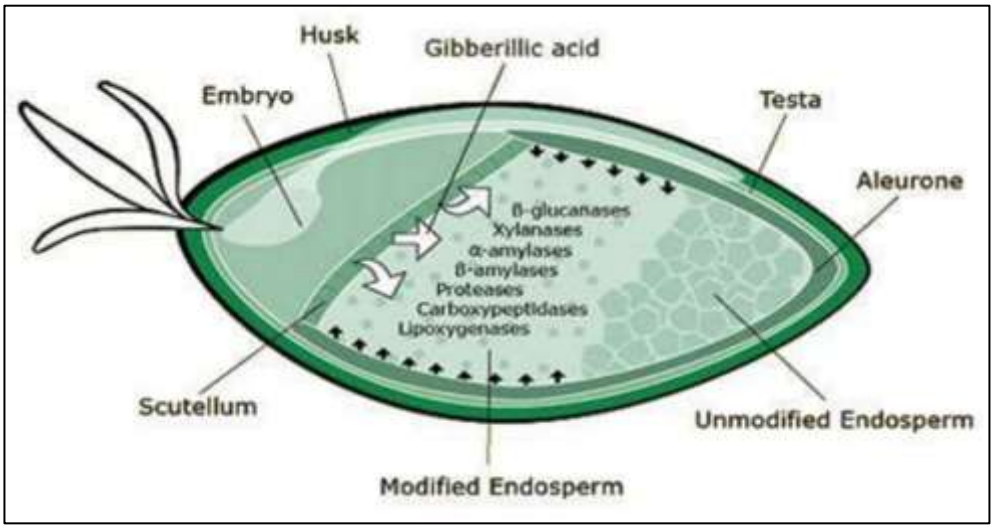

Figure 5.3: Structure of barley kernel

Wine is the product of the biochemical transformations of the compounds present in grape juice by means of a controlled alcoholic fermentation. Yeasts convert sugars into ethanol and other metabolites, as well as into a wide range of volatile and non-volatile compounds that significantly contribute to the sensory properties of wine such as colour, flavour, bitterness, sourness and aroma. Enzymes play a vital role in the wine making process. Many of these enzymes originate from the fruit itself. The indigenous microflora on the fruit and the microorganisms presents during wine making increase the fermentation. The most widely used enzymes for wine making are pectinase, glucanase, xylanase and protease are used to improve the clarification and processing of wine. Glycosidase is used to release of varietal aromas from precursor compounds. Urease is used to reduce the ethyl carbamate formation. Glucose oxidase play a vital role in the regulation of alcohol levels (Table 5.3).

Table 5.3: Enzymes used in wine industry

Application	Enzymes	References
Filtration and clarification	Pectinolytic enzymes	Mojsov (2013)
Mash fermentation	Pectinase	Ramirez *et al.* (2015)
Late fermentation (white wine)	Glycosidases	Merin *et al.* (2015)
Young wine	Gluconases	Ramirez *et al.* (2015)
Ageing	Ureases	Cerreti *et al.* (2016)

The use of commercial enzymes has proved to be quite advantageous in modern wine making. Wine production considers four main stages schematized in Figure 5.4. First, the grapes are crushed by pressing and kept in maceration with the purpose of extracting as much as juice as possible for must formation. Here, the use of enzymes is considered as a pre-treatment step, which precedes wine making. Second, the alcoholic fermentation takes

place, where the main specific features of the wine are obtained such as aroma release is an important feature that can be enhanced by the use of some specific enzymes, as explained below. Third, clarification step has the purpose of reducing the turbidity and viscosity of wine, as well as avoiding operational issues such as filter stoppages due to the high concentration of polysaccharides. The addition of pectic enzymes facilitates the clarification and filtration process. Lastly, aging and stabilization operations aim at obtaining the physicochemical properties of the final product, which can be improved by the use of suitable enzymes (Ottone *et al*., 2020).

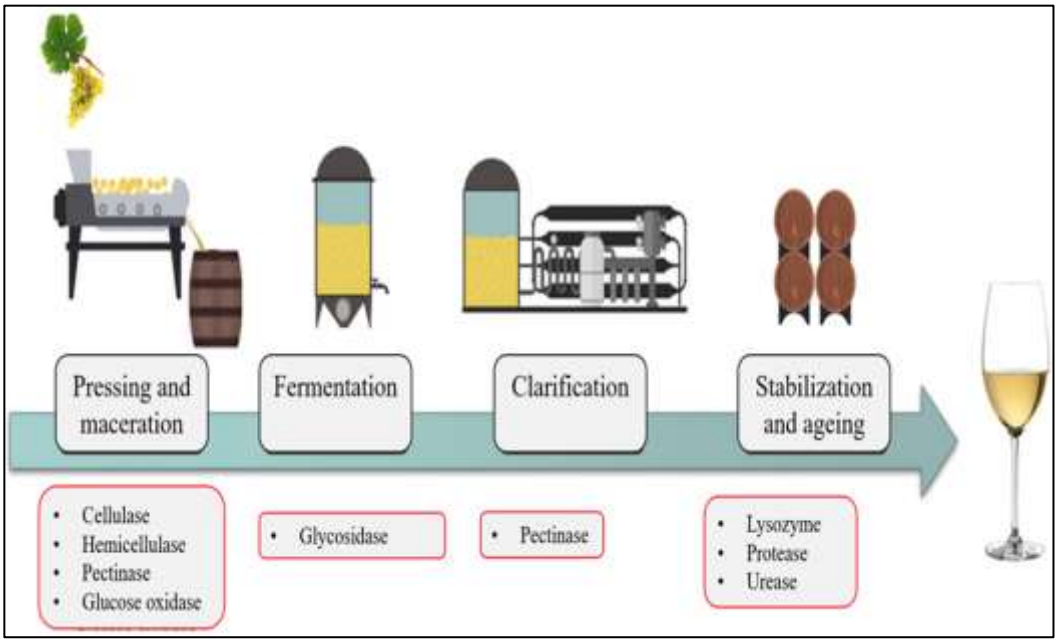

Figure 5.4: Commercial wine making process

5.8 Starch Industry:

Starch is a widely used renewable resource. It is present as a storage compound in the leaves, tubers, seeds and roots of many plants. Unprocessed native starches are structurally too weak and functionally too restricted for application in pharmaceutical, food and non-food technologies. Modifications are necessary to create a range of functionality (Berski *et al*., 2011). Raw starch properties should be improved using modification. Starch modification can be done by modifying the structure including the hydrogen bonding in a controlled manner to enhance and extend their application in industrial prospective. Starch is composed of two fractions, they are amylose and amylopectin. The respective ratio of amylose and amylopectin, significantly affects the physicochemical properties of starch which in turn, influences its functionality and eventual applications. Modification can be chemical, physical and enzymatic. Enzymes are ideal catalysts for the conversion of starch into products like high fructose corn syrup, maltodextrin, maltose syrup etc. (Esmaeili and Noorolahi, 2017). Applications of different enzymes in starch industry are detailed in Table 5.4.

Table 5.4: Applications of different enzymes in starch industry

Application	Enzymes	References
Starch liquefaction	α-amylase	Kammoun *et al.* (2008)
Starch saccharification	α-amylase Glucoamylase Pullulanase Isoamylase Maltogenic amylase	Hii *et al*. (2012); Zareian *et al.* (2010)
Anti-staling	α-amylase, β-amylase, pullulanase, debranched enzymes, branching enzymes, maltogenic amylase, glucoamylase, cyclodextrin glucanotransferases	Van der Maarel and Leemhuis (2013); Esmaeili and Noorolahi (2017)

There are basically four groups of starch-converting enzymes. They are endoamylases, exoamylases, debranching enzymes and transferases. Endoamylases are able to cleave α,1-4 glycosidic bonds present in the inner part (endo) of the amylose or amylopectin chain. α-amylase is a well-known endoamylase. Exoamylases cleave α,1-4 glycosidic bonds α,1-6 glycosidic bonds. Exoamylases act on the external glucose residues of amylose or amylopectin and thus produce only glucose (glucoamylase and α-glucosidase), or maltose and β-limit dextrin (β-amylase).

The third group of starch-converting enzymes are the debranching enzymes that exclusively hydrolyse α,1-6 glycosidic bonds. Most commonly using debranching enzymes are isoamylase and pullulanase type I. The fourth group of starch converting enzymes are transferases that cleave an α,1-4 glycosidic bond of the donor molecule and transfer part of the donor to a glycosidic acceptor with the formation of a new glycosidic bond. Enzymes such as amylomaltase and cyclodextrin glycosyltransferase are commonly used in food industry (Van der Maarel *et al.*, 2002).

Enzymatic conversion of starch involves three basic steps (Figure 5.5). They are liquefaction, saccharification and isomerization. The raw material is milled to separate the starch from the oil, protein and fibers. Enzymes ease this process and the starch is usually present in a water slurry which is passed on to the next stage, known as liquefaction. The enzyme breaks down the large starch molecules into maltodextrins. In the saccharification stage, enzymes break the maltodextrins into glucose molecules. During isomerization, the glucose is converted into fructose which in turn enables the production of high fructose syrup and crystalline fructose used commonly in the food and beverage industries (Li *et al.*, 2016).

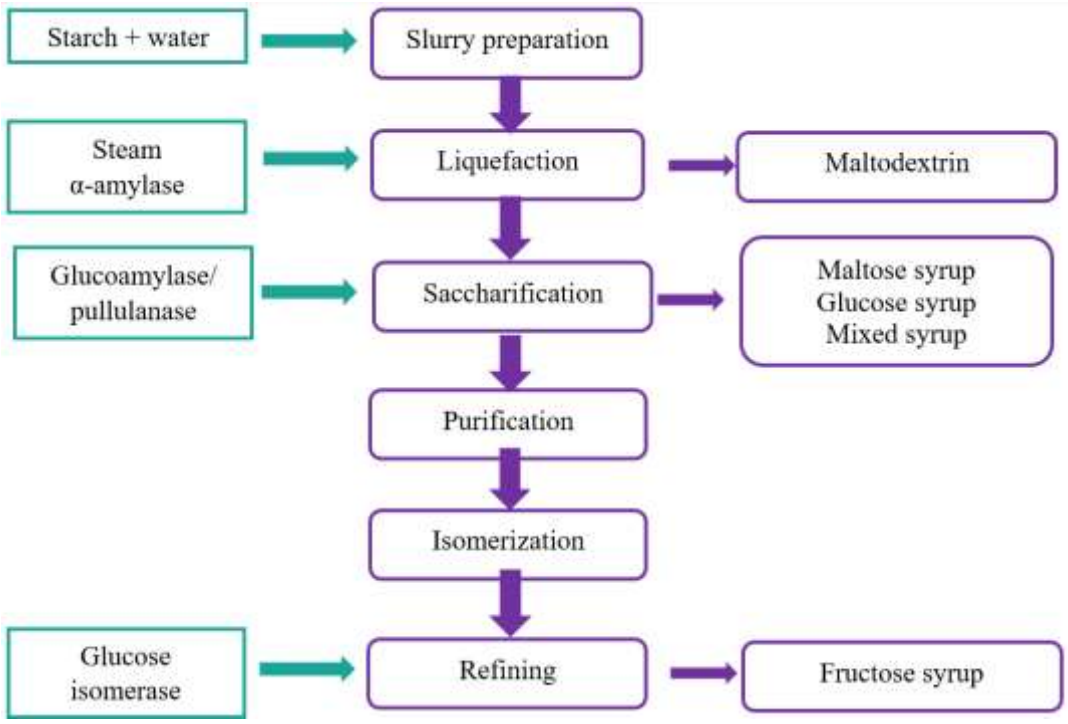

Figure 5.5: Enzymatic conversion of starch

5.9 Baking Industry:

Baked goods are prepared from flours such as wheat flour, which has starch as its main constituent. Amylolysis enzymes break down flour starch into small dextrin that become better substrates for yeast to act upon in the bread making process. The use of enzymes in the baking industry is expanding to replace the use of chemicals in making high-quality products, in terms of better dough handling, anti-staling properties, as well as texture, colour, taste, and volume. Baking comprises the use of enzymes from three sources, they are endogenous enzymes in flour, enzymes associated with the metabolic activity of the dominant microorganisms and exogenous enzymes which are added in the dough (Di Cagno *et al*., 2003). The supplementation of flour and dough with enzyme improvers is a usual practice for flour standardization and also as baking aids. Enzymes are usually added to modify dough rheology, gas retention and crumb softness in bread manufacture, to modify dough rheology in the manufacture of pastry and biscuits, to change product softness in cake making and to reduce acrylamide formation in bakery products. The enzymes can be added individually or in complex mixtures, which may act in a synergistic way in the production of baked goods and their levels are usually very low (Penella *et al*., 2008). The baking industry predominantly makes use of different types of enzymes (Table 5.5). Amylases are used to convert starch to sugar and to produce dextrins. For strengthening and bleaching of the dough, oxidases are used. Hemicellulases and proteases are the enzymes which have an effect on wheat gluten. While hemicellulases improve gluten strength and proteases reduce gluten elasticity. Xylanases are most often combined with amylases, lipases and many oxidoreductases to attain specific effects on the rheological properties of dough and organoleptic properties of bread.

Xylanases have also been used to improve the quality of biscuits, cakes and other baked products. Glucose oxidase can be used as alternative oxidizing agent instead of potassium bromate in breadmaking.

Potassium bromate is an oxidizing agent that was traditionally used in baking, and its use was prohibited in many countries after it was recognized as carcinogenic. All these enzymes together play an important role in maintaining volume, crumb softness, crust crispiness, crust colouring or browning and in maintaining freshness (Leman *et al.*, 2005).

Table 5.5: Different Enzymes Used in Baking Industry and Their Functions

Enzyme	Functions
α-amylase	• Degrading starch in flours • Controlling the volume and crumb structure
β-xylanases	• Improving dough handling and dough stability
Maltogenic α-amylases	• Improves shelf-life of bread and cake • Anti-staling effect
Hemicellulose	• Improve gluten strength
Glucose oxidase	• Make weak doughs into stronger • Make elastic
Lipoxygenase	• Bleaching and strengthening dough

5.10 Juice Industry:

Enzymes are processing aids used worldwide for fruit processing, particularly for the production of clear fruit juice and concentrate. Enzymes can increase the yield of solid recovery during pulp washing, facilitate the production of highly concentrated citrus bases, improve essential oil recovery from peel, debitter juice, clarify lemon juice or increase the worth of waste products (Grassin and Fauquembergue, 1996).

Pectinases are one of the important upcoming enzymes of the commercial sector especially for fruit juice industry as prerequisites for obtaining well clarified and stable juices with higher yields.

Other enzymes used in the juice industry are amylases, glucoamylases, cellulases, hemicellulose, laccase, naringinase and limoninase (Table 5.6).

Vegetable juice processing therefore requires more cellulases in addition to pectinases to reduce viscosity sufficiently for juice extraction using a decanter (Sandri *et al.*, 2012).

Table 5.6. Different enzymes used in juice industry and their functions

Enzyme	Functions
Carbohydrase	• Increase juice yield • Increase sugar and acid extraction
Amylase, glucoamylase	• Breaking down starch into glucose • Clarifying cloudy juice
Pectinases	• Degrading pectin • Increase overall juice production
Cellulases, hemicellulases	• Maintenance of texture • Lowering viscosity
Naringinase	• Remove bitterness of citrus juice • Remove haze

5.11 Meat Industry:

Tenderness of meat is considered as the most important quality of meat (Zor *et al.*, 2009). Tenderness in meat results from a combination of breakdown within muscle fibres, primarily because of the activity of enzymes and loosening of connective tissue, in particular collagen.

Various pre-slaughter and post-slaughter factors and their mutual effect influence tenderness of meat. In meat industry and catering predominantly protein-degrading enzymes have been used.

Enzymes such as papain, bromelain, ficin, proteases and actinidin breakdown the muscle fibres in the meat and helps to tenderise meat. Widely using enzymes, sources and their functions are described in Table 5.7.

Table 5.7: Enzymes used in meat industry

Enzymes	Source	Functions
Plant source Papain Ficin Bromelain	Papaya Fig Pineapple	• Meat tenderization • Increases protein dispersability • Increase palpability, solubility and digestibility
Actinidin	Kiwi	• Improve tenderness in processed meat

Enzymes	Source	Functions
Microbe source Acid proteases	Aspergillus niger A. oryzae	• Improve flavour, nutritional and functional properties of proteins • Converts animal carcasses into flavourous compounds
Lipase	Aspergillus spp. Candida spp.	• Hydrolyse triglycerides • Improves flavour in sausages

Papain was obtained through a series of processes. The first phase eliminates small organic and inorganic molecules and other proteins present on the extracted latex by adding ammonium sulphate and EDTA.

The latex was diluted with alcohol using 95°C water as heating medium. The enzyme was ground to get a fine powder (Andrade-Mahecha *et al.*, 2011) (Figure 5.6).

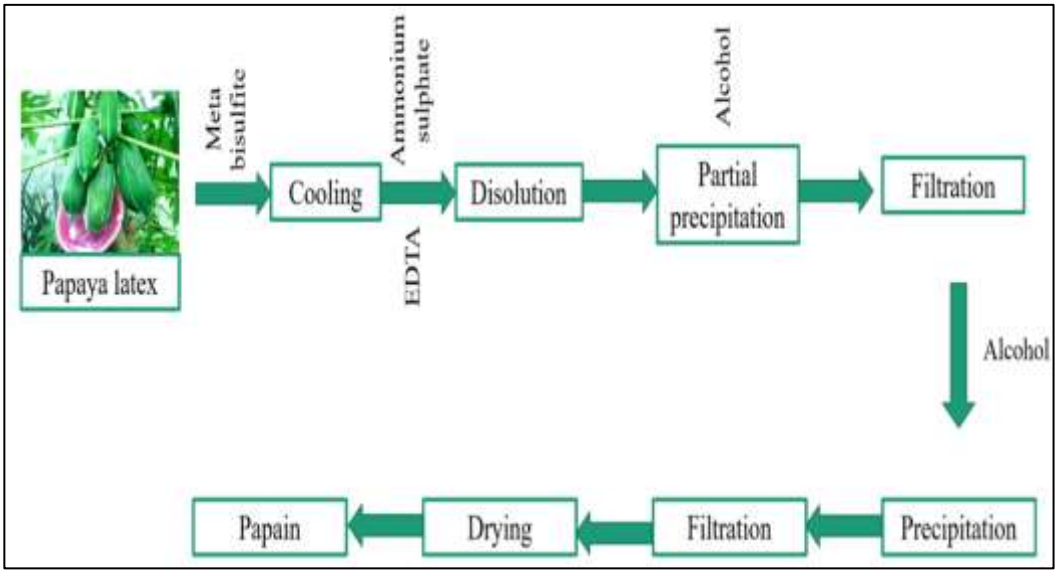

Figure 5.6: Extraction of Papain from Papaya Latex

The use of enzymes in the food industry is a well-established approach, in particular due to the specificity of enzyme action and their green, environmentally friendly nature. As mentioned above, enzymes are currently used in several different food products and processes and new areas of application are constantly being added.

The introduction of enzymes as effective biocatalysts working under mild conditions results in significant saving in resources such as energy and the environment. Evidence clearly shows that dedicated research efforts are consistently being made so as to make this application of biological agents more effective and diversified.

5.12 Reference:

1. Andrade-Mahecha, M., Morales-Rodríguez, O., and Martinez-Correa, H. (2011). Study of the extraction process of papain from the latex of the fruit of papaya (*Carica papaya* L.). *Maradol. Acta Agronomica* 60: 218-224.
2. Benjamin, S., Xin, R., and Sappasith, K. (2012). Enzymes in Food Processing. In: Benjamin, S., Nollet, L., Paliyath, G., Benjakul, S., Nip, W. K., and Hui, Y. (eds.), *Food Biochemistry and Food Processing* (2nd Ed.). Blackwell, New York, pp.181-206.
3. Berg, J. S., Powell, B.C. and Cheney, R.E. (2001) A millennial myosin census. *Mol. Biol. Cell* 12(4): 780-794.
4. Berski, W., Ptaszek, A., Ptaszek, P., Ziobro, R., Kowalski, G., Grzesik, M., and Achremowicz, B. (2011). Pasting and rheological properties of oat starch and its derivatives. *Carbohyd.Polyms.* 83(2): 665- 671.
5. Bhoopathy, R. (1994). Enzyme technology in food and health industries. *Indian Food Ind.* 13: 22-31.
6. Cerreti, M., Fidaleo, M., Benucci, I., Liburdi, K., Tamborra, P., and Moresi, M. (2016). Assessing the Potential Content of Ethyl Carbamate in White, Red, and Rosé Wines as a Key Factor for Pursuing Urea Degradation by Purified Acid Urease. *J. Food Sci.* 81(7): 1603-1612.
7. Di Cagno, R., De Angelis, M., Aldo, C., Paola, L., Arnault, P., Tossut, P., Giovanni, G., and Gobbetti, M. (2003). Interactions between sourdough lactic acid bacteria and exogenous enzymes: Effects on the microbial kinetics of acidification and dough textural properties. *Food Microbiol.* 20: 67-75.
8. Dulieu, C., Moll, M., Boudrant, J., and Poncelet, D. (2000). Improved performances and control of beer fermentation using encapsulated alpha-acetolactate decarboxylase and modeling. *Biotechnol. Prog.* 16(6): 958-965.
9. Esmaeili, S. and Noorolahi, Z. (2017). Application of starch processing enzymes in food technology - A review. *Carpathian J. Food Sci. Technol.* 9: 114-127.
10. Eva-Maria D., Engels, W., and Huppertz, T. (2017). Salting of Cheese. *Food Sci.* 13: 1-5.
11. Fox, P. F. (2002). Significance of Indigenous Enzymes in Milk and Dairy Products. *Handbook of food enzymology*. CRC Press, Florida, pp. 270-293.
12. Grassin, C. and Fauquembergue, P. (1996). Fruit juices. In: Godfrey, T. and West, S. (eds.), *Industrial Enzymology* (2nd Ed.). Stockholm Press, New York, pp. 225-264.
13. Guerra, N. P., Torrado-Agrasar, A., López-Macías, C., Martínez-Carballo, E., García-Falcón, S., Simal-Gándara, J., and Pastrana-Castro, L. M. (2009). Use of Amylolytic Enzymes in Brewing. In: Preedy, V. R. (ed.). *Beer in Health and Disease Prevention*. Academic Press, Cambridge, Massachusetts, United States, pp. 113-126.
14. Hii, S. L., Tan, J. S., Ling, T. C., and Ariff, A. B. (2012). Pullulanase: Role in Starch Hydrolysis and Potential Industrial Applications. *Enzyme Res*. 12: 1-14.
15. Kammoun, R., Naili, B., and Bejar, S. (2008). of a statistical design to the optimization of parameters and culture medium for alphaamylase production by *Aspergillus oryzae* CBS 819.72 grown on gruel (wheat grinding by-product). *Bioresour. Technol*. 99: 5602-5609.
16. Lei, H., Zhao, H., and Zhao, M. (2013). Proteases supplementation to high gravity worts enhances fermentation performance of brewer's yeast. *Biochem. Eng. J*. 77: 1-6.

17. Li, H., Prakash, S., Timothy, M., Melissa A. N., Robert, F., and Gilbert, G. 2016. The importance of amylose and amylopectin fine structure for textural properties of cooked rice grains. *Food Chem*. 196: 702-711.
18. Leman, P., Goesaert, H., Vandeputte, G. E., Lagrain, B., and Delcour, J. A. (2005). Maltogenic amylase has a non-typical impact on the molecular and rheological properties of starch. *Carbohydr. Polym*. 62(3): 205-213.
19. Merheb-Dini, C., Gomes, E., Boscolo, M., and da Silva, R. (2010). Production and characterization of a milk clotting protease in the crude enzymatic extract from the newly isolated *Thermomucor indicae-seudaticae* N31: (Milk clotting protease from the newly isolated *Thermomucor indicae-seudaticae* N31). *Food Chem.* 120: 87-93.
20. Merin, G. M., Martín, C. M., Rantsiou, K., Cocolin, L., and Ambrosini, V. M. (2015). Characterization of pectinase activity for enology from yeasts occurring in Argentine Bonarda grape. *Braz. J. Microbiol*. 46(3): 815-823.
21. Mojsov, K. (2013). Use of enzymes in wine making: a review. *Int. J. Mark. Technol*. 3: 112-127.
22. Nelson, M. (2005). The Barbarian's Beverage: A History of Beer in Ancient Europe. *Routledge* 5: 306- 315.
23. Ottone, C., Romero, O., Aburto, C., Illanes, A., and Wilson, L. (2020). Biocatalysis in the winemaking industry: Challenges and opportunities for immobilized enzymes. *Compr. Rev. Food Sci. Food Saf*. 19(2): 595-621.
24. Penella, J., Collar, C., and Haros, C. M. (2008). Effect of wheat bran and enzyme addition on dough functional performance and phytic acid level in bread. *J. Cereal Sci*. 48: 715-721.
25. Rabin B. R. (1970). The mechanism of enzyme action. *J. Clin. Pathol*. 4:1-7.
26. Ramirez, Y. A., Rivero, C. W., Britos, C. N., and Trelles, J. A. (2015). Alkaline and thermostable polygalacturonase from Streptomyces halstedii ATCC 10897 with applications in waste waters. *Biocatal. Agric. Biotechnol*. 4(2): 221-228.
27. Razzaq, A., Shamsi, S., Ali, A., Ali, Q., Sajjad, M., Malik, A., & Ashraf, M. (2019). Microbial Proteases Applications. *Frontiers Bioeng. Biotechnol*. 7: 1-20.
28. Robinson, K. P. (2015). *Enzymes: Principles and Biotechnological Applications*. Portland Press Ltd., Queen Street Place, London, 41p.
29. Salim, R., Fiza Nazir, F., Yousf, N., Amin, F., Rathe, A. H., and Reshi, M. (2017). Food processing applications of enzymes. *J. Pharmacog. Phytochem.* 6(6): 2238-2240.
30. Sammartino, M. (2015). Enzymes in brewing. *MBAA TQ* 52(3): 156-164.
31. Sandri, I. G., Fontana, R. C., Barfknecht, A., and Da Silveira, M. M. (2012). Clarification of fruit juices by fungal pectinases. *Food Sci. Technol.* 44: 2217-2222.
32. Silva, C. R. D., Delatorre, A. B., Martins, M. L. L. (2007). Effect of the culture conditions on the production of an extracellular protease by thermophilic *Bacillus* sp. and some properties of the enzymatic activity. *Braz. J. Microbiol.* 38: 253-258.
33. Tomasi, I., Marconi, O., Sileoni, V., and Perretti, G. (2017). Validation of a high-performance size-exclusion chromatography method to determine and characterize β-glucans in beer wort using a triple-detector array. *Food Chem*. 214: 176-182.
34. Van der Maarel, M. J. E. C. and Leemhuis, H. (2013). Starch modification with microbial alpha-glucanotransferase enzymes. *Carbohydr. Polym*. 93: 116-121.
35. Van der Maarel, M. J., Van der Veen, B., Uitdehaag, J. C., Leemhuis, H., and Dijkhuizen, L. (2002). Properties and applications of starch-converting enzymes of the alpha-amylase family. *J. Biotechnol*. 94(2): 137-155.

36. Wilkinson, A. P., Gee, J. M., Dupont, M. S., Needs, P. W., Mellon, F. A., Williamson, G., and Johnson, I. T. (2003). Hydrolysis by lactase phlorizin hydrolase is the first step in the uptake of daidzein glucosides by rat small intestine in vitro. *Xenobiotica* 33(3): 255–264.
37. Zareian, S., Khajeh, K., Ranjbar, B., Dabirmanesh, B., Ghollasi, M., and Mollania, N. (2010). Purification and characterization of a novel amylopullulanase that converts pullulan to glucose, maltose and maltotriose and starch to glucose and maltose. *Enzyme Microbial Technol*. 46: 57-63.
38. Zor, K., Ortiz, R., Saatci, E., Bardsley, R., Parr, T., Csoregi, E., and Nistor, M. (2009). Label free capacitive immunosensor for detecting calpastatina - meat tenderness biomarker. *Bioelectrochem*. 76(2): 93-99.

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6. Food Fortification– The Indian Scenario

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Abstract:

WHO and FAO recognized that there are over 2 billion people worldwide, who suffer from a variety of micronutrient deficiencies. It is statistically proved that approximately 1 in 3 people worldwide were at risk for iodine, vitamin A, or iron deficiency. For obtaining compensation of micronutrients in the foods, innovative technologies like food fortification or enrichment of food products were used through which these micronutrients are compensated in the regular diet of the common people. Food fortification is defined as the addition of one or more essential nutrients to a food, whether or not it is normally contained in the food). Fortification is being promoted through both, the open market and the government safety net programmes, such as Integrated Child Development Services (ICDS), Mid-Day Meal Scheme (MDM) and public distribution system. Food safety and Standards Authority of India (FSSAI) operationalised standards for fortification of five staples, namely wheat flour and rice (with iron, vitamin B12 and folic acid), edible oil and milk (with vitamin A and D) and salt (with iron in addition to iodine).

Keywords:

Food fortification, milestones, Status, Micronutrients, Enrichment, Food safety and standards.

6.1 Introduction:

[1]India is 94 out of 107 countries on Global Hunger Index, 2020. One third of about two billion people who are suffering from vitamin and micronutrient deficiencies globally, are in India. Micronutrient deficiency diseases such as anaemia, vitamin A insufficiency, and iodine insufficiency are highly common in India.

Initially, India's focus has been on addressing iodine, vitamin A and iron deficiencies. While there has been substantial improvement in Iodine Deficiency Disorders (IDD), severe vitamin A deficiency and anaemia still continues to be a serious cause for concern. National Family Health Survey (NFHS) 2015- 16 showed that 58.4 per cent of children in the age of 6 to 59 months are anaemic, 35.7 per cent of children under 5 years are underweight, 53 per cent of women in the reproductive age group (15 to 49 years) and 22.7 per cent of men in the same age group are anaemic

The micronutrient deficiency also known as - hidden hunger is a serious health risk. Economically deprived people, lack access to safe and healthy meals, well-balanced diet with enough micronutrients. Often, there is considerable loss of nutrients during the processing of food.

Micronutrient deficits can be addressed in three ways: dietary adjustments, supplementation and food fortification with specific nutrients. While dietary modifications are good, they are a long-term solution that may include adjustments in food preparation procedures and societal norms. Supplementation is an effective and rapid approach, but it requires appropriate medical infrastructure/administration and thus it is costly. Food fortification is a cost-effective solution that requires no intentional action on the part of the customer and no changes in the target populations' dietary patterns. It may also be easily integrated into current food production and distribution networks.

6.2 Food Fortification:

The process of adding micronutrients (essential trace elements and vitamins) to food is known as food fortification or enrichment. It could be a strictly commercial decision to add extra nutrients to a meal, or it might be a public health policy aimed at reducing the number of persons suffering from dietary deficiencies in a population. Staple foods of a region can lack particular nutrients due to the soil of the region or from inherent inadequacy of a normal diet. In these circumstances, adding micronutrients to staples and condiments can help prevent large-scale deficiency disorders.

As defined by the World Health Organization (WHO) and the Food and Agricultural Organization of the United Nations (FAO), fortification refers to "the practice of deliberately increasing the content of an essential micronutrient, i.e. vitamins and minerals

(including trace elements) in a food irrespective of whether the nutrients were originally in the food before processing or not, so as to improve the nutritional quality of the food supply and to provide a public health benefit with minimal risk to health", whereas enrichment is defined as "synonymous with fortification and refers to the addition of micronutrients to a food which are lost during processing".

WHO/FAO identified food fortification as the second of four strategies (the four strategies are dietary diversification, food fortification, public health and food safety measures) to begin reducing the global incidence of nutritional deficiencies. Cereals (and cereal-based goods), milk (and milk derivatives), fats and oils, auxiliary food items, tea and other beverages, and newborn formulas are the most prevalent fortified foods, according to the FAO. Under nutrition and nutrient deficiency is estimated globally to cause between 3 and 5 million deaths per year. Restoration is the addition of a nutrient to a food in order to restore the original nutrient content. The inclusion of nutrients that are naturally available or present in the food product is common in both restoration and enrichment programmes.

6.3 Milestones in Food Fortification[2]:

Food fortification or enrichment is the process of addition of key vitamins and minerals to the staple foods to improve their nutritional value and could address nutritional gaps in the population. Food fortification is not a new concept. The earliest evidence of food fortification was discovered around 4000 BC when the Persian physician Melampus added iron filings to sweet wine to strengthen the sailor's resistance to spears and arrows and to enhance sexual function. In the modern times, United States and Switzerland started adding iodine to the salt at the same time in 1920. Later, in 1932 they started adding vitamin D and vitamin A to the dairy products, and in 1941 they started adding thiamine to flours. Subsequently, the addition of iron and folic acid to flour become common in the western countries. Vanaspati has been fortified with Vitamin A since 1953 and iodine fortified salt since the late 1950s took significant role eradicating goiter in India. However, the attention was not enough which could satisfy the nutritional level of the population. Despite evidential malnutrition, according to Food Safety and Standard (Food Products Standards and Food Additives) Regulation 2011, manufacturers were not obliged to fortify a significant number of foodstuffs except margarine and infant formula. FSSAI established a panel on food fortification and nutrition to identify major nutritional gaps in the Indian diet, realising the urgency of the situation. Rice, salt, milk, flour (products) and vanaspati are all required to be fortified under the revised food safety and standards (fortification) regulation 2016.[3]

6.4 Fortification Efforts in India:

Food fortification comprises biofortification, microbial biofortification and synthetic biology; commercial and industrial fortification, and home fortification. The numerous methods of Food fortification are distinct because different techniques and procedures are employed to fortify the target foods. Biofortification is the process of using traditional breeding techniques and/or technologies to create micronutrient-dense staple crops. Biotechnology (genetic engineering) is a more modern method of biofortifying staple crops, and it has received a lot of attention in recent years.

The transgenic 'Golden Rice,' which contains twice the normal levels of iron and large amounts of beta carotene and other nutrients, is the most well-known example of this strategy. Microbial biofortification involves using probiotic bacteria (mostly lactic acid bacteria), which ferment to produce β-carotene either in the foods we eat or directly in the human intestine. Home fortification is providing deficient populations with micronutrients in the form of packets or pills that can be added to meals prepared at home (basically a merger of supplements and fortification). Commercial and industrial fortification is the process of adding micronutrients to commercially available items such as flour, rice, cooking oils, sauces and butter while they are being manufactured. Some of the FSSAI certified commercial products are.

6.4.1 Fortified Rice:

Rice is the staple food for 65 percent of India's population. Hence, fortification of rice can address micronutrient malnutrition caused by lack of Iron, folic acid, zinc and B Vitamins in the diet. Nearly 33.7 MT of rice is distributed annually through public funded programmes nationwide. Fortified rice can, reach 740 million vulnerable people in India, especially women and children. Globally, rice fortification began in the 1940's. Since then, 86 countries have mandated fortification of at least one industrially milled grain–wheat flour, maize, or rice. Six countries have mandated rice fortification[4].

6.4.2 Fortified Wheat Flour:

Fortification of wheat flour is cost-effective public intervention that can reduce micronutrient deficiencies (MNDs) and prevent birth defects (NTDs) due to folic acid deficiency. Wheat flour is an appropriate vehicle to fortify with iron, folic acid, zinc and the B Vitamins as per FSSAI standards, to address micronutrient deficiencies and reach a large segment of the population[3].

6.4.3 Fortified Edible Oil:

Edible oil is considered an appropriate vehicle for fortification to address vitamin A and D deficiency in our population. Fortification of edible oils and fats with vitamin A and D is a powerful practice for combating micronutrient malnutrition, with fortified oil providing 25–30 % of the required dietary intakes for vitamin A and D. Globally, oil fortification was first introduced in 1965 with 27 countries mandating it since then Vitamin A and/or vitamin D are used for the fortification of oil, being fat soluble vitamins[1].

6.4.4 Fortification of Milk:

Vitamin A and D are important for various body functions. In India, there has been a rapid rise in consumption of milk, growing from 178 grams per day in 1990-91 to 337 grams per day by 2015-16. This sustained growth in availability of milk and milk products for a growing population offers an excellent vehicle to address the vitamin A and D deficiencies through fortification. Mandatory milk fortification legislation was first introduced in 1935. Total milk production in India for 2015-16 was 155.5 million MT. Fortification of milk is extremely affordable and cost effective[3].

6.4.5 Double Fortified Salt:

Double fortified salt is a fortified food product that provides humans with a modest but critical amount of iodine and iron through their diet. In general, double fortified salt formulations are intended to provide 100 per cent of daily dietary iodine requirement, and 30 to 60 per cent of daily dietary iron requirement. Daily consumption of salt is 7 to 9 g/person; Therefore, it is an excellent vehicle to deliver micronutrients to the entire population. Fortification of salt with iodine since 1962 has been one of the most successful public health programmes in India and has significantly reduced goitre and iodine deficiency disorders. A complementary technique to combat widespread anaemia in the country is to fortify iodized salt with iron, known as doubly fortified salt (DFS)[7]. In October 2016, the Food Safety Standards Authority of India published draft standards for food fortification. The preliminary fortification of wheat flour complies with worldwide iron, vitamin B_{12} and folic acid fortification requirements. It is believed that fortifying flour for the mid-day meal, infant child development, and public distribution systems will have a substantial health benefit in Haryana. Darjeeling, West Bengal was the first place in the world to fortify wheat flour in latest years. At present, the fortification status of industrially milled wheat flour in India is about 7.6 per cent. In the states of Odisha and Karnataka, fortified rice is offered through social safety net programmes. Rajasthan leads the way in enriched oil and fortified milk products, which are available throughout the state. The statuses of food fortification in India are furnished in Table 6.1. The Indian government and various state governments promote flour fortification. International organisations and national health and nutrition research institutes are actively involved and flour milling professionals have contributed toward wheat flour fortification. Most fortified flour in India is distributed in the government ‘s welfare system[4].

Table 6.1: Status of Food Fortification Across Indian States

States	Rank	MDM (Mid-day meal scheme)	ICDS (Integrated Child Development Services)	PDS (Public Distribution System)
Andhra Pradesh	1	Fortified rice (2 districts) DFS (4 districts) Fortified oil (4 districts)	Fortified rice (2 districts), DFS (All) Fortified oil (All)	DFS (All), Fortified rice (1 districts)
Uttar Pradesh	2	Fortified wheat flour (2 districts), fortified rice (districts), DFS(1districts), fortified oil (1 District)	Fortified wheat flour (1 district), fortified rice (1 districts), DFS (1 district), fortified oil (1 district)	DFS (10 districts), fortified wheat flour (1 district), fortified rice (1 district)

States	**Rank**	**MDM (Mid-day meal scheme)**	**ICDS (Integrated Child Development Services)**	**PDS (Public Distribution System)**
Tamil Nadu	3	DFS (All), fortified rice (5 districts), fortified oil (All)	DFS (All), fortified oil (All), fortified rice (5 districts)	DFS (All), fortified oil (All), fortified rice (pipeline)
Gujarat	4	Fortified wheat flour (4 districts), fortified rice (1 districts), DFS (pipeline)	Fortified edible oil (All), DFS (All), fortified wheat flour (pipeline)	Fortified oil (All), fortified wheat flour (Pipeline), fortified rice (1 district)
Madhya pradesh	5	Fortified milk (All), DFS (All)	DFS (All)	DFS (20 districts), fortified rice (1 district)
Kerala	6	Fortified rice (4 districts), fortified milk (All – pipeline)	Fortified rice (1 district) (3 districts – pipeline)	Fortified wheat flour (All in NPS and NPNS), fortified rice (Pipeline)
Chandigarah	6	DFS (1 district), fortified oil (1 district)	Fortified milk (All)	Fortified rice (pipeline)
Karnadaka	7	DFS (6 districts) Fortified oil (All districts), fortified rice (4 districts – pipeline)	DFS (4 districts – pipeline)	Fortified rice (4 districts)
Bihar	8	DFS (2 districts)	DFS (6 districts)	
Haryana	8	Fortified oil (All), fortified milk (All), fortified wheat flour (6 districts)	Fortified oil (All), fortified wheat flour (6 districts), DFS (All –pipeline)	Fortified oil (All), fortified wheat flour (5 districts)
Maharashtra	9	DFS (2 districts), fortified wheat flour (2 districts), fortified oil (2 districts)	-	Fortified rice (1 district)
West Bengal	10	-	-	Fortified wheat flour (All)

States	Rank	MDM (Mid-day meal scheme)	ICDS (Integrated Child Development Services)	PDS (Public Distribution System)
Telangana	11	Fortified rice (1 district), fortified oil (4 districts), DFS (4 districts)	Fortified rice (1 district), DFS (2 districts), fortified oil (2 districts)	-
Himachal Pradesh	12	Fortified edible oil (All)	Fortified edible oil (All), DFS (All)	Fortified oil (All), fortified wheat flour (All), DFS (All)
Tripura	12	Fortified rice (All-pipeline), DFS (1 district), fortified oil (1 district)	Fortified rice (All-pipeline)	-
Odisha	13	Fortified rice (2 districts, 14 districts –pipeline), DFS (4 districts), fortified oil (4 districts)	-	Fortified rice (1 district – pipeline)
Rajasthan	14	Fortified wheat flour (1 districts), DFS (9 districts)	Fortified oil (All), DFS (As per availability), fortified wheat flour (2 districts)	-
New Delhi	15	Fortified oil (All), DFS(All)	-	-
Goa	17	Fortified oil (All), DFS (All)	-	Fortified rice (pipeline), fortified wheat flour (pipeline)
Chhattigrah	18	Fortified wheat flour (All), fortified rice (All)	Fortified rice (All), fortified wheat flour (All)	
Andaman and Nicobar	18		-	Fortified wheat flour (All)

Source (FFRC, 2021) (DFS –Double Fortified Salt, NPS- Non Priority Subsidy, NPNS-Non Priority Non Subsidy)

6.5 Government Supported Fortification Programmes:

6.5.1 Mid-Day Meal Scheme (MDM):

The Mid Day Meal (MDM) Scheme aims at improving nutritional levels among children studying in government, local body, and government-aided schools up to 8th class. As per norms, primary school children are provided 100 grams of grains (rice or wheat flour) daily and upper primary school children are provided 150 grams of grains daily, as part of a hot cooked meal served at school. The government allocates 2.16 million MT of food grains (wheat and rice) to feed 118.5 million children every year.

6.5.2 Integrated Child Development Services (ICDS):

Supplementary Nutrition (SN) supplied under ICDS Scheme is of two types for different beneficiaries, i.e., pregnant women, lactating mothers, and children aged 6 months to 3 years receive a Take Home Ration (THR); children aged 3 to 6 years receive a hot cooked meal. Supplementary nutrition served to the beneficiaries is to be prepared as per the National Food Security Act, 2013 which provides food security to the people.

6.5.3 Public Distribution System (PDS):

Public Distribution System (PDS) is the key channel of the government's food security system in India, reaching 67 percent of the population and implemented through the Ministry of Consumer Affairs, Food & Public Distribution, and Department of Food & Public Distribution.

The present food basket of PDS includes wheat, rice, sugar, and kerosene. Many states/UTs also permit sale of food items such as pulses, edible oils, iodized salt, spices, etc. through PDS outlets.

Under NFSA (National Food Security Act) 2013, beneficiaries are classified as AAY (Antyodaya Anna Yojana) or PHH (Priority Households /Non AAY) and get rice at INR 3 per kg, and wheat at INR 2 per kg. Antyodaya Anna Yojana beneficiaries are entitled to 35 kg per family per month; PHH beneficiaries are entitled to 5 kg per person per month[4]

6.5.4 SABLA: A Scheme for Adolescent Girls:

SABLA is a centrally sponsored scheme for all-round development of 11 to 18 years old adolescent girls. The scheme has a special focus on all out-of-school adolescent girls and is implemented using ICDS. The Anganwadi Centres (AWCs) are the focal point for the delivery of the services for 205 districts selected from all state governments/UTs, covering 1 crore beneficiaries. The nutrition component of the scheme aims at improving the health and nutritional status of these girls by provision of supplementary nutrition in the form of both THR (Take home ration) and HCM (Hot cooked meal). Inclusion of fortified staple foods here would be an ideal intervention to address micronutrient malnutrition at the right stage, i.e., among adolescent girls before they go on to be mothers[4]

6.5.5 Welfare Institutions and Hostels:

A bouquet of schemes is provided under the Ministry of Social Justice to address the basic needs of the underprivileged and the elderly. These include welfare institutions taking care of the elderly under the Integrated Programme for Older Persons (IPOP) Scheme which was implemented in 1992. The scheme's major goal is to improve older people's quality of life by providing basic necessities such as shelter, food, medical treatment, and entertainment options, as well as encouraging productive and active ageing. Along with this, many hostels catering to backward classes also get their rations from PDS through FCI. At the national level, fortifying wheat flour and rice will help to improve the nutritional status of the older persons.[4]

6.6 Laws for Food Fortification:

In order to promote fortification as a means to address micronutrient deficiencies, The Food Safety and Standards Authority of India (FSSAI) has approved the provisional Food Safety and Standards (Fortification of Foods) Regulations, 2016, that includes provisions for fortification of wheat flour, rice, milk, edible oil and salt with vitamins and minerals, among several other things. The updated Food Safety and Standards (Fortification of Food) Regulations, 2016 state that the FSSAI may mandate fortification of any food article specified under the regulations from time to time, in consultation with stakeholders, on directions from the Government of India or recommendations from States/UTs. Under Food Safety and Standards (Prohibition and Restriction on Sales) Regulations, 2011, sale of only iodized salt is permitted for direct human consumption. Further, Food Safety and Standards (Food Product Standards and Food Additives) Regulations, 2011 provide that vanaspati shall contain synthetic Vitamin A. The level of fortificants added to the food items are furnished in Table 6.2. The Ministry of Women and Child Development and Ministry of Human Resource Development have advised the use of double fortified salt (iron and iodine), wheat flour (with iron, folic acid and vitamin B-12) and edible oil with (vitamin A and D) under their Schemes i.e. Integrated Child Development Scheme and Mid-day Meal Scheme. Food Fortification Resource Centre (FFRC) was developed by FSSAI in partnership with Tata Trusts and numerous international nutrition NGOs as a resource centre to promote large-scale food fortification and to promote and encourage food industries to adopt fortification as a norm.

6.7 Standards on Fortification:

6.7.1 General Principles:

Essential nutrients may be appropriately added to foods for the purpose of contributing to any of the following:

- Preventing or reducing the risk of, or correcting a demonstrated deficiency of one or more essential nutrients in the population or specific population group.
- Reducing the risk of, or correcting inadequate nutritional status of one or more essential nutrients in the population specific population group.
- Meeting requirements or recommended intake of one or more essential nutrients

- Maintaining or improving health
- Maintaining or improving the nutritional quality of foods.

Table 6.2: Level of Fortificants in Food Products

Sr. No	Food product	Component	Level of nutrients	Source of nutrients
1	**Double fortified salt**	Iodine content a) Manufacture level b) Distribution channel including retail level	 20-30 ppm 15-30 ppm	Potassium iodate
		Iron content (as Fe)	850-1100 ppm	Ferrous sulphate or ferrous fumarate
2	**Fortified oil**	Vitamin A	6 µg RE-9.9 µg/gm of oil	Retinyl acetate or retinyl palmitate
		Vitamin D	0.11 µg RE-0.16 µg per gram of oil	Cholecalciferol or ergocalciferol (from plant source
3	**Fortified milk**	Vitamin A	270 µg RE-450 µg RE	Retinyl acetate or retinyl palmitate
		Vitamin D	5 µg -7 µg	Cholecalciferol or ergocalciferol (from plant source
4	**Fortified wheat flour and rice**	Iron	28 mg – 42.5 mg	Ferrous citrate or ferrous lactate or ferrous sulphate or ferric pyrophosphate or electric iron or ferrous fumarate or ferrous BisGlycinate
		Or sodium iron (III)	14 mg - 21.25 mg	ethylene Diamine Tetra Acetate Trihydrate (Sodium Feredetate – NA Fe EDTA)
		Folic acid	75 µg - 125µg	-
		Vitamin B12	0.75 µg-1.25 µg	Cyanocobalamine or hydroxycobalamine

Source (FFRC, 2021)

All fortified food shall be packaged in a manner that takes into consideration the nature of the fortificant added and its effect on the shelf life of such food. Every package of fortified food shall carry the words "fortified with (Name of the fortificant)" and the logo, as specified in the schedule of these regulations, on the label. All other provisions under the Food Safety and Standards (Packaging and Labelling) Regulations, 2011, also apply to the fortified foods.

Every package of food, fortified with iron shall carry a statement "Not recommended for people with Thalassemia and people on low iron diet." After subregulation, the Department of Food Safety and Standards (fortification of foods) amended regulations pertaining to compliance with standards on micronutrient content in fortified foods in 2020. The fortification of vitamin A and vitamin D in packed refined edible vegetable oil weighing less than 15 kilograms must meet the level set in amended regulation.

In the case of packed toned, double toned, skimmed, or standardised milk, vitamin A and vitamin D must be fortified to the level provided in the specified clause in FSSAI regulation (FSSAI, 2020).

6.8 Conclusion:

Globally nutritional deficiencies are severe issue faced by the people. The major 4 programmes put forward by India include dietary diversification, food fortification, public health and food safety measures, in which food fortification was more beneficial. Food fortification will remain a significant tool for treating and preventing specific nutritional deficiencies, as well as promoting a broader overview of well-being in certain groups and possibly preventing some chronic diseases.

As a result, food fortification research and technology application will have a larger scope of compensating for insufficient nutrients in food. Technological and scientific problems include identifying and developing fortifying substances that will ensure product quality and bioavailability. To attain the country's aim of nutritional security, it is critical to raise nutrition awareness through constant monitoring of population nutritional status and prompt implementation and adjustment of policies.

6.9 Reference:

1. Global Hunger Index (GHI). 2020. One decade to zero hunger linking health and sustainable food systems. DFS Druck Brecher GmbH, Cologne, Germany, 80p.
2. Bagriansky, J. and Ranum, P. 1998. Vitamin A fortification of P.L.480 Vegetable oil. Sustanin, Washington D.C. USA. pp.30.
3. FFRC (Food Fortification Resource Centre). 2023. Available: https://ffrc.fssai.gov.in/commodity?commodity=fortified-milk. [05 January 2023]
4. Bishai, D. and Nalubola R. 2002. The history of food fortification in the United States: Its relevance for current fortification efforts in developing countries. Economical and Development of Cultural Change.51: 37-53.
5. FFRC (Food Fortification Resource Centre). 2021. https://ffrc.fssai.gov.in/resource_other. [20 August 2021].

6. FSSAI (Food safety and standard Authority of India). 2020. Large scale food fortification in India. Food fortification resource centre, New Delhi. 134p
7. NIN (National Institute of Nutrition). 2005. Double fortified common salt as a tool to control iodine deficiency disorders and iron deficiency anaemia. Annual report, 117 p.
8. Sirohi, A. Pundhir, A. and Ghosh, S. Food fortification: A nutritional management strategy in India. 2018. Innovare Journal of Food Science. 6(2): 1-8.

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7. Functional Beverages: A Blend of Taste and Nutrition

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Abstract:

Beverages are one of the most widely used functional foods due to their convenience in packaging and distribution, variety of choice and capability to act as carriers for the essential nutrients and bioactive compounds. Functional beverages are defined as drinks that provide a health benefit beyond basic nutrition. Techniques used in the production of functional beverages include fortification and enrichment, altering a nutrient or the processing method and microencapsulation. Microencapsulation, a popular technology in functional beverage industry, entraps active agents within a carrier material which improves the incorporation of bioactive molecules and living cells into the beverages.

Dairy and non-dairy beverages are the two primary categories of functional beverages. Dairy based beverages are prepared from milk, whey and buttermilk, whereas non-dairy based beverages are from cereals, pulses, millets, fruits, vegetables, tea and coffee. Dairy based functional beverages are made by modifying the fat and protein content of milk, as well as fortifying with fibre, omega 3 fatty acids, phenolic compounds, prebiotics, probiotics, herbs and spices.

There are several forms of whey based beverages, including sports drinks, drinks with fruit juices, drinks with milk and milk products and carbonated whey beverages. Functional beverages based on fruits and vegetables are classified as fermented and non-fermented types. Tea and coffee based beverages are considered functional due to their high phenolic compounds and bioactive compounds including chlorogenic acid, cafestol and kahweol diterpenes. Functional beverages play an essential role in our modern life and contribute to nutritional wellbeing. Sports drinks are one of the most important categories of functional beverages, with the goal of reducing dehydration and maintaining the nutrition of athletes.

Functional beverages also play a role in improving the immune system. Ginger-clove-coffee powder is reported to have anti-microbial, anti-inflammatory and antioxidant property. The drinks with anti-diabetic, anti-hypertensive, anti-cancer and anti-obesity properties have formulated. Functional beverages provide the opportunity for assisting a healthy and active lifestyle, reducing healthcare costs and supporting economic development. Owing to the immense health benefits, increasing consumer demand and choices, there is a huge potential for the development of novel functional beverages.

Keywords:

Nutrition, Functional Beverages, Micro Encapsulation, Dairy Based, Milk Based, Immunity Boosting.

7.1 Introduction:

Food is a term which is basically related to the component necessary for several life sustaining functions like production of energy, supply of nutrients, support of various metabolic activities besides growth and maintenance of the body.

In the early 20th century, nutrition science was engrossed with preventing deficiencies and supporting body growth. During last two decades the knowledge of the dietary influence on health and well-being has been highly increased which has led to design new and healthier foods reducing the risk of several chronic diseases. The foods thus designed are called functional foods which are traditional foods modified in such a way that they have health benefits compared to the non-modified products (Doyon and Labrecque, 2008).

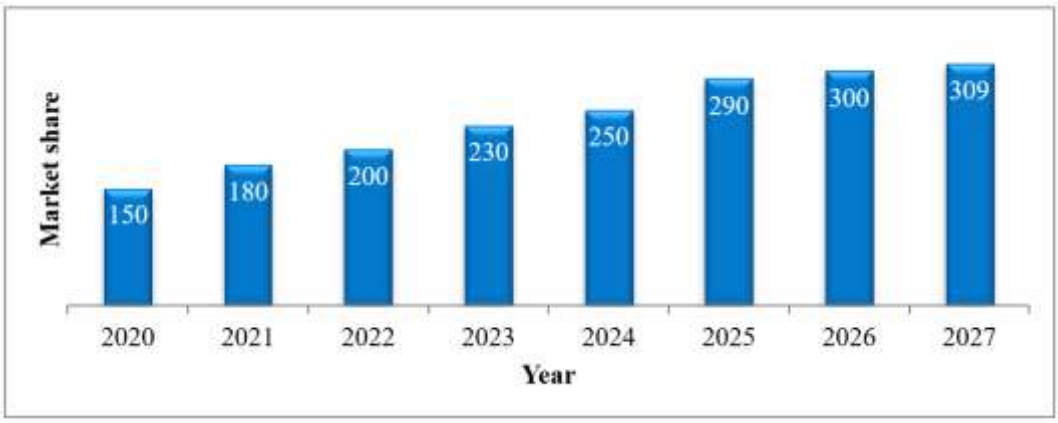

Figure 7.1: Functional food market size 2020-2027 (million dollars)

The functional food market share forecast for the years 2020 to 2027 has clearly shown that there is an increased demand for these functional in the market. In the year 2020 it was 150 million dollars and is estimated that by the year 2027 it may reach a 309 million dollars. We can also see that there are wide varieties of functional foods in the market. The share of dairy products is higher followed by the bakery products.

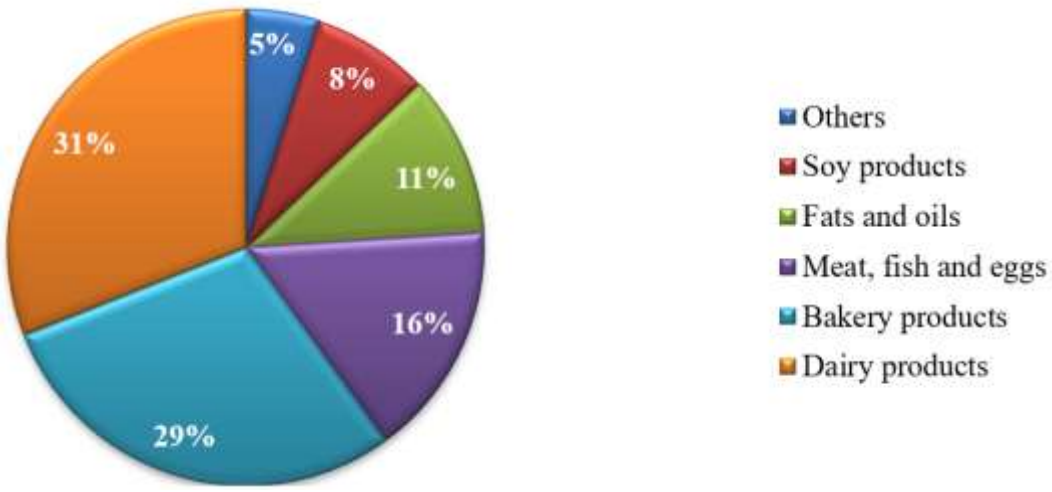

Figure 7.2: Functional food market by product (%)

Beverages are the most active category of functional foods because of their convenience and the ability to meet consumers demand in terms of content size and appearance of the packaging as well as the ease of distribution and storage.

Beverages also represent an excellent medium to incorporate necessary nutrients and bioactive compounds (Global Industries Analyst, 2020).

7.2 Functional Beverages:

In recent times, there has been growing recognition of the key role of foods and beverages in disease prevention and treatment. Thus, the production and consumption of functional foods has gained much importance as they provide a health benefit beyond the basic nutritional functions.

At present, beverages are by far the most active functional food category because of convenience and possibility to meet consumer demands for container contents, size, shape, and appearance, as well as ease of distribution and storage for refrigerated and shelf-stable products.

Moreover, they are an excellent delivering means for nutrients and bioactive compounds including vitamins, minerals, antioxidants, ω-3 fatty acids, plant extracts, and fiber, prebiotics, and probiotics.

However, in most cases, specific concerns have been raised over their safety. A functional beverage is a product that includes ingredients such as herbs, vitamins, minerals, amino acids or additional raw fruit or vegetables (Berner and Donnell, 1998).

Functional beverages are defined as drinks that provide a health benefit beyond basic nutrition (Corbo *et al.,* 2014).

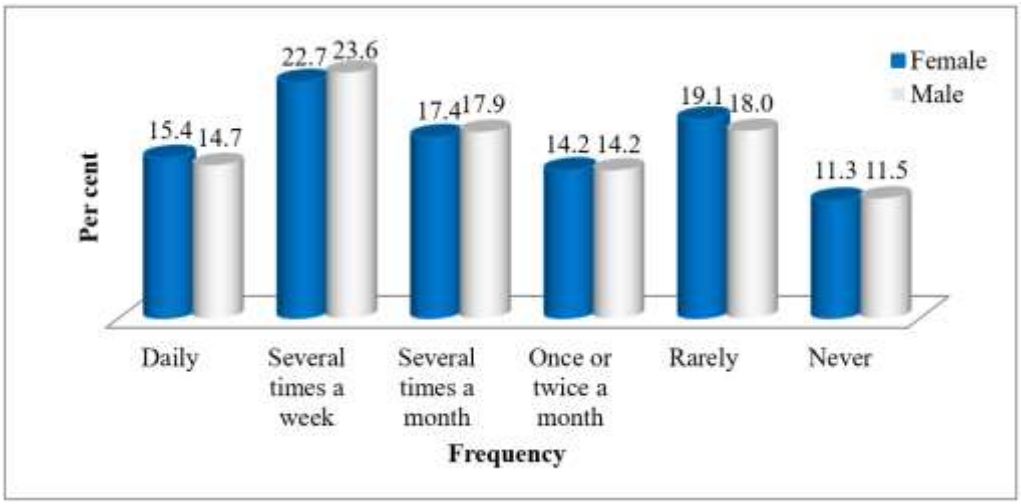

Figure 7.3: Frequency of Consumption of Functional Beverages

In a post covid survey conducted by Natarajan and co-workers in the year 2022 in the state of Tamil Nadu, it was found that 22.7 percentage of females and 23.6 percentage of males had functional beverages several times a week while 15.4 percentage of females and 14.7 percentage of male had functional beverages daily (Natarajan *et al.*, 2022).

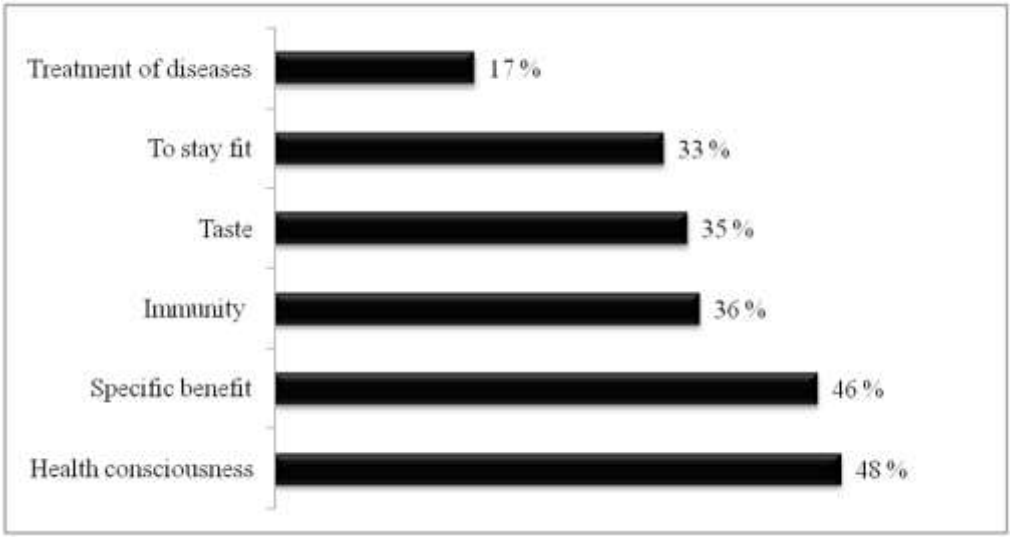

Figure 7.4: Reasons for Consuming Functional Beverages

They have also pointed out the reasons for the increased consumption of functional beverages. it is believed that rise in number of fitness enthusiast and growing consumer's inclination towards healthy lifestyle or expected to do to be the key growth drivers of the function of a wage packet the study also points out the same thing it is said that the persons who had a functional be high rates of functional bridges as due to their health consciousness and 46% of people believe that a specific benefit for these beverages.

7.3 Production Techniques of Functional Beverages:

7.3.1 Fortification or Enrichment:

Fortification is a process wherein we add a specific nutrient to our food to increase its profit new treaty family has all like that here also will add some kind of nutrients or bioactive compounds to the beverages and So that it may be converted to the functional beverages such examples include fortified milk foreign aid and as fortified into the normal milk to improve its nutritive value and Enriched juice wherein it is enriched with certain nutrients lost during its processing enrichment of vitamin c and b etc. Another such example is enhanced water where normal water is enriched with or enhanced with minerals or probiotics, vitamins and much more.

7.3.2 Altering A Nutrient or Processing Method:

By altering the nutrient or the by changing the processing method, certain beneficial factors can be preserved and can benefit in certain health benefits. Alteration of nutrient is seen in skimmed milk wherein the fat is reduced.
The change in processing method like in green tea is another technique wherein the fermentation process is not carried out and that improves the tea's phenolic compounds. Skimmed milk serves the needs of all the consumers who follow or are in need of a low fat diet while the preserved phenolic compounds in the green tea can contribute to various health benefits.

7.3.3 Micro Encapsulation:

A process by which micro- particles or droplets are surrounded by a coating or embedded in a homogeneous or heterogeneous matrix, to give small capsules with many useful properties. This process, suitable to entrap active agents within a carrier material, could be a beneficial tool to enhance the delivery of bioactive compounds and living cells into foods (Tolve *et al.*, 2016).

There are various types of microencapsulation. Some of them include spray and freeze drying, coacervation and microemulsion. In spray and freeze drying, the wall material is mixed with suspension and is evapoured. Another method is coacervation. The latin word *acervus* means heap. This method is mainly used for encapsulating flavors probiotics into beverages. Microemulsion is yet another method which is used for encapsulating bioactive compounds, vitamins, proteins, fatty acids (Sharma and Rathore, 2012).

Functions of micro encapsulation:

- Aroma and flavour stabilization
- Increasing bioavailability and targeted delivery of phenolic compounds
- Increased antioxidant activity
- Shelf life extension
- Protection of valuable nutritious compounds
- Increasing diversity of beverages

Table 7.1: Encapsulation of Probiotics

Functional beverage	Encapsulated micro organisms	Encapsulated technique	References
Grape juice	Lactobacillus casei	Extrusion	Krasaekoopt and Kitsawad, 2010
Carrot juice	L. casei	Spray-drying	Petreska-Ivanovska et al., 2014
Pineapple juice	Bacillus longum	Extrusion	Phoem et al., 2015
Apple juice	Lactobacillus rhamnosus GG	Extrusion	Gandomi et al., 2016

Table 7.2: Encapsulation of Vitamins

Functional beverage	Encapsulated vitamins	Encapsulated technique	References
Orange juice	Vitamin E and vitamin C	Dehydration-rehydration	Marsanasco et al., 2011
Apple juice	Ascorbic acid	Liposomes	Wechtersbach et al., 2012
Orange oil beverage	Vitamin E	Emulsion	Raikos, 2017

7.4 Types of Functional Beverages:

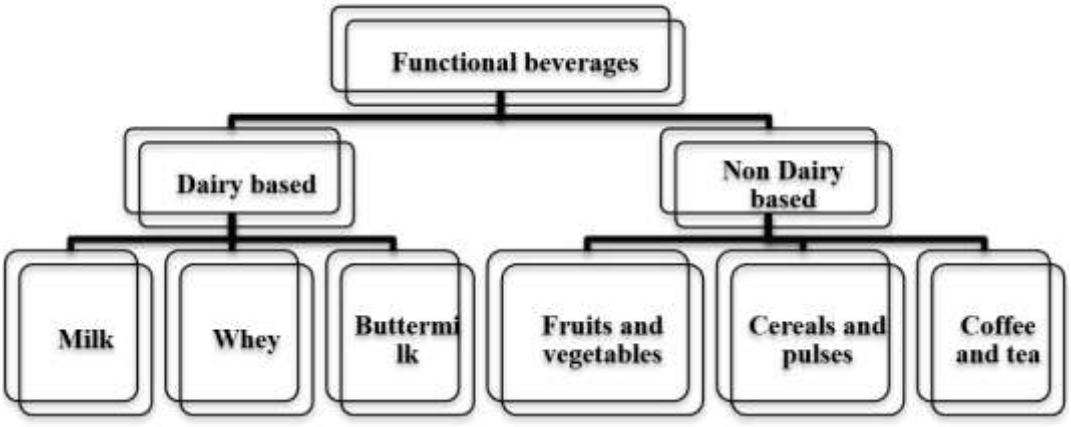

Figure 7.5: Types of Functional Beverages

7.5 Dairy Based:

Dairy based beverages are mainly classified into three milk based, whey based and butter milk based functional beverages (Mudgil and Barak, 2018).

7.5.1 Milk Based:

Milk based beverages can be produced by altering its fat, protein and by fortification. The functionality of normal milk can be improved by the addition of CLA, EPA and DHA into it. These are fatty acids essential for the brain development and brain functioning (Kolanowski and Laufenberg, 2006).

Altering the protein can also improve the functional properties of milk. Enzymatic hydrolysis of protein can result in protein hydrosylates which are bioactive compounds. Apart from this, addition of non-dairy protein sources like millets pulses and egg can also improve the protein content of milk (Makinen *et al*., 2016).

In a study conducted by Lotfia *et al.* (2019), 14% egg white powder was added into the milk to improve its protein quality. The final product was then compared with the normal milk to understand the amino acid content of both and they could find that almost all the amino acids were higher in the final product.

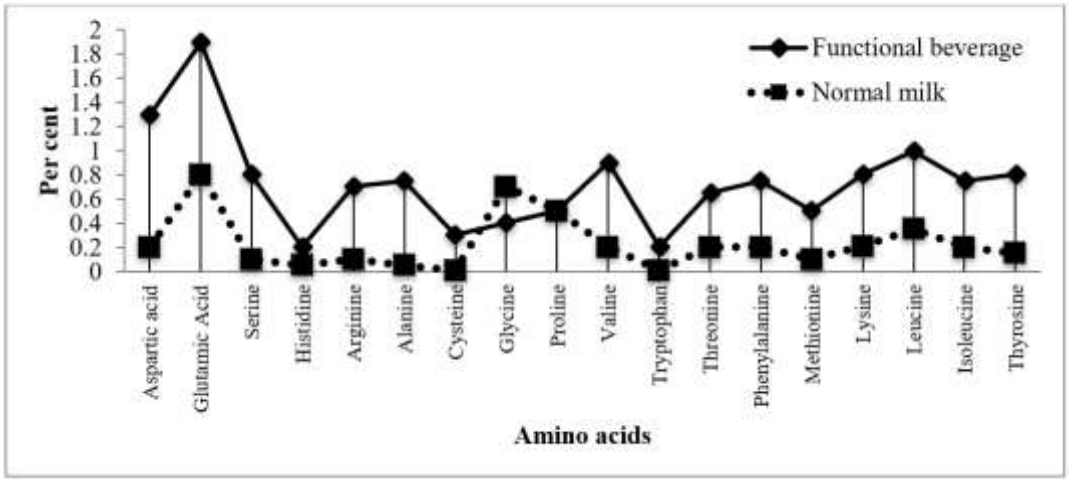

Figure 7.6: Amino Acid Contents in Functional Milk and Normal Milk

Fortification is also another method to improve the quality of beverages. Fortification of milk can be done with vitamins, minerals, fibre, omega 3 fatty acids, phenolic compounds, probiotics, prebiotics, herbs and spices to improve the functionality of milk beverages.

Milk fortified with Vitamin A and D, Calcium flooding in the market can be included under this category (Villegas *et al*., 2010). There are various studies which have undergone to formulate fortified milk beverages. A functional milk was developed by fortifying the normal milk with omega 3 fatty acids from flaxseed oil, phenolic compounds from

phytosetrols and fibre from polydextrose. Fortification of these compounds enhanced the nutritional as well as the therapeutical potential of milk (Nagarajappa and Battula, 2017). Apart from milk, functional yoghurt was formulated with functional ingredients. Johny *et al.* (2021) formulated functional yoghurt with the addition of fruit pulps and functional ingredients.

Fruit pulps of jackfruit, guava, sapota, njalipoovan banana and papaya was added to the yoghurt in the range 10-40 %, in which 10% addition came out best. To this the functional ingredients such as flaxseed and garden cress seed was added to make it a functional yoghurt. Apart from these, herbs can also be added to milk to improve it. Aloe vera pulp was added to milk which on consumption improved the immune system. Addition of betel vine leaf added health benefits such as improved digestion and also it had a high antioxidant property. Fennel, tulsi and lemon grass oil was also fortified to milk. That functional milk helped to decreases the risk of heart disease, it improved eyesight, lowered blood pressure and also it soothes fever, headache and sorethroat.

Table 7.3: Herbal Fortified Milk Beverages

Functional beverage	Herbs	Health benefits	Reference
Milk	Aloe vera pulp	Improved immune system	Pugazhenthi and Jyothilingam, 2013
Milk, yoghurt	Betel vine	Improved digestion, increased antioxidant property	Kamble *et al.*, 2019
Milk, yoghurt	Fennel, tulsi and lemon grass	Decrease the risk of heart diseases, improves eyesight, lowers blood pressure, soothes fever, headache, and sore throat	Kishore *et al.*, 2020

7.5.2 Whey Based:

Whey based milk beverage can be of four types. They are whey based sports drinks, drinks with fruit juice, Drinks with milk and milk products and carbonated whey beverages (Gurakan *et al*., 2009).

A. Whey Based Sports Drinks:

Whey can be efficiently used as sports drinks. After a sport event, the sports personnel will easily get dehydrated. So to overcome that, a rehydrating drink is provided such as ORS. Pushpa *et al.* (2018) formulated a hypotonic rehydration drink by using paneer and cheese whey suitable for sports persons.

All the drinks had electrolytes similar to the recommendation given by WHO for ORS drinks. Hydrolyzing lactose will convert lactose into glucose in whey which made it suitable for even lactose intolerance people.

Table 7.4: Nutritional Comparison of the Hypotonic Drink

Osmolarity (mOsmo/l)					
Constituents	**Untreated whey**		**Lactose hydrolyzed whey**		**WHO formula for ORS drinks**
	Paneer	**Cheese**	**Paneer**	**Cheese**	
Lactose	125.00	133.00	-	-	-
Glucose	-	-	250.00	266.00	75.00
Sodium	14.08	14.35	14.08	14.35	75.00
Potassium	30.94	28.34	30.94	28.34	20.00
Total osmolarity	261.00	232.00	370.00	356.00	245.00

B. Whey Based Drink with Fruit Juices:

Any fruits can be added with whey to improve its flavour, taste and its nutritional property. There are many researches which prove that fruit juices can be incorporated with whey milk to improve its taste and its nutritional quality.

Mango pulp and ginger extract added whey beverage had improved taste and also it had better therapeutical qualities such anti-inflammatory, immunity boosting property (Alane *et al.,* 2017).

C. Whey Based Drink with Milk and Milk Products:

Whey can also be added with the milk and milk products such as yoghurt, sour milk and butter milk to produce functional beverages. According to the product to which whey is added it is classified into unfermented and fermented types (Athanasiadis *et al*., 2004).

D. Carbonated Whey Based Drink:

Carbonated beverages always had a major part in thirst quenching drinks. Probiotic whey is carbonated which have its own functional benefits and at the same time it is thirst quenching. Alves *et al.* (2018) have formulated a probiotic functional drink using the whey.

The probiotic culture used in this study was *Bifidobacterum animalis* subsp. *Lactis* and the product had a viable count of 10^7 to 10^6 till 2 weeks.

7.5.3 Butter Milk Based:

Buttermilk is nothing but the leftover part after butter production. Buttermilk contains more phospholipids than milk because of its high content in milk fat globule membrane material. These phospholipids are having anticarcinogenic properties and also it can protect us from bacterial toxins and also infections.

There are two types of butter milk one is from cultured milk i.e. sour cream and the other from uncultured milk which is sweet cream (Shree *et al*., 2017). Buddhadasa *et al.* (2015) developed a functional beverage based on buttermilk by incorporating soursop pulp, fruit rich in bioactive compounds and having anti-tumorigenic property.

7.6 Non – Dairy Based:

7.6.1 Cereal Based Beverages:

Cereals, apart from being important staple crops and primary sources of energy and nutrition, are replete with bioactive phytochemicals with health properties. Cereal grains contain a diverse range of bioactive phytochemicals including phenolic compounds, dietary fibers, carotenoids, tocols, phytosterols, c-oryzanol, and phytic acid and therefore have great potential for processing into functional beverages.

Although there are a variety of cereal grain-based beverages produced world-wide, very little scientific and technological attention has been paid to them.

In this review, we have discussed cereal grain-based functional beverages based on 3 main categories: cereal grain-based milk alternatives, roasted cereal grain teas, fermented nonalcoholic cereal grain beverages (Xiong *et al.*, 2022).

7.6.2 Pulse Based Beverages:

Over the last decade, plant-based beverages have gained popularity amongst consumers who are seeking alternative and environmentally sustainable options to traditional dairy drinks.

Whilst these days, there is a variety of cereal-based beverages in the market, the legume-based beverage segment is dominated by soy milk products.

There is an opportunity to broaden and diversify this segment into other legumes which may offer better functionality and nutrition than soy.

However, little is known about the processability, functionality, health benefits and associated health risks of legume-based milk substitutes. Apart from soy bean, legumes such chick pea and cow pea can also be used to produce legume based milk substitutes (Nawas *et al.,* 2020).

Soybean milk is a milk alternative beverage due to its inexpensive high-quality vegetable protein. Soybean milk (soybean to water, 1:8 (w/v)) contains an equal amount of protein to a comparable amount of cow's milk but only about one-fifth of the calcium.

Soy milk was fortified with calcium carbonate and tri-calcium phosphate at a similar level of calcium to cow's milk to improve its nutritive quality (Chaiwanon *et al.,* 2000).

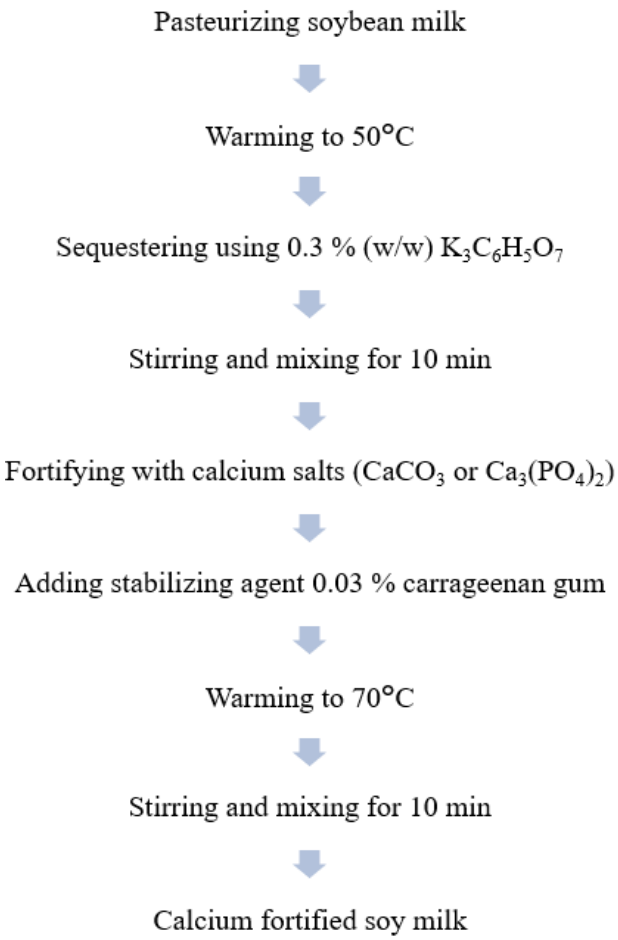

Figure 7.7: Pulse Based Beverages

7.6.3 Fruit/Vegetable Based Beverages:

Functional beverages based on fruits and vegetables are classified as fermented and non-fermented types (Mudgil and Barak, 2018). The functions of food have extended from satisfying hunger and providing nutrients to the body, health maintenance, well-being and prevention of diseases.

Probiotics are such functional foods and when they are incorporated to locally available foods, it helps to improve the nutritional profile and therapeutic value. Probiotic strains were incorporated into locally available fruit juices to improve its nutritive value.

Lactobacillus acidophilus was added to a juice mixture of passion fruit and pineapple (70:30) to develop a probiotic fruit juice (Meera *et al.,* 2021). Fortification of high pressure extracted pomegranate peel extract to carrot juice improved its phenolic content, antioxidant activity and several other beneficial factors in the juice than the normal carrot juice (Trigo *et al.,* 2019).

7.6.4 Tea and Coffee Based Beverages:

Tea and coffee based beverages are considered functional due to their high phenolic compounds and bioactive compounds.

The bioactive compounds seen in tea includes flavanoids, phenolic acids, hydrolysable tannins and that in coffee are chlorogenic acid, cafestol and kahweol diterpenes (Farah, 2009; Heck and Majia, 2009).

Table 7.5: Different Types of Tea/Coffee Based Functional Beverages

Tea / Coffee	Beneficial property	Reference
Green tea	antioxidantanti-inflammatory antimicrobial antimutagenic	Vishnoi *et al.*, 2018
White tea	Cardioprotective antidiabetic, neuroprotective anticarcinogenic antimicrobial antiobesity	Hinojosa-Nogueira *et al.*, 2021
Chrysnthemum tea	antiinflammatory, antipyretic antiarthritic antihypertensive	Li *et al*., 2019b
Fu brick tea	Antiobesity antioxidant	Zhou *et al*., 2021
Date seed coffee	antiinflammatory antidiabetic	Mojrian *et al.*, 2022
Mushroom coffee	anti cholesterolemic	Song, 2020
Green coffee	anti-hypertensive, anti-obesity	Pazmino-Arteaga *et al.*, 2022
Jackfruit seed coffee	anti-diabetic anti-microbial	Spada *et al.*, 2018

7.7 Health and Nutritional Benefits of Functional Beverages:

Functional beverages play an essential role in our modern life and contribute to nutritional wellbeing.

7.7.1 Sports Nutrition:

Sports drinks are one of the most important categories of functional beverages, with the goal of reducing dehydration and maintaining the nutrition of athletes.

It is believed that functional beverages were first confined to sports drinks. They are in need of extra energy which is mainly met by such beverages (Orru *et al.,* 2018).

7.7.2 Immunity Boosting:

Functional beverages also play a role in improving the immune system. Immune boosting beverages are characterized by their high phenolic content, high antioxidant content, hypo allergic property and high micronutrient content (Basak and Gokhale, 2022). Ginger-clove-coffee powder is reported to have anti-microbial, anti-inflammatory and antioxidant property (Lestari *et al.*, 2018). The antioxidant activity of this functional coffee is estimated as 22.42 µg / mL.

7.7.3 Disease Management

The drinks with anti-diabetic, anti-hypertensive, anti-cancer and anti-obesity properties have formulated.

Table 7.6: Different Types of Drinks for Disease Management

	Drinks	Functional properties	Reference
Anti-diabetic drinks	Cashew apple yacon drink	Flavanoid contents, high antioxidant activity, Lowers blood glucose, promotes probiotics, increases catalase enzyme activity in liver	Dionisio *et al.*, 2015
	Quercetin rich guava juice	Quercetin – antioxidant reduces the oxidative damage of pancreas Improves insulin sensitivity	Gayathry and John, 2021
Anti-hypertensive drinks	Fermented milk	Milk (dairy) fermented with lactobacillus bacteria (*Lactobacillus helveticus*), Bioactive peptides	Barrientos *et al*., 2016
	Apocynum tea	Neochlorogenic acid, chlorogenic acid, cryptochlorogenic acid, rutin, isoquercitin, isochlorogenic acid, astragalin	Li *et al*., 2019a
Anti-cancer drinks	Purple basil added drinks	bioactive flavonoids, phenolic and aromatic components, antioxidant activity, anti-inflammatory, anti-tumorigenic	Doguer *et al.*, 2021
	Citrus peel incorporated yoghurt	antioxidant activity phenols in citrus peel – cytotoxicity against human tumor cell lines of colon cancer	Zaki and Naeem, 2021

	Drinks	Functional properties	Reference
Anti-obesity drinks	Papaya seed coffee	Flavonoids, tannins and saponins - inhibitor for pancreatic lipase	Subandi and Nurowidah, 2019
	Kombucha tea	Catechins and flavonoids (theaflavins, theaflavinic acids, thearubigins or theasinensis) hypolipidemic properties	Sinir *et al.*, 2019

7.8 Conclusion:

Functional beverages provide the opportunity for assisting a healthy and active lifestyle, reducing healthcare costs and supporting economic development. Owing to the immense health benefits, increasing consumer demand and choices, there is a huge potential for the development of novel functional beverages.

7.9 References:

1. Alane, D., Raut, N., Kamble, D. B., and Bhotmange, M. 2017. Studies on preparation and storage stability of whey based mango herbal beverage. *Int. J. Chem. Studies* 5:237-241.
2. Alves, S. A. T., Spadoti, L. M., Zacarchenco, P. B., and Trento, F. K. 2018. Probiotic functional carbonated whey beverages: development and quality evaluation. *Beverages* 4(3):49-54.
3. Basak, S. and Gokhale, J. 2022. Immunity boosting nutraceuticals: Current trends and challenges. *J. Food Biochem.* 46(3): 13902-13910.
4. Beltrán-Barrientos, L. M., Hernandez-Mendoza, A., Torres-Llanez, M. J., Gonzalez-Cordova, A. F., and Vallejo-Córdoba, B. 2016. Fermented milk as antihypertensive functional food. *J. Dairy Sci.* 99(6): 4099-4110.
5. Berner, L. A., and O'Donnell, J. A. 1998. Functional foods and health claims legislation: applications to dairy foods. *Int. Dairy J.* 8(5-6): 355-362.
6. Buddhadasa, K., Abesinghe, A. M. N. L., and Luxman, R. A. J. N. 2015. Development of soursop pulp (*Annona muricata*) incorporated fermented sweet cream butter milk beverage. In: *Proceedings of the Research Symposium,* 29-30 January 2015, Sri Lanka, UvaWellassa University, pp. 53-56.
7. Chaiwanon, P., Puwastien, P., Nitithamyong, A., and Sirichakwal, P. P. 2000. Calcium fortification in soybean milk and in vitro bioavailability. *J. Food Compos. Anal.* 13(4): 319-327.
8. Corbo, M. R., Bevilacqua, A., Petruzzi, L., Casanova, F. P., and Sinigaglia, M. 2014. Functional beverages: The emerging side of functional foods. *Compr. Rev. Food Sci. Food Saf.* 13(6): 1192-1206.
9. Dionísio, A. P., de Carvalho-Silva, L. B., Vieira, N. M., de Souza Goes, T., Wurlitzer, N. J., de Fatima Borges, M., de Borito, E. S., Ionta, M., and de Figueiredo, R. W. 2015. Cashew-apple (*Anacardium occidentale* L.) and yacon (*Smallanthus sonchifolius*) functional beverage improve the diabetic state in rats. *Food Res. Int.* 77(2): 171-176.

10. Doguer, C., Yıkmıs, S., Levent, O., and Turkol, M. 2021. Anticancer effects of enrichment in the bioactive components of the functional beverage of Turkish gastronomy by supplementation with purple basil (*Ocimum basilicum* L.) and the ultrasound treatment. *J. Food Process. Preserv.* 45(5): 15436 - 15444.
11. Doyon, M. and Labrecque, J. A. 2008. Functional foods: A conceptual definition. *Brit. Food J.* 110: 1133-1149.
12. Farah, A. 2009. *Coffee as a speciality and functional beverage.* Woodhead Publishing, UK p.395.
13. Gandomi, H., Pourjafar, H., Noori, N., and Basti, A. A. 2016. Study of protective role of double coated beads of calcium alginate-chitosan-eudragit S100 nanoparticles achieved from microencapsulation of Lactobacillus acidophilus as a predominant flora of human and animals gut. *J. Veter. Res.* 71(3): 311-320.
14. Gayathry, K. S. and John, J. A. 2021. Functional beverages: Special focus on anti-diabetic potential. *J. Food Process. Preserv.* 45(11): 15974 - 15990.
15. Global Industries Analyst. 2020. Global health estimates 2021 [online]. Available: https://www.prnewswire.com/news-releases/global-industry-analysts-predicts-the-world-functional-foods-and-drinks-market-to-reach-218-3-billion-by-2026--301508843.html [09 May 2022].
16. Gürakan, G. C., Cebeci, A., and Özer, B. 2009. *Probiotic dairy beverages: microbiology and technology*. Academic Press, US, p.197.
17. Heck, C. I., and de Mejia, E. G. 2009. *Teas and tea-based functional beverages*. Woodhead Publishing, UK p.417.
18. Hinojosa-Nogueira, D., Pérez-Burillo, S., de la Cueva, S. P., and Rufián-Henares, J. Á. 2021. Green and white teas as health-promoting foods. *Food Funct.* 12(9): 3799-3819.
19. Johny, L. M., Panjikkaran, S. T., Aneena, E. R., Sharon, C. L., and Lakshmy, P. S. 2021. Standardisation and quality evaluation of fruit pulp based yoghurts. *J. Res. ANGRAU* 49(4):77-85.
20. Kamble, V. S., Patange, D. D., Kamble, D. K., Kamble, K. S., and Patil, S. J. 2019. Process optimization for flavoured milk added with piper betel leaves. *Int. J. Curr. Microbiol. Appl. Sci.* 8(01): 713-724.
21. Kishore, M. A. M., Chaturvedi, D. K., and Dantu, P. K. 2020. Herbal flavoured milk and sensory evaluation. *Int. J. Curr. Microbiol. Appl. Sci.* 9(05): 1861-1870.
22. Kolanowski, W. and Laufenberg, G. 2006. Enrichment of food products with polyunsaturated fatty acids by fish oil addition. *Europ. Food Res. Technol.* 222(3): 472-477.
23. Krasaekoopt, W. and Kitsawad, K. 2010. Sensory characteristics and consumer acceptance of fruit juice containing probiotics beads in Thailand. *A U J. Technol.* 14(1): 33-38.
24. Lestari, A. P., Legowo, A. M., and Susanti, S. 2018. Optimization of coffee-clove-ginger formulated powder based on antioxidant activity and physicochemical properties. *J. App. Food Technol.* 5(1): 10-14.
25. Li, C., Tan, F., Yang, J., Yang, Y., Gou, Y., Li, S., and Zhao, X. 2019a. Antioxidant effects of Apocynum venetum tea extracts on d-galactose-induced aging model in mice. *Antioxid.* 8(9): 381 - 387.
26. Li, Y., Yang, P., Luo, Y., Gao, B., Sun, J., Lu, W., Liu, J., Chen, P., Zhang, Y., and Yu, L. L. 2019b. Chemical compositions of chrysanthemum teas and their anti-inflammatory and antioxidant properties. *Food Chem.* 286: 8-16.

27. Lotfian, F., Karami, M., and Moeini, S. 2019. Functional protein beverage with milk and egg white; physical properties, formulation, protein contents and amino acids components. *J. Food Bioprocess Eng.* 2(1): 49-54.
28. Mäkinen, O. E., Wanhalinna, V., Zannini, E., and Arendt, E. K. 2016. Foods for special dietary needs: Non-dairy plant-based milk substitutes and fermented dairy-type products. *Critic. Rev. Food Sci. Nutr.* 56(3): 339-349.
29. Marsanasco, M., Márquez, A. L., Wagner, J. R., Alonso, S. D. V., and Chiaramoni, N. S. 2011. Liposomes as vehicles for vitamins E and C: An alternative to fortify orange juice and offer vitamin C protection after heat treatment. *Food. Res. Int.* 44(9): 3039-3046.
30. Meera, P. M., Sharon, C. L., Panjikkaran, S. T., Aneena, E. R., Lakshmy, P. S., and Gomez, S. 2021. Process Optimisation and Quality Evaluation of Passion Fruit and Pineapple based Probiotic Drink. *Asian J. Dairy Food Res.* 40(4):428-433.
31. Mojrian, F., Moeenfard, M., Farhoosh, R., and Mahdavian M. H. 2022. Investigation of the *Coffea Arabica* substitution with roasted date seed on physicochemical and sensory properties of coffee brew. *Iranian Food Sci. Technol. Res. J.* 18(1): 96-112.
32. Mudgil, D. and Barak, S. 2018. *Beverages - Processing and Technology*, Scientific Publishers, Jodhpur, 302p.
33. Nagarajappa, V. and Battula, S. N. 2017. Effect of fortification of milk with omega- 3 fatty acids, phytosterols and soluble fibre on the sensory, physicochemical and microbiological properties of milk. *J. Sci. Food Agric.* 97(12): 4160-4168.
34. Natarajan, T. and Jayadevan, G. R. 2021. COVID-19 pandemic and the Consumption Behaviour of Branded Functional Beverages in India: a conceptual framework. *Nutr. Food Sci*. 52(3): 423-444.
35. Nawaz, M. A., Tan, M., Oiseth, S., and Buckow, R. 2020. An emerging segment of functional legume-based beverages: A review. *Food Rev. Int.* 38(5):1064-1102
36. Orrù, S., Imperlini, E., Nigro, E., Alfieri, A., Cevenini, A., Polito, R., Daniele, A., Buono, P. and Mancini, A. 2018. Role of functional beverages on sport performance and recovery. *Nutrients* 10(10): 1470 - 1485.
37. Pazmiño-Arteaga, J., Gallardo, C., González-Rodríguez, T., and Winkler, R. 2022. Loss of Sensory Cup Quality: Physiological and Chemical Changes during Green Coffee Storage. *Plant Foods Human Nutr.* 1(10): 1-11.
38. Petreska-Ivanovska, T., Smilkov, K., Zivikj, Z., Petrusevska-Tozi, L., and Mladenovska, K. 2014. Comparative evaluation of viability of encapsulated *Lactobacillus casei* using two different methods of microencapsulation. *Int. J. Pharm. Phytopharm. Res.* 4(1):20-24.
39. Phoem, A. N., Chanthachum, S., and Voravuthikunchai, S. P. 2015. Applications of microencapsulated *Bifidobacterium longum* with *Eleutherine americana* in fresh milk tofu and pineapple juice. *Nutrients* 7(4): 2469-2484.
40. Pugazhenthi, T. R. and Jothylingam, S. 2013. Development of diabetic herbal flavoured milk and analysis for its physic chemical properties. *Int. J. Food Agric. Veter. Sci.* 3(1): 54-57.
41. Pushpa, B. P., Kempanna, C., and Murthy, N. 2018. Formulation of hypotonic electrolyte re-hydration whey drinks from paneer and cheese whey. *Asian J. Dairy Food Res.* 37(3): 197-201.
42. Raikos, V. and Ranawana, V. 2017. Designing emulsion droplets of foods and beverages to enhance delivery of lipophilic bioactive components–a review of recent advances. *Int. J. Food Sci. Technol.* 52(1): 68-80.

43. Sharma, N. and Rathore, K. S. 2012. A review on microencapsulation: A new multiutility advanced technology. *Int. J. Adv. Res. Pharm. Bio Sci.* 1(4): 15-21.
44. Shree, T. C., Venkatesh, M. M., Praveen, A. R., and Teja, V. 2017. Effect of whey protein concentrate and fruit juice on sensory quality of enriched misti dahi. *Asian J. Dairy Food Res.* 36(1): 21-25.
45. Sinir, G. Ö., Tamer, C. E., and Suna, S. 2019. *Kombucha tea: A promising fermented functional beverage.* Woodhead Publishing, UK, 323p.
46. Song, H. N. 2020. Functional cordyceps coffee containing cordycepin and β-glucan. *Prev. Nutr. Food Sci.* 25(2): 184–193.
47. Spada, F. P., Mandro, G. F., da Matta Junior, M. D., and Canniatti-Brazaca, S. G. 2020. Functional properties and sensory aroma of roasted jackfruit seed flours compared to cocoa and commercial chocolate powder. *Food Biosci.* 37: 100683 - 100694.
48. Subandi and Nurowidah, A. 2019. The Potency of *Carica papaya* L. Seeds Powder as Anti-Obesity 'Coffee' Drinks. *Materials Sci. Eng.* 515(1): 012098 -012106.
49. Tolve, R., Galgano, F., Caruso, M. C., Tchuenbou-Magaia, F. L., Condelli, N., Favati, F., and Zhang, Z. 2016. Encapsulation of health-promoting ingredients: Applications in foodstuffs. *Int. J. Food Sci. Nutr.* 67: 888-918.
50. Trigo, J. P., Alexandre, E. M., Oliveira, A., Saraiva, J. A., and Pintado, M. 2020. Fortification of carrot juice with a high-pressure-obtained pomegranate peel extract: chemical, safety and sensorial aspects. *Int. J. Food Sci. Technol.* 55(4): 1599-1605.
51. Villegas, B., Tárrega, A., Carbonell, I., and Costell, E. 2010. Optimising acceptability of new prebiotic low-fat milk beverages. *Food Qual. Prefer.* 21(2): 234-242.
52. Vishnoi, H., Bodla, R. B., Kant, R., and Bodla, R. B. 2018. Green Tea (*Camellia sinensis*) and its antioxidant property: A review. *Int. J. Pharm. Sci. Res.* 9(5): 1723-1736.
53. Wechtersbach, L., Ulrih, N. P., and Cigic, B. 2012. Liposomal stabilization of ascorbic acid in model systems and in food matrices. *LWT-Food Sci. Technol.* 45(1): 43-49.
54. Xiong, Y., Zhang, P., Warner, R. D., Shen, S., and Fang, Z. 2022. Cereal grain-based functional beverages: from cereal grain bioactive phytochemicals to beverage processing technologies, health benefits and product features. *Critic. Rev. Food Sci. Nutr.* 62(9): 2404-2431.
55. Zaki, N. and Naeem, M. 2021. Antioxidant, Antimicrobial and Anticancer Activities of Citrus Peels to Improve the Shelf Life of Yoghurt Drink. *Egyptian J. Food Sci.* 49(2): 249-265.
56. Zhou, F., Li, Y. L., Zhang, X., Wang, K. B., Huang, J. A., Liu, Z. H., and Zhu, M. Z. 2021. Polyphenols from Fu Brick tea reduce obesity via modulation of gut microbiota and gut microbiota-related intestinal oxidative stress and barrier function. *J. Agric. Food Chem.* 69(48): 14530-14543.

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8. Nutrigenomics – A Novel Way of Disease Diagnosis and Prevention

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Abstract:

Nutrigenomics is a study that combines genetic science and nutrition science. The emergence of nutrigenomics as a science opens up new avenues for better identifying individual dietary needs and the effect of food and its componentson gene expression, as well as understanding the nutrigenomics–disease interrelationship. Currently, nutrigenomics concentrates on Single Nucleotide Polymorphisms (SNPs) in genes. A SNP is a germline substitution of a single nucleotide at a specific position in the genome. SNPs are the most common type of human genetic variation and a valuable resource for mapping complicated genetic characteristics. The revelation of SNPs enabled us to diagnose numerous health conditions well before symptoms appeared. This can also help dieticians and health workers educate their patients with personalised nutrition and efficiently manage a healthier physique throughout their lifespan. However, because the tests are

primarily conducted at the laboratory level, the efficacy and feasibility of this are still in question. As a result, greater research on dietary components using tissue/cell model systems may aid in a better understanding of the interactions between nutrigenetics, nutritional epigenomics, nutritional transcriptomics, proteomics, and metabolomics.

Keywords:

Nutrigenomics, Personalised nutrition, Diabetes, Cancer, Disease diagnosis

8.1 Introduction:

Ever since the beginning of time, scientists have been working diligently to understand the etiology of human diseases. In recent decades, scientists could find that not only the nature and nurture of the human beings are the reason for disease conditions. The fact that even the presence of a gene or the mutation of the gene can be a cause of the diseases was recently unveiled. This has led to the development of various researches to understand the relation between genes and health. One such approach led way to the development of a branch of science named 'Nutrigenomics'.

Nutrigenomics is the study of integrating the genomic science and nutrition science. Initially, it was referred to the study of the effect of nutrients in the expression of a genetic makeup. Later on, the study was expanded to understand the nutritional factors which protected the genome from damage. It is more often termed as personalised nutrition, precision health care as it is a type of customised nutrition therapy that not only helps to combat diseases but also to maintain a healthy life[1].

The advent of nutrigenomics as a science, provides opportunities to better identify individual dietary demands and the effect of food and food components on gene expression, as well as to comprehend the nutrigenomics–disease interrelationship. It studies genetic differences, as well as the effects of epigenetic changes and transcriptome homeostasis on the response to individual bioactive dietary components. This concept is based on the notion that bioactive dietary components can alter the human genome, either directly or indirectly, and hence alter gene and gene product expression. As a result of this influence, dietary patterns and/or specific dietary components may alter many biological processes, including ageing, as well as the origin, incidence, progression, and/or severity of a variety of diseases. The health impacts of a diet are determined by the balance of health and disease in an individual's genetic makeup.

8.2 History of Nutrigenomics:

The history of nutrigenomics begins with the isolation of DNA. In 1869, the Swiss physician Friedrich Miescher, isolated DNA. He was researching the proteins in leucocytes when he discovered a material that was not a protein yet had special properties. Later in 1944, Avery, MacLeod and McCarty revealed that DNA is the hereditary material. Eventually, in 1953, Watson and Crick published the molecular structure of DNA. It was subsequently commercialised by 1980's. The first nutrigenomics company was launched in 1997. Nancy Fogg-Johnson and Alex Merolli renamed nutritional genomics as nutrigenomics in 1999 as

it provides a potent technique for uncovering genetic variables in disease. In 2003, the Human Genome Project was launched and the project contained the complete sequencing of the human genome which paved the way for the 'omics revolution'[2].

8.3 Nutrigenomics – The Food Genome Interface:

The balance of human health is maintained by the adequate intake of all nutrients in a balanced way and the proper utilisation of these is required by each human being. The deficiencies can be reduced by slightly increasing the quantities and improving the quality of food taken. Eventhough a person's intake of nutrients is sufficient, he may have nutrient deficiencies. Hence,it is understood that beyond the intake of food and the metabolism of the food, there are even more factors affectingthe occurrence of a disease. Studies have concluded that the problem of deficiency is not only due to overt poverty, food choices, conditions or medications which alter nutrient utilisation and malabsorption disorders but also because of the genetic polymorphisms which modify the individual needs[3].

Researchers have evidently shown that the macronutrients (fatty acid and proteins), micronutrients (vitamins), bioactive compounds (phytochemicals) and certain zoo-chemicals (Eicosapentanoic acid and Decosahexanoic acid) regulate gene expressions. Most of these nutrients are also involved in the metabolic reactions which maintain things from hormonal balance, detoxification and immunity to even the utilization of macronutrients for energy and growth. Some bioactive compounds in food are ligands for transcription factors and some alter transduction pathways and chromatin structure. These can alter gene expression directly and indirectly. Studies have also pointed out that the deficiency or excess of nutrients plays a major role in determining genome health.

At present, nutrigenomics focuses much on Single Nucleotide polymorphisms (SNPs) of the genes. A Single Nucleotide Polymorphism (SNP) is a germline substitution of a single nucleotide at a particular point in a genome. SNPs are the most abundant form of human genetic variation and a resource for mapping complex genetic traits. Some of the essential nutrient gene interactions and their clinical manifestations are furnished below (Table 8.1).

Table 8.1: Essential Nutrient- Gene Interaction and Their Clinical Manifestations

Nutrient	Gene polymorphism	Effects on nutrient status	Clinical manifestations
Carbohydrates	Beta-2-adrenergic receptors Q27E	Unknown	Higher risk of obesity in female carriers with carbohydrate intake >49% of energy
Omega 3 and 6 fatty acids	Fatty acid desaturase, FADS SNP rs174537	Lower plasma arachidonic and eicosapentaenoic acids and higher plasma alpha	The minor allele homozygotes (TT) have lower plasma total cholesterol and

Nutrient	Gene polymorphism	Effects on nutrient status	Clinical manifestations
		linolenic and linoleic acids in carriers of the minor allele versus non carriers.	LDL-C compared with non-carriers
Vitamin A	β-carotene 15,15′-monoxygenase (BCMO1) R267S (rs12934922) and A379V (rs7501331)	Carriers of 267S or 267S + 379V have reduced activity in converting B-carotene to retinal	Increased risk for vitamin A deficiency, when B carotene is the major dietary source
Vitamin D	Vitamin D binding protein DBP-1 (rs7041, exon 11 T>G) and DBP-2 (rs4588, exon 11C>A)	SNPs for DBP-1 and DBP-2 are inversely related to levels of circulating 25(OH) vit D3 in premenopausal women	Unclear whether carriers would benefit from dietary supplementation or sun exposure
Vitamin K	Vitamin K epoxide reductase complex subunit 1 (VKORC1)j – +2255T>C	Associated with vitamin K recycling, vitamin K–dependent clotting factors and Warfarin resistance	Increased risk of arterial vascular disease such as stroke, coronary heart disease, and aortic dissection
Vitamin B12 (cobalamin)	Methionine synthase TCN2 776C>G and 67A>G	Causes hyperhomocysteine mia	Associated with birth defects
Folate	5,10-methylenetetrahydrofol ate reductase (MTHFR) 677C>T	Causes a 70% reduction in MTHFR activity, hyperhomocysteine mia and reduced plasma folate concentration	Hyperhomocysteine mia is associated with increased risk of coronary heart disease, neural tube defects, occlusive vascular disease and breast cancer. In carriers, sufficient folate dietary intake decreases risk of colorectal cancer, and deficiencies increase risk of colorectal cancer
Calcium	Calcium sensing receptor (CASR) A986S	Loss of function for calcium, associated with higher serum calcium, and higher	Association with bone mineral density

Nutrient	Gene polymorphism	Effects on nutrient status	Clinical manifestations
		urinary calcium excretion	
Selenium	Missense mutation in selenium binding protein 2 (SBP2)	Causes defective selenocysteine insertion sequence (SECIS)-driven selenocysteine incorporation, downregulates expression of selenoproteins	Defective thyroid function
Iron	Human hemochromatosis protein (HFE) 187C>G or 845G>A	Both187C>G or 845G>A associated with iron overload (hemochromatosis)	Iron overload, liver cirrhosis, and cardiomyopathy, especially in diets high in iron
Sodium	Angiotensin gene (AGT) nucleotide −6 G>A,	The A substitution in AGT affects the interaction between at least one *trans*-acting nuclear factor and its promoter, resulting in increased gene transcription and increased angiotensin protein levels	Carriers of the A allele respond to low sodium diets with reductions in blood pressure; GG genotype is not salt-sensitive

In addition to the essential nutrients, there are several other factors dependent on the genetic expression and disease conditions. Other factors include diet composition, fibre, food structure and antioxidant capacity, environmental and metabolic regulation, including gut microbiota composition, prebiotics, metabolic phenotypeand physical activity[4]. Nutrients can affect gene expression via different mechanisms: (i) directly; (ii) through their metabolites and (iii) through signal transduction molecules. Nutrients present in food and diet can affect gene expression in a number of ways. They may directly act as ligands for transcription factors and change gene expression. Nutrients may be metabolized by different pathways, thereby modifying the concentration of substrates or intermediates that affect gene expression. Alternatively, the substrates or intermediates may act on or alter cell signaling pathways involved in gene expression. Moreover, nutrients may directly alter signal transduction pathways responsible for modifications in gene expression. Finally, the modifications in the signaling pathways, caused by nutrients, may modulate the metabolism of nutrients affecting gene expression. The modifications in gene expression may affect muscle, liver, pancreatic β cells, hypothalamus and adipose tissue, thereby regulating glucose homeostasis.

In short, Nutrigenomics involves the characterisation of gene products, their physiological function and interactions. By focusing on the effects of nutrients on genome, proteome, metabolome it explains the relationship between the nutrients and nutrient- regimes on human health. At the onset, nutrigenomics was concentrating on the genetics of the disease conditions such as obesity, diabetes mellitus and cardio vascular diseases. But advancements in researches, SNPs related to various other disease conditions like cancer, allergies, periodontitis, non-alcoholic liver diseases and many more were identified.

8.4 Nutrigenomics – Role in The Prevention of Diseases:

From several studies, it is understood that by examining the interaction of nutrients and their functions in the human body, the genetic changes occurring in them can be identified. This inturn helps to diagnose a disease in advance and thus helps to maintain good health. It is found that if there is a nutrient deficiency persisting in the body; it can lead to certain gene alterations. These gene alterations and the deficiency condition can together lead to certain disease conditions in thefuture. Some of such nutrient deficiencies, the gene alterations and the disease conditions are furnished below (Table 8.2).

Table 8.2: Nutrient Deficiencies, Gene Alterations and The Disease Conditions

Nutrients	Gene Alterations caused by deficiency	Deficiency diet and disease potential	Preventive foods
Protein	Alters gene expression	Kwashiorkor, Marasmus	Egg, milk, soya milk, tofu, yoghurt, cheese, broccoli, almonds, peanuts, cashew, poultry
Fatty acids	Alters gene expression	Obesity, CVD, Diabetes	Salmon, sardines, herring, mackerel, soyoil, sunflower oil, palm oil, flaxseeds, rapeseeds, peanuts, walnuts, almonds, mustard seeds, cloves, oregano, cauliflower, broccoli
Vitamin A(Retinol)	Repression of PEPCK gene	Termination of pregnancy and fetal death	Carrots, spinach, turnip, kale, apricots, Cantaloupe, bell pepper, Papaya, mango, peach, beef liver, chicken liver
Vitamin D (Calciferol)	Prevent gene variation	Colon, breast, prostate cancer	Beef liver, cod liver oils, salmon, mackerel, tuna, egg orange juice, cow milk, yogurt, cheese

Nutrients	Gene Alterations caused by deficiency	Deficiency diet and disease potential	Preventive foods
Vitamin E (Tocopherols)	Mimics radiation damage	Colon cancer, heart disease, immune dysfunction	Tomato, spinach, broccoli, blueberries, mangoes, kiwi, papaya, almonds, hazelnuts, peanuts, wholegrain cereals and vegetable oils
Vitamin B6 (Pyridoxine)		Cancer, heart disease, brain dysfunction, male infertility, leukemia	Spinach, potato, bell peppers, turnip, mushroom, garlic, cauliflower, banana, chicken, pork, beef, salmon, tuna, turkey
Vitamin B3 (Niacin)	Hampers DNA repair	Nerve problem, memory loss	Pork, tuna, prawns, kidney, liver, poultry, carrots, turnips and celery, mushrooms, beans, almonds, wheat products, rice bran, as well as milk and other dairy products
Vitamin B6 (Pyridoxine)		Cancer, heart disease, brain dysfunction, male infertility, leukemia	Spinach, potato, bell peppers, turnip, mushroom, garlic, cauliflower, banana, chicken, pork, beef, salmon, tuna, turkey
Vitamin B12 (Cobalamin)	Chromosome break and hampers DNA repair/methylation	Cancer, heart disease, brain dysfunction, male infertility, leukemia, memory loss	Liver, sardines, salmon, clam, beef, milk, cheese, yoghurt
Folic acid	Chromosome break and hampers DNA repair/methylation	Cancer, heart disease, brain dysfunction, male infertility, leukemia	Liver, kidney, egg yolk, asparagus pea, cowpeas, lentils, peanuts, spinach, beetroot, broccoli, orange
Zinc	Chromosome breaks	Brain and immune dysfunction	Oysters, beef, crab, pork, lobster, chicken, spinach, broccoli, cashew nuts, almond, milk, cheese, yogurt

Nutrients	Gene Alterations caused by deficiency	Deficiency diet and disease potential	Preventive foods
Flavonoids	Alters gene expression	Cancer	Onion, green bean, broccoli, curly kale, endive, celery, cranberry, orange juice, grape fruits, lemons, red, blue and purple berries, peppers, tomatoes and eggplants

What is the source for the Table 2:

Nutrigenomics and its involvement in the diagnosis and prevention of various diseases are discussed further.

8.4.1 Diabetes Mellitus:

Diabetes mellitus (DM) is a group of metabolic diseases characterised by hyperglycemia, which results from defects in insulin secretion, insulin activity or both. It is associated with the dysfunction and failure of different organs, such as the blood vessels, heart and kidneys [5]and this disease is considered asa global burden[6]. Food intake is a key component that affects the incidence of DM. Thus, the identification and analysis of nutrient/gene interactions can assist in understanding the DM etiopathogenesis. Diabetic Mellitus is one of the first diseases, the nutrigenomics have intervent.

There are several factors which help to identify the incidence of DM. The intake of excess fat and calorie can increase the prevalence of diabetes. It was also reported that adinopection gene polymorphism can contribute to insulin resistance and can cause DM. This is said to aggravate in the persons consuming foods witha high glycemic index.

Likewise, the sufficient or insufficient intake of many bioactive compounds, amino acids, vitamins and other major or minor nutrients predispose to the exposition of genetic variations related to DM. The intake of dietary fibre in the diet is interrelated to the microbiota in the body. The activity of this microbiota is highly influential in the absorption of various nutrients. The deficiency caused because of the improper absorption or utilisation of the essential nutrients may cause gene polymorphism. This gene polymorphism may in turn increase the prevalence of diseases like DM[7]. It is found that apart from the absorption and utilisation of nutrients in the microbata, the change in the microbial activities may affect the gut immunity. The alterations in gut immunity can precipitate diabetes in DM prone persons.

Studies revealed that not only dietary factors but other environmental factors also influence DM incidence and development. These factors primarily include the use of breast milk *vs.* infant formula, highly hydrolyzed infant formula *vs.* conventional infant formula, early/late exposure to gluten and vitamin D.

Identifying the SNPs related directly and indirectly to these changes in the body can thus diagnose the incidence of DM in people. Scientists working in the field of nutrigenomics have already pointedoutseveral SNPs associated with both Type 1 and Type 2 Diabetes Mellitus.

8.4.2 Cardiovascular Diseases:

Cardiovascular diseases include heart attacks, stroke, hypertension, rheumatic heart disease, congenital heart disease and heart failure[8]. Diet and exercise plays a major role in controlling these conditions to a great extent. In spite of the advances in the diagnosis and treatments of cardiovascular diseases, there were some lacunae[9]. These lacunae were addressed to some extent when genetics was employed to identify the gene-disease relationship.

There are several foods related factors linked with cardiovascular diseases starting with the increased intake of saturated fatty acids (SFA), andlower intake of dietary fibre. The potential molecular mechanisms for nutrigenomic interactions in CVD risk include (1) differential intestinal metabolism and uptake of nutrients depending on the gut microbiota, (2) differential absorption and nutrient binding, desponding of the genotype and phenotype, (3) modulation of gene expression through specific transcription factor binding, (4) effects on methylation and epigenetic modification and (5) modulation of metabolic signalling through lipids, metabolites and proteins. The interaction of genetic variants with the environment and specific dietary consumption can alter the overall risk of CVD. There are many genes and SNPs identified which is associated with cardiovascular diseases.

With sufficient knowledge on the connection between certain genetic variants, diet and CVD risk, it may be capable of giving individuals dietary counselling suited to their genotype, hence extending life expectancy and maintaining health.

8.4.3 Obesity:

The fraction of the global population that is overweight or obese is reaching epidemic proportions, with all of the associated health, social and economic consequences. Although there are several causes for the rise in obesity, the most plausible reason is the modern lifestyle's increased calorie consumption and decreasing exercise.

Most people who eat more and moveless will gain weight,but being overweight or obese is a gradual process that takes years of even little excess calorie consumption. Although weight reduction is challenging, sustaining weight loss is even more challenging.

In fact, just a few non-surgical therapies for obesity succeed in long-term weight loss. Long-term weight loss maintenance necessitates permanent lifestyle changes in exercise and food habits. One such approach paved the way for the inclusion of nutrigenetically personalised diets to such persons. A study conducted by Arkadianos *et al.* [10] on the patients who strived to reduce theirweight revealed that the adoption of nutrigenetically personalized diets resulted in improved long-term BMI reduction. The inclusion of such a diet also helped in maintaining the blood glucose levels in the persons.

Obesity susceptibility is influenced in part by hereditary factors, but "obesogenic" environment is often required for its phenotypic expression. As a result, while new evidence of genetic influence and neuroendocrine imbalance emerges on a daily basis, it is crucial to analyse a holistic model in which biological and psychological factors interact in a complex manner.

As a result of several studies, several genes and SNPs associated with obese phenotypes were discovered. The important genes associated with obesity are the FTO gene, INSIG2 Gene, MC4R gene and APO-A gene. Several SNPs connected with these genes were uncovered, and they had an impactonweight loss in a variety of ways[11].

8.4.4 Cancer:

According to WHO, cancer is a vast category of disease that can begin in practically any organ or tissue of the body when abnormal cells develop uncontrollably, invade neighbouring tissues, and/or spread to other organs. The latter phase is known as metastasizing, and it is a primary cause of cancer death. Cancer is also known as a neoplasm and a malignant tumour. Globally, cancer is the second most important reason for death.

As the incidence of cancer is rising day by day and the mortality increases because of the late diagnosis, an effective preventive strategy has to be developed. In such scenario, cancer is a disease which can be more benefitted with the advent of nutrigenomics. Dietary changes have the potential to be an effective approach of lowering cancer risk. Many studies have pointed out the relationship of nutrients and cancer.

Dietary components are believed to be important predictors of cancer risk in humans. Genetic variations influence absorption and metabolism, resulting in altered response to dietary components. Epigenetic processes can alter DNA methylation patterns, affecting overall gene expression, which can be modified in response to diet components.

Many dietary constituents influence post-translational events and may contribute for some of the variances in response to dietary components. Bioactive food components have the potential to influence cellular and molecular activities that are crucial in cancer prevention.

Covalent adducts with individual nucleic acids of DNA or RNA is produced as a result of carcinogen activation. It has also been discovered that reactive oxygen species (ROS) such as superoxide anions, hydrogen peroxide, and hydroxyl radicals damage DNA bases, potentially resulting in DNA sequence mistranscription. Such interruptions can affect DNA replication, resulting in alterations in oncogenes and tumour suppressor genes.

ROS can also cause DNA strand breaks, resulting in mutations or deletions of genetic material. There are certain DNA repair mechanisms in the body such as base excision repair, direct repair, nucleotide excision repair and double strand break repair, which helps in maintaining the genome stability which will help in cancer prevention[12]. Deficiency in the dietary components such as flavonoids, vitamin E and C; isothiocyanates can disrupt the mechanisms of DNA repair. The interactions of food with these actions can be clearly estimated with the help of nutrigenomics.

8.5 Other Disease Conditions:

Non Alcoholic Fatty liver disease (NAFLD) is a liver disease where the fat accumulation exceeds 5% other liver weight which is not attributed to alcohol intake. NAFLD develops with a complex interaction between genetic susceptibility and other environmental factors such high calorie diet and physical inactivity[13]. Epigenetic factors such as liver specific DNA methylation and microRNAs, which regulate liver transcriptome also contributeto the NAFLD development and progression.

Esterification in the form triglycerides, excess hepatocellular triglycerides, oxidative stress, inflammation triggered by endotoxin, activation of hepatic stellate cells, insulin resistant and altered profile of adipokines are some of the factors which aggravates the disease incidence. There are various genes which are related to these and identifying the genetic variations can thus help in the early diagnosis of the disease condition. Periodontics is an area where nutrigenomics has intervent very recently. Periodontics is the study of supporting structures of teeth and the disease conditions related to it. Zinc deficiency is said to have an increased susceptibility to periodontal disease progression. Disease like DM, insulin resistance can also contribute to the periodontal diseases. The SNPs related to zinc absorption and utilisation is also associated with periodontal diseases. There are even other factors like this, to be estimated to completely identify the condition.

8.6 Nutrigenomics and Personalized Diet:

The identification of certain genes in the body which may be the potent reason for the cause of a specific disease can be a great advent in managing the disease condition as well as in reducing the mortality rates. The ultimate aim of personalized diet is to provide a diet by identifying those differences that are due to the heritable genetic sequence variation which can be evidently portrayed by nutrigenomics. The goals of nutrigenomics in determining a personalized diet can be summarized as: 1. Identification of transcription factors (as nutrient targets) and the genes they target; 2. Identification of signaling pathways involved at the cellular level and characterization of the main dietary signals; 3. Measurement of specific micronutrients and macronutrients inducing cell and organ specific gene expression signatures; 4.Identification of interactions between nutrient related regulatory pathways and pro-inflammatory stress pathways for a better understanding of diet related diseases; 5.Identification of genotypes which can be risk factors for the development of diet related human diseases (such as diabetes, hypertension or atherosclerosis); 6.Use of nutritional systems biology to discover biomarkers for early detection of disease and susceptibility (stress signatures) that are changed in response to diet. Nutrigenomics is an upcoming branch of science which reveals the relationship betweengenes and nutrients. The identification of Single Nucleotide Polymorphism (SNPs) helps us to diagnose the incidence of various disease conditionsfar before the symptoms are portrayed. This can also help the dieticians and health workers to guide their patients with personalised nutrition and helps to maintain a healthier body throughout the lifetime effectively. But since, the studies are only done atlaboratory levels, the efficiency and practicality of this is yet in vain. Hence, more studies of dietary components employing tissue/cell model systems may aid in a better understanding of the interrelationships between nutrigenetics, nutritional epigenomics, nutritional transcriptomics, proteomics and metabolomics.

8.7 References:

1. Mutch, D. M., Wahli, W. And Williamson, G., 2005, Nutrigenomics and Nutrigenetics: The Emerging Faces of Nutrition. *Faseb. J.* 19:1602–1616.
2. Priyadarshini, R. S., Vijayalakshmi, R., Ambalavanan, N., Ramakrishnan, T., And Logaranjani, A., 2016, Nutrigenomics InPeropdontics- An Overview. *Int. J. Curr. Res. Rev.* 1(1):31-35.
3. Refsum, H., And Smith, A. D., 2008, Are We Ready for Mandatory Fortification with Vitamin B-12? *Am. J. Clin. Nutr.*88:253–54.
4. Domínguez-Reyes, T., Astudillo-López, C. C., Salgado-Goytia, L., Muñoz-Valle, J. F., Salgado-Bernabé, A. B., Guzmán-Guzmán, I. P., Castro-Alarcón, N., Moreno-Godínez, M. E. And Parra-Rojas, I., 2015, Interaction of Dietary Fat Intake with Apoa2, Apoa5 and Lepr Polymorphisms and Its Relationship with Obesity and Dyslipidemia in Young Subjects. *Lipids Health Dis.*14:106–116.
5. Georgoulis, M., Kontogianni, M. D., And Yiannakouris, N., 2014, Mediterranean Diet and Diabetes: Prevention and Treatment. *Nutrients.*6: 1406–1423.
6. IDF [International Diabetes Federation], 2013, Idf Diabetes Atlas, 6th Ed.; International Diabetes Federation: Brussels, Belgium, P. 11.
7. Wu, G.D., Chen, J., Hoffmann, C., Bittinger, K., Chen, Y.Y., Keilbaugh, S.A., Bewtra, M., Knights, D., Walters, W.A., And Knight, R. 2011, Linking Long-Term Dietary patterns with gut microbial enterocytes. *Sci*. 334: 105–108.
8. Mozaffarian, D., Benjamin, E. J., Go, A. S., Arnett, D. K., Blaha, M. J., Cushman, M., Das, S. R., De Ferranti, S., Després, J. P., Fullerton, H. J., Howard, V. J., Huffman, M. D., Isasi, C. R., Jiménez, M. C., Judd, S. E., Kissela, B. M., Lichtman, J. H., Lisabeth, L. D., Liu, S., Mackey, R. H., Magid, D. J., Mcguire, D. K., Mohler, E. R. 3rd, Moy, C. S., Muntner, P., Mussolino, M. E., Nasir, K., Neumar, R. W., Nichol, G., Palaniappan, L., Pandey, D. K., Reeves, M. J., Rodriguez, C. J., Rosamond, W., Sorlie, P. D., Stein, J., Towfighi, A., Turan, T. N., Virani, S. S., Woo, D., Yeh, R. W., Turner, M. B., 2016, American Heart Association Statistics Committee And Stroke Statistics Subcommittee. Heart Disease and Stroke Statistics-2016 Update: A Report from The American Heart Association. *Circulation.* 133: E38–360.
9. Nishi, S., Kendall, C. W., Gascoyne, A. M., Bazinet, R. P., Bashyam, B., Lapsley, K. G., Augustin, L. S., Sievenpiper, J. L. And Jenkins, D. J., 2014, Effect of Almond Consumption On the Serum Fatty Acid Profile: A Dose-Response Study. *Br. J. Nutr.*112:1137–1146.
10. Arkadianos, I., Valdes, A. M., Marinos, E., Florou, A., Gill, R. D., And Grimaldi, K. A., 2007, Improved Weight Management Using Genetic Information ToPersonalise A Calorie Controlled Diet. *Nutr. J.*6:29
11. Pena-Romero Alicia Cristina, Diana Navas-Carrillo, Francisco Marín And Esteban Orenes-Piñero , 2018, The Future Of Nutrition: Nutrigenomics And *Nutrigenetics* In Obesity And Cardiovascular Diseases. *Criticalrev. Food Sci. Nutr*. 58:17, 3030-3041.
12. Cooke, M. S., Evans, M. D., Dove, R., Rozalski, R., Gackowski, D., Siomek, A., Lunec, J., And Olinski, R., 2005, Dna Repair Is Responsible for The Presence of Oxidatively Damaged Dna Lesions in Urine. *Mutat. Res.* 574(1-2):58-66.
13. Dongiovanni, P., Anstee, Q.M. And Valenti, L., 2013, Genetic Predisposition in NAFLD and Nash: Impact on Severity of Liver Disease and Response to Treatment. *Curr. Pharm. Des*. 19: 5219–5238.

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9. Bioavailability of Nutrients

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Abstract:

This chapter focuses on the bioavailability of calcium (Ca), zinc (Zn), iron (Fe), and vitamins in food. Bioavailability is defined as the proportion of ingested nutrient that is absorbed and utilized by the body. The availability of these nutrients varies greatly depending on multiple factors, including food processing, nutrient interaction, food structure and individual differences. Adequate intake of these micronutrients is essential for the proper functioning of various physiological systems, and deficiencies can lead to severe health problems. In this chapter, we aim to summarize the current understanding of the factors that affect the bioavailability of Ca, Zn, Fe, and vitamins from food sources and their implications for optimal human nutrition. We discuss evidence-based strategies to optimize the bioavailability of these nutrients and ensure adequate intake from dietary sources, which can ultimately improve health outcomes.

Keywords:

Bioavailability, Antioxidants, Nutrients, Inhibitors, Phytate.

9.1 Introduction:

Bioavailability is the measure of nutrient absorption, which means how easily a nutrient can be absorbed by our body (Nancy F. Krebs, 2001). Before, the nutrients after consumed first need to be broken down, by our digestive system, into small similar forms that our body can use then they can be used for their health benefits. The nutrients that can be easily broken down are called 'bioavailable'. Bioavailability refers to the proportion or fraction of a nutrient, in the diet, that is consumed, absorbed and then utilized by the body for functioning. Bioavailability is influenced by several factors like our diet, nutrient concentration, nutritional status, health, gender, age, and life stage. Diet-affecting foods include the structure of food, the chemical form of a food nutrient, interactions between nutrients and foods, and food processing methods or treatment.

Some nutrients are readily absorbed and quickly utilized to work in the body, while others may be a little slower in absorption and utilization. Macronutrients e.g., carbohydrates, proteins, and fats generally have high bioavailability. More than 90% of the amount of these nutrients we consume gets absorbed and used by our body. (Hettie Schonfeldt et.al., 2016)

On the other hand, micronutrients e.g. vitamins, minerals, and antioxidants, can vary in the extent to which they are absorbed and used once consumed. (Alida Melse-Boonstra, 2020).

9.2 Factor Affecting the Bioavailability:

A. Life-Stage:

There is a normal decline in gastric acid according to age, so younger individuals can have a higher bioavailability of micronutrients while it is slower in older individuals. This means our body ability to absorb micronutrients is reduced as we age.

B. Food Structure:

Nutrients in foods with less complex tissue structures can easily absorb so more bioavailable than Nutrients from plant foods or other foods that have complex tissue structure take longer to digest such as corn or meat are less bioavailable. This type of Foods first must be broken down or cooked so that certain micronutrients to be available for absorption.

C. Chemical Form:

Heme iron is more bioavailable than non-heme iron. Heme iron is available in meat, fish or poultry foods and non-heme iron is available in plants. Since plant food is not easy to absorb or digest, the non-heme iron in plants is less bioavailable. So recommendations for iron intake for vegetarians are higher than for those who eat meat.

D. Interactions with Compounds in Foods:

Antioxidants (polyphenols or phytates) have the ability to bind with certain micronutrients in the gastrointestinal tract and they prevent absorption into the body. Polyphenols are found in plants that can prevent mineral absorption in the intestines. Phytates are found in the outer layer of plants and bind with minerals like zinc, calcium or iron, which interfere and prevents their absorption in the intestines. (https://extension.msu.edu/newsletters)

On considering all of the different factors that affect the bioavailability of nutrients, for healthy individuals, eating food with proteins, whole grains, plenty of fruits, and vegetables is the most simple and effective way to ensure you're taking a healthy and balanced diet.

9.3 Different Influences:

So, The factors that might positively or negatively affect bioavailability varies from nutrient to nutrient because every vitamin and mineral is unique. Such as

A. Vitamin C and Iron:

Vitamin C effects the iron absorption in a positive way and increase nutrient bioavailability (Lynch, S, et. al. 2003 and Schonfeldt, H & Hall, 2011). Vitamin C coverts non-haem iron which is the less easily absorbed form of iron into a more bioavailable form that the body prefers to absorb in gut. which helps absorption.

B. Vitamin D and Calcium:

Vitamin D effects the absorption of calcium helps to increase the bioavailability (Patwardhan, UN, et. al. 2001).

C. Fats and Fat-Soluble Vitamin:

Vitamins A, D, E and K are stored in the body within the fat cells. They are called fat soluble vitamins. Fat soluble vitamins are more easily absorbed by the body in the presence of fat. Some 'healthy' fats such as the monounsaturated fats found in avocados may help to increase the absorption of vitamins A, D, E and K.

9.4 Some Nutrients:

A. Iron:

There are two forms of dietary iron; haem and non-haem. Haem iron is present in animals and can be easily absorbed in humans, while non-haem iron is present in plants. While the absorption of haem iron depends only on our stored amount of iron, the absorption of non-haem iron is depend upon the diet and may influenced by other factors. For example, Haem iron found in animal sources have the ability to increase the absorption of non-haem iron. Phytates found in certain vegetables and cereals, polyphenols found in tea and coffee and dietary calcium are inhibitors of non heam iron bioavailability. So it's important to be aware of how to increase your iron absorption.

While non-haem iron found in plant sources may be less easily absorbed, Research suggests that this can be increased by increasing the consumption of vitamin C with plant-based iron sources. Many studies have shown that ascorbic acid (vitamin C) may reduce the negative effects of all of the inhibitors like phylates and polyphenols. (Gibson, 2007), So it is very important to include a source of vitamin C with plant-based meals to ensure you're absorbing iron from the foods you're eating. Drinking tea or coffee in-between mealtimes rather than at the meal time may also limit the inhibiting effect certain compounds on the absorption of iron from plant-based sources.

B. Calcium:

Bioavailability of Calcium which is another important mineral can be affected by various factors. Calcium is present in adequate amount in Dairy, eggs and fish foods and calcium is more readily absorbed from milk and dairy products so if you're following vegan diet it is important to include plenty of alternative sources of calcium in your diet.

Some , naturally occurring compounds like oxalates, found in spinach rhubarb and beetroot as well as phytates found in plant foods, can inhibit the absorption of calcium as they bind with calcium and may prevent its absorption into the blood. Broccoli, kale, calcium-set tofu, Brussels sprouts, and calcium-fortified milks are some examples of plant-based foods where calcium can easily be absorbed. Many studies have shown that Vitamin D promotes the bioavailability of calcium so must include Vitamin D supplements in your diet (Connie M Weaver, 1999).

C. Zinc:

Zinc is a nutrient that is highly bioavailable from animal sources and therefore the bioavailability of Zinc from non-vegetarian diets is more than that of vegetarian diets. Animal protein may enhance Zinc absorption and its bioavailability while Plant foods such as cereals, seeds, legumes and nuts which are the major part of of vegetarian diets are high in phytates, which inhibits the absorption of Zinc, while. Unlike Iron, how much a person can intake Zinc from diet is the principle determinant of a person's Zinc status, rather than how much of a store your body may have (Hambidge et al., 2010), i.e. we can ideally be consistent in consuming enough Zinc from our diet to avoid deficiency. Phytate content can be reduced by Consuming fermented foods such as miso or tempeh, fortified breads and cereals or soaking dried beans before cooking to include great sources of Zinc in your diet. If not possible to soak dried beans for hours on end, try using miso paste as a base for noodle soups and choose fortified breads and cereals where possible – kimchi, sauerkraut and sourdough bread are all great fermented options that can increase Zinc bioavailability.

D. Cooking & Processing:

It is general assumed and suggested that cooking foods lowers the nutrient content and while this can sometimes be opposite, is often also true. Research has shown that bioavailability of beta-carotene from carrots and green leafy vegetables, including spinach is improved through cooking. Similarly, a beneficial nutrient lycopene found in tomatoes is more bioavailable in pureed and canned (cooked or processed tomatoes) than fresh, uncooked tomatoes.

In the case of plant sources of Zinc and Calcium, processing (such as milling, soaking, germination and fermentation) can lower the phytate content and reduce their inhibiting effect on bioavailability of nutrients (Rosalind S Gibson, 2018).

E. Importance of Bioavailability of Nutrients:

The bioavailability of the nutrients you are consumed is directly referred to the positive effects they have on your overall health. If a nutrient is not bioavailable, it won't be absorbed, which caused its insufficiency or become a deficiency in the long run.

For example, spinach is the most calcium rich leafy green. but, only few amount nearly 4-5 percent of its calcium content is absorbed and used by the body. This is due to the presence of certain anti-nutrients called 'oxalates' (interfere with the absorption of other nutrients) present in spinach (Weston Petroski et. al. 2020 and R P Heaney et. al. 1989).

Thus, the calcium is low bioavailable in spinach. it means, if you're largely depend on spinach for getting calcium, you cannot absorb at an optimum level, resulting in an inadequate intake. Consistent low absorption of, inadequate amounts of calcium can result in weak bones (osteoporosis) (Gabriela Cormick and Jose M Belizán, 2019). This doesn't mean to avoid spinach, it must be because it contains other valuable nutrients, but to consume a variety of sources of calcium where calcium is more bioavailable like dairy, soybean, chickpeas, almonds, etc.

9.5 References:

1. Nancy F. Krebs. Bioavailability of Dietary Supplements and Impact of Physiologic State: Infants, Children and Adolescents, The Journal of Nutrition, Volume 131, Issue 4, (1351S–1354S), doi.org/10.1093/jn/131.4.1351S. (2001).
2. Hettie Schonfeldt, Beulah Pretorius, Nicolette Hall Bioavailability of Nutrients, doi:10.1016/B978-0-12-384947-2.00068-4. (2016).
3. Alida Melse-Boonstra, Bioavailability of Micronutrients From Nutrient-Dense Whole Foods: Zooming in on Dairy, Vegetables, and Fruits, Front. Nutr., Volume 7, doi.org/10.3389/fnut.2020.00101. (2020).
4. https://extension.msu.edu/newsletters
5. Lynch, S & Stoltzfus, R. Iron, and Ascorbic Acid: Proposed Fortification Levels and Recommended Iron Compounds. The J.Nutrition, 133 (9). 2978S-2984S. doi: 10.1093/jn/133.9.2978S. (2003).
6. Schonfeldt, H & Hall, N. Determining iron bio-availability with a constant heme iron value. Journal of Food Composition and Analysis, 24 (4). 738-740. doi:10.1016/j.jfca.2011.01.002. (2011).
7. Patwardhan, UN, Pahuja, D & Samuel, A. Calcium bioavailability: an in vivo assessment. Nutrition Research, 21 (4), 667-675. doi:10.1016/S0271-5317(01)00278-0. (2001).
8. https://www.srutrition.co.uk/2019/09/bioavailability-absorption-of-nutrients.

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10. Biochemical Metabolism and Disease

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Abstract:

Biochemical Metabolism is the set of chemical processes that occur within living organisms to maintain life. Dysregulation of metabolism can contribute to the development of various diseases, including metabolic disorders such as diabetes, obesity, and metabolic syndrome.

This chapter will provide an overview of the biochemical processes involved in metabolism and how they are dysregulated in disease states. The role of hormones, such as insulin and thyroid hormone, in regulating metabolism will be discussed, as well as the impact of environmental factors such as diet and exercise. Overall, this chapter aims to provide a comprehensive understanding of the complex interplay between metabolism and disease.

Keywords:

Proteins Metabolism, Biochemical Metabolism, Lipid Metabolism, Carbohydrates Metabolism, Nutrients.

10.1 Introduction:

Biochemical metabolism is the set of chemical reactions that occur within a living organism to maintain life. These reactions involve the conversion of nutrients into energy and the synthesis of new molecules necessary for growth, repair, and reproduction. **(Berg, J.M. et.al., 2015).**

Biochemical metabolism is the set of chemical reactions that occur within living organisms to maintain life. These reactions involve the conversion of small molecules into larger ones, and vice versa, and are coordinated by a series of enzymes and other proteins. Understanding the intricacies of biochemical metabolism is crucial for developing treatments for metabolic diseases and for optimizing cellular processes in biotechnology applications. **(Voet, D. et.al. 2016).**

10.2 Types of Metabolic Processes:

There are numerous metabolic processes that occur in living organisms, including catabolic and anabolic reactions. Here are some examples of different metabolic processes. **(Nelson, D.L. & Cox, M.M. 2017).**

1. ***Glycolysis:*** This is a catabolic pathway that occurs in the cytoplasm of cells and involves the breakdown of glucose to produce ATP.
2. ***Citric Acid Cycle:*** This is also known as the Krebs cycle or the tricarboxylic acid cycle, and it is a central metabolic pathway that occurs in the mitochondria of cells. It involves the breakdown of acetyl-CoA to produce ATP, NADH, and FADH2.
3. ***Photosynthesis:*** This is an anabolic pathway that occurs in plants and some bacteria. It involves the conversion of light energy into chemical energy, which is stored in the form of glucose.
4. ***Protein Synthesis:*** This is an anabolic pathway that occurs in cells and involves the formation of proteins from amino acids. This process involves transcription and translation.
5. ***Lipid Metabolism:*** This involves the breakdown and synthesis of lipids, including fatty acids, triglycerides, and phospholipids. Lipid metabolism occurs in various organs, including the liver, adipose tissue, and muscle.

10.2.1 Biochemical Metabolism and Nutrients:

Biochemical metabolism and nutrients are closely related as nutrients serve as the building blocks for various metabolic pathways in the body. Nutrients, such as carbohydrates, proteins, and lipids, are essential for the production of energy and the maintenance of cellular function. **(Gropper, S. S.et. al. 2009).**

Carbohydrates are broken down into glucose, which is used as a primary source of energy in the body. Glucose is then metabolized through glycolysis, the citric acid cycle, and oxidative phosphorylation to produce ATP, which is the main energy currency of the body.

Proteins are broken down into amino acids, which are then used for the synthesis of new proteins, enzymes, and other molecules required for cellular function. Amino acids also play a role in the regulation of metabolic pathways, such as the urea cycle and gluconeogenesis.

Lipids, such as triglycerides and phospholipids, are broken down into fatty acids and glycerol, which are used for the production of ATP, as well as for the synthesis of cell membranes, hormones, and other molecules.

The metabolism of nutrients is highly regulated, with enzymes and other proteins controlling the flow of metabolites through various pathways. Dysregulation of these pathways can lead to metabolic disorders, such as diabetes, obesity, and cardiovascular disease. Overall, understanding the relationship between biochemical metabolism and nutrients is crucial for developing treatments for metabolic disorders and for optimizing nutrient utilization in the body.

10.2.2 Carbohydrates Metabolism:Metabolism of Carbohydrates

Carbohydrate metabolism is a complex process that involves the breakdown and synthesis of carbohydrates for energy production and other cellular functions. Understanding the mechanisms and regulation of carbohydrate metabolism is important for treating metabolic disorders such as diabetes, obesity, and cardiovascular disease. **(Berg, J.M., et.al. 2012)**

10.2.3 Proteins Metabolism:

Protein metabolism is the process by which the body breaks down and synthesizes proteins, which are essential for cellular function and survival. Proteins are involved in a wide range of biological processes, such as enzymatic catalysis, structural support, and immune defense.

Protein metabolism is a complex process that involves multiple pathways, including protein digestion, amino acid transport and utilization, and protein synthesis and degradation. The breakdown of proteins begins in the stomach and continues in the small intestine, where proteases and peptidases break down proteins into amino acids and di- and tri-peptides. These amino acids are then transported to various tissues throughout the body, where they are used for protein synthesis or energy production.

Protein synthesis occurs through a process called translation, which is catalyzed by ribosomes and involves the assembly of amino acids into polypeptide chains. This process is regulated by a complex network of enzymes, hormones, and signaling pathways that control the rate of protein synthesis in response to various stimuli, such as nutrient availability and growth factors.

Protein degradation, on the other hand, involves the breakdown of proteins into smaller peptides and amino acids, which can be used for energy production or for the synthesis of new proteins. This process is also tightly regulated by a variety of enzymes and signaling pathways.

Understanding the mechanisms and regulation of protein metabolism is crucial for treating metabolic disorders such as obesity and muscle wasting, as well as for optimizing athletic performance and muscle building. **(Berg, J.M., et.al. 2015)**

10.2.4 Lipid Metabolism:

Lipid metabolism refers to the complex set of biochemical processes that involve the synthesis, transport, and breakdown of lipids in the body. Lipids play essential roles in a wide range of biological functions, including energy storage, membrane structure and function, and cell signaling.

Lipid metabolism is divided into two major pathways: anabolism, which involves the synthesis of lipids from simpler precursors, and catabolism, which involves the breakdown of lipids for energy production. The major types of lipids involved in these processes include fatty acids, triglycerides, phospholipids, and cholesterol.

The anabolic pathway of lipid metabolism involves the synthesis of fatty acids, triglycerides, and phospholipids from simpler precursors such as acetyl-CoA, glycerol, and amino acids. This process is regulated by a variety of enzymes and hormones, such as insulin and glucagon, and involves the transport of lipids from the liver to other tissues via lipoproteins.

The catabolic pathway of lipid metabolism involves the breakdown of fatty acids and triglycerides to generate energy through a process called beta-oxidation. This process occurs primarily in the liver and adipose tissue and involves the transport of fatty acids from the cytoplasm to the mitochondria, where they are oxidized to produce ATP.

Abnormalities in lipid metabolism can lead to a variety of metabolic disorders, including obesity, type 2 diabetes, and cardiovascular disease.

Therefore, understanding the mechanisms and regulation of lipid metabolism is important for developing effective treatments for these conditions. **(Berg, J.M., et.al. 2015)**

10.3 Hormones and Metabolism:

Hormones are chemical messengers that are produced by endocrine glands and play a crucial role in regulating metabolism, which refers to the chemical processes that occur within an organism to maintain life. Hormones influence metabolism by regulating the uptake, use, and storage of energy in the body.

Insulin is a well-known hormone involved in metabolism, which is produced by the pancreas. Insulin helps to regulate the level of glucose in the bloodstream by promoting the uptake of glucose into cells, where it can be used for energy or stored for later use. Insulin resistance, which occurs when cells become less responsive to insulin, can lead to metabolic disorders such as type 2 diabetes **(Kahn & Flier, 2000).**

Thyroid hormones, produced by the thyroid gland, also play a critical role in metabolism. These hormones regulate the body's metabolic rate, which is the rate at which the body burns calories to produce energy. Hypothyroidism, which occurs when the thyroid gland produces too little thyroid hormone, can lead to a slower metabolic rate and weight gain **(Mullur, Liu, & Brent, 2014).**

Cortisol is another hormone that influences metabolism, which is produced by the adrenal gland. Cortisol helps to regulate glucose metabolism and also plays a role in the body's stress response. Chronic stress and high levels of cortisol can contribute to metabolic disorders such as obesity and insulin resistance **(Pivonello, De Leo, Cozzolino, & Colao, 2015).**

Leptin, produced by fat cells, is a hormone that helps to regulate appetite and energy expenditure. Leptin signals to the brain to reduce appetite and increase energy expenditure when fat stores are sufficient. However, in obesity, leptin resistance can occur, leading to a decrease in leptin signaling and an increase in appetite and decreased energy expenditure **(Vella, Burguera, & Clegg, 2017).**

In conclusion, hormones play a critical role in regulating metabolism and the dysregulation of hormones involved in metabolism can contribute to the development of metabolic disorders such as diabetes, obesity, and metabolic syndrome.

10.4 Metabolism and Disease:

Metabolism plays a critical role in the development and progression of many diseases. Here are some examples of how metabolism is linked to different diseases:

1. Cancer: Metabolic reprogramming is a hallmark of cancer. The Warburg effect, where cancer cells rely on glycolysis for energy even in the presence of oxygen, is a well-known example of how metabolism is altered in cancer cells. **(Pavlova and Thompson., 2016).**
2. Cardiovascular disease: Disorders such as atherosclerosis, hypertension, and heart failure are linked to alterations in energy metabolism, oxidative stress, and inflammation. **(Kolwicz and Tian., 2018).**
3. Neurodegenerative diseases: Metabolic dysfunction has been implicated in the development of neurodegenerative diseases such as Alzheimer's disease and Parkinson's disease. Disruptions in glucose metabolism, mitochondrial dysfunction, and oxidative stress are common features of these diseases**. (Butterfield et al., 2017).**
4. Autoimmune diseases: Autoimmune diseases such as type 1 diabetes and multiple sclerosis are characterized by dysregulation of immune cells and inflammation. Recent evidence suggests that alterations in cellular metabolism play a role in the pathogenesis of these diseases. **(Michalek et al., 2013).**
5. Obesity and metabolic syndrome: Obesity and metabolic syndrome are linked to alterations in glucose and lipid metabolism, chronic inflammation, and insulin resistance. These conditions increase the risk of developing type 2 diabetes, cardiovascular disease, and other metabolic disorders. **(Després and Lemieux, 2006).**

These examples illustrate the diverse ways in which metabolism is involved in the pathogenesis of many diseases.

How to Improve Metabolism:

There are several actions that can be taken to improve metabolism:

1. Regular exercise: Regular exercise can boost metabolism by increasing muscle mass and reducing fat mass. **(Jakicic et al., 2003).**
2. Eating a balanced diet: Eating a balanced diet with adequate protein, healthy fats, and complex carbohydrates can help improve metabolism. **(Ludwig et al., 1999).**
3. Drinking enough water: Staying hydrated is important for metabolism as it helps in the breakdown of fats and carbohydrates. **(Thornton, 2016).**
4. Managing stress: Stress can increase cortisol levels which can negatively impact metabolism. Therefore, managing stress through techniques such as meditation, yoga, or deep breathing can help improve metabolism**. (Epel et al., 2000).**
5. Getting enough sleep: Lack of sleep can reduce metabolic rate, so getting enough sleep is important for maintaining a healthy metabolism. **(Nedeltcheva et al., 2010).**

6. Avoiding crash diets: Crash diets or very low-calorie diets can reduce metabolic rate and can be harmful to overall health.
7. Medical treatment: Certain medical conditions such as hypothyroidism or diabetes can affect metabolism. In such cases, medical treatment may be required to improve metabolism. **(American Diabetes Association, 2021)**

10.5 References:

1. Berg, J.M., Tymoczko, J.L., & Stryer, L. Biochemistry. 8th edition. Chapter 2: Basic Concepts of Metabolism. New York: W.H. Freeman and Company. (2015).
2. Voet, D., Voet, J.G., & Pratt, C.W. Biochemistry. 5th edition. Introduction to Metabolism. New York: John Wiley & Sons. (2016).
3. Nelson, D.L. & Cox, M.M.. Lehninger Principles of Biochemistry. 7th edition. Metabolism: Basic Concepts and Design. New York: W.H. Freeman and Company. (2017)
4. Gropper, S. S., Smith, J. L., & Groff, J. L. Advanced Nutrition and Human Metabolism. Belmont, CA: Wadsworth Cengage Learning. (2009).
5. Berg, J.M., Tymoczko, J.L., & Stryer, L. Biochemistry. 7th edition. Chapter 16: Glycolysis, Gluconeogenesis, (2012).
6. Berg JM, Tymoczko JL, Stryer L. Protein turnover and amino acid catabolism. In: Biochemistry. 8th ed. New York: W. H. Freeman;. p. 925-946. (2015)
7. Berg JM, Tymoczko JL, Stryer L. Lipid metabolism. In: Biochemistry. 8th ed. New York: W. H. Freeman;. p. 739-779. (2015)
8. Kahn, C. R., & Flier, J. S. Obesity and insulin resistance. Journal of clinical investigation, 106(4), 473-481. (2000).
9. Mullur, R., Liu, Y. Y., & Brent, G. A. Thyroid hormone regulation of metabolism. Physiological reviews, 94(2), 355-382. (2014).
10. Pivonello, R., De Leo, M., Cozzolino, A., & Colao, A. The metabolic syndrome and cardiovascular risk in Cushing's syndrome. Frontiers in hormone research, 44, 49-62. (2015).
11. Vella, C. A., Burguera, B., & Clegg, D. J. Mechanisms of leptin resistance in obesity. Current opinion in endocrine and metabolic research, 2, 26-31. (2017).
12. Pavlova and Thompson. "The Emerging Hallmarks of Cancer Metabolism." Cell Metabolism, DOI: 10.1016/j.cmet.2016.08.018) (2016).
13. Kolwicz and Tian. "Cardiac Energetics: From Physiology to Clinical Applications." Current Cardiology Reviews,. DOI: 10.2174/1573403X13666180511124651. (2018)
14. Butterfield et al. "Metabolic Dysregulation in the Pathogenesis of Alzheimer's Disease: Opportunities for Drug Development." Current Pharmaceutical Design,. DOI: 10.2174/1381612822666161005144913. (2017)
15. Michalek et al. "Metabolic Regulation of T Lymphocytes." Annual Review of Immunology,. DOI: 10.1146/annurev-immunol-032712-095956. (2013)
16. Després and Lemieux. "Abdominal Obesity and Metabolic Syndrome." Nature,. DOI: 10.1038/nature05488. (2006)
17. American Diabetes Association. Type 2 diabetes. Retrieved from https://www.diabetes.org/diabetes/type-2 (2021).
18. Epel, E., McEwen, B., Seeman, T., Matthews, K., Castellazzo, G., Brownell, K. D., ... & Ickovics, J. R. Stress and body shape: stress-induced cortisol secretion is

consistently greater among women with central fat. Psychosomatic medicine, 62(5), 623-632. (2000).
19. Jakicic, J. M., Marcus, B. H., Gallagher, K. I., Napolitano, M., & Lang, W. Effect of exercise duration and intensity on weight loss in overweight, sedentary women: a randomized trial. Jama, 290(10), 1323-1330. (2003).
20. Ludwig, D. S., Majzoub, J. A., Al-Zahrani, A., Dallal, G. E., Blanco, I., & Roberts Jr, S. B. High glycemic index foods, overeating, and obesity. Pediatrics, 103(3), E26. (1999).
21. Nedeltcheva, A. V., Kilkus, J. M., Imperial, J., Schoeller, D. A., & Penev, P. D. Insufficient sleep undermines dietary efforts to reduce adiposity. Annals of internal medicine, 153(7), 435-441. (2010).
22. Thornton, S. N. Increased hydration can be associated with weight loss. Frontiers in nutrition, 3, 18. (2016).

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11. Functional Foods and Phytochemicals

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Abstract:

Functional foods and phytochemicals are both interconnected concepts that have gained popularity among people in recent years because of the health benefits they provide when eaten in the right quantities as part of our routine diet.

Functional food is defined as natural or processed food containing biologically active substances that provide health benefits in addition to nutritional value. Phytochemicals, on the other hand, are organically occurring bioactive compounds that have a variety of biological activities, including neuroprotective, anti-diabetic, antioxidant, anti-cancer, and anti-inflammatory properties.

Phytochemicals can be found in various functional foods, such as fruits, vegetables, grains, nuts, seeds, herbs, spices, and beverages. According to a recent report of WHO noncommunicable diseases (NCDs) such as type 2 diabetes, heart disease and cancer contribute to 41 million yearly deaths, or 74% of all fatalities worldwide and the main causative factors claimed for it, is unhealthy lifestyle, especially poor eating habits.

Fruits, vegetables, Indian herbs and spices, grains, nuts, and beans are examples of plant-based foods which are rich in Vitamins, minerals, fiber, antioxidants, omega-3 fatty acids, & phenolic compounds that help the body to fight against chronic diseases including cancer, cardiovascular disease, and gastrointestinal related illness. This chapter delivers an overview of the definition, classification, sources, and health benefits of functional food and phytochemicals.

Keywords:

Functional foods, Phytochemicals, Flavonoids, Bioactive compound, Nutraceuticals.

11.1 Introduction:

Food is a term that refers to the chemicals that are needed for a variety of critical tasks, including energy production, nutritional provision, and support for numerous metabolic processes, as well as body growth and maintenance. Earlier, nutrition science was primarily concerned with avoiding vitamin deficiencies and encouraging healthy body growth. Earlier, nutritionists were primarily concerned with ensuring that individuals received adequate nutrients to support their health and growth (Doyon & Labrecque, 2008). In the past few decades, research on nutrition has expanded its focus to include both nutrients and non-nutritive compounds and their potential impact on disease prevention and risk reduction (Crowe & Francis, 2013). A direct association between foods and one's health has resulted in several scientific investigations to determine the impact of foods or dietary elements on distinct bodily processes (Kaur & Das, 2011).

Many individuals struggle to achieve the goal of eating for health and wellness due to the complicated marketplace and conflicting information from various sources. However, the desire for a healthy and pain-free lifestyle has led to the availability of functional foods that contain higher levels of bioactive compounds or physiologically active nutrients and non-nutrients which are known to have beneficial effects on health (Crowe & Francis, 2013). According to recent statistics, noncommunicable diseases (NCDs) are prevalent in India and are likely to rise in the future years. NCDs are expected to account for around 67% of the illness profile in the country by 2030 (Kanwal, 2022). In India, the proportion of mortality caused by NCDs has climbed of nearly 163% from year 1990 to 2016. The most common NCDs include cardiovascular illnesses, cancer, diabetes, and stroke. Furthermore, the use of food as medicine has been practiced for millennia and is not a new phenomenon. Although Hippocrates did not start the functional foods movement, he did state roughly 2,500 years ago that "food should be used as medicine and medicine should be used as food" (Meyer, 1998). Even though genetics have an influence in the development of some diseases, the majority of them may be avoided or decreased by living a healthy lifestyle that incorporates a suitable food, physical exercise, weight control, and a healthy environment. People can also improve their diet's health-promoting features by taking supplements or eating meals enriched with health-promoting ingredients. A nutritious diet can help avoid malnutrition as well as noncommunicable illnesses such as heart disease, obesity, and cancer. Whole grains, vegetables, fruits, and plant-based diets lower the risk of heart disease and can aid with weight loss. Individual qualities, cultural environment, and locally accessible foods all influence what constitutes a healthy diet (Baker et al., 2022; Health, 1989; world health organization, 2020). There is growing evidence from several types of research, including epidemiological, pre-clinical, and clinical investigations, suggesting there is a substantial link between food habits and quality of life. This research demonstrates that both essential and non-essential components of our meals can influence growth, development, performance, and prevention of illness (Milner, 2000). Likewise, the majority of food items possess functional properties that contribute to enhancing overall well-being. Functional components can be found in various food groups, including fruits, vegetables, grains, meat, fish, and dairy products. It is important to acknowledge the diverse array of naturally occurring compounds derived from plants and animals that contain active elements, which actively contribute to physiological functions. Therefore, these substances deserve special awareness for their efficacy in promoting and maintaining good health (Essa et al., 2023).

11.2 Definition of Functional Food:

A Japanese scholarly group proposed the concept of functional food in the early 1980s. The first functional foods regulation was introduced in the same decade under the acronym FOSHU, which stands for "Foods for Specified Health Use." Functional foods were initially characterized as foods capable of regulating biological activities and hence assisting in illness prevention (Shimizu, 2003).

The FSGs law covers certain food groups that are thought to be important for human health, especially among vulnerable populations. These food classes include processed cereal-based diets, baby food, weight reduction meal replacements, infant formula, follow-up formula, and specialized medicinal meals (D. M. Martirosyan & Singharaj, 2016). Furthermore, a functional food is both a food component or a natural food that has undergone a technical or biotechnological addition or extraction procedure. The consequences must be portrayed in quantities that are reasonably expected to be ingested as part of the food (Castillo, M., Iriondo-DeHond, A., & Martirosyan, 2018). These functional foods are intended to prevent, treat, or manage chronic illnesses or their related problems (D. Martirosyan & Miller, 2018). Definitions of functional foods given by different organizations are shown in Table 11.1.

Table 11.1: Definitions of Functional Foods Given by Different Organizations

Source	Functional food definition	References
Functional Food Center (FFC)	"Adequate & non-toxic amounts of natural or processed foods containing either identified or unidentified biologically active components that have been scientifically demonstrated to offer health benefits for the prevention, management, or treatment of chronic illnesses are recommended."	(D. Martirosyan & Miller, 2018)
International Life Sciences Institute (ILSI)	“Foods that provide health benefits beyond basic nutrition due to the presence of physiologically active dietary components.”	(Crowe & Francis, 2013)
European Food Safety Authority (EFSA)	"A functional food is a food that, in addition to providing basic nutrition, positively impacts specific functions in the body, resulting to an improved state of health and well-being or a lower risk of disease." It could be a natural food or one that has been altered through technological or biotechnological processes, such as the addition or removal of certain components. To be designated as a functional food, it must demonstrate its therapeutic effects in quantities typical of a regular diet."	(D. M. Martirosyan & Singharaj, 2016)

Source	Functional food definition	References
Institute of Food Technologists (IFT)	"Foods and food components which offer benefits to health beyond basic nutrition are products that provide essential nutrients in quantities that frequently exceed normal requirements for normal functioning, health, and development." They also include other bioactive components that are beneficial to general health."	(MacAulay, J., Petersen, B., 2005)
The European Commission Concerted Action Group on Functional Food Science in Europe (FUSOSE), The International Life Sciences Institute	"Food that qualifies as 'functional' is defined as food that has been scientifically proven to positively impact one or more bodily functions, surpassing basic nutritional requirements. Such food contributes to an enhanced state of health and well-being or lowers the risk of certain conditions."	(Blades, 2000)
Food and Nutrition Board (FNB)	“A functional food is defined as a product consist of potentially helpful ingredients, which includes "any altered food or food component that has the potential to provide a health benefit beyond the conventional nutrients it contains."	(Havel et al., 1994; Kruger & Mann, 2003)
US General Accounting Office (GAO)	Food that purports to offer additional health advantages beyond fundamental nourishment.	(Noonan, 2004)
Health Canada	Functional foods are foods that mimic traditional diets while providing physiological benefits.	(Shahidi, 2009)

Functional foods are frequently used interchangeably with nutraceuticals. The two names, however, are not equivalent. Functional foods are items that look like regular foods but have established physiological advantages. Nutraceuticals, on the other hand, are products obtained from foods that are used medicinally in the form of pills, capsules, or liquids and have exhibited physiological benefits. Functional foods are whole foods that have been transformed or enhanced to give a specific health advantage, whereas nutraceuticals are isolated components or extracts from foods that have been found to provide a specific health benefit. Additionally, Nutraceuticals are chemicals derived from whole foods that have both medicinal and nutritive properties, whereas dietary supplements are products that include one or more dietary elements such as vitamins, minerals, herbs, or other botanicals.

11.3 Types of Functional Foods:

The main types of functional foods are conventional foods and modified foods (shown in Figure 11.1) Conventional food items are in their original, unaltered form and have not underwent any modifications.

Convectional foods can be further classified as plant based conventional foods and animal based conventional foods such as vegetables, dairy, legumes, fruits, fish, as well as grains, which possess noteworthy health benefits. Conventional functional food refers to food made from natural or whole-food ingredients. They contain beneficial substances like vitamins, minerals. healthy fatty acids, and antioxidants. The traditional plant based conventional foods include dry fruits, fresh fruits, leafy green and non-leafy vegetables, legumes, seeds, nuts, herbs & spices. Such as brown rice, buckwheat, kiwi, pears, peaches, apples, cashews, chia seeds, chickpeas, oats, salmon, kimchi, cod, tempeh, kefir, turmeric, ginger, cinnamon, green tea, coffee, black tea, kale, spinach, pistachios, flaxseeds, almonds, hemp seeds, black beans, barley and many more. While animal based conventional foods are milk, eggs, fish and meat. A safe and organic diet prioritizes bioactive compounds while minimizing harmful substances such as prolonged toxins, metabolites, pesticides, and fertilizers. Opting for organic and whole food promotes a balanced lifestyle and lowers the likelihood of health issues (Arshad et al., 2021; Di Renzo et al., 2020). Modified foods, on the other hand, refer to food products that have been modified to enhance or supplement with specific nutrients to promote health benefits. In these additional nutrients, like probiotics, fiber, vitamins, and minerals are added for specific health benefits. These include fortified juices, dairy products like milk and yoghurt, fortified milk substitutes like coconut,

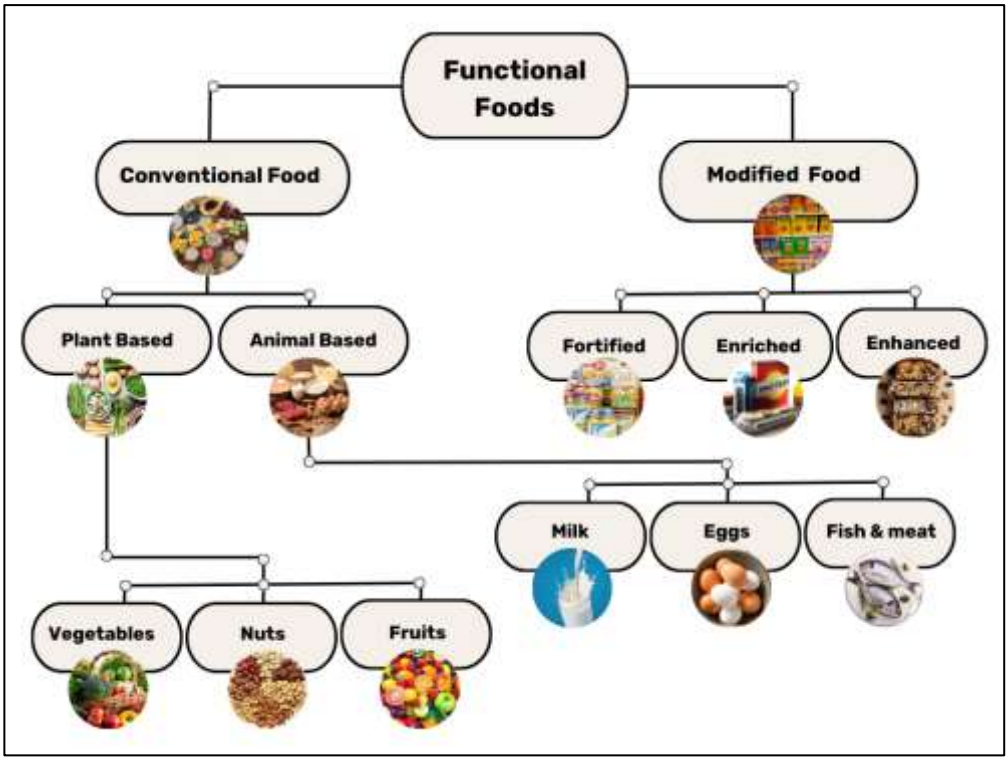

Figure 11.1: Classification of Functional Food

almond, cashew, and rice milk, fortified grains like pasta and bread, fortified granola and, cereal and fortified eggs. Modified foods can be divided into fortified, enriched & enhanced foods.

Fortification is the process of adding vitamins or nutrients that aren't typically found in that food. Fortification can be employed to fix or avoid prevalent nutrient intake deficiencies, to balance a diet's total nutrient profile, recover nutrients lost during processing, or to attract consumers who are interested in enhancing their diet. On the other hand, food enrichment is the process of reintroducing micronutrients lost while processing into a food product. Some nutrients may be lost or eliminated during food processing, especially in the case of refined grains. In order to restore or raise the levels of certain nutrients in the food to match recommended dietary standards, enrichment is used. The presence and quantity of the additional nutrients are noted on the labels of enriched foods. Foods that have been enhanced beyond their natural state in order to offer more functional or health benefits are referred to as enhanced foods (Siró et al., 2008). Incorporating bioactive chemicals, antioxidants, probiotics, or other substances that help with boosting health or enhancing particular physiological functions are just a few examples of enhancement approaches. The elimination or reduction of undesired ingredients, such as lowering the sodium or sugar content, may also be a part of enhanced foods. The phrase "enhanced foods" can be used broadly to refer to a variety of products, each with unique additions. These foods may have labels promoting certain health advantages or useful qualities.

11.4 Functional Food and Phytochemicals:

As discussed earlier Functional foods are foods that offer health benefits in addition to basic nutrition. Apart from that, they often contain phytochemicals, which are naturally occurring compounds found in plants. There is a strong correlation between functional foods and phytochemicals. Many functional foods contain high levels of phytochemicals, which are believed to be responsible for their health benefits. For instance, blueberries are a functional food that contains high levels of phytochemical named anthocyanin. These substances, which give the berries their blue color have been found to have anti-inflammatory and antioxidant qualities. In the same way, the isoflavone and other compounds found in soybeans make them a functional food. Numerous health advantages of these substances have been demonstrated, including a decreased risk of heart disease and some cancers. Tomatoes are another example of functional foods that include phytochemicals. Lycopene, a phytochemical found in tomatoes, has been demonstrated to have antioxidant qualities and may lower the risk of some types of cancer. Additionally, allicin-containing garlic and catechin-containing green tea. These phytochemicals have been proven to have anti-inflammatory and anti-cancer effects.

11.5 What Are Phytochemicals?

Phytochemicals, commonly known as phytonutrients, are naturally occurring active compounds abundant in various food sources such as vegetables, fruits, nuts, seeds, tea, whole grains, legumes, and dark chocolate. While there exists a vast array of phytochemicals, only a limited selection has been discovered and characterized from plants (Cao et al., 2017; Singh & Chaudhuri, 2018). Phytochemicals found in food are diverse and plentiful, encompassing various types such as carotenoids, polyphenols, coumarins, flavonoids, isoflavones, indoles, lignans, catechins, organosulfures, phenolic acids, isothiocyanates, stilbenoids, phenylpropanoids, saponins, ginsenosides, anthraquinones (Cao et al., 2017; Zhao et al., 2018). The majority of food items, including whole grains, fruits, vegetables, and nuts, contain phytochemicals. These phytochemicals, whether

individually or in combination, have significant potential for therapeutic purposes in the treatment of various diseases. The single fruit or vegetable can contain hundreds of theses phytochemicals. The presence of phytochemicals in food provide protection against numerous diseases such as cancer, heart disease, diabetes, hypertension, inflammation, infections caused by microorganisms, viruses, parasites, mental disorders, spasms, ulcers, osteoporosis, and related conditions (Srilakshmi, 2018; Thakur et al., 2020).

11.5.1 Types of Phytochemicals:

Phytochemicals can be classified into different groups, including polyphenols, alkaloids, terpenoids, organosulfur compounds, and nitrogen-containing compounds, depending on where they are produced in plants or food source (Carrera-Quintanar et al., 2018; Lara et al., 2020; Liu, 2004). Dietary phytochemical classification with food sources are shown in Figure 23.2. Polyphenols are the most abundant category. Each type of phytochemical is further described below in depth along with food sources and therapeutic benefits.

A. Polyphenols: Polyphenols are a diverse group of compounds found in many foods derived from plants, including vegetables, fruits, nuts, seeds, and grains. They are well-known for their antioxidant properties, which aid in the protection of cells from free radical damage. Polyphenols may also play a role in regulating obesity by modulating lipogenesis and regulating inflammatory cytokines and adipokines involved in the mechanisms of this disease (Martinez et al., 2022). Polyphenols are sub categorized into 6 types phenolic acids, coumarins, stilbenes, tannins, curcumins and flavonoid.

a. ***Phenolic Acids:***Phenolic acids have two subtypes namely hydroxybenzoic acid and hydroxycinnamic acid. Fruits, including tropical fruits like blackberry, raspberry and white vegetables like potatoes and onion are good sources of hydroxybenzoic acid. Kiwi, plum, carrots, wheat, eggplant, lettuce are some natural sources of hydroxycinnamic acids (Kaseke et al., 2021). They offer several health benefits, including antioxidant and anti-inflammatory properties, which protect against oxidative stress and chronic diseases. Phenolic acids also contribute to improved cardiovascular health by positively influencing lipid profiles, blood pressure, and insulin resistance. Additionally, phenolic acids can positively impact gut health by influencing the composition of the gut microbiome. It is vital to keep in mind that the health advantages of hydroxycinnamic acids are dependent on a variety of factors, including food processing, dietary intake, bioaccessibility, and pharmacokinetics.
b. ***Coumarins:*** Coumarins can be found in citrus fruit varieties like oranges, lemons, limes, grapefruit, strawberries, cherries, carrots, and tomatoes. Some types of cinnamon contain higher amount of Coumarins. Coumarins act as antioxidants, lower cardiovascular disease risk, suppress cancer cell growth, manage diabetes and hypoglycemia, act as hepatoprotectants, reduce inflammation, and provide photoprotection. However, it's important to note that the specific health benefits depend on the type of coumarin and the plant source.
c. ***Stilbenes:*** Stilbenes are a group of polyphenolic compounds that are naturally found in various dietary sources such as grapes, berries, peanuts, almons, red wine (Tsai et al., 2017). They have intricate structures with various numbers of stilbenes and polymeric types and are distinguished by the presence of a 1,2-diphenylethylene nucleus. Stilbenes

have diverse bioactivities including anti-tumor, anti-oxidant, anti-inflammatory, anti-fungal, anti-diabetic and anti-Alzheimer's disease effects.

d. ***Curcumins:*** Curcumin is a phytochemical agent that can be extracted from the powder rhizome of the plant Curcuma longa Curcumin has been reported to possess a wide range of pharmacological properties such as antimicrobial, antioxidative, anti-inflammatory, anticancer, and lipid-lowering properties

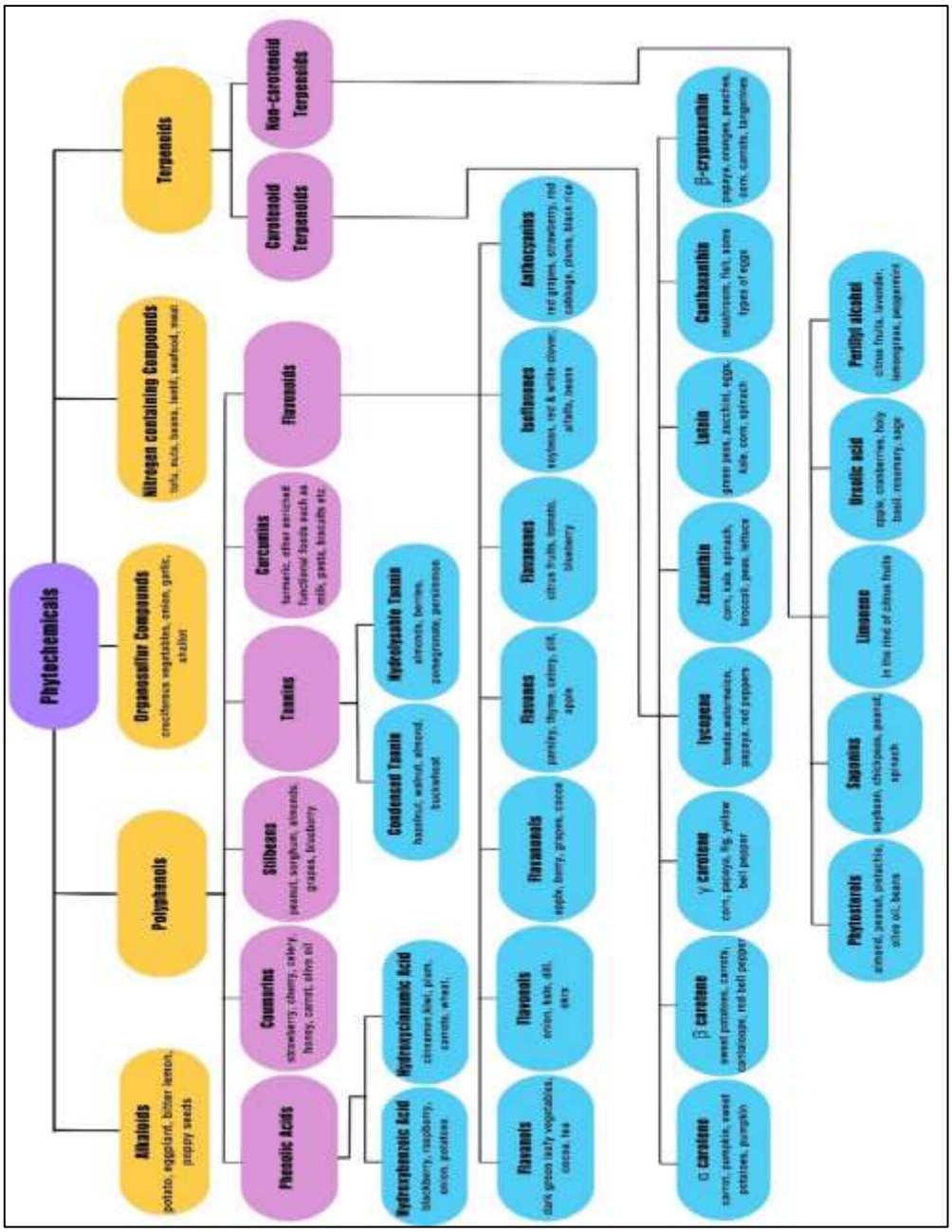

Figure 11.2: Dietary Phytochemical Classification with Food Sources

(Ba & Fá, 2019; Nosrati-Oskouie et al., 2022). Foods that may contain curcumin include mustard, cheese, and butter. However, the amount of curcumin in these foods may be relatively low, and it may be difficult to consume enough curcumin through diet alone to achieve its potential health benefits. There are curcumin fortified foods products as well such as buffalo ghee incorporated with curcumin, macaroni fortified with green tea and turmeric curcumin extract, kulfi, butter cookie and many more.

e. ***Tannins:*** Tannins are highly reactive and eco-friendly, and can be found in various foods, including green coffee beans, fruits, and dates. Tannins can also affect the bioavailability of iron in the diet by binding to it, which can reduce the bioavailability of iron (Gaffney et al., 2004). However, tannins can also have antioxidant and antibacterial properties, making them useful for wound healing applications. They are further classified into two categories. Condensed Tannin & Hydrolysable Tannin. Some foods that are rich in condensed tannins include hazelnuts, walnuts, almonds, buckwheat and buckwheat grits. Hydrolysable tannins are a type of polyphenol found in almonds, berries, soybean, pomegranate, persimmon, grapes and so on.
f. ***Flavonoids:*** Many plants, fruits, vegetables, and leaves contain phytochemical compounds called flavonoids. Flavonoids have a number of health benefits, including antiviral, anti-inflammatory, antioxidant, anticancer, cardioprotective and neuroprotective properties. The kind of flavonoid, its (potential) method of action, and its bioavailability all affect these functions within the body (Ullah et al., 2020). There are seven different types of flavonoids found in food: flavanols, flavonols, flavanonols flavones, flavanones, isoflavones, and anthocyanins (Santhiravel et al., 2022).
g. ***Flavanols:***Flavanols are a class of secondary plant metabolites that exhibit several beneficial health properties, including acting as antioxidant, anticarcinogen, cardioprotective, anti-microbial, anti-viral, and neuroprotective agents (Luo et al., 2022). Flavanols are found in many foods, including cereals, legumes, fruits, vegetables, forages, cocoa, grapes, and apples and many more.
h. ***Flavonols:*** Flavonols are a type of flavonoid, which are compounds found in many plant-based foods that have antioxidant properties. Some foods that are rich in flavonols include kale, dill, apples, broccoli, onions, and tofu. Flavonols have been studied for their potential health benefits, including reducing the risk of cancer and degenerative diseases.
i. ***Flavanonols:*** Flavanonols are a subclass of flavonoids, which are a group of plant compounds that have antioxidant properties and are associated with various health benefits. Apples are a good source of flavanonols, particularly the flavan-3-ols catechin and epicatechin. Berries, such as blueberries, raspberries, and strawberries, are rich in flavanonols, including quercetin and myricetin. Grapes and Cocoa are a good source of flavanonols, particularly catechin and epicatechin.
j. ***Flavones:*** Flavones are a type of flavonoid, which are antioxidants of plant origin with a beneficial role in the prevention of different diseases. flavones are particularly rich in green leaf herbs, such as dill, parsley, and celery leaves. The main food sources of flavonoids were found to be apples, tea infusions, onions, strawberries, and oranges.Epidemiological studies have linked dietary flavonoid consumption to lower risk of various cancers, including breast, gastric, colorectal, and prostate cancers.
k. ***Flavanones:*** Flavanones are a type of flavonoid, which are a group of plant compounds that have antioxidant and anti-inflammatory properties. There are several foods that are rich in flavanones, including citrus fruits like lemons, oranges, and grapefruits. Other

foods that are rich in flavanones include tomatoes, strawberries, and blueberries (Rodríguez-García et al., 2019). Flavanones have been shown to have potential health benefits, including conferring neuroprotection and reducing the risk of cardiovascular disease.

l. ***Isoflavones:*** Isoflavones are found in high amounts in soybeans and soy products, as well as in other legumes and some fruits and vegetables. Isoflavones have been the subject of many studies due to their potential health benefits, such as reducing the risk of certain cancers and improving bone health. They have also been investigated for their pharmacological properties, such as their ability to inhibit xanthine oxidase and cyclooxygenase-2 enzymes, which are involved in gout and inflammation.

m. ***Anthocyanins:*** Anthocyanins are a type of water-soluble pigment in the phenolic family. They are accountable for the red, purple, and blue colors found in vegetables and fruits. Anthocyanins are abundant in vegetables and fruits, with berries, grapes, and a few tropical fruits having the highest concentrations. Additionally, they can be found in cereal grains, roots, and tubers which vary in color from red to purplish blue. The health benefits of anthocyanins have been widely described, especially in the prevention of diseases associated with oxidative stress, such as cardiovascular and neurodegenerative diseases.

B. Alkaloids: A class of naturally found organic substances known as alkaloids primarily have basic nitrogen atoms. Caffeine, morphine, and nicotine are a few typical alkaloids. Some examples of foods containing alkaloids are: potato, eggplant, bitter lemon, poppy seeds, chocolate, tea and coffee. Some alkaloids have therapeutic properties and are used to treat various health conditions (Heinrich et al., 2021). Excessive consumption of certain alkaloids can lead to toxic effects, such as liver damage, neurological disorders, and even death (Kamarul Zaman & Mohamad Azzeme, 2018).

C. Organosulfur Compounds: Organosulfur compounds are found in many different dietary sources, but two main sources are alliaceous and cruciferous vegetables. Alliaceous vegetables include garlic, onions, and shallots, while cruciferous vegetables include broccoli, kale, and cauliflower. Studies have shown that the consumption of these vegetables is beneficial for heart diseases, tumors and other chronic diseases (Mi ekus et al., 2020; Verma et al., 2023). Organosulfur compounds have anti-inflammatory properties and play a significant role in preventing various human pathological progressions, including chronic inflammation, by decreasing inflammatory mediators.

D. Nitrogen-Containing Compounds: Nitrogen is present in variety of foods in the form of proteins, nucleotides, choline, free amino acids, and creatine. Foods rich in nitrogen-containing compounds are broccoli, spinach, kale, beet, nuts, tofu, seafood and meat. Furthermore, black soya bean, edible mushrooms, sorghum grain and black chia seeds are rich in nitrogen-containing compounds. Nitrogen-containing compounds have been shown to have potential health benefits, including antioxidant, anti-inflammatory, anti-proliferative, anti-diabetic, and anti-atherogenic activities.

E. Terpenoids: Terpenoids are biologically active compounds with a wide range of pharmacological effects, involving anticancer activity. Terpenoids have anti-tumor, anti-inflammatory, anti-bacterial, anti-viral, and anti-malarial properties, as well as the ability to

favor transdermal absorption, prevent and manage cardiovascular disease, and have hypoglycemic properties. They are classified into two types: carotenoid terpenoids and non-carotenoid terpenoids. Carotenoid terpenoids have been linked to a variety of health benefits, including a lower risk of neurodegenerative diseases, cardiovascular disease, type 2 diabetes, obesity, and few types of cancer. Carotenoids have bioactive properties like antioxidant, anti-inflammatory, and autophagy-modulatory activities, which contribute to their protective function and have been associated with the treatment and prevention of various diseases. α carotene, β carotene, γ carotene, lycopene, Zeaxanthin, Lutein, Canthaxanthin and β-cryptoxanthin are the subcategories of carotenoid terpenoids (Santhiravel et al., 2022).

a. ***α carotene:*** Alpha-carotene is a provitamin A compound, meaning it can be transformed into vitamin A in the body. Foods that are rich in alpha-carotene include various fruits and vegetables, like carrots, pumpkins, sweet potato, and dark leafy greens like spinach and kale. These foods are often orange or yellow in color due to their high carotenoid content. dietary intake and tissue levels of carotenoids, including alpha-carotene, have been associated with a reduced risk of several chronic diseases such as cardiovascular diseases, type 2 diabetes, obesity, brain-related diseases, and some types of cancer.
b. ***β carotene:*** It is a vitamin A precursor that can be converted in the body to retinol, the active form of vitamin A. Beta-carotene is abundant in vegetables and fruits, particularly those with yellow, red, and orange colors. Carrots, sweet potatoes, pumpkins, mangoes, apricots, spinach, kale, and red peppers are a few of the best sources. Beta-carotene is a powerful antioxidant that can defend cells from oxidative stress involved in several diseases. It can also help to prevent chronic diseases like type 2 diabetes, heart disease, obesity, and other metabolic syndrome. Beta-carotene is associated with decreasing adipocyte and body adipose tissue size, lower proinflammatory markers such as LDL-c and VLDL-c, and increase HDL-c. It can also improve insulin resistance and preserve insulin receptors, which can control oxidative stress involved in these diseases.
c. ***γ carotene:*** Gamma-carotene is a pigment found in corn, papaya, fig, yellow bell pepper. It belongs to the same family as beta-carotene, which is a well-known carotenoid with antioxidant properties. Gamma-carotene is less well-studied than other carotenoids, so its specific health benefits and effects on the body are less well-known.
d. ***Lycopene:*** Lycopene is a non-provitamin A carotenoid and it is currently unknown whether the beneficial effects are from the native structure of lycopene or its metabolic derivatives: lycopenals, lycopenols, and lycopenoic acids (Arballo et al., 2021). Lycopene is found in various foods, including red raw tomatoes, tomato juice, watermelon, pink and red grapefruits, red peppers, ketchup, etc. It is better absorbed when consumed with fats. Lycopene can have positive effects on many stages of atherosclerosis and can affect serum lipid levels, endothelial dysfunction, inflammation, blood pressure, and antioxidative potential.
e. ***Zeaxanthin:*** Zeaxanthin is a carotenoid that is yellow in color and is a member of the xanthophyll family of plant pigments. Zeaxanthin is found in kale, spinach, egg yolks, broccoli, savoy cabbage, peas corn, and parsley (Mrowicka et al., 2022). It offers benefits such as blue light filtering and antioxidant activities, which promote eye health. Additionally, it has been associated with reducing symptoms of colds and influenza in

older adults and may contribute to cardiovascular health by lowering the risk of cardiovascular disease.

f. ***Lutein:*** Lutein is one of the few carotenoids found in high concentration in the macula of the human retina. It is an organic pigment with nutritional benefits that can be found in parsley, kale, egg yolks, spinach, and foods fortified with lutein. Corn, zucchini, green peas, and other foods also contain lutein. Numerous positive health effects of lutein include antioxidant, anti-hypertensive, anti-inflammatory, anti-atherogenic, anti-cancer, anti-ulcer, and anti-diabetic properties (Kim & Park, 2016). Furthermore, it is used to prevent eye diseases including age-related macular degeneration (AMD), cataract, and retinitis pigmentosa.

g. ***Canthaxanthin:*** Canthaxanthin is a reddish-orange xanthophyll with strong antioxidant activity and higher bioavailability than carotenes (Naz et al., 2021). Some types of eggs, mushroom, seafood, red papers are few food sources having canthaxanthin. Canthaxanthin offers several potential health benefits, including antioxidant properties that help scavenge free radicals and protect cholesterol from oxidation. It can also reduce oxidative stress in the body. Additionally, canthaxanthin exhibits immunomodulatory activity, increasing the growth and performance of immune competent cells. Furthermore, it plays a role in gap junction communication. While it is generally considered safe in small amounts, consuming large amounts of canthaxanthin can cause a condition known as canthaxanthin retinopathy, which can affect vision.

h. ***β-cryptoxanthin:*** β-Cryptoxanthin is a carotenoid that offers health benefits, including reduced cardiovascular disease risk and decreased osteoporosis and hip fracture risk. β-Cryptoxanthin may regulate cellular functions, but it's important to note that carotenoids can act as free-radical scavengers and may behave as pro-oxidants in high oxygen concentrations. It is present in many vegetables and fruits, particularly those that are orange or red in color. For example, β-cryptoxanthin is found in high concentrations in sweet red peppers, persimmons, carrots, peaches, oranges, and papayas.

i. ***Non-Carotenoid Terpenoids:*** Non-carotenoid terpenoids are a diverse group of organic compounds that belong to the larger class of terpenoids. There are 5 subtypes of it namely Phytosterols, Saponins, Limonene, Ursolic acid and Perillyl alcohol.

j. ***Phytosterols:*** Phytosterols are plant-based compounds with various health benefits. They can reduce cholesterol absorption, lower total cholesterol levels, reduce the risk of cardiovascular diseases and have other pharmacological properties. They also have potential benefits for cancer prevention and possess anti-inflammatory and antioxidant properties. Other health-promoting effects of phytosterols include anti-obesity, anti-diabetic, anti-microbial, and immunomodulatory effects. Phytosterols can be found in nuts, seeds, vegetable oils (especially olive oil), whole grains, legumes, and fruits & vegetables (like avocados & broccoli). Fortified foods like margarine, orange juice, and yogurt may also contain phytosterols. However, it's important to consume them in moderation to avoid interfering with the absorption of fat-soluble vitamins and nutrients.

k. ***Saponins:*** Saponins are widely distributed in many foods and raw food materials, but occur primarily in peanut and spinach, legumes such as soybean, chickpea. Saponins have a range of medicinal properties, such as anti-inflammatory, immune stimulating, hypo-cholesterolemic, hypoglycemic, antifungal, and cytotoxic effects.

l. ***Limonene:*** Limonene is a monoterpene that possesses multiple biological properties including antioxidant, anticancer, antinociceptive, anti-inflammatory, &

gastroprotective characteristics. Limonene also demonstrates neuroprotective potential by mitigating oxidative stress, inflammation, and regulation of apoptotic cell death. It shows promise in treating neurodegenerative disorders like Alzheimer's disease, multiple sclerosis, epilepsy, anxiety, and stroke (Eddin et al., 2021). It is a volatile compound present in various fruits specially in the rind of fruits like berries, grapefruit, lemon, and cashew nuts.

m. ***Ursolic acid:*** Natural substance known as ursolic acid has a variety of medicinal benefits, such as antioxidant, anti-inflammatory, anti-apoptotic, & anti-carcinogenic effects. It has shown potential in treating various diseases such as metabolic disorders, heart conditions, cancer, and neurological disorders. Ursolic acid also has antimicrobial properties against bacteria, HIV, HCV viruses, and the malaria-causing plasmodium protozoa. It acts on different tissues and organs by suppressing cancer cell signaling, improving insulin signaling in adipose tissues, reducing cardiac damage, decreasing brain inflammation, increasing antioxidant levels in the brain, reducing liver damage, and enhancing skeletal muscle function. Ursolic acid is present in apple peel, cranberry juice, grape skin, holy basil, rosemary, thyme, oregano, sage, and other herbs.(Chan et al., 2019)

n. ***Perillyl alcohol:*** Perillyl alcohol is a monoterpene that is found naturally in cherries, mint, and lavender, in the essential oils of citrus fruits, such as oranges and lemon. Perillyl alcohol has antidiabetic potential and can reduce and normalize blood glucose levels in high-fat diet and low-dose streptozotocin induced diabetic rats. It exhibits antifungal properties and is linked to opioids. It also has increased antiproliferative activity in lung cancer, melanoma, and fibrosarcoma cells, with no significant adverse health effects.

Majority of the phytochemicals have a very low bioavailability in the human body in comparison to micro- and macronutrients because of their convoluted chemical makeup and ability to be broken down. It is significant to note that a variety of factors, such as pH, light, temperature, water activity (aw), and conditions of storage impact the stability of bioactive compounds and that certain processing methods can cause these substances to degrade. To increase the bioavailability of a specific compound, it must be consumed in a specific manner or after processing or with other supporting foods that enhance the absorption, digestion, and distribution of specific phytochemicals and this requires knowledge. Anything in excess or consuming them exclusively while ignoring other foods can be dangerous to one’s health.

11.6 Conclusion:

Functional foods are natural or processed food having a quality of enhancement of health and disease prevention. They are mainly of two types conventional foods and modified foods. Majority of functional foods which have medicinal health benefits contain phytochemicals. Phytochemicals are the reason for medicinal properties of functional foods majority of the times. Phytochemicals are non-essential, nonnutritive chemical compounds found in plants as their secondary metabolites as defense system. In this chapter detailed phytochemical classification with food sources are given. Phytochemicals gives many health benefits to human body such as reducing risk of chronic diseases, reducing the risk of chronic non-communicable diseases (NCDs), improving gut health, providing antioxidant, anti-inflammatory benefits, improving immune system function, protection

against cell and DNA damage, reducing inflammation, slowing down growth rate of some cancer cells, regulation of hormones. Although these phytochemicals and the foods that are having it have medicinal health benefits, it should not be considered as ultimate magical chemical or treatment. All foods and phytochemicals are best effective when taken in moderation and with balanced nutritious diets.

11.7 References:

1. Arballo, J., Amengual, J., & Erdman, J. W. (2021). Lycopene: A Critical Review of Digestion, Absorption, Metabolism, and Excretion. *Antioxidants*, *10*(3), 1–16. https://doi.org/10.3390/ANTIOX10030342
2. Arshad, M. S., Khalid, W., Ahmad, R. S., Khan, M. K., Ahmad, M. H., Safdar, S., Kousar, S., Munir, H., Shabbir, U., Zafarullah, M., Nadeem, M., Asghar, Z., Suleria, H. A. R., Arshad, M. S., Khalid, W., Ahmad, R. S., Khan, M. K., Ahmad, M. H., Safdar, S., … Suleria, H. A. R. (2021). Functional Foods and Human Health: An Overview. *Functional Foods - Phytochemicals and Health Promoting Potential*. https://doi.org/10.5772/INTECHOPEN.99000
3. Ba, P., & Fá, B. (2019). Curcumin: Phytochemical Therapy in the Treatment of Hyperlipidemia. *Glasnik Hemicara i Tehnologa Bosne i Hercegovine*, *52*. https://doi.org/10.35666/GHTBH.2019.52.02
4. Baker, M. T., Lu, P., Parrella, J. A., & Leggette, H. R. (2022). Consumer Acceptance toward Functional Foods: A Scoping Review. *International Journal of Environmental Research and Public Health 2022, Vol. 19, Page 1217*, *19*(3), 1217. https://doi.org/10.3390/IJERPH19031217
5. Blades, M. (2000). Functional foods or nutraceuticals. *Nutrition & Food Science*, *30*(2), 73–76. https://doi.org/10.1108/00346650010314313/FULL/PDF
6. Cao, H., Chai, T. T., Wang, X., Morais-Braga, M. F. B., Yang, J. H., Wong, F. C., Wang, R., Yao, H., Cao, J., Cornara, L., Burlando, B., Wang, Y., Xiao, J., & Coutinho, H. D. M. (2017). Phytochemicals from fern species: potential for medicine applications. *Phytochemistry Reviews 2017 16:3*, *16*(3), 379–440. https://doi.org/10.1007/S11101-016-9488-7
7. Carrera-Quintanar, L., Roa, R. I. L., Quintero-Fabián, S., Sánchez-Sánchez, M. A., Vizmanos, B., & Ortuño-Sahagún, D. (2018). Phytochemicals That Influence Gut Microbiota as Prophylactics and for the Treatment of Obesity and Inflammatory Diseases. *Mediators of Inflammation*, *2018*. https://doi.org/10.1155/2018/9734845
8. Castillo, M., Iriondo-DeHond, A., & Martirosyan, D. M. (2018). Are functional foods essential for sustainable health?. *Annals of Nutrition & Food Science*.
9. Chan, E. W. C., Soon, C. Y., Tan, J. B. L., Wong, S. K., & Hui, Y. W. (2019). Ursolic acid: An overview on its cytotoxic activities against breast and colorectal cancer cells. *Journal of Integrative Medicine*, *17*(3), 155–160. https://doi.org/10.1016/J.JOIM.2019.03.003
10. Crowe, K. M., & Francis, C. (2013). Position of the academy of nutrition and dietetics: functional foods. *Journal of the Academy of Nutrition and Dietetics*, *113*(8), 1096–1103. https://doi.org/10.1016/J.JAND.2013.06.002
11. Di Renzo, L., De Lorenzo, A., Merra, G., & Gualtieri, P. (2020). Comment on: "A Systematic Review of Organic Versus Conventional Food Consumption: Is There a Measurable Benefit on Human Health? Nutrients 2020, 12, 7." *Nutrients 2020, Vol. 12, Page 696*, *12*(3), 696. https://doi.org/10.3390/NU12030696

12. Doyon, M., & Labrecque, J. A. (2008). Functional foods: A conceptual definition. *British Food Journal*, *110*(11), 1133–1149. https://doi.org/10.1108/00070700810918036
13. Eddin, L. B., Jha, N. K., Meeran, M. F. N., Kesari, K. K., Beiram, R., & Ojha, S. (2021). Neuroprotective Potential of Limonene and Limonene Containing Natural Products. *Molecules*, *26*(15). https://doi.org/10.3390/MOLECULES26154535
14. Essa, M. M., Bishir, M., Bhat, A., Chidambaram, S. B., Al-Balushi, B., Hamdan, H., Govindarajan, N., Freidland, R. P., & Qoronfleh, M. W. (2023). Functional foods and their impact on health. *Journal of Food Science and Technology*, *60*(3), 820–834. https://doi.org/10.1007/S13197-021-05193-3
15. Gaffney, S., Williams, V., Flynn, P., Carlino, R., Mowry, C., Dierenfeld, E., Babb, C., Fan, J., & Tramontano, W. A. (2004). Research Article: Tannin/Polyphenol effects on iron solubilization in vitro. *Https://Doi.Org/10.1893/0005-3155(2004)75<43:PEOISI>2.0.CO;2*, *75*(2), 43–52. https://doi.org/10.1893/0005-3155(2004)75
16. Havel, R. J., Erdman, J. W., Garza, C., Goodridge, A. G., King, J. C., Clydesdale, F. M., Cousins, R. J., Drewnowski, A., Harlander, S. K., Kolonel, L. N., Leveille, G. A., Constatine-Paton, M., Pi-Sunyer, F. X., Quandt, S. A., Rizvi, S. S. H., Rosenberg, I. H., Ross, A. C., St. Jeor, S. T., & Stunkard, A. J. (1994). Opportunities in the nutrition and food sciences: Research challenges and the next generation of investigators. *Journal of Nutrition*, *124*(6), 763–769. https://doi.org/10.1093/JN/124.6.763
17. Health, N. R. C. (US) C. on D. and. (1989). *Genetics and Nutrition*. https://www.ncbi.nlm.nih.gov/books/NBK218767/
18. Heinrich, M., Mah, J., & Amirkia, V. (2021). Alkaloids Used as Medicines: Structural Phytochemistry Meets Biodiversity—An Update and Forward Look. *Molecules*, *26*(7). https://doi.org/10.3390/MOLECULES26071836
19. Kamarul Zaman, M. A., & Mohamad Azzeme, A. (2018). Plant toxins: alkaloids and their toxicities. *GSC Biological and Pharmaceutical Sciences*, *6*(2), 021–029. https://doi.org/10.30574/GSCBPS.2019.6.2.0003
20. Kanwal, S. (2022). *Breakdown of disease present in population in India 1990-2030*.
21. Kaseke, T., Fawole, O. A., & Opara, U. L. (2021). Chemistry and Functionality of Cold-Pressed Macadamia Nut Oil. *Processes*, *10*(1). https://doi.org/10.3390/PR10010056
22. Kaur, S., & Das, M. (2011). Functional foods: An overview. *Food Science and Biotechnology*, *20*(4), 861–875. https://doi.org/10.1007/S10068-011-0121-7/METRICS
23. Kim, J. K., & Park, S. U. (2016). Current results on the potential health benefits of lutein. *EXCLI Journal*, *15*, 308. https://doi.org/10.17179/EXCLI2016-278
24. Kruger, C. L., & Mann, S. W. (2003). Safety evaluation of functional ingredients. *Food and Chemical Toxicology*, *41*(6), 793–805. https://doi.org/10.1016/S0278-6915(03)00018-8
25. Lara, M. V., Bonghi, C., Famiani, F., Vizzotto, G., Walker, R. P., & Drincovich, M. F. (2020). Stone Fruit as Biofactories of Phytochemicals With Potential Roles in Human Nutrition and Health. *Frontiers in Plant Science*, *11*, 1323. https://doi.org/10.3389/FPLS.2020.562252/BIBTEX
26. Liu, R. H. (2004). Potential Synergy of Phytochemicals in Cancer Prevention: Mechanism of Action. *The Journal of Nutrition*, *134*(12), 3479S-3485S. https://doi.org/10.1093/JN/134.12.3479S

27. Luo, Y., Jian, Y., Liu, Y., Jiang, S., Muhammad, D., & Wang, W. (2022). Flavanols from Nature: A Phytochemistry and Biological Activity Review. *Molecules*, *27*(3). https://doi.org/10.3390/MOLECULES27030719
28. MacAulay, J., Petersen, B., S. F. (2005). Functional foods: Opportunities and challenges. *Institute of Food Technologists (IFT) Expert Report. Institute of Food Technologists.*
29. Martinez, R. M., Almeida, C. de O. R. P. de, Lima, T. P. B., Figueiredo, M. S., & Teodoro, A. J. (2022). Obesity mechanisms and importance of bioactive compounds from fruits in its regulation – a narrative review. *Research, Society and Development*, *11*(4), e11411427153. https://doi.org/10.33448/rsd-v11i4.27153
30. Martirosyan, D. M., & Singharaj, B. (2016). Health Claims and Functional Food: The Future of Functional Foods under FDA and EFSA Regulation. *Functional Foods for Chronic Diseases; Food Science Publisher: Dallas, TX, USA*, 410–424.
31. Martirosyan, D., & Miller, E. (2018). Bioactive compounds: The key to functional foods. *Bioactive Compounds in Health and Disease*, *1*(3), 36–39. https://doi.org/10.31989/BCHD.V1I3.539
32. Meyer, A. (1998). No Title. *Food Process*, *58*(8), 32–40.
33. Mi ekus, N., Marszałek, K., Podlacha, M., Iqbal, A., Puchalski, C., & Swiergiel, A. H. (2020). Health Benefits of Plant-Derived Sulfur Compounds, Glucosinolates, and Organosulfur Compounds. *Molecules*, *25*(17). https://doi.org/10.3390/MOLECULES25173804
34. Milner, J. A. (2000). Functional foods: the US perspective. *The American Journal of Clinical Nutrition*, *71*(6 Suppl). https://doi.org/10.1093/AJCN/71.6.1654S
35. Mrowicka, M., Mrowicki, J., Kucharska, E., & Majsterek, I. (2022). Lutein and Zeaxanthin and Their Roles in Age-Related Macular Degeneration—Neurodegenerative Disease. *Nutrients*, *14*(4). https://doi.org/10.3390/NU14040827
36. Naz, T., Yang, J., Nosheen, S., Sun, C., Nazir, Y., Mohamed, H., Fazili, A. B. A., Ullah, S., Li, S., Yang, W., Garre, V., & Song, Y. (2021). Genetic Modification of Mucor circinelloides for Canthaxanthin Production by Heterologous Expression of β-carotene Ketolase Gene. *Frontiers in Nutrition*, *8*. https://doi.org/10.3389/FNUT.2021.756218/FULL
37. Noonan, C. (2004). Legal requirements for "functional food" claims The effects of a melatonin-based drink on sleep patterns of healthy adults View project. *Article in Toxicology Letters*. https://doi.org/10.1016/j.toxlet.2003.05.002
38. Nosrati-Oskouie, M., Aghili-Moghaddam, N. S., Tavakoli-Rouzbehani, O. M., Jamialahmadi, T., Johnston, T. P., & Sahebkar, A. (2022). Curcumin: A dietary phytochemical for boosting exercise performance and recovery. *Food Science & Nutrition*, *10*(11), 3531. https://doi.org/10.1002/FSN3.2983
39. Rodríguez-García, C., Sánchez-Quesada, C., Gaforio, J. J., & Gaforio, J. J. (2019). Dietary Flavonoids as Cancer Chemopreventive Agents: An Updated Review of Human Studies. *Antioxidants*, *8*(5). https://doi.org/10.3390/ANTIOX8050137
40. Santhiravel, S., Bekhit, A. E. D. A., Mendis, E., Jacobs, J. L., Dunshea, F. R., Rajapakse, N., & Ponnampalam, E. N. (2022). The Impact of Plant Phytochemicals on the Gut Microbiota of Humans for a Balanced Life. In *International Journal of Molecular Sciences* (Vol. 23, Issue 15, p. 8124). Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/ijms23158124
41. Shahidi, F. (2009). Nutraceuticals and functional foods: Whole versus processed foods. *Trends in Food Science & Technology*, *20*(9), 376–387.

https://doi.org/10.1016/J.TIFS.2008.08.004
42. Shimizu, T. (2003). Health claims on functional foods: the Japanese regulations and an international comparison. *Nutrition Research Reviews*, *16*(2), 241–252. https://doi.org/10.1079/NRR200363
43. Singh, D., & Chaudhuri, P. K. (2018). A review on phytochemical and pharmacological properties of Holy basil (Ocimum sanctum L.). *Industrial Crops and Products*, *118*, 367–382. https://doi.org/10.1016/J.INDCROP.2018.03.048
44. Siró, I., Kápolna, E., Kápolna, B., & Lugasi, A. (2008). Functional food. Product development, marketing and consumer acceptance-A review. In *Appetite* (Vol. 51, Issue 3, pp. 456–467). Academic Press. https://doi.org/10.1016/j.appet.2008.05.060
45. Srilakshmi, B. (2018). *Food Science , New Age International(P) Ltd,.Publishers*.
46. Thakur, M., Singh, K., & Khedkar, R. (2020). Phytochemicals: Extraction process, safety assessment, toxicological evaluations, and regulatory issues. *Functional and Preservative Properties of Phytochemicals*, 341–361. https://doi.org/10.1016/B978-0-12-818593-3.00011-7
47. Tsai, H. Y., Ho, C. T., & Chen, Y. K. (2017). Biological actions and molecular effects of resveratrol, pterostilbene, and 3′-hydroxypterostilbene. *Journal of Food and Drug Analysis*, *25*(1), 134. https://doi.org/10.1016/J.JFDA.2016.07.004
48. Ullah, A., Munir, S., Badshah, S. L., Khan, N., Ghani, L., Poulson, B. G., Emwas, A. H., & Jaremko, M. (2020). Important Flavonoids and Their Role as a Therapeutic Agent. *Molecules*, *25*(22). https://doi.org/10.3390/MOLECULES25225243
49. Verma, T., Aggarwal, A., Dey, P., Chauhan, A. K., Rashid, S., Chen, K. T., & Sharma, R. (2023). Medicinal and therapeutic properties of garlic, garlic essential oil, and garlic-based snack food: An updated review. *Frontiers in Nutrition*, *10*. https://doi.org/10.3389/FNUT.2023.1120377
50. world health organization. (2020). *Healthy diet*.
51. Zhao, C., Yang, C., Liu, B., Lin, L., Sarker, S. D., Nahar, L., Yu, H., Cao, H., & Xiao, J. (2018). Bioactive compounds from marine macroalgae and their hypoglycemic benefits. *Trends in Food Science & Technology*, *72*, 1–12. https://doi.org/10.1016/J.TIFS.2017.12.001.

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12. Inulin: Wonder Fiber – Health, Nutritional and Technological Aspects

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Abstract:

In recent times, there has been an increased interest to adapt healthy diets, which help in preventing diseases, improved nutrition, and as a consequence, the study and development of new functional foods have gained much importance. Dietary fibers are found naturally in the plants that we eat. They do not break down in our stomachs, and instead pass through our system undigested. All fibers either soluble or insoluble are equally important for health. (Guarner, 2005). Inulin, a soluble fibre extracted from chicory roots, is accumulating value in the functional food market, as ongoing research finds the ingredient has several health, nutritional and technological benefits. These physiological responses to fiber consumption are the basis for associating high fiber diets with reduced risk of chronic diseases, diabetes and intestinal cancer (Kelly, 2009). Inulin attracts water and form a gel, which slows down digestion. It delays the emptying of your stomach and makes you feel full, which helps control weight. Slower stomach emptying may also affect blood sugar levels and have a beneficial effect on insulin sensitivity, which may help control diabetes (Tako et al., 2007). The benefits of inulin ingestion are not only limited to its condition as a dietetic fibre, but also include aspects related to its prebiotic (stimulation of growth of health-promoting bacteria e.g. bifidobacteria) nature, and the regulation of intestinal flora in the colon (Kaur & Gupta, 2002). In addition inulin has unique technological properties such as fat, sugar substitute, texture agent etc. The benefits of inulin on human health coupled with interesting technological properties have focused the research in this ingredient, to be used for incorporation in many dairy and food products including pharmaceutical products (Roberfroid, 2007). Therefore, this review focuses to promote the uses of inulin in various dairy as well as functional foods.

Keywords:

Dietary fiber, Dairy, Functional foods, Inulin, Fat replacer, Probiotic.

12.1 Introduction:

A. Dietary Fiber:

Dietary fibers are found naturally in the plants that we eat. They are parts of plant that do not break down in our stomachs, and instead pass through our system undigested. All dietary fibers are either soluble or insoluble. Both types of fiber are equally important for health, digestion, and preventing conditions such as heart disease, diabetes, obesity, diverticulitis, and constipation. All dietary fibers are either soluble or insoluble.

B. Insoluble Fibers:

Insoluble fibers are considered gut-healthy fiber because they have a laxative effect and add bulk to the diet, help to prevent constipation. These fibers do not dissolve in water, so they pass through the gastrointestinal tract relatively intact, and speed up the passage of food and waste through your gut. Insoluble fibers are mainly found in whole grains and vegetables. Various sources of insoluble fibers are whole wheat, whole grains, wheat bran, corn bran, seeds, nuts, barley, couscous, brown rice, bulgur, zucchini, celery, broccoli, cabbage, onions, tomatoes, carrots, cucumbers, green beans, dark leafy vegetables, raisins, grapes, fruit, and root vegetable skins **(**Kathleen, 2013**).**

C. Soluble Fibers:

Soluble fibers attract water and form a gel, which slows down digestion. Soluble fiber delays the emptying of your stomach and makes you feel full, which helps control weight. Slower stomach emptying may also affect blood sugar levels and have a beneficial effect on insulin sensitivity, which may help control diabetes. Soluble fibers can also help lower LDL (“bad”) blood cholesterol by interfering with the absorption of dietary cholesterol. Various sources of soluble fiber are oatmeal, oat cereal, lentils, apples, oranges, pears, oat bran, strawberries, nuts, flaxseeds, beans, dried peas, blueberries, psyllium, cucumbers, celery, and carrots **(**Kathleen, 2013**)**.

Soluble fiber absorbs water to become a gelatinous, viscous substance and is fermented by bacteria in the digestive tract. Insoluble fiber has bulking action and is not fermented (Eastwood, 2005).

Chemically, dietary fiber consists of non-starch polysaccharides such as arabinoxylans, cellulose, and many other plant components such as resistant dextrins, inulin, lignin, waxes, chitins, pectins, beta-glucans, and oligosaccharides. A novel position has been adopted by the US Department of Agriculture to include *functional fibers* as isolated fiber sources that may be included in the diet. The term "fiber" is something of a misnomer, since many types of so-called dietary fiber are not actually fibrous.

Advantages of consuming fiber are the production of healthful compounds during the fermentation of soluble fiber, and insoluble fiber's ability (via its passive hygroscopic properties) to increase bulk, soften stool, and shorten transit time through the intestinal tract (Anderson, 2009).

12.2 Inulin:

Inulin, a nondigestible carbohydrate, is a fructan that is not only found in many plants as a storage carbohydrate, but has also been part of man's daily diet for several centuries. It is present in many regularly consumed vegetables, fruits and cereals, including leek, onion, garlic, wheat, chicory, artichoke, and banana. Industrially, inulin is obtained from chicory roots, and is used as a functional food ingredient that offers a unique combination of interesting nutritional properties and important technological benefits. In food formulations, inulin significantly improves the organoleptic characteristics, allowing an upgrading of both taste and mouthfeel in a wide range of applications. In particular, this taste-free fructan increases the stability of foams and emulsions, as well as showing an exceptional fat-like behavior when used in the form of a gel in water. By contrast, as an ever-increasing amount of information becomes available on inulin, its nutritional attributes continue to amaze both researchers and nutritionists alike. Consequently, fat and carbohydrate replacement with inulin offers the advantage of not having to compromise on taste and texture, while delivering further nutritional benefits. Hence, inulin represents a key ingredient that offers new opportunities to a food industry which is constantly seeking well balanced, yet better tasting, products of the future (http://www.wileych.de/books/biopoly/pdf_v06/ bpol6014_439 _448.pdf). Inulin is a group of naturally occurring polysaccharides produced by many types of plants. They belong to a class of fibers known as fructans. Inulin is used by some plants as a means of storing energy and is typically found in roots or rhizomes. Most plants that synthesize and store inulin do not store other materials such as starch. Unlike most carbohydrates, inulin is non-digestible. This allows it to pass through the small intestine and ferment in the large intestine (Roberfroid M., 2005).

12.3 Definition:

Inulin falls under the general class of carbohydrates called fructans, those polymers containing fructose. Fructans serve as storage polymers in many members such as *Cichorium intybus* (chicory), *Inula helenium* (elecampane), *Taraxacum officinalis* (dandelion), and *Helianthus tuberosus* (Jerusalem artichoke). Inulin extracted from chicory is a natural polydisperse carbohydrate.

12.4 Historical Origin:

Inulin was discovered by Rose, a German scientist, who in 1804 found "a peculiar substance" from plant origin in a boiling water extract from the roots of *Inula helenium*, a genus of perennial herbs of the group Composite, natives of the temperate regions of Europe, Asia, and Africa. The substance was named inulin but was also identified by other names such as helenin, alantin, meniantin, dahlin, sinanternin, and sinisterin. The biochemical production was elucidated around the middle of the 19th century (Goudberg, 1913).

The German plant physiologist Julius Sachs (1864) was the pioneer in fructan research and, by using only a microscope, was able to detect the spherocrystals of inulin in the tubers of Dahlia, Helianthus tuberosus and Inula helenium after ethanol precipitation. Although today, chicory is the major crop used for the industrial production of inulin, the first reference to chicory being consumed by humans was made during the first century by Pedanios Dioscoride who, as a physician in the Roman army, praised the plant for its beneficial effects on the stomach, liver, and kidneys (http://www.wiley-vch.de/books/biopoly/pdf_v06/bpol6014_439 _448.pdf).

Much later, in about 1850, Jerusalem artichoke (Helianthus tuberosus) pulp, when prepared by cooking and drying the tubers, was added in a 50:50 ratio to flour when baking bread to provide cheap food for laborers (Franck, 2002).

12.5 Structure:

It is known as a fructan consisting predominately of linear chains of 1,2-β-linked d-fructofuranose units bound by a (α_1- β_2) type linkage (as in sucrose) to a terminal glucose moiety. The gross molecular formula of inulin is GF_n, with G being a terminal glucosyl unit, F representing the fructosyl units and "n" representing the number of fructosyl units. The basic structure of inulin shown in Figure 1 (Tungland and Meyer, 2002).

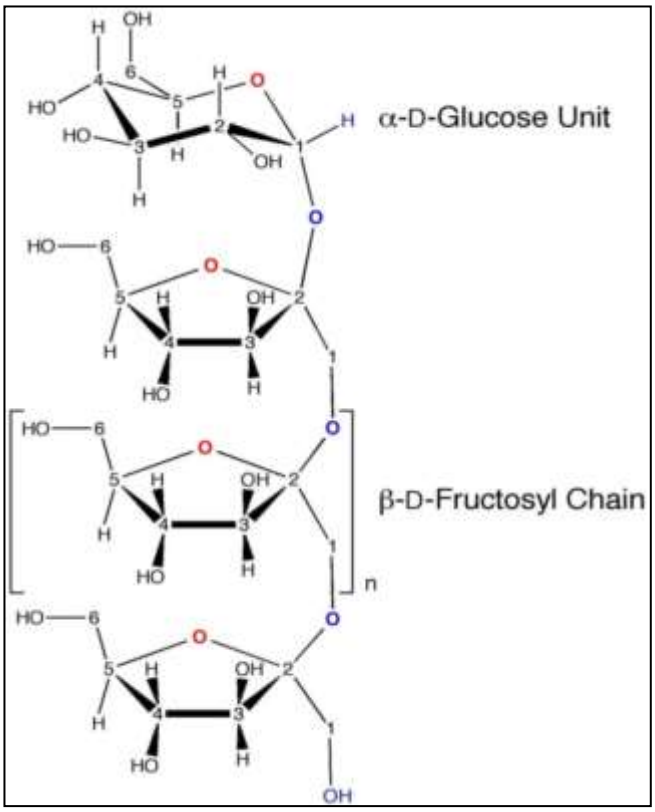

Figure 12.1: Chemical Structure of Inulin

Sources: Inulin belongs to the group of naturally-occurring carbohydrates known as non-digestible oligosaccharides (NDO). It is produced naturally in over 36,000 plants worldwide, including 1,200 native grasses belonging to 10 families. After starch, they are the most plentiful carbohydrates occurring in the plant kingdom (Carpita *et al*., 1989 and Marchetti, 1993). It has been estimated that as much as one third of the total vegetation on earth consists of plants that contain fructans. Inulin-type carbohydrates obtained from fungal fermentation have been reported in commercial use but the predominant commercial source for Inulin/FOS is of chicory root origin shown in Table 12.1 (Van Loo *et al*., 1995).

Table 12.1: Inulin content of plants that are commonly used in Human nutrition

Source	Edible parts	Dry solid content (per cent)	Inulin content (per cent)
Onion	Bulb	6	2
Jerusalem artichoke	Tuber	19	14
Chicory	Root	20	15
Leek	Bulb	15	3
Garlic	Bulb	40	9
Artichoke	Leaves-heart	14	3
Banana	Fruit	24	0.3
Rye	Cereal	88	0.5
Barley	Cereal	NA	0.5
Dandelion	Leaves	50	12
Burdock	Root	21	3.5
Camas	Bulb	31	12
Murnong	Root	25	8
Yacon	Root	13	3
Salsify	Root	20	4

NA, data not available.

Chicory Roots: Chicory (*Chicorium intybus* var. *sativum*) is a herb with its unique blue flowers, found in many parts of India. Chicory has many uses in current cuisine and commonly in coffee substitute, or coffee additive. Chicory ***inulin*** can be extracted from the root shown in Figure 2.3 and used as an ideal ingredient in functional foods

(http://www.chicoryindia.net/main.php).

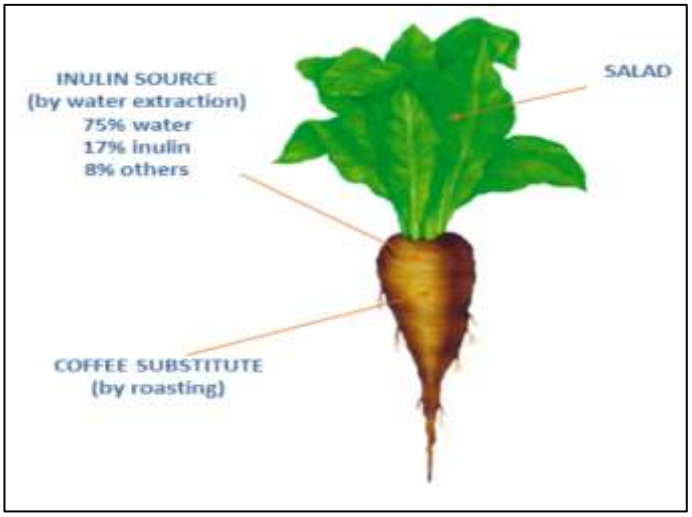

Figure 12.2: Chicory Root *(Chichorium Intybus)*

Chicory root inulin is not synthesized or modified during the extraction process. Acquiring inulin from the root of the chicory involves processing steps where the inulin is extracted, purified, and then spray-dried. However, the extracted inulin is chemically indistinguishable from "native" inulin. Though the inulin cannot be considered unprocessed, the process is completely natural (http://www.prebiotic.ca/inulin.html).

12.6 Industrial Production of Inulin:

Inulin as a pure compound was not produced economically on an industrial scale and was not available as a food ingredient for human consumption. It was produced on a pilot scale in Deutsche Kulorfabrik in the early 1920s (Sloane, 1920), and later was extracted on an industrial scale. The inulin can be extracted by two methods and shown in Figure 3 and 4 respectively.

a. Natural Extraction (http://www.foodingredientsfirst.com/newsmaker_article.asp).
b. Industrial Production Process (http://www.prebiotic.ca/inulin.html)

The industrial production process involved following steps

a. extraction of raw inulin with hot water,
b. purification of the raw inulin and
c. spray drying of the purified juice to a pure inulin powder.

Although inulin is spray dried, the molecule is quite flexible, and crystallizes easily (French, 1989).

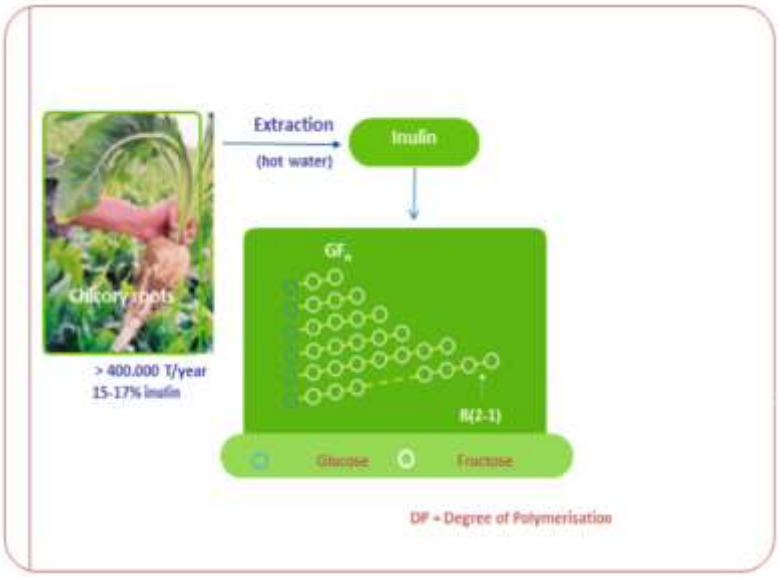

Figure 12.3: Natural Extraction Process

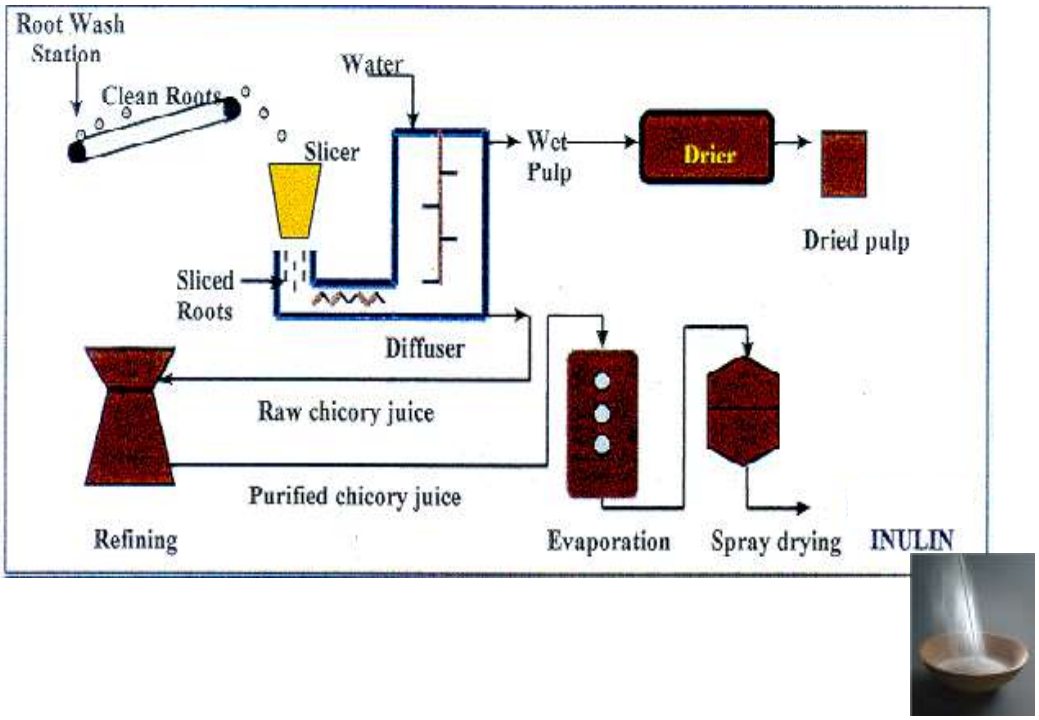

Figure 12.4: Inulin Production Process

Physicochemical Properties and various forms of inulin

The various physico chemical properties of inulin are shown in Table 2.

Table 12.2: Physicochemical Properties of Inulin

Properties	Standard inulin	High Performance
Chemical Structure	GFn	GFn
Dry Matter (%)	95	95
Inulin Content (%on d.m.)	92	99.5
Sugars Content (%on d.m.)	8	0.5
p^H (10% w/w)	5-7	5-7
Heavy Metals (ppm on d.m.)	<0.2	<0.2
Appearance	White Powder	White Powder
Taste	Neutral	Neutral
Sweetness (v. sucrose=100%)	10%	None
Solubility in water at 25°C (g/l)	120	25
Viscosity in water (5%) at 10°C (mPas)	1.6	2.4
Functionality in foods	Fat as well as Sugar Replacer	Fat as well as Sugar Replacer

(Source: Franck, 2002)

12.7 Health Benefits:

A. Anti Colon Cancer Activity:

Barclay (2010) reported that dietary inulin inhibits development of colon cancers. Similarly tumor inhibitory effects are seen with fermentation products of inulin, particularly the short chain fatty acids, butyric and propionic acids, both of which inhibit growth of colon cancer cells and might reduce risk of cardiovascular disease. A recent report on human trial showed that dietary inulin reduced serum concentrations of the proatherogenic molecule, p-cresyl sulphate, in haemodialysis patients (Meijers *et al.*, 2010).

Life-long ingestion of inulin (10% diet) also reduced the number of colonic tumours in azoxymethane (AOM) treated rats (Verghese *et al.,* 2002). The higher the number of aberrant crypts per foci (ACF), the greater likelihood of tumour development and this might be taken as an indicator of relative cancer risk (Pretlow *et al.,* 1992 and Magnuson *et al.,* 1993). Several studies have confirmed the ability of inulin (fed at 10% w/w diet) to reduce the number of ACF in the colon of AOM treated rats (Rowland 1998; Reddy *et al.,* 1997 and Rao *et al.,* 1998).

B. Antitumor Activity:

Butyrate, the anion of the short-chain fatty acid (butyric acid), is produced by bacterial fermentation of inulin in the colon. Some studies suggested that butyrate might induce growth arrest, cell differentiation and upregulate apoptosis, three activities that could be significant for antitumor activity.

C. Hypolipidemic Activity:

Kelly (2009) reported that administration of inulin might lower cholesterol levels in some type 2 diabetes and might be attributed via decreased triglyceride synthesis in liver. The consumption of inulin and FOS has been linked to a modification of the serum levels of triglycerides and cholesterol in rodents (Delzenna and Williams, 2002). Due to the complexity of human lipid metabolism, comprehensive studies are difficult to undertake and few in number. Results between studies are often conflicting. Williams and Jackson (2002) have discussed possible bias in various experimental approaches. Available data tend showed either no effect or a slight decrease in circulating tricylglycerols and plasma cholesterol concentrations following the ingestion of inulin and FOS. The possible mechanisms of action of prebiotic on lipid metabolism have been reviewed by Pereira and Gibson (2002).

D. Antiosteoporotic Activity:

Inulins, similar to dietary fiber, might bind such minerals like calcium and magnesium in the small intestine. The short-chain fatty acids (acetate, propionate, and butyrate) formed from the bacterial fermentation of inulin in the intestinal tract could facilitate the colonic absorption of calcium and possibly also magnesium ions. This could be beneficial in preventing osteoporosis and osteopenia (http://www.jn.nutrition.org).

F. Inulin as a Prebiotic:

The term *prebiotic* was introduced by Gibson and Roberfroid (1995), who exchanged "pro" for "pre," which means "before" or "for." They defined prebiotics as "a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon."A prebiotic is a non-viable food component that confers a health benefit on the host associated with modulation of the microflora. Prebiotics are as substances that trigger the growth of bacteria having favourable effects on the intestinal flora. They remain intact throughout the digestive process, and deliver healthy bacteria directly to the large intestine. By consuming a non-digestible ingredient, it allows for growth of bio-cultures by reaching the intestine unaffected by the digestion process. This can provide good digestive health. A prebiotic effect occurs when there is an increase in the activity of healthy bacteria in the human intestine. The prebiotics stimulate the growth of healthy bacteria such as bifidobacteria and lactobacilli in the gut and increase resistance to invading pathogens. This effect is induced by consuming functional foods that contain prebiotics. These foods induce metabolic activity, leading to health improvements. Healthy bacteria in the intestine can combat unwanted bacteria, providing a number of health benefits (Cummings *et al.*, 1987).

The most common type of prebiotic is from the soluble dietary fibre inulin. Inulin is common in many plants containing fructan. Furthermore, many of these plants are frequently eaten as vegetables - asparagus, garlic, leek, onion, artichoke – and are an excellent source of inulin. However, as the need for functional foods rises, prebiotics are being added to many every day food choices such as cereals, biscuits, breads, table spreads, drinks, and yoghurts (http://www.prebiotic.ca/inulin.html).

12.8 Nutritional Benefits:

Kaur and Gupta (2002) reported that inulin improved the mineral absorption and balance. It may also aid in increasing the concentrations of calcium and magnesium in the colon. Dietary inulin has also been shown to increased calcium, magnesium and iron absorption, and bone mineralization in young adolescents, reduced bone loss and improved bone density.

Although the site of absorption of minerals is primarily the small intestine, oligosaccharides, and specifically, inulin and fructo-oligosaccharides have been linked to an improvement in the mineral absorption in the large bowel (Roberfroid, 2000). Enhanced absorption of calcium and magnesium has been demonstrated in ovariectomized rats fed FOS (50g/kg diet). This rodent model simulated bone demineralisation occurring during post-menopausal hormonal changes. Enhanced calcium uptake, observed in this animal model was correlated with an improvement of bone mineralization (Scholz-Ahrens and Schrezenmeir, 2000). The increase in butyrate production and pH acidification, resulting from the fermentation of oligosaccharides, were thought to be responsible for enhanced uptake of calcium by the colonic mucosa (Trinidad *et al.,* 1996). In human subjects, an improvement in mineral status is more difficult to observe. A double-blind, placebo-controlled, cross-over study using a stable isotope of calcium investigated the effect of fructo-oligosaccharide supplementation in post-menauposal women. An improvement of calcium uptake was only apparent in subjects at the late menopause phase (Tahiri *et al.,* 2003). The effect of bone mineralization at puberty has also been investigated in a human trial using dual stable isotopes of calcium as markers. A significant increase in calcium absorption was measured in adolescent girls who were given a drink fortified with FOS and inulin (4g/day) and a daily supplementation of calcium (1.5g/day) (Griffin *et al.,* 2002). An increase of magnesium absorption was also repeatedly observed in humans and animals following the consumption of oligosaccharides, and the mechanism of action of oligosaccharides in the metabolism of magnesium was recently reviewed (Coudray, 2003). Animal experiments showed that metabolism of other minerals such as iron, zinc, copper and phosphorous might be affected to a lesser extent by the supplementation of oligosaccharides in the diet (Scholz-Ahrens *et al.,* 2001).

12.9 Technological Benefits:

FDA approved use of inulin in food/dairy for human consumption. It is a fat as well as sugar replacer and used in various dairy products. Inulin does not have taste but enhances the flavor of the food with which it is mixed or blended. Its granulated form, has the “mouth feel” of sugar (Patton, 2005). It serves as a preservative when mixed with other foods (such as muffins or breads). Pure form of inulin has a long shelf life. It provides steady energy up to 4 to 12 hours, depending on the blend and the metabolism of the individual.

Inulin is an extremely versatile product for fiber fortification into beverages, such as meal replacements, dairy-based beverages and dry mixes. As a soluble source of fiber, it can be easily incorporated into dairy products, including yogurt, ice cream etc. A wide array of bakery products, including breads, cookies, cakes and crackers, can be developed with inulin. Longer chain inulin, can improve the body and texture of various food products. It is capable of forming a gel and can be successfully used for fat replacement and calorie reduction. (http://www.cargill.com/food/na/en/index.jsp)

In spreadable cheeses and low calorie sauces and dressings, it functions as a fat replacer, imparting a desirable creamy mouthfeel. It can also be used to improve the texture and mouthfeel of low fat dairy products. In fillings and confectionery products, including coatings, sugar and calorie reduction can be achieved through the addition of inulin. Inulin is also approved for use in meat applications (http://www.springerlink.com/)

Inulin may act as a useful fat replacer and texture enhancer in dairy products, said a new review from ingredient company Sensus and CSIC in Spain. The review, published in Food Hydrocolloids, investigated the uses of inulin in dairy systems as a fat replacer, exploring how the soluble fibre ingredient could be used to replace fats by mimic the features such as mouth feel and creaminess – and how these effects might be related to changes in rheology of the food system in liquid, semi-solid and solid dairy products. The reviewers said the inclusion of long-chain inulin in a dairy product as fat replacer "can have different effects on the rheological properties and on texture depending on the structure and composition of each product" (Meyer *et al.*, 2011).

12.10 Dosage and Administration:

Inulins are available in the form of Tablets,Powder or as Functional foods. Dosing is variable and ranges from 4 to 10 grams daily. Those who use more than 10 grams daily should split the dosage throughout the day. Doses higher than 30 grams daily may cause significant gastrointestinal discomfort. as flatulence, bloating and diarrhea (http://www.gettingwell.com /drug_info/ nmdrugprofiles/nutsupdrugs/inu_html)

12.11 Conclusions:

Rapidly expanding market, inulin has the advantage of the multiple functions. Growing awareness of the consumers and the increasing cost of the health care, lead to a lot of attraction from the dairy and food industry for products with healthy image. Inulin has the ability to create new business opportunity for Dairy/Food industry with special health oriented products as well as low and light products.

12.12 References:

1. Akalin, A.S. and Erisir, D. 2008. Effects of inulin and oligofructose on the rheological characteristic and probiotic culture survival in low-fat probiotic ice cream. *Journal Of Food Science* doi: 10.1111/j.1750-3841.2008.00728.x
2. Anderson, J.W., Baird P., Davis R.H. 2009. Health benefits of dietary fiber. *Nutr Rev*., 67 (4): 188–205. doi:10.1111/j.1753-4887.2009.00189.x. PMID 19335713.

3. Aryana, K.J., plausche, S., Rao, R.M., McGrew, P. and Shah, N.P. 2007. Fat free plain yoghurt manufactured with inulin of various chain lengths and *Lactobacillus acidophilus. J. Food Sci*, **72**:M79-84.
4. Barclay, Thomas; Milena Ginic-Markovica, Peter Cooperb, C., Nikolai Petrovskyc, D., 2010. Inulin - a versatile polysaccharide with multiple pharmaceuticaland food chemical uses. *J. Excipients and Food Chem, **1** (3): 27-50.*
5. Bowman, S.A. 2002. Beverage choices of young females: Changes and impact on nutrient intakes. *J Am Diet Assoc*, **102**:1234-1239.
6. Carpita, N.C., Kanabus, J., & Housley, T.L. 1989. Linkage structure of fiuctans and fiuctan oligomers from Triticum aestivum and Festuca arundinacea leaves. *J. Plant Physiol*,. 134:162-168.
7. Choonhahirun, Anchan and Akesowan, Adisak. 2012. Partial fat and sugar replacement with soy milk, inulin and sucralose on quality of Thai *Pandanus* custard. *African Journal of Biotechnology*. , **11** (20):4611-4619. DOI: 10.5897/AJB11.4192
8. Coudray, C., Demigne, C., Rayssiguier, Y. 2003. Effects of dietary fibers on magnesium absorption in animals and humans. *J Nut.*, **133**: 1- 4.
9. Cummings, J.H., Pomare, E.W., Branch, W.J., Naylor, C.P.E., Macfarlane, G.T. 1987. Short chain fatty acids in human large intestine, portal, hepatic and venous blood. *Gut.*, **28**:1221-7.
10. Davidson, M.H., Maki, K.C., Synecki, C. 1998. Evaluation of the influence of dietary inulin on serum lipids in adults with hypercholesterolemia.
11. Franck, A. 2002. Technological functionality of inulin and oligofructose. *British Journal of Nutrition*, **87**(2): 287–291.
12. Gibson, G.R. and Roberfroid, M.B. 1995. Dietary modulation of the human colonic microbiota. Introducing the concept of prebiotics. *J Nutr*, **125**:1401–12.
13. Goldberg, A. 1913. The utilization of inulin in the metabolism for nutritional cures. *Z. Exp. Path. They*, **13**:310-325,ciited by: http://www.prebiotic.ca/inulin.html
14. http://www.cargill.com/food/na/en/index.jsp
15. http://www.chicoryindia.net/main.php
16. http://www.jn.nutrition.org
17. http://www.prebiotic.ca/inulin.html
18. Kathleen, M. Zelman. 2013. The Benefits of Fiber: For Your Heart, Weight, and Energy. Skip to Article Content Fiber for Weight Control Fiber fills you up and helps you lose weight. How can you get more in your diet.
21. Kaur, N. and Gupta, A. K. 2009. Applications of inulin and oligofructose in health and nutrition. Journal of Biosciences, **27**: 703–714.
22. Kelly, Greg. 2009. Inulin-Type Prebiotics: A Review (Part 2). *Alternative Medicine Review Volume,* **14**(1): 36-55.
23. Kolida, S., Tuohy, K. and Gibson, G.R. 2002. Prebiotic effects of inulin and oligofructose. *British Journal of Nutrition*, **87**(2):193–197.
24. Megala1, P. and Hymavathi, T.V. 2011. Inulin and Fructooligosaccharides Incorporated Functional Fruit Bars. World Academy of Science, Engineering and Technology, **59**: 600-605.
25. Meijers, B.K.I. 2010. *P-Cresyl Sulfate Serum* Concentrations in Haemodialysis Patients Are Reduced by the Prebiotic Oligofructose-Enriched Inulin. *Nephrology Dialysis Transplantatio,* **25**: 219-224.
26. Patton, Dominique. 2005. Inulin gaining in health benefits by: http://www.nutraingredients.com/Industry.

27. Pierre, F., Perrin, P., Champ. M., Bornet, F., Meflah, K. and Menanteau, J. 1997. Short-chain fructo oligosaccharides reduce the occurrence of colon tumours and develop gut associated lymphoid tisseu in Min mice. *Cancer Research,* **57**: 225-8.
28. Rao, C.V., Chou, D., Simi, B., Ku, H. and Reddy, B.S. 1998. Prevention of colonic aberrant crypt foci and modulation of large bowel microbial activity by dietary coffee fiber, inulin, and pectin. Carcinogenesis, **19**:1815-1819.
29. Reddy, B.S., Hamid, R. and Rao, C.V. 1997. Effect of dietary oligofructose and inulin on colonic preneoplastic aberrant crypt foci inhibition. Carcinogenesis, **18**:1371-4.
30. Roberfroid, M.B. 2000. Prebiotics and probiotics: are they functional foods?. *Am J Clin Nut.*, **71**:1682S-7S.
31. Roberfroid, M.B. 2007. "Inulin-type fructans: functional food ingredients". *J Nutr.* **137** (11): 2493–2502.
32. Scholz-Ahrens, K. and Schrezenmeir, J. 2000. Inulin, oligofructose and mineral metabolism - experimental data and mechanism. *British Journal of Nutrition,* **87**:S186-S219.
33. Scholz-Ahrens, K.E., Schaafsma, G., van den Heuvel, E.G. and Schrezenmeir, J. 2001. Effects of prebiotics on mineral metabolism. *Am J Clin Nut.,* **73**:459S-64S.
34. Tahiri, M., Tressol, J.C., Arnaud, J., Bornet, F.R.J., Bouteloup-Demange, C. and Feillet-Coudray, C. 2003. Effect of short chain fructo oligosaccharides on intestinal calcium absorption and calcium status in postmenauposal women: a stable-isotope study. *Am J Clin Nut.,* **77**:449-57.
35. Tako, E., Glahn, R.P., Welch, R.M., Lei, X., Yasuda, K. and Miller, D.D. 2007. Dietary inulin affects the expression of intestinal enterocyte iron transporters, receptors and storage protein and alters the microbiota in the pig intestine. *Br J Nutr.*, **99**(9):1–9. http://www.ncbi.nlm.nih.gov/pubmed/17868492.
36. Tungland, B. C., and Meyer, D. 2002. Non digestible oligo-and polysaccharides (dietary fiber): Their physiology and role in human health and food. *Comprehensive Reviews in Food Science and Food Safety,* **1**:73–92.
37. Van Loo, J., Coussement, P., de Leenheer, L., Hoebregs H., and Smits, G. 1995. On the presence of inulin and oligofr|uctose as natural ingredients in the western diet. *Crit. Rev. Food Sci. Nutr.,* **35**(6):525-552.
38. Verghese, M., Rao, D.R., Chawan, C.B., Williams, L.L. and Shackelford, L. 2002. Dietary inulin suppresses azoxymethane-induced aberrant crypt foci and colon tumors at the promotion stage in young Fischer 344 rats. *J Nutr.*, **132**:2809-2813.
39. Williams, C.M. and Jackson, K.G. 2002. Inulin and oligofructose: effects on lipid metabolism from human studies. *Br J Nutr.*, **87**:S261-4.

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13. Traumatic Brain Injury and Use of Antiepileptic Drugs

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Figure 13.1: Traumatic Brain injury

Abstract:

Anti-epileptic drug (AED) prophylaxis in the first seven days of post-traumatic brain injury (TBI) is known to reduce seizure frequency acutely. AED efficacy is equivalent; therefore, the choice of AED may rest with its side effects. We hypothesize that AEDs that impair balance will prolong recovery, shown by a longer hospital stay. In our study, we aimed to evaluate the severity of trauma and the frequency of antiepileptic drug use in patients diagnosed with post-traumatic brain injury.138 patients with head trauma presenting for various reasons were included in the study with a retrospective file review. Patients were classified as mild, moderate, and severe according to the Glasgow Coma Scale at the time of admission to the hospital emergency department. It was determined that most of the cases were scored as mild-moderate at the time of admission to the hospital emergency department. it was observed that there was no need for the use of antiepileptic drugs. When the duration of antiepileptic drug use was analyzed, 65.1% (n=58) had 12 months, 16.7% (n=15) one month, 11.1% (n=10) 15 days, 4.9% (n) =4) six months, 2.2% (n=2) three months.

Keywords:

Head trauma, post-traumatic epilepsy, Glasgow coma scale, Anticonvulsants, Antiepileptic

13.1 Introduction:

Head trauma is a frequently observed situation in many countries and, accordingly, its mortality and morbidity are quite high [1]. The incidence of head trauma has extended to about 50 million cases per year worldwide; Therefore, it is foreseen that about half of the world's population will have a head injury in their lifetime [2]. Patients with head trauma constitute a significant part of the hospitalized patients in the emergency department, neurosurgery, general surgery, orthopedics, and pediatric surgery clinics [3].

Cortical lesions that occur secondarily in trauma may cause the occurrence of epileptic activity [4]. Traumatic brain injury in humans is not homogeneous and varies depending on the way the injury occurs, the distribution of damage caused by the injury, and the extent of the injury. The degree of the head injury may depend on the mechanical force applied directly to the head and secondary complications that may occur indirectly (hypoxia, ischemia, edema, and infection) [5].

The severity of head trauma can be measured with the Glasgow Coma Scale (GCS). They are classified into three groups including severe trauma (GCS 3-8), moderate (GCS 9-13), and mild trauma (GCS 14-15), and after trauma, long-term neuropsychological problems, and, in particular, epilepsy may develop. Post-traumatic epilepsy occurs in the form of recurrent epileptic seizures that develop secondarily in head trauma and can also manifest itself with spontaneous and recurrent seizures [5]. These seizures are classified as acute seizures if they occur within the first 24 hours, early-onset seizures within the first week, and late-onset seizures after a week. Acute seizures are caused by brain injury, but late-onset seizures are caused by oxidative stress factors and are more common in young adults [6]. Early-onset seizures after a head injury are commonly recognized as epilepsy [recurrent unprovoked seizures] because they have different mortality and prognosis [7]. Post-traumatic epilepsy is a disorder that develops secondary to traumatic brain injury and is characterized by symptomatic recurring seizures, and medications such as phenytoin, carbamazepine, sodium valproate, and levetiracetam are used to prevent it at an early stage [8-9]. The purpose of this study was to assess the severity of trauma and the frequency of antiepileptic drug usage in individuals with traumatic brain injury caused by head trauma.

13.2 Materials and Methods:

Between April 2013 and April 2021, 138 patients with head trauma were admitted to Gaziantep Medical Park Hospital emergency department and neurosurgery outpatient clinic for the reason of traffic accidents, falling from a height, gunshot injuries, assault, etc., followed up in the neurosurgery clinic and intensive care unit due to a risk factor for posttraumatic epilepsy (PTE), were enrolled in the study. The cases included in the study were retrospectively examined. The patient's age, GCS, gender, presence of chronic disease, cause of trauma, post-traumatic computed tomography scan (CT), magnetic resonance image (MRI), post-traumatic seizure history, frequency of post-traumatic antiepileptic

medication use, trauma severity, presence of seizures, other organ injuries along with head trauma, antiepileptic drugs use, and duration of the use were evaluated. Patients with a known history of epilepsy and patients taking antiepileptic drugs, children under 12 years of age, and pregnant patients were not enrolled in the study.

Seizure development periods after head trauma are divided into six groups; Group 1: Those who do not have seizures after head trauma, Group 2: Seizures observed simultaneously with head trauma or within 15 days, Group 3: Seizures observed within 15-30 days, Group 4: Seizures observed within 30-90 days, Group 5: Seizures observed within 90-180 days, Group 6: Seizures observed within 180-365 days. All data were statistically analyzed using the "SPSS for Windows 16.0" version, and comparisons were made using the Pearson chi-square test. As descriptive statistics, the average standard deviation (SD) values were provided. The results were deemed significant at the P0.05 level and 95% confidence interval. Before the study (01/2021), it received approval from the SANKO University clinical research ethics committee.

13.3 Results and Discussion:

The patients in the study ranged in age from 12 to 84 years old, with an average age of 39 of the 138 patients, 34 of whom were women and 104 of whom were men. The women's average age was 32.6, while the men's average age was 43.4. During the application of the cases to the hospital emergency service, they were scored as mild, moderate, and severe according to GCS. GCS 3-8 denotes mild traumatic brain injury, GCS 9-12 denotes moderate traumatic brain injury, and GCS 13-15 denotes severe traumatic brain injury. During hospital admission, it was established that the majority of the cases were classified as mild to moderate, and the average hospital admission GCS score was 11.8 points. The patient's Glasgow Coma Scales were rated, and the results are shown in Table 1.A. Fifty-two (37.7%) of patients admitted to the emergency room for head injury did not have an accompanied disease, whereas 86 (62.3%) had an associated disease. When the etiologies of the cases involved in the study were examined: Falling from height accounted for the highest rate of patient groups at 53.6% (n = 74), and traffic accidents at 34% (n = 47). It was observed that 5.7% (n=8) of the patients were admitted to the emergency room as a result of the assault, 3 (1.8%) patients had gunshot injuries, and 6 (4.5%) patients were admitted to the emergency room for other reasons. When the radiological images of the patients after head trauma were examined, it was determined that there was subdural hematoma in mostly 66.7% (n=92), and no finding was encountered in 0.7% (n=1). CBT/MRI out comes of the cases are given in detail in Table A.2.

Table A.1: Glasgow coma scales of the patients

Glasgow Coma Scale Rating	Patient	Ratio
1	2	% 1.44
2	14	% 10,14
4	9	% 7.96
5	113	% 81.8

Table A.2: CBT/MRI Outcomes of Patients

CBT/MRI	Patients (n)	Percent (%)
No finding	1	0.7
Epidural Hematoma	14	10.1
Subdural Hematoma	92	66.7
Intraparenchymal Hematoma	10	7.2
Subdural Hematoma + Intraparenchymal Hematoma	5	3.6
Epidural Hematoma + Subdural Hematoma + Intraparenchymal Hematoma	3	2.2
Epidural Hematoma+ Intraparenchymal Hematoma	10	7.2
Epidural Hematoma+ Subdural Hematoma	2	1.4
Total	138	100

Accompanied organ injuries of the patients with head trauma admitted to the emergency department were evaluated and it was observed that % 90,6 (n=125) of patients had only head trauma, 2.9% (n=4) of patients had chest trauma and head trauma, and 1.4% (n=2) of patients had head trauma and abdominal trauma, 1.4% (n=2) of patients had extremity trauma and head trauma, and 1.4% (n=2) of patients had head trauma, 0.7% (n=1) of the patients had head trauma and pelvic trauma, chest trauma, pelvic trauma, and extremity trauma, 0.7% (n=1) of the patients had head trauma, chest trauma, and abdominal trauma, and 0.7% (n=1) patients had head trauma, chest trauma, and extremity trauma (Table:A.2).

Also, 64.5% (n=89) of the patients had a history of posttraumatic seizures, and 65.2% (n=90) had seizures depending on the severity of the trauma. However, 64.5% (n=89) of the patients with a history of seizures after head trauma began taking antiepileptic drugs. Since 35.5% (n=49) of the patients had no history of posttraumatic epilepsy, antiepileptic drug use was not required. Antiepileptic drug use duration was examined, 65.1% of 89 patients (n=58) needed the use of anticonvulsant drugs over 12 months, 16.7% (n=15) needed one month, 11.1% (n=10) needed 15 days, 4.9% (n=4) needed six months, 2.2% (n=2) needed three months. When the posttraumatic antiepileptic drug use periods of 89 patients were examined, it was determined that 80.8% (n=72) used Phenytoin, 14.6% (n=13) used Levetiracetam, 2.2% (n=2) used Carbamazepine and 2.2% (n=2) used Valproic Acid.

The International League Against Epilepsy (ILAE) and the International Bureau of Epilepsy (IBE) define epilepsy as a brain disorder marked by a chronic proclivity to generate epileptic episodes. Epilepsy is a non-infectious chronic brain illness that affects people of all ages. Epilepsy affects roughly 50 million people globally and is one of the most frequent neurological illnesses [10]. The global incidence of brain injuries is 939 incidents per

100,000 persons per year, affecting approximately 69 million people [11]. Individuals with head injuries who develop posttraumatic epilepsy are reported to have a higher mortality rate compared to head injury patients who do not develop posttraumatic epilepsy. In addition, posttraumatic epilepsy is associated with worse chronic consequences, including neurological, intellectual, and psychological activities [12].

A large-scale study conducted annually in the United States in 2002-2006 included falling from height (35.2%), traffic accidents (17.3%), gunshot injuries (16.5%), assault (10%), and other causes (21%) in the etiologies of head injuries [13]. When the etiologies of our cases were examined, it was seen that falling from height constituted the highest patient group and traffic accidents rank the second. Assault and gunshot injury and other causes were also other factors involved in the etiology, 74 (53.6%) patients fell from a height, 47 (34%) patients had a traffic accident, 8 (5.7%) patients had an injury, 3 (1.8%) patients had a gunshot injury, and 6 (4.5%) patients had other causes to apply to the emergency service. Accordingly, the frequency of causes of head trauma is similar to the studies conducted on this subject.

According to a prior study, the causes of damage are directly associated with age. Head injuries from motor vehicle accidents and attacks, for example, peak in adolescence and early adulthood, and the incidence and mortality associated with head injuries are higher in men in this age range [13]. When the etiologies of our cases were investigated, it was discovered that falling from a great height comprised the largest patient group, with 20 female and 54 male patients, and average ages of 24 and 47.3, respectively. The second most common cause was traffic accidents, with 10 female patients and 37 male patients, with an average age of 48.2 and 47.8 years, respectively. Then there are assaults, gunshot wounds, and other causes. Two of the assault instances were females, six included males, and the average ages were 61 and 62, respectively. The average age of the six male patients with gunshot wounds was 30 years old. Patients who went to the emergency room for various reasons included those who had been involved in occurrences such as work accidents, being trapped beneath rubble, and large things falling on their heads; additionally, two of them were female patients and four were male patients. Children (particularly newborns till the age of four), young people (15- to 24-year-olds), adults over the age of 60, and men of all ages are at the highest risk of traumatic brain damage [14].

In this study, 52 (37.7%) of patients who presented to the emergency room owing to head trauma did not have a chronic condition, whereas 86 (62.3%) patients did. The average age of those who did not have a chronic disease was 26.65 years, while the average age of those who did have a chronic disease was 64.13 years, with 104 men and 34 women participating. As a result, older people and men are more likely to have brain injuries. Tseng et al. found that 96 patients (46.7%) had a skull bone fracture in the emergency room, 28 patients (14.2%) had a midline shift, and 29 patients (14.7%) had head traumas. Head traumas are often accompanied by other system injuries, the other system injuries most commonly associated with cranial cerebral injury are the face, thorax, and abdomen injuries [15]. According to the findings of the study by Bahloul et al, 437 patients with head trauma suffered injuries in areas other than the head. Extracranial pathology was found in 61.6% of the patients, with 31.6% having rib or long bone fracture, 24.9% having facial damage, 23.6% having chest, 10.8% having abdomen, 8.9% having pelvic, and 1.8% having spinal injury [16].

In our study, accompanied organ injuries were evaluated in patients admitted to the emergency department due to head trauma, and 90.6% of patients had isolated head injuries, while 2.9% had chest injuries, 1.4% had abdominal injuries, 1.4% had limb injuries, 0.7% pelvis injuries, 0.7% chest and limb injuries, 1.4% chest, pelvis and limb injuries, 0.7% chest and abdominal injuries, and the results were similar to the reports in the literature.

In a community-based study conducted in the United States, 2.118 patients hospitalized with head injuries were followed up on for three years to establish the cumulative incidence of posttraumatic epilepsy. After accounting for a large decline in posttraumatic epilepsy (55% in 3 years), a risk of 4.4 was discovered per person. Post-traumatic epilepsy is more likely in people who have a history of psychiatric illnesses and depression [17]. Due to the severity of the stress, posttraumatic epilepsy seizures emerged in 64.5% of patients in our study.

A study assessing the risk of long-term epilepsy in children and young people following traumatic brain injury followed over 1.6 million children and young adults for up to 30 years after head trauma. The risk of epilepsy persists for more than ten years following mild brain injury, severe brain injury, and skull fracture, according to research. The relative risk of epilepsy increased with age in mild and severe injuries and was found to be higher, particularly in those over the age of 15 with mild and severe injuries. Women were found to be at somewhat higher risk than men. After mild and severe brain injury, the likelihood of epilepsy increased in patients with a family history of epilepsy [18]. The level of brain damage associated with traumatic brain injury increases the likelihood of epilepsy. Although traumatic brain damage is one of the few potentially preventable causes of epilepsy, it accounts for less than 10% of all cases [19]. Posttraumatic epilepsy is responsible for 20% of symptomatic seizures in the general community and 5% of all epilepsy patients sent to specialized epilepsy centers, according to another study [20].Seizures that occur within the first 24 hours after head trauma is referred to as acute seizures, those that occur between 24 hours and the first 7 days (early post-traumatic epilepsy) are referred to as provocative seizures and seizures that occur after 7 days (late post-traumatic epilepsy) are referred to as unprovoked seizures [21].

Temkin et al. evaluated the risk factors for early-onset seizures and found that a depressed skull fracture and subdural hematoma are related to approximately 25% of the risk of acute or early posttraumatic seizures. However, acute and early post-traumatic seizures are also indicators of the severity of brain injury and may account for the observed link between late-onset seizures [22]. The incidence of acute posttraumatic seizures is 1-4%, early-onset seizures are 4-25%, and late-onset seizures are 9-42%, according to Agrawal et al. [1].

In our study, it was found that 50 (36.2%) patients had a posttraumatic epilepsy seizure similar to the studies in the literature, and 88 (63.8%) patients had no epileptic seizure depending on the severity of the trauma. Seizures were observed within the first 24 hours in 1.6% of cases, within a week in 10.2% of cases, and began after the first week in 24.4% of the cases. According to a study, the risk of developing late-onset epilepsy is higher in patients who have an early-onset seizure after a head injury, and the recurrence rate of seizures was also found to be higher in such patients[23].A study, which deciphers the risk factors in a 2-year cohort of all patients aged 18 years and over with head trauma through the US National Trauma Data Bank, expanded the knowledge of the frequency of early-onset seizures, and it was shown that more than 80% of seizures are tonic-clonic rather than

focal. This number is relatively low compared to other studies such as smoking, obesity, hypertension, or vascular disease were more common in those with seizures [24]. Although prophylactic seizure treatment is effective in preventing early posttraumatic seizures, it does not reduce the risks of long-term seizures, death, or neurological deficits [25].

Head trauma is an important risk factor for the development of epilepsy. A fifth of epilepsies are post-traumatic epilepsy, this type of epilepsy is a syndrome with generalized and focal seizures which have a structural cause. Clinical trials of antiepileptic drugs in this group do not distinguish between etiologies, and there are no tests for medicines, especially for patients with posttraumatic epilepsy. Therefore, the considerations to be taken into account are to ensure seizure control if possible and to avoid specific head trauma [26]. Phenytoin and Levetiracetam used to treat early-onset seizures caused by PTE have been revealed to be effective at an early stage but not prevent the occurrence of late-onset epilepsy, however, phenytoin is still the first choice. However, anti-epileptic drugs have narrow therapeutic limits and high toxicity even in neurologically stable patients. A new generation of antiepileptics such as gabapentin, topiramate, and lamotrigine are preferred in patients with PTE who experience post-traumatic stress disorders [27-28]. In a study conducted by Mee et al., it was concluded that prophylactic anti-epileptic drugs were not preferred in 52% of posttraumatic patients, but were used in 38% for a month, but 90% of doctors could not make a joint decision in determining the duration of treatment [29].

When choosing a drug to treat PTE, the patient's pre-traumatic psychological state should be considered. If there is such a problem, lamotrigine, lacosamide, oxcarbazepine or carbamazepine should be preferred by assessing their side effects for long-term treatment. Phenytoin and carbamazepine are effective in preventing early-onset PTE in high-risk patients after head trauma; However, prophylactic use of phenytoin, carbamazepine, or phenobarbital for preventing late-onset post-traumatic seizures is not recommended [30].

When deciding on epilepsy treatment, it should also be questioned whether the patient has drug or alcohol use. Likewise, late mortality was observed at a higher rate in people who had seizures of posttraumatic epilepsy than in patients with similar injuries and who did not have epilepsy [31-32]. It has been discovered that around one-third of epilepsy, cases are drug-resistant, and it has yet to be established whether there is a systematic difference in posttraumatic instances compared to other causes. In some drug-resistant PTEs, epilepsy surgery can be explored, and surgical treatment has been accepted for many years. Modern studies demonstrate that surgery, whether single-focus or multi-focus, can be successful in well-selected situations. This study demonstrates that only one area is epileptogenic and that the patient can deal with the cognitive effects of excision [34].

Antiepileptic medicines were started in 50 (36.2%) of the patients in our research who had a history of seizures following head trauma. We did not need the use of antiepileptic drugs for 88 (63.8%) patients with complaints of head trauma. Of the 50 patients with epilepsy after the head injury, 65.1% needed to use antiepileptic drugs for 12 months and over, 4.9% needed them for 6 months, 2.2% needed them for 3 months, 16.7% needed them for 1 month, and 11.1% needed them for 15 days. In the treatment of such patients, phenytoin was used in 80.8% of the patients, levetiracetam was used in 14.6% of the patients, valproic acid was used in 2.2% of the patients, carbamazepine was used in 2.2% of the patients.

13.4 Conclusion:

Inconclusion, a person carries an increased risk of epilepsy in connection with the severity of brain damage that can occur after a head injury. In our study, the GCS score was found to be 11.8 points (moderate). In addition, the frequency of antiepileptic drug use was also found to be 36.2%. When deciding on PTE treatment, the patient's pre-traumatic psychological status, previously diagnosed psychiatric diseases, and drug or alcohol use should also be questioned. In light of all these results, we think that effective emergency antiepileptic drug treatment, if necessary, is important in preventing secondary brain damage in patients with head trauma.

13.5 References:

1. Agrawal A, Timothy J, Pandit L, Manju M. Post-traumatic epilepsy: an overview. Clin Neurol Neurosurg 2006;108(5):433-9.
2. Thornhill S, Teasdale GM, Murray GD, McEwen J, Roy CW, Penny KI. Disability in young people and adults one year after head injury: prospective cohort study. BMJ2000;320(7250):1631-5.
3. Güzel A, Ceylan A, Tatli M, Başoğul M, Ozer N, Kahraman R. Falls from height in childhood in Diyarbakir province: a questionnaire study combined with clinical data. **Ulus Travma Acil Cerrahi Derg**2009 ;15(3):277-84.
4. Annegers JF, Coan SP. Therisks of epilepsy after traumatic brain injury. **Seizure**2000; 9:453–457,
5. Guzel A, Er U, Tatli M, Aluclu U, Ozkan U, Duzenli Y. Serum neuron-specific enolase as a predictor of short-term outcome and its correlation with Glasgow Coma Scale in traumatic brain injury. **Neurosurg Rev** 2008 ;31(4):439-44
6. Hesdorffer DC, Benn EK, Cascino GD, Hauser WA. Is a first acute symptomatic seizure epilepsy? Mortalityand risk for recurrent seizure. **Epilepsia** 2009;50(5):1102-8.
7. Englander J, Bushnik T, Duong TT, Cifu DX, Zafonte R, Wright J. Analyzing risk factors for late post-traumatic seizures: a prospective, multi-center investigation. **ArchPhysMedRehabil** 2003;84(3):365-73.
8. Szaflarski JP, Nazzal Y, Dreer LE. Post-traumatic epilepsy: Current and emerging treatment options. **NeuropsychiatricDiseaseandTreatment**2014;10:1469–1477.
9. Fisher RS, Acevedo C, Arzimanoglou A, Bogacz A, Cross JH, Elger CE. ILAE official report: a practical clinical definition of epilepsy. **Epilepsia** 2014;55(4):475-82.
10. Dewan MC, Rattani A, Gupta S, Baticulon RE, Hung YC, Punchak M. Estimatingthe global incidence of traumatic brain injury. **J Neurosurg** 2018; 1:1-18.
11. Yaşan A, Guzel A, Tamam Y, Ozkan M. Predictive factors for acute stress disorder randpost-traumaticstressdisorderafter motor vehicle accidents. **Psychopathology**. 2009;42(4):236-41.
12. Centers for Disease Control and Prevention. Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations, and Deaths, 2002–2006. **Atlanta**, GA: Centers for Disease Control and Prevention; 2012.
13. Taylor CA, Bell JM, Breiding MJ, Xu L. Traumatic Brain Injury-Related Emergency Department Visits, Hospitalizations, and Deaths - United States, 2007 and 2013. **Surveill Summ**. 2017;66(9):1-16.

14. Tseng WC, Shih HM, Su YC, Chen HW, Hsiao KY, Chen IC. The association between skull bone fractures and outcomes in patients with severe traumatic brain injury. **J Trauma** 2011;71(6):1611-4
15. Wright DW, Merck LH. Head Trauma. In: Tintinalli JE, Stapczynski J, Ma O, Yealy DM, Meckler GD, Cline DM. eds. Tintinalli's Emergency Medicine: A Comprehensive Study Guide, *8e*. McGraw-Hill; 2016. Accessed December 16, 2021.
16. Bahloul M, Chelly H, Ben Hmida M, Ben Hamida C, Ksibi H, Kallel H.Prognosis of traumatic head injury in South Tunisia: a multivariate analysis of 437 cases. **J Trauma** 2004;57(2):255-61.
17. Bahloul M, Chelly H, Ben Hmida M, Ben Hamida C, Ksibi H, Kallel H. Prognosis of traumatic head injury in South Tunisia: a multivariate analysis of 437 cases. **J Trauma**2004;57(2):255-61.
18. Christensen J, Pedersen MG, Pedersen CB, Sidenius P, Olsen J, Vestergaard M. Long-term risk of epilepsy after traumatic brain injury in children and young adults: a population-based cohort study. **Lancet** 2009;373:1105-10.
19. Christensen J. The Epidemiology of Posttraumatic Epilepsy. **Semin Neurol**2015; 35(3):218-22.
20. Semah F, Picot MC, Adam C, Broglin D, Arzimanoglou A, Bazin B. Is the underlying cause of epilepsy a major prognostic factor for recurrence? **Neurology** 1998;51(5):1256-62.
21. Moreno A, Peel M. Posttraumatic seizures in survivors of torture: manifestations, diagnosis, and treatment. **J ImmigrHealth**2004; 6:179-86.
22. Temkin NR, Dikmen SS, Wilensky AJ, Keihm J, Chabal S, Winn HR. A randomized, double-blind study of phenytoin for theprevention of post-traumatic seizures. **N Engl J Med**1990;323(8):497-502.
23. Raymont V, Salazar AM, Lipsky R, Goldman D, Tasick G, Grafman J. Correlates of posttraumatic epilepsy 35 years following combat brain injury. **Neurology**2010;75(3):224-9.
24. Majidi S, Makke Y, Ewida A, Sianati B, Qureshi AI, Koubeissi MZ. Prevalence and Risk Factors for Early Seizure in Patients with Traumatic Brain Injury: Analysis from National Trauma Data Bank. **NeurocritCare** 2017;27(1):90-95.
25. Servadei F, Murray GD, Teasdale GM, Dearden M, Iannotti F, Lapierre F, Traumatic: Ademographic and clinical study of 750 patients from the European brain injury consortium survey of head injuries. **Neurosurgery** 2002;50(2):261-7
26. Scheffer IE, French J, Hirsch E, Jain S, Mathern GW, Moshé SL. Classification of the epilepsies: New concepts for discussion and debate-Special report of the ILAE Classification Task Force of the Commission for Classification and Terminology. **Epilepsia Open** 2016;1(1-2):37-44.
27. Yang Y, Zheng F, Xu X, Wang X. Levetiracetam Versus Phenytoin for Seizure Prophylax is Following Traumatic Brain Injury: A Systematic Review and Meta-Analysis. **CNS Drugs** 2016;30(8):677-88.
28. Iudice A, Murri L. Pharmacological prophylaxis of posttraumatic epilepsy. **Drugs,**2000; 59:1091–9.
29. Mee H, Kolias AG, Chari A, Ercole A, Lecky F, Turner C. Pharmacological management of post-traumatic seizures in adults: current practice patterns in the UK and the Republic of Ireland. **Acta Neurochir,** 2019;161(3):457-464.

30. The Brain Trauma Foundation, The American Association of Neurological Surgeons, Role of antiseizure prophylax is following head injury. **J Neurotrauma** 2000;17:549–553.
31. Uski J, Lamusuo S, Teperi S, Löyttyniemi E. Mortality after traumatic brain injury and the effect of post-traumatic epilepsy. **Neurology** 2018;91(9): 878-883.
32. Horsley V. Brain surgery. BrMed J 1886; 2:670–675.
33. Hakimian S, Kershenovich A, Miller JW. Long-term outcome of extratem poral resection in post-traumatic epilepsy. **NeurosurgFocus**2012; 32(3):1-10.

About the Book

*This book, **Current Trends and Research in Medical Nutrition Therapy to Control Diseases**, is an essential part of everyday life. It has an impact on our health and can be used to prevent and treat disease. Substantial interventions in dietary intake and lifestyle changes have been shown to reduce disease risk in both the general population and patients suffering from various diseases. Traditional plant-based diets and medicines have received a lot of attention as an alternative to modern science-based drugs, while recent technological advancements in bioinformatics, genomics, and proteomics have provided a better understanding of plant-based drugs, improved quality assurance, and allowed clinical trials to be accelerated to bridge the gap with Western medicine. Furthermore, research in nutrigenomics and epigenomics has increased understanding of the relationship between nutrition and disease. The book addresses concerns about our planet's future well-being, the health of the global human population as a result of the worldwide obesity epidemic, issues concerning sustainable food production, and the need for a shift to a healthier, more plant-based diet.*

This advanced nutrition therapy book will cover topics such as the cause, diagnosis, and reversal of lifestyle diseases such as diabetes and hypertension. Simple and illustrative examples are provided for communicating complex topics. The simplified explanations of topics can benefit anyone with no prior knowledge of medical science, nutrition, or diet. This book focuses solely on a plant-based diet rich in raw fruits and vegetables to reverse diseases labelled as irreversible or incurable by a modern-day medical industry driven by profits and greed rather than compassion and healing. You will be able to maintain a healthy body weight, reverse chronic lifestyle diseases, get rid of harmful drugs and medications, teach healthy eating habits to your friends and family, and become an asset to society and community after reading this book.

Upper division undergraduates and graduate students in nutrition and dietetics, as well as professional nutritionists, dieticians, epidemiologists, general practitioners, nurse practitioners, and family medicine physicians, will benefit from this book.

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