Advances in Food Science and Nutrition

(Volume - 4)

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Scripown Publications
New Delhi

Editor: *Dr. Rajni Goyal*

Edition: *1st*

Publication Date: *22/12/2025*

Pages: *119*

Paperback ISBN: *978-81-19915-56-9*

E-Book ISBN: *978-81-19915-63-7*

Price: *₹790/-*

DOI: *https://doi.org/10.63258/afsn.vol.4*

Scripown Publications
2nd Floor, 304 and 305, Pocket - 4,
Sector - 22, Rohini, North West Delhi,
Delhi, 110086, India

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CHAPTER 1

Sensory and Food Quality

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Abstract

Food Quality Management is a necessity for every industry. Especially for the food industry, a good quality assurance program is very critical in order to reduce waste, save money, and protect consumers and companies from any damage. Food quality monitoring has many aspects, the most popular aspect being Sensory Evaluation which uses 5 basic senses to analyze food preferences and likeability. In addition, quality of food is also determined using physical parameters (color, appearance), chemical attributes (moisture content, pH and acidity), nutritional stability and microbiological safety.

In conclusion, promoting and implementing good food quality management is very critical in food safety, minimizing waste, and fostering consumer trust within the food industry.

Keywords: Sensory Evaluation, Food Quality, Quality Assurance, Shelf-Life Testing, Food Safety.

Introduction

This chapter explores the concept of food quality monitoring and its significance within the food industry. It highlights the various aspects that contribute to food quality, including sensory evaluation, physical properties, chemical composition, nutritional value, and microbiological safety etc.

Sensory Evaluation is a widely used tool in industry and academic fields which uses five senses (Sight, Smell, Sound, Taste and Touch) to analyze likeability and preferences. A range of sensory tests exists, each designed to yield specific information about perception, likeability or preferences of test items.

This comprehensive approach to food quality management isn't just about aesthetics and taste; it has significant other benefits. By meticulously examining food throughout the supply chain, waste is minimized. Spoilage and inconsistency are identified and addressed before perfectly good food ends up in landfills. More importantly, rigorous quality control measures protect consumers from the dangers of foodborne illnesses. By testing for harmful bacteria and other pathogens, processors can prevent contaminated products from reaching store shelves. This not only protects public health but also shields companies from the financial repercussions of product recalls.

Ultimately, effective food quality management isn't just about regulations and checklists; it's about building trust. By consistently delivering safe, high-quality food, the industry fosters a sense of confidence among consumers. They can be assured that the food they bring home is not only delicious but also free from harmful contaminants and delivers the promised nutritional value. This trust between consumers and the food industry is the cornerstone of a healthy and sustainable food system for everyone.

Chapter Content

Food quality is a state of food that is holistically determined by analyzing various attributes such as physical parameters, chemical parameters, microbiological safety, nutritional stability, adulteration check and probably most commonly used ‘sensory evaluation’.

Importance of Food Quality Management:

1. Food Wastage

Food loss and waste (FLW) represents a significant challenge to global food security, economic stability, and environmental well-being. According to the National Center for Biotechnology Information (NCBI), staggering quantities of food, roughly one-third of all production, are lost or wasted throughout the global food supply chain each year. This translates to approximately 1.3 billion tons of food annually. The World Bank and the Food and Agriculture Organization (FAO) predict a concerning escalation of this trend, with potential food waste reaching 2.2 billion tons annually if left unaddressed [1].

2. Financial loss

Inadequate quality management systems significantly increase the risk of product recalls. This happens because recalls are typically triggered by the

discovery of safety or quality issues that could potentially harm consumers [2].

Food recalls are associated with significant financial burden. While the immediate, direct costs associated with a recall can be substantial, averaging around $10 million, this figure merely scratches the surface of the true financial burden. This initial $10 million encompasses expenses directly tied to the recall process, such as Product retrieval and disposal, Consumer refunds, logistical coordination, production disruptions etc. The consequences of recalls extend beyond money loss and food wastage. The long-term repercussions can inflict lasting damage on a company's financial well-being and reputation [3].

3. Public Health

A lack of good food quality and safety monitoring processes could impose a threat to public health**.** Consumers could face serious consequences from the potential for contracting foodborne illnesses or the risk of allergic reactions due to undisclosed allergens. An estimated 600 million individuals, nearly one in ten people worldwide, succumb to illness annually after consuming contaminated food. This translates to a devastating loss of life, with 420,000 fatalities each year. Even more concerning, this translates to a collective loss of 33 million healthy life years (DALYs). This metric captures the years of healthy life lost due to premature death or disability from illness, highlighting the immense burden foodborne illness places on global health and well-being [4].

4. Consumer protection

The term "food adulteration" refers to the deliberate act of compromising the integrity of food. This can be accomplished in two ways: by incorporating or replacing food components with unlisted alternatives, or by removing valuable components [5].

These practices are primarily driven by economic gain: reducing production costs, maximizing profits, or stretching supplies during periods of scarcity (such as diluting juices or milk with water). Regardless of the rationale, the outcome remains the same - it is a form of consumer exploitation. Individuals pay a premium for a specific product, yet unknowingly receive an inferior or potentially hazardous substitute. This act jeopardizes consumer trust in the food system.

Protecting public health, upholding ethical business practices, and preventing losses are all important reasons why checking Quality Assurance

is a top priority in the food industry. QA has become an indispensable element for every organization within the food supply chain, from manufacturing and processing to packaging, distribution, and even final service. While the terms "Quality Assurance" and "Quality Control" (QC) are frequently used interchangeably, a crucial distinction exists between them.

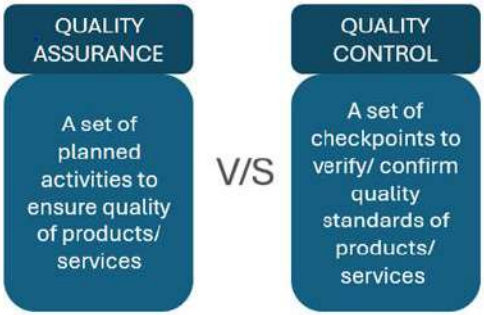

Fig. 1: Quality Assurance v/s Quality Control

Shelf-Life Studies

Shelf life studies are an integral aspect of determining food product longevity within the food industry. These studies provide crucial insights into how long a product remains in an acceptable, consumable state before requiring disposal. This information directly translates to the "Best By" or "Best Before" dates consumers encounter on food labels.

The process is methodical and involves defining key attributes for monitoring throughout a product's lifespan. These attributes can be categorized into two main areas: sensory and analytical.

1. **Sensory Attributes:** These encompass the organoleptic properties perceived through the senses – primarily taste, smell, texture, and appearance. For instance, in a potato chip shelf life study, crispness would be a critical sensory quality to monitor closely.
2. **Analytical Parameters:** These tests look closely into the product's chemical composition. For the same example of potato chips, analytical tests would measure moisture content and peroxide value. As the shelf life progresses, potato chips are prone to absorbing moisture from the environment. This not only compromises their crispness, leading to a soggy or soft texture, but also initiates a process called rancidity. Peroxide value serves as a measurable indicator of this undesirable phenomenon.

By closely monitoring these sensory and analytical attributes over time, shelf life studies empower food companies to establish accurate "Best By" or "Best Before" dates. This information safeguards consumers by ensuring they have a clear understanding of a product's optimal consumption window.

While traditional shelf-life studies are the gold standard for determining product longevity, they come with a significant drawback – time. These studies can be lengthy endeavors, requiring substantial investments in time and resources. The extended waiting period for results can translate into lost opportunities and financial burdens for companies.

This is where accelerated shelf-life testing act as a valuable alternative. Similar to traditional methods in terms of parameter selection and monitoring processes, accelerated testing offers a crucial advantage – speed. By employing techniques like storing products at elevated temperatures, this approach accelerates the natural rate of chemical reactions within the food. This translates to significantly faster results. For instance, one month of storage under ambient conditions might be equivalent to just one week in an accelerated shelf-life chamber [6].

This expedited timeline offers several benefits for food companies:

- **Reduced Costs:** Faster results minimize the time and resources required for shelf-life determination, leading to cost savings.
- **Quicker Product Launches:** By streamlining the shelf-life determination process, companies can bring products to market more efficiently.
- **Improved Decision-Making:** Access to quicker data allows for more informed decisions regarding product formulation and packaging to optimize shelf life.

However, it's important to acknowledge that accelerated shelf-life testing does not entirely replace traditional methods. The data obtained needs to be carefully correlated with real-time storage studies to ensure accurate predictions of shelf life under normal conditions.

Aspects of Food Quality

1. Sensory

Sensory evaluation is an important technique used to analyze the organoleptic properties of food. This method harnesses the power of our five

senses – sight, smell, taste, touch, and sound – to create a comprehensive picture of a food product's sensory experience.

It's important to acknowledge that all five senses play a crucial role in how we perceive and appreciate food. Sight allows us to admire the visual appeal of a dish, while aroma and smell tantalize our olfactory receptors, whetting your appetite. Taste buds on our tongue detect the basic flavors (sweet, sour, salty, bitter, and umami), while texture perceived through touch adds another layer of dimension to the eating experience. We don't usually think about the sounds while we eat, but they can actually affect how much we enjoy our food! It's an underrated factor that plays in the background. Consider the delightful crunch of a fresh salad or the satisfying snap of potato chips. Even the effervescent fizz of a soda can as you crack it open adds a layer of auditory intrigue to the beverage. These seemingly minor sonic details subconsciously enhance the overall enjoyment of food.

By employing sensory evaluation, food scientists and industry professionals can gain valuable insights into consumer preferences and ensure that food products deliver a multi-sensory experience that is both enjoyable and meets expectations.

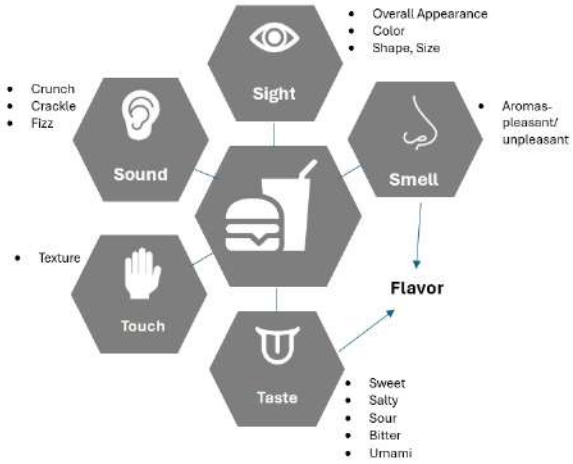

Fig. 2: Sensory Evaluation Overview

"Taste" and "flavor" are often used interchangeably, but they're distinct. However, flavor is a combined perception of taste and aroma. This is why when we have a cold and congestion, we can still ‘taste’ food but it feels flavorless.

Sensory evaluation stands as an unparalleled asset within the food industry and academic research spheres. This technique plays a pivotal role in assessing food quality across a multitude of applications such as analyzing consumer preferences, developing new products, recipe changes, cost optimization, shelf life studies etc. Sensory evaluation acts as a quality control safeguard. By scrutinizing a product's sensory characteristics, it can identify potential issues with the manufacturing process or signal the onset of spoilage. This information is crucial for ensuring food safety and delivering high-quality products to consumers.

Most Commonly Used Sensory Evaluation Methods

A. Discrimination tests:

Discrimination tests are employed within sensory evaluation to assess whether perceptible differences exist between two products. These tests prove particularly valuable during product formulation. Imagine attempting to match the flavor profile of a competitor's brand or seeking to replace an ingredient for cost savings, all while ensuring consumers remain oblivious to the change. Discrimination tests provide the necessary tools to achieve this goal.

There are several established discrimination tests, each with specific applications:

- **Paired Comparison Test:** This test presents participants with two samples, one from each product being compared. Participants are then asked to identify which sample, if any, tastes different.
- **Duo-Trio Test:** Participants are presented with three coded samples, two of which are identical and one is different. The challenge lies in identifying the odd sample out.
- **Triangle Test:** Similar to the duo-trio test, participants receive three coded samples, but in this case, all three could be different. The task for participants is to correctly identify the sample that stands out from the others.

B. Affective Tests:

While discrimination tests focus on detecting differences, affective tests delve deeper into the realm of consumer preferences. These tests aim to understand how consumers react to a product on an emotional level, specifically their level of acceptability and overall preference.

Affective tests are particularly beneficial during the pre-market phase of

product development. They allow companies to gauge consumer reactions to a new product concept and determine if it aligns with market expectations.

One of the most widely used and straightforward affective tests is the Hedonic Rating Scale. This scale typically utilizes a 9-point system, ranging from "dislike extremely" to "like extremely." Consumers rate the product based on their level of enjoyment, providing valuable insights into its overall appeal.

Another popular tool within affective testing is the Just-About-Right (JAR) scale. This scale assesses consumer perception of specific product attributes, such as sweetness or saltiness. Participants indicate whether they find the level "just about right," "too strong," or "too weak." This information helps developers refine product formulations to achieve optimal consumer satisfaction.

By employing both discrimination and affective tests, food scientists gain a comprehensive understanding of how consumers perceive and respond to new or reformulated products. This enables to create food experiences that are not only sensorially indistinguishable from competitors but also highly desirable and enjoyable for consumers [7].

Fig. 3: Example of 5-Point Hedonic Scale for Children's Panel [8].

C. Descriptive Tests

These tests explore details of a product's sensory experience. Unlike discrimination tests that focus on differences, descriptive analysis serves to comprehensively understand specific attributes or the overall flavor profile. This method can be qualitative or quantitative, depending on the desired level of detail. Descriptive tests utilize highly trained panels. These panelists undergo rigorous screening and selection processes to ensure they possess the necessary sensory acuity and ability to articulate their perceptions accurately and objectively. The training program equips panelists with a standardized vocabulary and methodology for describing sensory characteristics, ensuring consistency and reliability across evaluations [7].

2. **Physical**

Physical properties, often taken for granted, play an essential role in maintaining food quality throughout the production process. These encompass aspects like size, shape, weight, volume, and count. Consistent monitoring of these attributes ensures each food item aligns with its intended specifications.

Let's consider an example of a bag of mixed dry-fruits and nuts. To optimize costs, companies might incorporate a higher proportion of readily available and affordable nuts like peanuts, while potentially reducing the inclusion of more exotic and expensive components like pistachios. This adjustment, whether intentional (economic efficiency) or unintentional (equipment malfunction), highlights the importance of physical property monitoring.

By meticulously examining these physical properties throughout production, companies can guarantee a consistent experience for consumers with every purchase. This consistency fosters brand trust and encourages repeat customers who come to expect the familiar taste, texture, and visual appeal associated with their favorite product.

The importance of monitoring physical properties extends beyond the initial production line. They also tell a story about the product's shelf life. Consider the delicate structure of gels – susceptible to breakdown over time, leading to changes in thickness or consistency. Here, specialized instruments like Brookfield viscometers and Bostwick consistometer come into play. These tools measure viscosity (resistance to flow) and consistency, respectively, providing numerical values that can be tracked over time. By monitoring these values, manufacturers can identify potential quality degradation before it reaches consumers, ensuring products maintain their desired texture and sensory experience throughout their designated shelf life.

3. **Analytical/ Chemical**

While physical properties offer valuable information about product quality, analytical characteristics explore deeper into chemical reactions within food. These chemical properties have a profound impact on a product's shelf life, flavor, color, and nutritional value. One crucial aspect of analytical evaluation is chemical stability. This refers to a food's ability to resist changes in its chemical composition over time. Chemical instability can lead to a cascade of undesirable effects, altering the flavor, color, and even nutritional value of the food [9].

Monitoring moisture content and water activity levels plays a critical role in most food items. High water activity not only affects the growth of microorganisms but also influences the texture of the product. Foods intended to be low in moisture, like potato chips, become soggy and lose their crispness with high moisture content. Furthermore, high moisture can accelerate spoilage and increase susceptibility to rancidity in fats.

Another key analytical parameter is acidity**,** measured by pH. The pH scale ranges from 0 (highly acidic) to 14 (highly alkaline) with 7 being neutral. Maintaining the optimal pH level is crucial for achieving the desired texture and flavor properties in food. For instance, in gels like jams, jellies, and cheeses, proper pH ensures the desired gel formation and textural characteristics [10].

4. **Nutritional Stability**

The landscape of food advertising is increasingly populated by products touted for their nutritional benefits. Manufacturers often enrich or fortify these items with essential vitamins and minerals, promising consumers a boost in their dietary intake. However, ensuring these promised nutrients reach consumers in their full potency necessitates meticulous attention to detail throughout the food supply chain.

Certain vitamins and minerals are inherently sensitive to external factors like light, temperature, and moisture. Exposure to these elements during processing, packaging, distribution, and even storage can lead to significant degradation, diminishing the very nutrients the product was fortified with.

Regulatory bodies like the Food and Drug Administration (FDA) play a vital role in ensuring consumer protection. The FDA actively monitors and recalls nutritional products with nutrient levels that fall below the labeled claims. These recalls serve as a reminder of the critical importance of maintaining nutrient potency throughout the food supply chain [11].

5. **Microbiological**

Microbiological safety stands as an integral part of food quality control. Its importance extends far beyond ensuring a pleasant eating experience – it is a critical line of defense against foodborne illness. The economic and health consequences of unsafe food are staggering. Low- and middle-income countries bear a significant brunt, with an estimated US$110 billion lost annually in productivity and medical expenses due to foodborne illnesses. This highlights the urgent need for prioritizing and implementing rigorous

microbiological safety measures throughout the global food supply chain [4].

Microbial testing plays a critical role in safeguarding food quality. This process delves into the world of microorganisms, specifically focusing on two distinct groups: indicator microorganisms and pathogenic microorganisms**.**

- **Indicator microbes:**

Indicator organisms serve as valuable sentinels within the food testing process. While not inherently pathogenic themselves, these microorganisms provide vital clues about the overall hygienic conditions of food or the environment where it's processed and stored. Their presence suggests a likelihood of potentially harmful pathogens or spoilage organisms being present.

By monitoring and evaluating indicator levels, food manufacturers can assess the effectiveness of sanitation protocols and process controls. This proactive approach ensures the safety of the food chain and ultimately protects public health. Common tests for indicator organisms include Total Plate Count**,** Aerobic Plate Count**,** Standard Plate Count**,** Enterobacteriaceae**,** and E. coli etc. High levels of these indicators serve as a red flag, prompting further investigation and potentially stricter hygiene measures [11].

- **Pathogens:**

In contrast to indicator organisms, pathogenic microbes pose a direct threat to human health. These harmful bacteria, viruses, and parasites can cause serious illness, and in extreme cases, even death. Examples include Salmonella and Listeria**.**

Salmonella is a group of bacteria notorious for causing salmonellosis, a gastrointestinal illness characterized by fever, nausea, vomiting, and diarrhea. Contamination often occurs through improper food handling practices, such as inadequate handwashing or the use of contaminated surfaces during food preparation. Additionally, consuming raw or undercooked foods can harbor Salmonella [12].

Listeria is another potentially dangerous pathogen capable of causing severe illness, particularly in vulnerable populations like pregnant women, newborns, the elderly, and individuals with compromised immune systems.

Listeria monocytogenes (L. monocytogenes)**,** a bacterium lurking in moist environments like soil, water, and decaying vegetation, poses a significant threat to human health. Unlike most bacteria, it thrives in cold

temperatures, even persisting and potentially growing under refrigeration – a surprising ability that can bypass traditional food preservation measures. Consuming food contaminated with L. monocytogenes can lead to a serious illness called listeriosis. The severity of listeriosis varies greatly, with symptoms ranging from mild to life-threatening [13].

In summary, effective food quality management goes beyond ensuring a pleasant eating experience. It minimizes food waste, protects consumers from illness, and prevents financial losses for food companies. By prioritizing these objectives through robust quality assurance (QA) practices, the food industry can deliver safe, high-quality food products that consumers can trust.

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CHAPTER 2

Bitter Gourd: When Bitter Is Better for Health

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Abstract

Bitter gourd is a tropical vine grown mainly in India, China and South East Asia. The plant is cultivated mainly for its fruit part which is edible. Bitter gourd is not very popular among many people due to its bitter taste. Nevertheless, the fruit is a source of several key nutrients. The plant, as a whole contains, more than 60 phyto-medicines that are active against more than 30 diseases, including cancer and diabetes. Currently, the incorporation of the bioactive compounds isolated from bitter gourd into functional foods and beverages finds a new horizon. The present chapter is an attempt to highlight the nutritional aspects, various bioactive compounds present and important nutraceutical properties of the bitter gourd plant in detail.

Keywords: Bioactive, Bitter gourd, Folklore medicine, Genomic, Nutraceutical

1. Introduction

Bitter gourd (*Momordica charantia* L.) belongs to the order Cucurbitales and family Cucubitaceae. It is also known as bitter apple or bitter melon or balsam pear, which is a tropical vine. It is widely cultivated in India, China and South East Asia (Behera *et al*., 2008). Many people consume the fruits after blanching or par boiling or soaking in salt water to reduce bitterness (Saeed *et al*., 2018). Besides cooking, fruits can also be consumed after canning, pickling, dehydration, etc.

The plant is grown as a fruit vegetable crop that possesses many medicinal properties. All part of the plants mainly the fruits and seeds, contain more than 60 phyto-medicines active against more than 30 diseases (Kole *et al*., 2020). In Asia, South America, India and East Africa, It is

widely used as a traditional medicine against diabetes from ancient times (Joseph and Jini, 2013). Recent studies also shown that the bitter gourd contains an insulin like principle, which is often being designated as plant insulin, exerts positive effects in lowering the blood and urine glucose content (Janagal *et al*., 2018). Traditionally fruits, roots, leaves and vines are also used as a suppressant for toothache, diarrhoea and furuncle. Among many other health benefits reported elsewhere, anti-cholesterol (Saeed *et al*., 2018), anti-cancer (Bai *et al*., 2016), anti-dementia (Joshi *et al*., 2017), anti-bacterial and anti-fungal (Mahmood *et al*., 2019), antioxidant and anti-inflammatory activities (Bortolotti *et al*., 2019), etc. are just a few to be mentioned. Of late herbal tea or 'gohyah' made from dried slices of bitter gourd is gaining popularity among health conscious people (Jia *et al*., 2017).

2. Bitter Gourd – A Nutrient Rich Plant

The monoecious plant is a slender climbing annual vine of 2 to 4 m length. The plant leaves are serrated. Plant produces separate yellow male and female flowers. Fruits are discoid or ovoid or ellipsoid to oblong and pointed towards the end (Kole *et al*., 2020). Usually fruits are 2 to 10 cm long. The exterior of the fruits are warty and the cross section is hollow with a thin layer of flesh. Flattened seeds and pith are seen in the central cavity which is surrounded by the thin fleshy layer (Gupta *et al*., 2011). The immature fruits are whitish or pale green in colour whereas the mature ones can be seen in light green, green and dark green and on ripening the colour turns to orange-yellow. To attain maturity, the fruits take 45 to 80 days (Sorifa, 2018). The seeds are straw coloured and 8 to 15 mm long (Poolperm and Jiraungkoorskul, 2017).

Bitter gourd is a source of several key nutrients. It has a higher nutritional value than other cucurbits such as squash, pumpkin, cucumber and zucchini owing to its high mineral and vitamin content (Krawinkel and Keding, 2006). The fruit is rich in vitamin A, C, E, thiamine, riboflavin, niacin, folate, etc. Similarly, it is also a rich source of minerals like potassium, iron, calcium, magnesium, phosphorous and zinc. It contains a good amount of dietary fibre. Detailed nutritional composition of bitter gourd fruit is given in Table 1.

Table 1: Nutritional composition of bitter gourd

Constituents	Amount
Water (%)	83.2–92.4
Lipids (%)	0.1–1
Carbohydrates (%)	4.2–9.8
Proteins (%)	1.6–2.9
Fiber (%)	0.8–1.7
Ash (%)	7–18
Calcium (mg/100mg)	20–50
Phosphorus (mg/100mg)	70–140
Iron (mg/100mg)	2.2–9.4
Magnesium (mg/100mg)	16
Sodium (mg/100mg)	3–40
Potassium (mg / 100mg)	8–170
Zinc (mg/100mg)	0.1
Manganese (mg/100mg)	0.08–0.32
Copper (mg/100mg)	0.18–5
Vitamin A as carotenes	210–220 IU
Vitamin C	70–120 mg
Thiamine (mg)	0.05
Ribofavin (mg)	0.03
Niacin (mg)	0.4

* Adapted from Behera *et al*. (2008), Nagarani *et al*. (2014), Sorifa (2018) and Saeed *et al*. (2018)

The calorific value for leaf, fruit and seed are 213.26, 241.66 and 176.61 kcal/100 g, respectively (Joseph and Jini, 2013). Bitter gourd is a rich source of amino acids (Table 2). Bitter gourd is one of the few edible fruit which contains conjugated α-linolenic acid in its seeds. The presence of a long chain PUFA, α eleostearic acid has been reported in bitter gourd seed oil (Yoshime *et al*., 2016). It is one of the best natural source of chromium (5.65 mg/100 g) and zinc (45.45 mg/100 g) (Saeed *et al*., 2018).

Table 2: Amino acid composition of bitter gourd mature fruit and seed

Amino acid	**Mature fruit (mg/g protein)**	**Mature seed (mg/g protein)**
Cystine	22.3	16.5
Aspartic acid	93.8	78.0
Threonine	25.2	17.4

Serine	55.0	43.5
Glutamic acid	96.0	124.0
Proline	54.4	49.7
Glycine	44.9	39.9
Alanine	51.2	46.7
Valine	42.2	36.7
Isoleucine	30.8	30.7
Leucine	64.9	60.5
Tyrosine	59.4	44.7
Phenylalanine	40.2	34.5
Methionine	27.6	23.6
Histidine	72.8	40.9
Lysine	101.0	98.7
Arginine	45.6	80.8

***** Adapted from Nagarani *et al*. (2014) and Sorifa (2018)

3. Bioactive Compounds Present in Bitter Gourd

Common sugars, proteins and chlorophylls are the primary metabolites found in bitter gourd, while secondary metabolites are curcubitane triterpenoids, phenolics, carotenoids, alkaloids, saponins etc. Secondary metabolites are responsible for the nutraceuticals properties, which produce beneficial physiological effects in the body (Daniel *et al*., 2014). Around 228 different compounds were identified from different parts of *M. charantia* (Nagarani *et al*., 2014) and some of them are depicted in Table 3.

Table 3: List of different bioactive compounds identified from different parts of bitter gourd plant

Broad category	Compounds identified	Plant parts
Phenolic compounds	Flavonoids such as catechin, epicatechin Non favonoids such as gallic acid, gentisic acid, chlorogenic acid, tannic acid, tannins	Fruits, Leaves, Stem
Carotenoids	Lutein, α & β carotene, zeaxanthin, β cryptoxanthin, lycopene	Fruits
Cucurbitane Triterpenoids	Charantin, kuguacins A – S, momordicine I, II and III, Karavilagenin A, B, C, D, E, saponins (triterpenoid glycosides), goyasaponins, sapogenins such as diosgenin	Fruits, Leaves
Phytosterols	Decortinone, clerosterol, ergosterol	Fruits

	peroxide, stigmasterol, campesterol, β sitosterol	
Alkaloids	-	Fruits, Leaves, Seeds

* Adapted from Gayathry and John (2022)

4. Nutraceutical Properties

Though bitter in taste, of late bitter gourd is gaining popularity all over the world because of its numerous nutraceutical properties, some of which are depicted in Fig. 1.

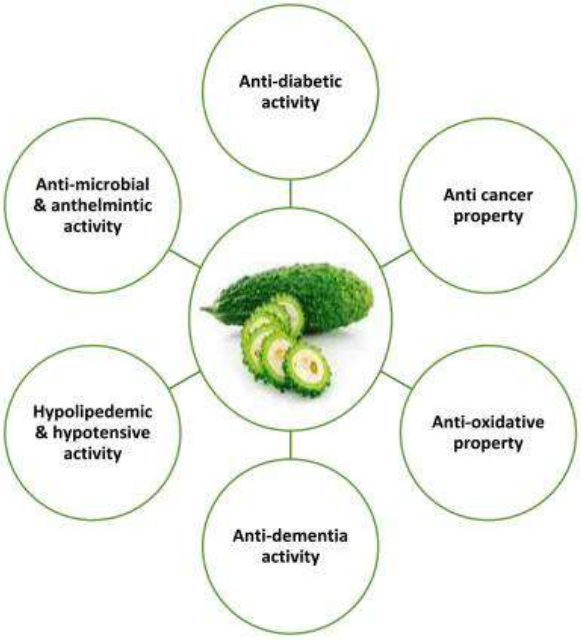

Fig. 1: Nutraceutical properties of bitter gourd (Gayathry and John, 2022)

4.1. Anti-diabetic Activity: Defects in insulin secretion, insulin action or both results in diabetes mellitus, a metabolic disease characterised by hyperglycaemia. Diabetes is a global pandemic that affects more than 540 m people as on 2021 (WHO, 2024). It is estimated about 9.6% population in India are diabetics, which is estimated to cross 10.6% by the year 2030. An amount of 966 billion USD has been spent for treatment of diabetes globally. Bitter gourd is a traditional remedy used since ages for management of diabetes in alternative and complementary medicine. A pilot study

reported reduction of blood sugar level 90 minutes after intake of bitter gourd juice (Selvakumar *et al*., 2017).

4.2. Anticancer Property: Several studies suggest the role of bioactive compounds in bitter gourd in the regulation of cervical cancer, breast cancer, liver cancer, nasopharyngeal carcinoma, leukemia, colon cancer etc. Further clinical trials are on explore the activity against carcinoma.

4.3. Anti-oxidative Property: Many life-style diseases such as hypertension, diabetes, obesity etc. are caused by oxidative stress in the human body. Various compounds present in bitter gourd are found to be effective against oxidative stress. Bitter gourd showed good anti-oxidant capacity in comparison with colocasia (Gayathri, 2014) and pumpkin (Hamissou *et al*., 2013). Appropriate doses of bitter gourd polysaccharide would scavenge the peroxide free radicals and play a certain role in anti-oxidation and anti-ageing processes. Superdioxide mutase is an important antioxidant defense in living cells by balancing the oxidation and anti-oxidation. Similarly, catalase protects cells from oxidative damage caused by hydroxyl anion (Gayathry and John, 2022).

4.4. Anti-dementia Activity: Neurodegenerative diseases lead to irreversible effects in movement, memory, speech and intelligence. This group of illnesses affect the brain cells that causes miscommunication. Degeneration of certain neurons in a progressive manner due to certain metabolic or toxic stress results in neurodegenerative diseases, which are untreatable (Valarmathi *et al*., 2020). Some examples for neurodegenerative diseases are dementias, Parkinson's disease and PD related disorders, prion disease, motor neuron diseases (MND), Huntington's disease (HD), spinocerebellar ataxia (SCA) and spinal muscular atrophy (SMA). Dementia is a disease, which affect the memory power of the brain. Various compounds present in bitter gourd have shown promising result against dementia.

4.5. Hypolipidemic and hypotensive Activity: The unhealthy food choices, chronic stress and obesity may lead to abnormally high levels of lipids (cholesterol and triglycerides) in the blood, which is known as hyperlipidemia. It is considered as a potential risk factor for cardiovascular diseases. Research is undergoing in exploring the role of bioactive ingredients from bitter gourd fruit and its parts

against this condition. Studies are also conducted to establish the anti-hypertensive effect of bitter gourd. Lestari and Mahayasih (2017) positively correlated the presence of phenolic compounds in bitter melon and increased anti-hypertensive activity.

4.6. Anti-microbial and anthelmintic Activity: Bitter gourd is a folklore medicine for various skin and stomach ailments owing to anti-microbial activities and the potential of bitter gourd as an antimicrobial agent is proven (Braca *et al*., 2008; Saeed *et al*., 2018). The ethanol extract of bitter gourd leaves is effective against proliferation of *Eschericia coli*, *Staphylococcus aureus*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Klebsiella pneumonia* (Leelaprakash *et al*., 2011; Ingle and Kapgatte, 2018). The inhibition activity is mostly attributed to the presence of alkaloids, favonoids, saponins, tannins, anthraquinones and terpenoids.

5. Genomic Study for Harnessing Nutraceutical Benefits:

In a recent study, *de novo* genome sequence win Illumina HiSeq 2000 platform, revealed that the gene (Bi gene cluster) regulating cucurbitane triterpenoid biosynthesis, that produce characteristic bitter taste in members of cucurbitaceous family like cucumber, melon, and watermelon is absent in bitter gourd. In another phygenic analysis, bitter gourd was found to be distantly related to cucumber (*Cucumis sativus*) and melon (*C. melo*) (Urasaki, 2017). This gene cluster is presumed to be evolved after the divergence of the species, suggestive of bitter gourd being an early-branching clad of the family *Cucurbitaceae*. It suggested influence of different tailoring genes, such as P450s and UGTs over the *cucurbitane triterpenoids* contributing to the bitter taste in the species (Cui *et al*., 2020).

Published draft genome sequencing of 285.5 Mb lengths, i.e. nearly 84% of the estimated total genome size identified 45,859 structural genes in the species (Urasaki, 2017). Transposable elements amounting 15.3% of whole genome was also reported. Genome annotation revealed unique properties in protein coding genes. There was twofold increase in the number of genes that encode ribosome-inactivating protein (RIP) in the bitter gourd genome in comparison to other cucurbits. This protein is found to have several antitumour and antiviral activities. Even though the biological functions of RIP gene is still obscure, it might confer certain medicinal values to the plant (Matsumura and Urasaki, 2020).

6. Conclusions

Bitter gourd is a wonder vegetable which has nutritional and functional properties but due to its bitter taste, usage among population is limited. Not only the fruit but other parts of the plant also have proven functional attributes. Numerous researches had identified the bioactive compounds present in the bitter gourd and different parts of the plant. In vitro and in vivo studies have also extensively investigated bioactive properties such as anti-diabetic, anti-cancer, hypocholesterolomic, anti-dementia activities among others. The applications of bitter gourd and the identified phytochemicals in food and pharmaceutical industries are yet to be explored widely. The long term effects of consumption of bitter gourd have not been studied and moreover the bioactivities are proven mostly in vitro and in vivo trials. Proper clinical trials are required to know the efficient and effective positive effects of these properties on human systems.

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CHAPTER 3

Tomato Waste Meets Nutrition: A Sustainable Approach

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Abstract

The health crises (pandemics, chronic diseases, and healthcare resources), poverty and inequality, hunger and malnutrition, water scarcity are rising as the major challenges to global human community. That shifted the focus of food industry towards food security and health driven revolutions. Lycopene, a principal carotenoid found in tomatoes has laid the interest because of its health benefits in preventing the risk of heart diseases and cancer. Alongside, tomato processing industry generates substantial waste (skin, seeds, pulp, spoiled or rejected fruits), though challenging to manage presents opportunity for reuse and value addition.

Effective management of tomato waste through recycling and reuse, is a need of hour to reduce environmental impacts preventing a damage to soil and water, while contributing sustainability and profitability. This chapter discovers the potential of an innovative way to effectively manage an agricultural or food processing waste by utilizing lycopene rich tomato waste in enriching food formulations. Lycopene enriched food products using tomato industry by products offer a novel and sustainable approach to functional food development. Rich in lycopene, an antioxidant known for its cancer-preventing and heart health benefits, tomato waste also provides dietary fiber, making it an ideal ingredient for fortifying multigrain cookies. By combining grains like wheat, oats, and millet, the cookies gain a balanced nutritional profile, offering consumers a health-conscious snack alternative. The chapter also addresses key aspects, including the stability of lycopene and other nutrients during baking.

Keywords: Tomato waste, Lycopene, Multigrain, Cookies

1. Introduction

Nowadays, food is envisioned to reduce the risk against diseases linked to malnutrition, improve general health and wellbeing, and provide the vital nutrients to humans in addition to satisfy hunger. Researchers and scientists are now focused on improvement in functional foods for the benefit of people on the basis of growing consumer awareness and advancements in technology that points to a significant relationship between diet and health. Food processing industry by-products are the prominent sources of bioactive ingredients and color pigments. Nutraceuticals, functional foods, food components, additives, and cosmetics can all be made with these by-products. For the purposeful community, foods with functional ingredients are foods that provide nutritional benefits beyond basic sustenance. Conventional foods as well as supplemented, or enriched foods as well as dietary supplements are included in functional food category.

Products from bakeries are preferred segments of the food processing industry as they are easily fortified and improved to compensate a diversified dietary requirement. Because of its flavor, aroma, and taste, cookies are the most often utilized bakery item by people of all ages. This is mostly because it is inexpensive, readily available in a variety of flavors, ready to eat, and high in nutrients. Dry fruits, nuts, chocolate pieces, candies, and other flavoring elements are also added either inside or on the surface of the cookies. Cookies provide significant amounts of essential nutrients and vitamins to our daily food demands. Many nutrition improvement programmes use cookies in many parts of the world particularly for low-income groups.

Today's cookies are evolving through the addition or subtraction of various ingredients. The use of whole grains derived composite flour made from wheat, oats, millets etc. enhances nutritional value of product. Multigrain flour due to its high fiber content, minerals, and antioxidants, contribute to reduce the risk of noncommunicable diseases or lifestyle diseases like cancer, diabetes mellitus, obesity, and heart disease. The nutritional advantages of grains including wheat, oats, and millet are combined in multigrain cookies, which provide a flexible way to increase dietary fiber and micronutrient intake. Multigrain cookies, that collate the nutritional benefits of grains like wheat, oats, and millet, offer a versatile platform for enhancing dietary fiber and micronutrient intake. Integrating tomato waste into multigrain cookies, not only delivers the health benefits of lycopene, but the food waste can also be curtailed, aligning with sustainable development goals. This chapter deals

with utilization of tomato waste in development of lycopene-rich multigrain cookies, offering a dual benefit of incorporating bioactive compounds while promoting sustainable practices.

2. Nutritional Status of Tomato Waste as a Source Of Lycopene

Tomatoes and tomato products are recognized as the primary sources of lycopene molecule in the human diet (John and Marc, 2000). Even though it lacks provitamin an activity, lycopene has nearly twice the ability of β-carotene to quench singlet oxygen. Lycopene being effective antioxidant influences development and progression of receptor motion and cell cycle growth which is responsible for development of carcinogenic tumor (Heber and Lu, 2002). Tomato waste is primarily comprised of the peel and seeds and provides fibers as 25.2 – 50.6 % (Marcos *et al.*, 2006). Other components of tomato waste include 15.4–23.7 % protein, 5.4–20.5 % fat, and 4.4–6.8 % mineral content. The chemical composition representing overall protein content, ash content, total fibers and moisture content in tomato waste as 8.80 %, 0.62 % 1.82 %, and 93.9 % respectively (Suarez *et al.*, 2008). Tomato pomace is an industrial by-product, comprised of seeds, skin, and a minor amount of flesh (Ariadne *et al.*, 2015). The study conducted on tomato pomace reported the main carotenoid components in tomato peel as lycopene, phytoene, phytofluene and beta-carotene (Effat *et al.*, 2014). In tomato processing unit around 5-10 % of overall mass is identified as waste. Approximately 16 % crude protein and 57 % fibers are found tomato pomace (Ariadne *et al.*, 2015) and has high concentrations of bioavailable substances that are used as food additives (Krzysztof *et al.*, 2019). Specialized metabolites, mainly polyphenolic substances such as flavanones, and carotenoids like lycopene, are also present in significant amounts in tomato waste (Krzysztof *et al.*, 2019).

3. Health Benefits of Tomato and Tomato Pomace

Tomatoes possess antioxidant properties. Several recent pharmaceutical studies have revealed the importance of tomato fruit as a source of antioxidant compounds required for human metabolism. Phenolic acids are the main antioxidants in tomato pomace. They activate a defensive mechanism against oxidants as they are absorbed in the body (Serio *et al.* (2006). Daily intake of tomato base products has proven its linkage with lower possibility of breast cancer and prostate cancer (Story *et al.*, 2010). Tomato seeds are about 13% more rich in lysine as in case of soy protein (Majzoobi *et al*., 2011). Moreover, No anti-nutritional factors have been discovered in tomato waste. Marques *et*

al. (2015) analyzed the antioxidant properties and health benefits of tomato pomace. As per their study, increasing plasma lycopene levels can be linked to a lower risk of CVD and has been shown to improve CVD biomarkers. The main risk factor for CVD is bad cholesterol (LDL), which is related to an increase possibility of cardiac disease. Tomato lycopene inhibits cholesterol synthesis and may improve LDL degradation, thereby preventing cardiovascular disease in humans (Ghadge *et al.*, 2019).

4. Utilization of Tomato Waste in Food Product Development

The utilization of dried ground form of tomato in tomato ketchup was assessed by Belovic *et al.* (2018). Dried ground form of tomato ketchup's nutrient content revealed an increase in dietary fiber and energy value (4.19 g/100 g and 3.74 kcal, respectively). Dried ground form of tomato ketchup is rich in total dietary fibers content than fresh tomato pomace ketchup because no seeds were removed during the manufacturing process. Dried ground form of tomato ketchup contains significantly more protein than fresh tomato pomace ketchup. The effects of adding tomato powder (2 to 4 g per 100 g of flour), in wheat flour cookies were assessed (Bhat *et al.*, 2020). There was a notable improvement in the total phenolic content (0.52–0.71mg GAE/g) of tomato powder dough than control (0.38 mg GAE/g). The incorporation of tomato powder notable improved the antioxidant effects of cookies, like DPPH scavenging activity. The dried ground form of tomato was used in yoghurt fortified with fibers and antioxidant (Alqahtani *et al.*, 2020). Yogurt is low in fibers and antioxidants. The dried ground form of tomato was incorporated in proportion ranging from 0% to 2% to UHT milk. The addition of dried ground form of tomato increased the acidity and phenolic content. As a result of the addition of dried ground form of tomato, palatable yoghurt is successful product rich in dietary fibers.

5. Enhancing Value of Multigrain Cookies with Tomato waste Lycopene

Mudassir and Hafiza (2015) prepared the cookies with dried ground form of tomato and studied their physicochemical properties. The nutritional characteristics of cookies containing variable quantities of tomato waste powder (0-25%) were studied. Cookies containing 20 and 25% tomato pomace powder had significantly higher crude protein and ash contents than the control and other treatments. The overall acceptability scores of the control and dried ground form of tomato incorporated cookies were not significantly different, according to sensory analysis. Consumers reported their satisfaction

for up to 5% replacement of wheat flour with tomato waste powder in cookies based on organoleptic properties.

The multigrain (wheat, finger millet, oats) cookies formulated by substituting wheat flour with tomato waste powder presents an appropriate way towards sustainability through functional food development. The cookies baked at 140-150 °C for 15-20 min (Pal et al., 2018) in rotary baking oven contain 0.78-1.50 mg/100 gram of lycopene (Kadam and Mane, 2022). The enhanced functional properties are associated with lycopene content in tomato pomace powder cookies. The total phenolic content as 0.82 -1.34 mg GAE/g and antioxidant activity as 21.88-40.95% represents functional efficacy tomato waste integrated multigrain cookies.

6. Challenges of Tomato Waste Incorporation

Incorporating waste from tomato processing into food products presents significant opportunities but also poses challenges in terms of safety and quality, consumer acceptance, technical challenges, economic viability, scalability and research and development gaps. It's challenging to maintain sensory quality of such tomato waste utilized food product. Tomato waste may impose unpleasant flavour and has fibrous texture that may affect the mouthfeel of multigrain cookies. Thus, standardized formulations in terms of sweeteners and fats are required to balance the overall flavor and texture profile of cookies. Ensuring the integrity of lycopene during baking process is equally important to justify its probable use in functional food formulations. High temperature during thermal processing can degrade lycopene affecting its antioxidant efficacy (Jatau et al., 2017). However, multiple studies have revealed improved bioavailability of lycopene as a result of heat induced maceration enhancing lycopene release from tissue matrix (Unlu et al., 2007; Honest et al., 2011; Li et al., 2023). Hence, monitoring the heat treatment during baking process with respect to time and temperature is crucial to minimize lycopene degradation while achieving desired bioavailability. Advanced techniques like encapsulation and post treatment addition have also been explored for retaining the lycopene quality (Li et al., 2023). Further research is required to attain the finest practices for integrating tomato waste to develop lycopene enriched products. Apart from this tomato processing waste is perishable imposing complications in its storage and conveyance. Extracting lycopene from tomato waste often requires advanced technologies which are cost costly. Also, diversity in waste quality, based on different industries and seasons affects consistency. Another major challenge is to deal

with consumer mindset as they think waste derived products as substandard or unsafe despite of their effectiveness. They demand clarity for the sources and treatments of constituents.

7. Sustainability and Economic Impact

Functional food development enriching lycopene through addition of tomato wastes aligns with sustainable development goals driven by food waste utilization and contribute to circular economy. Although tomato waste utilization to develop functional food products lower the raw material cost, producing scaling technologies for utilizing this waste as a safe and usable functional food ingredient may incur extra cost. However, this extra expenditure is often balanced by enhanced value of the food product.

8. Conclusion

Functional food development using tomato waste by integrating the benefits of lycopene in multigrain cookies projects a sustainable approach and healthy innovation in value added food products cluster. Incorporating tomato waste into cookies provides an opportunity to offer heathy snack option to health cautious consumers while perceiving effective waste utilization for sustainable approach. Imminent inventions to improve the sensorial and functional quality of cookies and similar products could address the consumer demand for healthy food while meeting sustainable goals.

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CHAPTER 4

Micro Greens: The Tiny Titans of Nutrition

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Introduction to Microgreens

Over the past twenty years, interest in fresh, functional and nutraceutical foods has been on the rise, compelled by the growing interest of society in healthy eating (Ebert, 2012). Consumers are seeking for new products that support health and longevity combined with gastronomic delight (Drewnowski & GomezCarneros, 2000). The public and private sectors are showing significant interest in urban farming, particularly in controlled environment farming. This encompasses various techniques such as vertical farms, greenhouses, hydroponics, aquaponics, and more (Benke, K.B.T., 2007). Many experiments have consistently shown that diets high in plant-based foods have positive health effects. There is evidence that the edible parts of plants in the families of Brassicaceae, Fabaceae, Solanaceae, Apiaceae, and Amaranthaceae contain compounds that are physiologically active and have health-promoting qualities (U. Choe *et al.*, (2018), Di *et al.*, (2020), Ghoora *et al.*, (2020), Lima *et al*, (2021)). All people ought to have access to safe, nutritious, and sufficient food all year round by 2030 (Anonymous). Microgreens, often referred as "functional foods," are tender seedlings of various edible plants, including vegetables, herbs, and flowering plants, harvested shortly after the first true leaves appear, but without roots or seed

coats. These nutrient-dense greens have attracted significant scientific interest owing to their potential to deliver concentrated nutrients, beneficial phytochemicals, and health-promoting properties. Defined by their short growth cycle (usually 7–21 days) and harvested when only a few inches tall, microgreens can offer substantially higher levels of vitamins, minerals, and antioxidants than mature leaves of the same plants. Common types of microgreens include young shoots of arugula, radish, kale, basil, and cilantro, all of which exhibit unique nutrient compositions and flavors.

Microgreens are typically grown from the seeds of vegetables, herbs, and grains using a range of cultivation systems, from soil-based to hydroponic setups. Their adaptability makes them well suited to indoor farming, small urban spaces, and vertical growing systems. This flexibility, along with its relatively high market value, has led to an increase in commercial and home-based microgreen production, particularly in urban areas with limited access to farmland.

With rising chronic health issues, such as cardiovascular disease, diabetes, and certain cancers linked to nutrient-poor diets and oxidative stress, microgreens offer a convenient, nutrient-dense dietary option. Studies have also suggested that microgreens have stronger antioxidant properties than mature greens, potentially offering greater protection against cellular damage associated with aging and chronic illness. In addition to their health benefits, microgreens are a promising approach for sustainable agriculture. Growing microgreens requires significantly less water, energy, and time than traditional crop production, making them an eco-friendly food option. Their rapid growth cycle and high nutritional yield allow them to contribute to local food systems and food security solutions, especially in urban areas, where space and resources are limited.

Given the growing interest in nutrient-dense, sustainable food sources, microgreens stand out as both a culinary and agricultural innovation. This chapter explores the science behind microgreens, including their nutrient profiles, health benefits, and potential role in sustainable diets, as well as practical approaches to cultivation and market expansion.

Microgreens Vs Baby Greens Vs Sprouts

Sprouts are considered germinated seeds that can be harvested before the growth of true leaves and consumed whole with the seed (Di Gioia *et al*., 2017). Sprouts are generally grown in dark, moisture saturated conditions conducive to microbial proliferation, and their consumption, unlike that of

micro- and baby-greens, has been implicated in outbreaks of foodborne epidemics (Ebert, *et al.*, 2012; Xiao, *et al.*, 2014). On the other hand, microgreens are defined as tender, immature greens that need light for photosynthesis, growing medium (soil or nutrient solution medium), and represent a 7–28 days growth cycle. Microgreens can be developed from the seeds of cereals, vegetables, legumes, and herbs, comprising two completely expanded cotyledon leaves with or without the appearance of arudimentary pair of first true leaves (Xiao *et al*., 2012). Depending on species and growing conditions, microgreens are generally harvested at the soil level, *i.e.* at the base of hypocotyls, upon appearance of the first pair of true leaves, when cotyledons are fully expanded and still turgid (Sun *et al*., 2013) Nutritional Profile: Studies have shown that microgreens contain significantly higher levels of vitamins (such as C, E, K, and beta-carotene) and minerals (including calcium, iron, and magnesium) than their mature counterparts because of their early harvest stage, where bioactive compounds are concentrated. Variations in both micro-minerals (iron, zinc, copper, and manganese) and macro-mineral content (calcium, phosphorus, sodium, magnesium, chloride, potassium, and sulfur), phytochemical profile and antioxidant capacities have been found to vary with genotype rather than growth stage as studied in microgreens of four Brassicaceae genotypes-Komatsuna, Mizuna, Pak Choi and Mibuna (Kyriacou *et al*., 2021a). Microgreens are rich in bioactive compounds such as polyphenols and antioxidants, which help reduce oxidative stress and may lower the risk of chronic diseases. Microgreens are ready for harvest within 1–3 weeks, making them a rapidly growing source of fresh produce. They add intense flavors, colors, and textures to dishes, enhancing both taste and appearance. The major drawbacks are the higher cost of microgreen production due to the intensive growing conditions and short shelf life (perishable with a 5–10 days under optimal refrigeration), because of it microgreens tend to be more expensive than other greens. Another set back is that microgreens have lower fiber content compared to mature leaves. Microgreens are produced both at a small-scale level and along with large scale production of commercial vegetables and edible flowers. Upon their meteoric rise and demand, various varieties of commonly grown vegetables were used to cultivate microgreens that belong to various families, such as Amaranthaceae (amaranth, beet, quinoa, spinach, buckwheat, chard), Amaryllidaceae (garlic, onion, leek), Apiaceae (parsley, carrot, fennel, celery, dill, carrot, chervil, cilantro, coriander), Asteraceae (lettuce, radicchio, chicory, endive, tarragon, common dandelion), Boraginaceae (phacelia), Brassicaceae (radish, watercress, arugula, broccoli, cauliflower, cabbage,

chicory, wild-rocket), Convolvulaceae (water convolvulus), Cucurbitaceae (melon, cucumber, squash), Malvaceae (jute mallow/Nalta jute), Poaceae (corn, lemongrass), Lamiaceae (chia), Leguminosae (chickpea, alfalfa, bean, green bean, fenugreek, fava bean, lentil, pea, clover), Onagraceae (evening primrose), Portulacaceae (common purslane, moss-ross purslane) Tan, *et al*. (2019), Di Bella, *et al*. (2019), Ebert, (2022), Marchioni *et al*. (2021). The interest in different promising genotypes of microgreens offers different appearances, flavors, textures, phytochemical compositions, and nutritional values. Microgreens vary in taste. For example, some can be bitter, spicy, mild, bland, or even sour tasting (Michell *et al*., 2020). Other herbaceous species commonly used to produce microgreens are cereals (oat, soft wheat, durum wheat, corn, barley and rice), oleaginous plants (sunflower), and even fiber plants, such as flax, as well as many aromatic species such as basil, chives, cilantro, and cumin. The microgreens species are selected from an agronomic and commercial point of view and are strongly characterized by the availability of good quality seeds, homogeneous nature, germination capacity, hygienically safe, and, at the same time, are available at a low cost. Above all, the selected species should be available around the year with no particular thermal and environmental needs during the germination phase. The species selection is also sometimes based on shape, color (green, yellow, purple, red, crimson, and multicolor), texture (juicy, crunchy), and shelf-life

Baby Greens

Baby greens are defined as plants harvested after the microgreen stage, but before maturity, typically 2–4 weeks after planting. They are larger than microgreens, averaging 4–6 in height. Baby greens offer a balanced nutritional profile with moderate levels of vitamins, minerals, and fiber. Their fiber content is higher than that of microgreens because of their larger size and more developed leaves. Baby greens provide a good balance between vitamins and dietary fiber, making them beneficial for digestive health and blood sugar regulation. They have a longer shelf-life than microgreens, lasting 1–2 weeks when refrigerated. Baby greens are less labor intensive to grow than microgreens, making them more affordable and accessible. Lower nutrient density than microgreens while nutrient-dense, baby greens have a lower concentration of antioxidants and bioactive compounds than microgreens due to their later harvest. Require more growing space: baby greens need more space to grow than microgreens or sprouts, which may limit their suitability for small-scale urban farming.

Sprouts

Sprouts are the earliest stage of plant growth and are typically harvested within 2–7 days after germination, before any true leaves appear. They are grown from the seeds of grains, legumes, and vegetables in a warm, moist environment. Sprouts contain essential enzymes, vitamins, and amino acids with high levels of enzymes that assist in digestion. They are rich in protein (from legumes such as mung beans and alfalfa) and contain beneficial plant compounds, although their antioxidant content is lower than that of microgreens. Because of early harvest, sprouts are enzyme-rich, which can aid in digestion and nutrient absorption. Sprouts require minimal time, water, and space, making them an inexpensive fresh food option. Certain sprouts, such as alfalfa and mung bean, are a good source of plant-based proteins. Because of the warm, moist conditions required for germination, sprouts are susceptible to bacterial contamination by E. coli and Salmonella Similar to microgreens, sprouts have a very short shelf life and require careful handling to maintain safety and freshness. Although nutritious, sprouts generally contain fewer vitamins and antioxidants than microgreens.

Table1: Comparison of microgreens, baby greens and sprouts

Nutrient/Health Factor	Microgreens	Baby Greens	Sprouts
Vitamin C, E, K	Very high concentrations, particularly in varieties like red cabbage and cilantro	Moderate levels, depending on plant variety	Lower than microgreens but still beneficial, with good Vitamin C in some types
Antioxidants	High levels, especially in darker varieties; may reduce oxidative stress and inflammation	Moderate antioxidant content, offering some protection against cellular damage	Lower antioxidant concentration than microgreens; however, they still contain beneficial plant compounds.
Minerals (Iron, Calcium, Magnesium)	Rich in minerals; can support immune function, bone health, and blood pressure regulation	Moderate mineral content; provides steady intake without as high concentration as microgreens.	Lower mineral concentration than microgreens; however, minerals are present in legume sprouts like mung beans.
Fiber	Low fiber, as harvested at a young stage.	Moderate to high fiber; helpful for digestive health	Very low fiber, as sprouts are in an early growth phase.

Protein	Low protein content due to early harvest.	Moderate protein, especially in leafy greens like spinach.	High in legume sprouts (e.g., mung beans), which contain plant-based protein.
Health Benefits	Supports immunity, reduces inflammation, potential anticancer properties	Provides balanced nutrition with digestive and cardiovascular benefits	Enhances digestion through enzymes, moderate levels of vitamins aid in immune support

Cultivation Techniques

Microgreens can be grown using various cultivation techniques, each impacting on nutrient concentration, growth rate, and yield. The primary methods include soil-based, hydroponic, and aeroponic systems. Studies have shown that the growth medium and environmental factors, such as light and humidity, can influence the levels of vitamins, minerals, and bioactive compounds in microgreens. Soil-Based Cultivation: Soil-based cultivation is the most traditional method, using nutrient-rich soil to provide natural minerals and support plant growth. Seeds are sown in shallow trays filled with soil and are typically harvested within 7–21 d. Microgreens grown in soil have higher concentrations of minerals, especially iron, calcium, and magnesium, because soil offers a natural mineral base. Studies suggest that soil-grown microgreens may also have higher levels of certain antioxidants and polyphenols because natural soil microorganisms influence plant metabolism. Soil-grown microgreens often have a robust flavor and can develop more complex nutrient profiles owing to soil-based mineral availability. Soil systems may increase the risk of contamination if not managed properly, and the need for soil increases the resource requirements. Hydroponic Cultivation: Hydroponic systems grow microgreens in a water-based nutrient solution, eliminating the need for soil. This method often involves floating trays or mats that suspend roots in the nutrient solution, providing consistent access to water and nutrients. Hydroponically grown microgreens may show enhanced levels of certain vitamins, particularly vitamin C and E, because the nutrient solution can be optimized. However, mineral content, especially of soil-dependent minerals like iron and calcium, might be lower in hydroponic-grown greens. Hydroponic systems are highly efficient, using up to 90% less water than soil systems. They are also ideal for controlled environments, where nutrient concentration can be precisely managed. Microgreens grown hydroponically may lack certain soil-specific minerals, and setup costs for hydroponic

systems can be high. Aeroponic Cultivation: Aeroponic systems grow microgreens by suspending them in air while periodically misting the roots with a nutrient-rich solution. This soilless method ensures high oxygen levels for the roots and allows precise nutrient delivery. Aeroponically grown microgreens have shown increased levels of antioxidants and vitamins due to optimized nutrient misting and oxygen exposure. Some studies report higher chlorophyll and carotenoid levels in aeroponically grown greens, which enhance their antioxidant activity. Aeroponic systems use less water than soil and hydroponic systems and can produce high yields. They are also suited for vertical farming, making them efficient for urban areas. Aeroponic setups are technologically complex and costly, and plants may require supplemental mineral sprays to match soil-grown nutrient profiles. Aquaponic Cultivation: Aquaponic systems combine aquaculture (fish farming) and hydroponics, using nutrient-rich water from fish tanks to fertilize microgreens. This closed-loop system recycles water and nutrients. Aquaponic microgreens may have higher protein content due to nitrogen availability from fish waste, and they often exhibit balanced mineral content, as the fish waste provides essential nutrients. However, nutrient consistency can vary depending on fish health and species. Aquaponic systems are highly sustainable, conserving water and minimizing waste. They also produce two crops (fish and microgreens), maximizing space use. System maintenance is challenging, requiring careful monitoring of both plant and fish health. Nutrient levels can be harder to control than in pure hydroponic systems. Peat or Coco Coir-Based Substrates: Peat moss or coconut coir can be used as growing mediums in place of soil. These substrates are sustainable alternatives that retain moisture and allow good root development. Peat or coco coir-grown microgreens show similar mineral profiles to soil-grown greens, although levels may vary slightly based on nutrient supplementation. Coco coir is known for supporting high potassium levels in plants, while peat can support mineral retention. These substrates are lightweight, sustainable, and free from soil pathogens, making them safer for indoor use. While eco-friendly, these substrates may need supplementation with specific nutrients, as they lack certain minerals found in natural soil.

Table 2: Comparison of cultivation techniques for microgreens

Cultivation Method	Vitamins (C, E)	Minerals (Iron, Calcium)	Antioxidants	Other Nutritional Traits
Soil-Based	Moderate to High	High	High	Strong flavor, complex nutrient profiles due to soil microorganisms
Hydroponic	High (with solution)	Moderate	Moderate	Efficient nutrient use, lower mineral content for soil-dependent nutrients
Aeroponic	High	Moderate	Very High	Increased chlorophyll and carotenoids
Aquaponic	Moderate	Balanced	Moderate	Higher protein levels from nitrogen-rich fish waste
Peat/Coco Coir-Based	Moderate	Similar to soil-based with supplementation	Moderate to High	Potassium-rich in coco coir, eco-friendly substrate

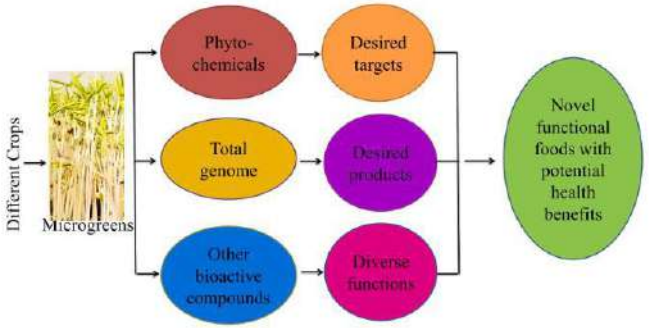

Fig. 1: Microgreen role as functional foods

Growing Practices

Microgreens can be cultivated year-round in controlled environments, benefiting from innovations in artificial lighting and nutrient management. These conditions significantly influence yield, nutritional composition, and bioactive compound levels in microgreens. Light, in particular, is crucial for photosynthesis and affects the concentration of bioactive compounds. Studies show that different light spectra, including red, blue, and ultraviolet, each impact growth metrics and phytochemical profiles differently. For instance, higher light intensities increase fresh weight and chlorophyll content in microgreens like mizuna and mustard Specific light treatments have been

shown to enhance the concentration of antioxidants, vitamins, and pigments in microgreens. For example, purple kohlrabi and mustard microgreens exposed to higher daily light integrals of red/blue combinations demonstrated increased dry weight and pigment levels. Additionally, blue light intensity has been found to promote greater antioxidant enzyme activity in arugula and mizuna, while continuous light (24 hours) boosted anthocyanin and flavonoid levels in broccoli and radish microgreens. Other studies suggest that supplementing sodium and zinc biofortification can elevate specific nutrient contents in microgreens, making these microgreens even more nutritionally dense.

Furthermore, studies report that varying the ratios of red, blue, and green light can optimize nutrient concentration. Red:blue:green (1:1:1) LEDs in broccoli microgreens increased fresh weight, dry weight and moisture content, further, elevated chlorophyll and reduced carotenoid content with increasing light intensity. Contents of some other phytochemicals like vitamin C, soluble proteins and sugar, flavonoid, free amino acid, and glucosinolates except progoitrin also increased Gao *et al.* (2021). Whereas use of white LED, blue LED and red LED among these Blue light is most effective in promoting growth and nutritional qualities. Red light had pronounced effects on accumulation of fresh biomass as well as growth of hypocotyl Toscano *et al*. (2021). In Chinese kale usage of Red, white, blue LED and sunlight (control) Low intensity red light increased fresh weight and hypocotyl growth. White LED promoted accumulation of phenolic compounds, glucosinolates and ascorbic acid Tantharapornrerk *et al*. (2021). In Leafy vegetable amaranth and Red amaranthus red + blue in ratio 70R:30B (PPFD-280 $\mu mol/m^{-2}/s^{-1}$ Photoperiod-16 h) improved fresh yield, vitamin C, content of photosynthetic pigments (carotenoids and chlorophylls), anthocyanins, and levels in both red amaranth and leafy vegetable amaranth microgreens. Further, total antioxidant capacity was increased Meas *et al*. (2020). Wheareas Mustard, Beet and Parsley use of blue light treatment Quantity of chlorophylls, carotenoids, alpha-carotenes and beta-carotenes, zeaxanthin, violaxanthin, and lutein, increased 1.2 to 4.3 folds Samuolienė *et al.* (2017). In Soybean use of LED light spectra decreased seedling height as well as yield while increase in phenols. UV-A and Blue light significantly increased antioxidant capacity, total phenols and total flavonoid content Zhang *et al*. (2019)

Pre and Postharvest Technology

After harvesting, packets of microgreens should be kept at 4 to 5 degrees

and consumed within 8–10 days. Storage conditions and maintenance of shelf-life are very important to preserve the microgreens in good quality with stable nutrition. Several factors, viz., storage temperature, atmospheric composition, post-harvest light exposure, and packaging technologies, are associated with conserving fresh-cut microgreens. Further, during value-added product development, processing avenues (freezing, drying, waving, microwaving, frying, toasting, and boiling) are equally required to maintain the bio-availability of bioactive and phytochemical components of microgreens.

Extending the shelf life of microgreens while maintaining nutritional and sensory quality requires specific postharvest treatments. Common methods include modified atmosphere packaging (MAP), LED light exposure, and the use of edible coatings. Research shows that MAP combined with red light can effectively preserve chlorophyll, reduce respiration rates, and delay senescence in mircogreens like pak choi and mustard. Additionally, exposure to blue LED light during storage can help maintain carotenoid levels and minimize chlorophyll degradation, especially when stored at lower temperatures.

Preharvest treatments, such as 10Mm calcium chloride (Chandra *et al*., 2012) and UV-B applications, have also been reported to improve microgreens shelf stability. For instance, broccoli microgreens sprayed with calcium chloride showed enhanced visual quality and lower microbial growth when stored in polyethylene bags, extending freshness up to 21 days. Similarly, UV-B treatments applied preharvest increased glucosinolate and glucoraphanin levels in broccoli and radish microgreens, while also improving antioxidant retention during storage. Recent research also highlights the effectiveness of aloe vera-based edible coatings in reducing respiration rates and microbial growth, making them promising for improving microgreens shelf life in a natural way. Moreover, macro-perforated packaging, including PET clamshell and LDPE self-seal bags, was also assessed for longer shelf life in radish and roselle microgreens (Ghoora and Srividya, 2020). Very interesting plant regulator is 1-methyl cyclopropane (1MCP) which binds competitively to ethylene receptors and delays senescence resulting in active treatment to prolong the shelf life of fruits, vegetables, and edible flowers (Turner *et al*., 2020)

Applications and Health Benefits of Microgreens

All microgreens are increasingly recognized for their nutritional and functional applications, among which Brassicaceae microgreen largely due to

their high phytochemical content, including antioxidants, anti-inflammatory agents, and glucosinolates, studied showed positive support on cardiovascular health, improve immune function, and even offer anticancer benefits. Notably, the glucosinolates in microgreens can transform into isothiocyanates, bioactive compounds with demonstrated anticarcinogenic properties, particularly in broccoli and radish microgreens. Microgreens are also valued for their high levels of phenolics and flavonoids, which have been associated with reduced risks of diabetes and oxidative stress-related diseases. For example, red cabbage and purple kohlrabi microgreens have shown high phenolic content, enhancing their antioxidant capacities and making them suitable for novel food applications, such as fortification in health supplements or incorporation into functional food products additionally, the bioavailability of vitamins, especially C and E, makes microgreens beneficial for immune health, skin protection, and cardiovascular wellness. The combination of essential nutrients, bioactive compounds, and favourable sensory properties positions Brassicaceae microgreens as valuable additions to health-conscious diets. Their ease of cultivation, minimal input requirements, and adaptability make them a sustainable food option to address global challenges related to food security, malnutrition, and urbanization

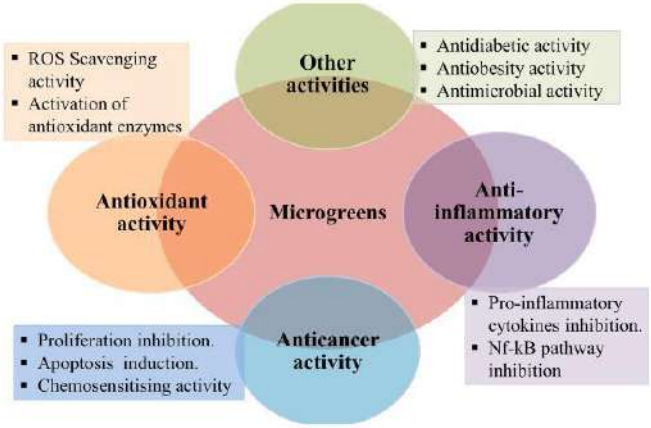

Fig 2: Therapeutic Potential of Microgreens

Cancer-Fighting Potential: Studies highlight that microgreens from the Brassicaceae family, such as broccoli and radish, contain polyphenols, vitamins, carotenoids, and minerals with anti-cancer properties. Accordingly, these compounds can inhibit the growth of colorectal cancer cells by inducing apoptosis and cell cycle arrest. Furthermore, the indoles and flavonoids in

these microgreens have been shown to reduce hormone-driven cancer risks by modulating estrogen receptor signalling, upregulating tumour-suppressor genes, and downregulating genes associated with cancer proliferation. Anti-Inflammatory Properties: Microgreens provide strong anti-inflammatory benefits, largely due to their high polyphenol and glucosinolate content and these compounds significantly reduce the production of pro-inflammatory cytokines, which are implicated in chronic diseases. Red cabbage microgreens, in particular, have demonstrated effectiveness in lowering liver lipid levels, thereby alleviating inflammatory responses associated with metabolic conditions. Antimicrobial Properties: the antimicrobial effects of broccoli microgreens, particularly against foodborne pathogens such as Staphylococcus aureus and Bacillus subtilis. This is largely attributed to compounds like gallic acid, esculetin, and ferulic acid. Additionally, sulforaphane, found in broccoli microgreens, has been shown to inhibit Helicobacter pylori, suggesting potential in food safety and infection prevention. Antidiabetic Effects: the sulforaphane in broccoli microgreens has shown promise in reducing serum insulin levels and improving insulin resistance, which is particularly beneficial in managing type-2 diabetes. The activation of protective pathways that reduce oxidative stress further highlights the role of microgreens in managing diabetic complications. Combatting Obesity: As a leading cause of serious metabolic diseases like type-2 diabetes and cardiovascular issues, obesity has been a growing concern.

Market Trends for Microgreens

Microgreens have experienced significant market growth due to their health benefits and culinary versatility. The COVID-19 pandemic further accelerated their popularity as individuals sought nutrient-dense foods to support immunity. Market analysis projects an annual growth rate of 7.5% to 13.1%, with high demand in North America and rapid expansion in Asia-Pacific. Vertical and hydroponic farming advances are enhancing year-round production and contributing to the global demand for these crops.

Research Gaps and Future Directions

Despite the growing body of research on microgreens, several areas remain unexplored, highlighting the need for further study. Firstly, the impact of different environmental factors such as light spectrum, intensity, and growth medium on the nutritional and phytochemical composition of microgreens requires more comprehensive research. While initial studies indicate positive effects of red and blue light combinations on chlorophyll and

carotenoid content, the optimal light conditions for maximizing specific bioactive compounds in various microgreens species remain unclear. Future studies could explore more precise light manipulation techniques to enhance the phytochemical profile in these microgreens. Another gap lies in the postharvest preservation methods of microgreens. Although modified atmosphere packaging (MAP), LED light exposure, and edible coatings have shown potential in extending shelf life and maintaining nutritional value, their effects across a broader range of microgreens species need further validation. Investigating the efficacy of natural preservatives or coatings, such as those derived from plant-based materials like aloe vera, could offer additional sustainable solutions to extend microgreens shelf life without compromising quality. Further research into the bioavailability and metabolism of microgreens's phytochemicals in the human body is also essential. While numerous studies have documented the antioxidant, anti-inflammatory, and anticancer properties of microgreens in vitro, understanding the bioavailability and mechanisms of these compounds in human health is still in the early stages. Longitudinal and clinical studies focusing on the effects of microgreens on health outcomes, such as cardiovascular health, diabetes management, and immune support, are recommended to substantiate their benefits for human health.

Finally, expanding research on microgreens cultivation methods especially sustainable practices like hydroponics, vertical farming, and biofortification could enable large-scale production with reduced environmental impact. Given their potential to address global food security issues, optimizing sustainable production techniques for microgreen can make them more accessible and environmentally friendly, supporting both urban agriculture and climate resilience

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5
CHAPTER

Anaemia in Adolescent Girls

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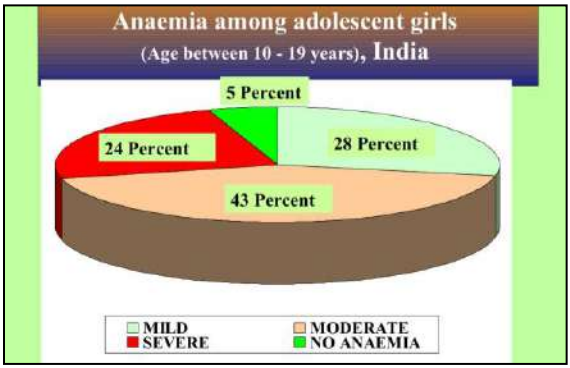
Abstract

The world's adolescent population is facing a series of serious nutritional challenges which are not only affecting their growth and development but also their livelihood as adults. Yet, adolescents remain a largely neglected, difficult to measure and hard to reach population, in which the needs of adolescent girls (10-19 years) are often ignored. Anaemia in adolescent girls contributes to maternal and foetal mortality and morbidity in future; an expressed as disability adjusted life years. Iron deficiency Anaemia is the most common cause of Anaemia. However, other conditions like nutritional deficiencies, acute and chronic inflammation, parasitic infections, growth spurt, increase in iron requirements and increased iron loss from the body during the menstruation, inherited or acquired disorders of haemoglobin synthesis, RBC production or survival are also considered cause of Anaemia.

Keywords: Adolescent girls, Anaemia, Haemoglobin, RBC and Mensturation.

Introduction:

Anaemia is the most common nutritional disorder worldwide. According to WHO, Adolescent age group can be defined as life span between the ages of 10-19 years. It is mainly caused due to Iron-deficiency. In India the prevalence of Anaemia among adolescent girls were 56% and these amounts to an average about 64 million girls at any point in time.



Adolescence refers to the phase of human development which encompasses the transition from childhood to adulthood. The nutritional and the health needs of the adolescents are also more because of the growth spurt and the increase in physical activity in them. In females, adolescence marks the beginning of the menstrual cycle or reproduction. Adolescents gain 30% of their adult weight and more than 20% of their adult height between the ages of 10-19 years, which is called Growth Spurt.

Rationale of the Study:

- To get a clear conceptual knowledge about Anaemia in adolescent girls and their risk factors.
- Identify the typical haemoglobin levels that define Anaemia in adolescent girls.
- To understand the reason behind growing cases of Anaemia in adolescent girls.
- To study the association of Anaemia with respect to the age of the participants and their socio-economic status.
- To spread awareness among people especially adolescent girls.

Anaemia is said to be present when the haemoglobin level in the blood is below the lower extreme of the normal range. Haemoglobin level in boys is 15.0 g/dl (lower limit 13.0 g/dl), whereas in girls it remains 13.5 g/dl (lower limit 12.0 g/dl) (9). According to the WHO criteria.

WHO Cut-off points for haemoglobin values for diagnosis of Anaemia

Group	Haemoglobin g/dl
Adult men	<12
Adult women	<12
Pregnant women	<11
Lactating women	<12
Children <6 years	<11
Other Children	<12

Types of Anaemia: There are various types of Anaemias, such as Iron-deficiency Anaemia, Pernicious Anaemia, Aplastic Anaemia and HaemolyticAnaemia. The different types of Anaemia are linked to various diseases and conditions.

Iron-Deficiency Anaemia: The main way to get iron is from food. At certain timessuch as during pregnancy, growth spurts or blood lossbody may need to make more RBCs than usual.

PerniciousAnaemia: Vitamin B12 and folate (B9 vitamin) are needed to make healthy RBCs. Body absorbs these vitamins from foods. Pernicious Anaemia occurs if body can't make enough RBCs because it can't absorb enough vitamin B12 from food.

HaemolyticAnaemia: Normally, RBCs have a lifespan of about 120 days. Body constantly makes new RBCs to replace ones that die. Sometimes, RBCs are destroyed before their normal lifespan is up. Haemolyticanaemia occurs if body can't make enough RBCs to replace those destroyed. Acquired haemolyticanaemia occurs if body gets a signal to destroy RBCs even though they are normal.

Causes of Anaemia in adolescent girls:

1. At the time of menarche.
2. Gender discrimination.
3. Iron depletion occurs in girls who take part in Intensive exercise.
4. Early marriage with pregnancy.

Risk factors of Anaemia in adolescent girls:

Adolescents girls (age 10-19 years) are at high risk of iron deficiency and cause Anaemia due to:

- Low dietary intake by adolescents and bio-availability of iron.
- Adolescent pregnancy.
- Social norm of early marriage.
- Frequent infectious diseases and parasitic infections.
- Worm infestation.

Sign and symptoms:

- Look pale.
- Fatigue.
- Paleness of conjunctiva.
- Spoon shaped nails.
- Seem moody.
- Be very tired.
- Have a fast heartbeat.

Review of Literature:

1) Assessment of Anaemia in adolescent girls - Dr. Jayshree J. Upadhye, 10 June 2017

Abstract: The world's adolescent population is facing a series of serious nutritional challenges which are not only affecting their growth and development but also their livelihood as adults. The objectives of the study was to estimate the frequency of Anaemia among adolescent girls, to study the socio-demographic factors associated with Anaemia and to evaluate the cause and type of Anaemia.

2) Nutritional Anaemia in adolescent girls: an epidemiological study - Anurag Srivastava, Rakesh Kumar, Mukesh Sharma, 05 March 2016

Abstract: Adolescents are the future generation of any country and their nutritional needs are critical for the wellbeing of the society. The present study was undertaken to find out the magnitude of Anaemia in adolescent girls in rural areas of district Amroha, Uttar Pradesh, India.

3) Anaemia: A disease or symptom - D A Newhall, R Oliver, S Lugthart, 20 Apr 2020

Abstract – Anaemia is a common diagnosis for clinicians. This mini-

review summarises criteria for diagnosing the cause of Anaemia. We aim to provide the readers a clear overview of Anaemia and when to refer to as haematologists.

Methodology

Due to pandemic situation of Covid-19, data collection is not possible by visiting the subjects physically. Therefore, the survey has been conducted by online mode. The entire study is based on Oral Questionnaire Survey Method. Oral questionnaire survey was performed via cell phones, email, whatsapp and within the locality, friends and family.

- **Sample Selection:** Due to pandemic situation samples were selected in random way. Subjects were selected from among my relatives, family members. The 10-18 years old girls participating in my project are suffering from Anaemia. All of the participants are students.
- **Sample Size:** The sample size has been consisting of 10 girls. The study connects with the adolescent girls who are suffering from Anaemia and they are recovering through diet chart.

Data:

Details of the Adolescent girls (10-19 years)

Sl. No.	*Name*	*Age (Yrs)*	*Height (cm)*	*Weight (Kg)*	*BMI*	*Grade*	*Haemoglobin (g/dl)*	*Grading of Anaemia (Hb in g/dl)*
1	Arushi Dutta	13	157	47	19.1	Normal	8	Moderate
2	Arpita Das	18	165	55	20.2	Normal	9	Moderate
3	Juin Dey	16	168	60	21.3	Normal	10.5	Mild
4	Puja Roy	13	167	57	20.4	Normal	7.5	Severe
5	Riya Saha	11	132	40	23	Normal	9.5	Mild
6	Priya sen	10	137	39	20.8	Normal	7.5	Severe
7	Soma Sen	17	175	60	19.6	Normal	7	Severe
8	Sonali Gupta	18	170	62	21.5	Normal	9.5	Moderate
9	Rupa Ghosh	18	165	65	23.9	Normal	8.5	Moderate
10	Rai Sarkar	16	155	56	23.3	Normal	10	Mild

Above Mention 10 Adolescent girls Anaemia Diet chart :

Healthy food is important for a healthy body. By adopting the natural foods will get a big difference in the level of iron. So, here is a Anaemia diet

plan that can help to improve the condition of an Anaemia patient.

Sample Menu Planning With Timings for Anaemia Adolescent Girl (10-12YRS)

Early morning (7:00 A.M.): Milk (200 ml) (1glass) + Sugar (1tsp).

Breakfast (8:00-8:30 A.M.): Vegetable stuffed parantha (any 2) / Dosa stuffed with potato vegetables (2-3) / Bread slices with butter (2) / Idlis with (Coconut/Mint) chutney (4) / Vegetable upma (1cup) + Tea (with sugar).

Mid-morning (11.30-12.00A.M.): Fruit (Banana/Apple/Guava) (Any1).

Lunch (1:30-2:00 P.M.): Chapati (2) / Cooked Rice (1bowl) + Green leafy vegetables (50 gm) (cooked in oil (1tsp)) + Cooked dal or sprouts (1bowl) + Potato vegetable curry (1bowl) + Fish/Mutton/Egg (cooked in Curry)(1) (cooked in 1 tsp oil) + Curd (200 ml) + Vegetables Salad (Onion/Carrot/Tomato) (1plate)

Snacks (5:00-5:30 P.M.): Tea (with sugar) (1cup) + Rusk/ Biscuits /Vegetable Chat (Any1)

Dinner (9:00-9:30 P.M.): Chapati (3) /Cooked Rice (1bowl) + Cooked dal/pulses vegetables (1bowl) (cooked in 1 tsp oil) + Vegetable Curry (1bowl) + vermicelli kheer (1bowl).

Bedtime (10:00-10:30 P.M.): Hot Milk (1glass).

Sample Menu Planning With Timings for Anaemia Adolescent Girl (13-18YRS)

Early morning (7:00 A.M.): Hot milk (200 ml) (1glass)+ Sugar (1tsp).

Breakfast (8:00-8:30 A.M.): Fenugreek parantha (2) with Chole Curry (1 bowl) /Bread slices with butter (2) / Idlis with (Coconut/Mint) chutney (4) / Vegetable upma (1cup) + Tea (with sugar).

Mid-morning (11:00-11:30 A.M.): Apple Shake (1glass).

Lunch (1:30-2:00 P.M.): Lemon Rice (1bowl) /Chapati (3) + Dal with butter (1small bowl)+ Green leafy vegetables (Spinach) (100gm) + Nabaratna (1bowl) /Potato vegetable curry (1bowl) + Fish/Mutton/Egg (cooked in Curry)(1) + Vegetables Salad (Onion/Carrot/Tomato) (1plate) + Sweet Curd (200 ml)

Snacks (5:00-5:30 P.M.): Bread Sandwich with Coriander chutney (3).

Dinner (9:00-9:30 P.M.): Spinach chapati (3)/ Cooked Rice (1bowl) +

Mixed Vegetable Curry (1bowl) + Plain Custard (Apple/Banana/Pomegranate/Grapes) (1bowl).

Bedtime (10:00-10:30 P.M.): Hot Milk (1glass).

Results & Discussion

Anaemia is a major public health concern in adolescent girls of age 10-19 years in the developing world. There is a paucity of data on anaemia among adolescents who were living in developing countries. The reasons for the high incidence of anaemia among the adolescent girls are: a) Increased iron requirements because of growth b) Menstrual loss c) Discrepancy between high iron need for haemoglobin formation and low intake of iron containing foods d) Erratic eating habits, dislike for foods which are rich in iron, like green leafy vegetables e) Iron absorption inhibitors in food: phytates/tannins. The following cut-off points which were suggested by the WHO were used to determine whether iron deficiency anaemia was a major problem among the general population.

After the completion of this study which was consist of 10 anaemic girls. Out of 10 girls, two were mildly anaemic, five were moderately anaemic and three were severely anaemic. The range of haemoglobin among the participants was 7-10.5g/dl. Here prevalence of moderate anaemia higher than mild and severe anaemia. After that, haemoglobin level slowly increases by taking of ironic diet chat.

Conclusion

Nutritional status of adolescent girls contributes to the nutritional status of the community. There is a need to initiate intervention measures to improve the nutritional status of adolescent girls who are the future 'mothers-to-be'. Hence, there is a need to create awareness among adolescents and their family about nutrition and health. The major factors associated with anaemia were menstruation, improper personal hygiene like hand washing before food intake and after toileting, worm infestation, improper foot wear usage and decreased intake of jaggery.

In this study, we can see that there are mild, moderate and severe anaemia patients. After that increasing the intake of iron food sources, haemoglobin level slowly increases. Those patients are suffering from mild, moderate and severe anaemia; that patients are going to the normal haemoglobin level.

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6
CHAPTER

Clinical Nutrition and Metabolism

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Abstract

Clinical nutrition examines how food and nutrients affect the body in health and disease, with metabolism at its core producing energy, repairing tissues and regulating bodily functions. Diet influences inflammation, blood sugar, hormone balance and even gene activity, making it essential in preventing and managing conditions like diabetes, heart disease, obesity, liver and digestive disorders, malnutrition and cancer. Foods rich in omega-3s, healthy fats, fiber and functional ingredients (e.g., nuts, soy, green tea) support heart health and reduce inflammation, while diets high in unhealthy fats, sugar and refined grains increase metabolic and cardiovascular risk. Obesity and metabolic syndrome can be managed through balanced eating, portion control, regular exercise and healthy lifestyle habits. In digestive, liver and cancer-related conditions, tailored nutrition helps meet increased nutrient needs, manage inflammation, maintain weight and improve recovery. Overall, nutrition is a cornerstone of health, disease prevention and clinical care.

Keywords: Epigenetics, malnutrition, protein-energy, Mediterranean diet, hypercholesterolemia, metabolic syndrome, inflammatory bowel disease, fatty liver, cancer, cachexia.

Introduction

Clinical Nutrition

According to Cederholm *et al*. (2016), as outlined in the ESPEN consensus statement, clinical nutrition is a field of medicine focused on identifying, preventing and managing both undernutrition and overnutrition. It deals with nutrient imbalances that can result from illness, inflammation or insufficient intake, as well as problems related to excessive nutrition, such as obesity. The discipline also addresses conditions often associated with malnutrition, including sarcopenia and frailty. By performing nutritional assessments and providing individualized dietary interventions and medical nutrition therapy, clinical nutrition aims to enhance overall health, aid recovery and reduce the likelihood of chronic disease.

Metabolism

According to National Institute of Health, Metabolism refers to the body's network of chemical processes that produce energy, support tissue formation and sustain essential functions. Nutrients from food supply the building blocks for growth, repair and daily activity, while enzymes regulate the breakdown and synthesis of these compounds. Factors such as age, gender, activity level, nutritional status and health conditions influence the body's baseline energy use, known as basal metabolic rate (BMR).

Link between Nutrition, Metabolism and Disease Outcomes

- **Metabolic Syndrome (MetS):** MetS involves abdominal fat, insulin resistance, high blood pressure and abnormal lipid levels. While genetics contribute, dietary habits strongly influence the condition through effects on inflammation, glucose regulation and fat metabolism.
- **Early-Life Nutrition:** Nutrition during pregnancy and infancy can shape long-term metabolic health. Inadequate fetal nutrition may increase the risk of obesity and insulin resistance later in life, whereas maternal overnutrition can predispose offspring to type 2 diabetes and cardiovascular disease.
- **Inflamation:** Metabolic problems can develop and worsen as a result of persistent, moderate inflammation. Inflammatory processes may be exacerbated by diets heavy in processed foods, added sweets and unhealthy fats. On the other hand, diets high in fiber, omega-3 fatty

acids and plant-based bioactive substances can support good digestive function and lessen inflammation.

- **Insulin Sensitivity:** Diet directly affects how the body responds to insulin. High-sugar or high-glycemic foods can impair insulin function, while magnesium, vitamin D, chromium, unsaturated fats and lean proteins help maintain insulin efficiency and support muscle and energy metabolism.
- **Epigenetic Regulation:** Some nutrients, like folate, vitamin B12, choline and methionine, can modify gene activity through DNA methylation, affecting metabolism. Early-life nutrition shapes long-term metabolic patterns and nutrigenomics aims to tailor diets based on genetic and epigenetic profiles.

Fundamentals of Human Metabolism

Carbohydrate Metabolism

Carbohydrates are the primary source of energy in human metabolism, with glucose giving quick fuel for cellular activities and glycogen serving as a readily available energy reserve. Recent studies highlight that the type of carbohydrates consumed is more important for health outcomes than their total amount. Diets high in refined carbohydrates and added sugars are closely linked to a higher incidence of obesity, reduced insulin sensitivity and a greater risk of type 2 diabetes mellitus. On the other hand, eating carbohydrates with a low glycaemic index helps achieve better glycaemic control and enhances cardiovascular health.

Essential nutritional elements like whole grains, dietary fiber and resistant starch are critical for maintaining a healthy diet as they help regulate blood glucose spikes after meals, increase feelings of fullness and promote the creation of short-chain fatty acids that benefit gut microbiota. Additionally, personal factors such as insulin sensitivity, body composition and levels of physical activity greatly influence carbohydrate metabolism by affecting how well glucose is absorbed and stored.

In medical settings, accurately adjusting carbohydrate intake is vital for managing diabetes and metabolic syndrome. Studies indicate that consuming whole grains can reduce glycated hemoglobin (HbA1c) levels and diminish the risk of cardiovascular disease. Therefore, carbohydrate metabolism includes not only established biochemical processes—such as glycolysis and glycogenolysis—but also wider components like dietary quality, glycaemic control and sustained metabolic health.

Protein Metabolism

Proteins are a vital macronutrient in the human diet. When consumed, dietary proteins are broken down into their basic amino acids, which are then carried through the bloodstream to different tissues and organs. These amino acids play essential roles in building muscle tissue, repairing cellular components and generating enzymes and hormones. Unlike fats and carbohydrates, the body does not have the ability to store proteins, which requires a constant intake through diet. During times of inadequate protein consumption or physiological stress, the body breaks down its own muscle proteins to free amino acids for metabolic functions.

Amino acid metabolism mainly occurs through two processes. First, amino acids are used to create new proteins and other biologically significant compounds. Second, when energy demands are high, amino acids are broken down: their amino groups are stripped and converted to urea in the liver, which is then eliminated by the kidneys, while the remaining carbon skeletons are redirected for gluconeogenesis, lipogenesis or oxidized for energy production.

The protein requirements vary with age, illness and levels of physical activity. Children in growth, pregnant individuals, athletes and those recovering from injuries or infections have higher protein needs. In medical care, adequate protein intake can help prevent muscle deterioration, enhance wound healing and aid in recovery from long-term illnesses. Insufficient protein can lead to an increased chance of weakness, susceptibility to infections and delayed recovery. Thus, the metabolism of proteins and amino acids involves not just the generation of energy but also the maintenance of structure, support for immune function and facilitation of recovery during both health and illness.

Lipid Metabolism

Lipids including fats, oils, cholesterol and phospholipids—serve as the body's primary energy storage. They deliver more than twice the energy per gram compared to carbohydrates, making them the most efficient and dense fuel for the body. Once digested, fats are split into fatty acids and glycerol, which are then recombined into triglycerides and transported in the blood by lipoproteins.

Once lipids are taken up by tissues, they enter various metabolic pathways. Within the mitochondria, fatty acids undergo beta-oxidation, resulting in the production of acetyl-CoA. Typically, this molecule drives the citric acid cycle to produce ATP. However, when carbohydrates are limited,

the liver transforms acetyl-CoA into ketone bodies, providing an alternative energy source for organs like the brain and muscles.

In addition to storing energy, lipids play several crucial roles. Cholesterol is essential for making steroid hormones and vitamin D, while phospholipids are fundamental components of cell membranes. Disruptions in lipid metabolism, such as elevated LDL cholesterol or triglycerides, are closely associated with heart disease. Consequently, nutrition guidelines advise reducing the intake of saturated and trans fats and choosing more unsaturated fats from foods like fish, nuts and plant oils.

Lipid metabolism plays a crucial role in conditions such as obesity, diabetes and metabolic syndrome. Consuming moderate quantities of beneficial fats can enhance insulin sensitivity, decrease inflammation and lower the risks associated with cardiovascular diseases. Thus, a comprehensive understanding of lipid metabolism is vital for creating nutritional plans that promote energy balance and long-term health.

Micronutrient in Metabolism

Micronutrients, including vitamins and minerals, are required in small amounts but are essential for proper metabolism and overall health. Unlike macronutrients, they do not provide energy directly but act as cofactors and coenzymes in biochemical reactions. Deficiencies can disrupt metabolic pathways and lead to health problems.

B-vitamins such as thiamine, riboflavin, niacin and pantothenic acid—play a vital role in the breakdown of carbohydrates, fats and proteins, helping the body extract and use energy efficiently through pathways like glycolysis, the citric acid cycle and oxidative phosphorylation. Similarly, minerals such as zinc and magnesium are important for maintaining enzyme stability and supporting reactions that transfer and store energy.

Micronutrients also function as antioxidants and signalling molecules. Vitamins C and E, along with selenium, protect cells from oxidative damage, while iron, copper and iodine are vital for oxygen transport, mitochondrial function and thyroid hormone production. Even minor deficiencies can reduce energy efficiency, impair growth and weaken immune response.

In clinical nutrition, monitoring and correcting micronutrient levels is important, especially for critically ill, elderly or patients on enteral or parenteral feeding. Targeted supplementation can restore metabolic balance and improve health outcomes.

Energy Balance and Hormone Regulation

Energy balance pertains to the correlation between the calories consumed from food and the energy used through metabolic processes, physical activity and bodily functions. When energy intake is equal to energy expenditure, body weight stays constant. A surplus in energy intake results in weight gain, whereas a deficit causes weight loss.

Hormones are crucial in maintaining this equilibrium. Insulin, which is released after eating, encourages the uptake and storage of glucose, while glucagon triggers the release of glucose from the liver stores during periods of fasting. Leptin, produced by fat tissue, informs the brain about fullness and decreases food consumption, whereas ghrelin, made by the stomach, initiates feelings of hunger. The interaction of these hormones enables the body to adjust to both short-term and long-term variations in energy availability.

Thyroid hormones, specifically T3 and T4, manage the basal metabolic rate by affecting mitochondrial function and the consumption of oxygen. Cortisol, known as a stress hormone, boosts glucose availability but may also encourage fat storage when its levels are persistently high. Growth hormone and catecholamine provide additional regulation over the metabolism of fat and glucose. Collectively, these hormonal signals work together to regulate how energy is stored, released and utilized across various tissues.

Disruptions in this system lead to obesity, metabolic syndrome and type 2 diabetes. For instance, resistance to leptin or insulin hinders normal feedback mechanisms, resulting in increased food consumption and decreased energy output. Thus, comprehending energy balance and hormonal regulation is essential for both preventive and therapeutic nutrition.

Clinical Nutrition in Health and Disease

Malnutrition

Types and Definitions

According to F.P Antia and Philip Abraham, Protein-energy malnutrition (PEM) is a broad term that includes different levels of insufficient nutrient consumption. At one end of the spectrum, marasmus occurs due to a lack of both protein and energy, resulting in significant weight loss and stunted growth, while kwashiorkor mainly stems from inadequate protein intake despite having relatively sufficient caloric intake. A mixed variant known as marasmic-kwashiorkor incorporates characteristics of both conditions.

Causes and Risk Factors

The origins of protein-energy malnutrition (PEM) are complex. The primary cause is insufficient protein or caloric intake linked to factors like poverty, food scarcity or diets lacking in quality. Other contributing factors include:

- Problems with digestion or absorption caused by gastrointestinal disorders.
- Increased physiological needs during periods of growth, pregnancy or recovery from illness or injury.
- Nutrient losses resulting from chronic diarrhoea or infections.
- Toxins such as aflatoxins, which may worsen liver dysfunction.
- Children are especially at risk due to their rapid growth needs, although PEM can also impact adults facing chronic illnesses or severe lack of resources.

Clinical Consequences and Outcomes

PEM presents with a variety of systemic impacts:

- **Growth failure** is the most significant aspect observed in children.
- **Gastrointestinal issues** include loss of appetite, diarrhoea and malabsorption resulting from compromised pancreatic enzyme activity and poor regeneration of the intestinal lining.
- **Oedema**, typically seen in kwashiorkor, is associated with low albumin levels and sodium retention.
- **Changes in hair** and skin may manifest as colour loss, fragile hair and patches of varying pigmentation on the skin.
- **Liver involvement** frequently causes fatty liver changes, which, in some cases, may advance to liver dysfunction and jaundice.
- **Deficiencies in micronutrients** (such as vitamin A, B-complex vitamins, zinc, iron, magnesium and potassium) exacerbate the clinical situation, leading to anaemia, visual problems and weakened immune responses.
- **Immune system** compromise causes suboptimal antibody and cellular responses, increasing vulnerability to infections.
- **Neurological and developmental repercussions i**nclude delays in intellectual development and reduced cognitive abilities in children.

Investigations

Laboratory results often indicate reduced serum proteins, particularly albumin, along with potential electrolyte imbalances (such as hypokalaemia, hypocalcemia and hypomagnesemia). Anaemia is frequently observed, typically presenting as normocytic or macrocytic. Imaging and biopsy can show signs of fatty liver changes. Key anthropometric measurements—weight-for-height, mid-arm circumference and triceps skinfold thickness—are crucial for diagnosis and monitoring at the population level.

Management Approaches

It is essential that treatment addresses both nutritional shortcomings and related complications:

- **Replenishing calories and protein** is vital, with energy requirements estimated at around 90–100 kcal/kg/day and protein comprising about 20% of the total caloric intake. Commonly available foods (such as pulses, skimmed milk and legumes) tend to be quite effective.
- **Micronutrient supplementation** is necessary and should include potassium, calcium, magnesium, zinc and multivitamins. Iron should be introduced cautiously and only after protein levels have improved, to avoid negative effects.
- **Infections** need to be quickly recognized and treated, as they significantly contribute to mortality rates.
- **Dietary management** focuses on interventions that are culturally suitable, cost-effective and sustainable, rather than on expensive proprietary products.
- It is advisable to **avoid intravenous feeding** unless absolutely necessary, as this can exacerbate fluid and electrolyte imbalances.

Outcome and Prognosis

The level of malnutrition, liver complications and the presence of concurrent infections play a significant role in mortality rates. With proper nutritional recovery and supportive treatment, a return to health is achievable; however, in cases of severe childhood protein-energy malnutrition, long-lasting physical and cognitive impairments may remain.

Undernutrition

According to F.P Antia and Philip Abraham, Undernutrition is still a significant public health issue, especially in low- and middle-income countries where poverty, food scarcity and lack of nutritional knowledge are common. In contrast to developed countries, where obesity is the main concern, people in tropical regions are more likely to be underweight due to inadequate food intake or ongoing health problems. Being underweight is not just an aesthetic concern; it is linked to a greater risk of infections, including tuberculosis, acute febrile illnesses and a higher overall mortality rate. Interestingly, certain groups, such as hill tribes, may have relatively low body weight yet exhibit robust physical endurance and stamina, indicating a possible adaptive physiological response.

Starvation and Metabolic Adaptations

Starvation can result from famine, lack of food or voluntary dietary restriction for weight loss. During extended periods of energy deficiency, fat tissue is utilized, followed by the breakdown of skeletal and cardiac muscles. The mucosa of the small intestine experiences atrophy, leading to reduced absorptive capabilities, while the glycogen stores in the liver get used up. The liver responds by producing glucose through gluconeogenesis, mainly from alanine, lactate and pyruvate. As starvation continues, the brain adjusts by using ketone bodies—especially β-hydroxybutyrate—as a substitute energy source. In a clinical setting, starvation is evident through symptoms such as bradycardia, low blood pressure, extreme weight loss, hair loss and reduced skin elasticity.

Pharmacological and Nutritional Interventions

Despite the widespread use of "tonics" and vitamin supplements aimed at increasing weight, research shows that they do not significantly enhance nutritional status unless paired with sufficient caloric intake. Various pharmacological approaches, including insulin therapy (which promotes appetite and gastrointestinal function), cyproheptadine (an antihistamine that stimulates appetite) and megestrol acetate (notably used for cachexia associated with AIDS), have been tested to facilitate weight gain. Nonetheless, their effectiveness is considered supplementary, with potential side effects restricting their long-term application.

Nutritional management is a fundamental aspect of treatment. It is advisable to gradually introduce a diet that is high in calories, protein and fats to avoid gastrointestinal issues. Energy intake should surpass baseline needs

by 500–700 kcal/day, with protein intake recommended to be more than 1.2 g/kg/day to promote tissue growth. Suitable food sources include grains, legumes, dairy products, peanuts, root crops, oils and nuts. Fats should be added later in the meal to prevent diminishing appetite, while fluids are better taken after meals to avoid early feelings of fullness.

Eating Disorder and Undernutrition

Eating disorders like anorexia nervosa and bulimia nervosa are significant contributors to undernutrition among adolescents and young adults, especially in affluent urban areas.

- **Anorexia nervosa** is marked by self-induced starvation stemming from a distorted perception of body image, often linked to psychosocial issues. Complications can include imbalances in electrolytes, severe infections and potentially fatal outcomes if left untreated.
- **Bulimia nervosa** is defined by episodes of binge eating followed by behaviors aimed at compensation, such as inducing vomiting, using laxatives or abusing diuretics.
- In contrast, **binge eating disorder** can lead to being overweight or obese, but it may initially manifest as nutritional deficiencies.

Managing eating disorders often necessitates hospitalization in critical situations organized meal planning, therapy and when appropriate, nutritional support through enteral or parenteral feeding.

Dietary Recommendations for Individuals with Low Body Weight

A well-structured meal plan should prioritize frequent consumption of calorie-dense foods such as cereals, legumes, dairy products, eggs, starchy vegetables, nuts, dried fruits, fats, sugars and traditional desserts. A moderate use of seasonings, pickles and fermented foods is encouraged to enhance flavor. It is advisable to engage in regular physical activity to stimulate appetite, while maintaining bowel regularity is crucial to prevent appetite loss due to constipation.

Diabetes Milletus

“According to F.P Antia and Philip Abraham, Diabetes mellitus is a chronic metabolic disorder characterized by persistently elevated blood sugar levels and disruptions in the metabolism of carbohydrates, proteins and fats. It occurs due to problems with either insulin secretion, insulin action or a

combination of both. Without proper management, it can result in serious long-term complications such as retinopathy, nephropathy, neuropathy, coronary artery disease and stroke. Among the various treatment options available, nutritional management remains a crucial component of care for both Type I and Type II diabetes."

Pathophysiology and Hormonal Role

The pancreas has specialized islet cells that manage glucose metabolism.

- **Insulin** allows glucose to enter cells, encourages the storage of glycogen, supports protein synthesis and promotes fat accumulation.
- **A lack of insulin** results in high blood sugar levels, reduced glycogen stores, the creation of ketone bodies and the breakdown of muscle tissue.
- **Glucagon**, produced by α-cells, functions as a physiological counter to insulin, activating glucose production during periods of fasting.

Etiological Factors

The onset of diabetes is affected by a combination of genetic and environmental influences.

- **Genetic factors are significant**, as the likelihood of developing the condition increases significantly if both parents have diabetes.
- **Obesity, especially abdominal obesity**, is a key risk factor for Type II diabetes.
- Certain **viral infections**, including mumps, coxsackie, measles and hepatitis, have been suggested as potential triggers in those who are vulnerable.

Diagnostic Criteria and Monitoring in Diabetes

Diagnostic Criteria

- The WHO advises administering a glucose load of 75 grams, whereas the USA National Diabetic Data Group recommends a 100-gram load.
- For non-diabetics, fasting glucose levels should be under 100 mg/dL and all post-load measurements should be below 180 mg/dL.
- During pregnancy, the WHO uses the same criteria, but women with impaired glucose tolerance should be regarded as having diabetes.

Table 1: Criteria for the diagnosis of diabetes and intermediate hyperglycaemia, WHO

	Fasting plasma mg/dl	**2 hours after glucose load mg/dl**
Diabetes	≥ 126	>200
Impaired glucose tolerance, IGT	126	140- 200
Impaired fasting glucose, IFG	110-125	<140
Normal	< 110	<140

Source: B Srilakshmi, 2024, Dietetics, New Age International Publisher, 414

Chemical and False Diabetes

- **Chemical diabetes** describes people who have normal fasting glucose levels but exhibit abnormal glucose tolerance without experiencing any symptoms.
- **False diabetes** can arise from extended periods of fasting, a deficiency in potassium or the use of specific medications (such as oral contraceptives, salicylates, thiazides and corticosteroids).

HbA1c as a Monitoring Tool

HbA1c indicates the average blood glucose levels over the past 2 to 3 months, as it is based on the permanent glycosylation of hemoglobin. Typically, a normal HbA1c falls between 6% and 8%, whereas individuals with poorly managed diabetes can exhibit levels as high as 17%. While HbA1c is not used for diagnosis, it plays a crucial role in monitoring long-term glucose control. Its limitations include the possibility of inaccurate results in cases of hemolytic anemia, hemoglobin disorders or elevated fetal hemoglobin levels**.**

Clinical Types (WHO Classification)

The WHO classification categorizes diabetes into several types:

- **Type I diabetes mellitus (insulin-dependent)** typically starts during childhood or adolescence, necessitates continuous insulin treatment and has a higher risk of ketosis.
- **Type II diabetes mellitus (non–insulin-dependent)** is prevalent among adults, closely linked to obesity and has a lower tendency for ketosis.

- **Secondary diabetes** can develop due to pancreatic diseases, endocrine issues or the long-term use of medications that induce diabetes.

Dietary Management – Key Principles

Nutritional therapy serves as the foundation of diabetes management, especially for overweight individuals with Type II diabetes, while also promoting effective management in Type I diabetes. The primary principles include:

- **Caloric consumption must be tailored to the individual:** it should be limited for those who are obese, sufficient for those with a healthy weight and increased for individuals who are underweight.
- **Carbohydrates should account for 50–60% of daily caloric intake**, focusing on complex carbohydrates and high-fiber options like legumes, pulses and whole grains.
- **Protein consumption should be around 1 g/kg of body weight**, making up 10–14% of total calories, to aid in tissue repair and maintain metabolic balance.
- **Fat consumption should be restricted to 20–25% of total daily calories**, focusing on unsaturated fats to promote heart health.
- **Foods that are low on the glycemic index (GI)**, including oats, apples and legumes, should be emphasized, as they help mitigate spikes in blood sugar levels after meals.
- **A diet rich in fiber (35–40 g per day)** helps to regulate blood sugar levels, increases feelings of fullness and lowers the risk of long-term complications.
- **The distribution of meals is important:** consuming 5–6 smaller meals throughout the day is better for preventing spikes in blood glucose after eating.

Additional Consideration

Regular engagement in physical exercise enhances insulin sensitivity and supports weight control. It's important to ensure sufficient intake of micronutrients, especially **B-complex vitamins** for nerve health and **vitamin A** for liver function. In moderation, artificial sweeteners can be safely incorporated to provide more dietary options. Lastly, ongoing tracking of blood sugar management through **HbA1c levels**, aiming for a target of less than 7%, is crucial for minimizing complications.

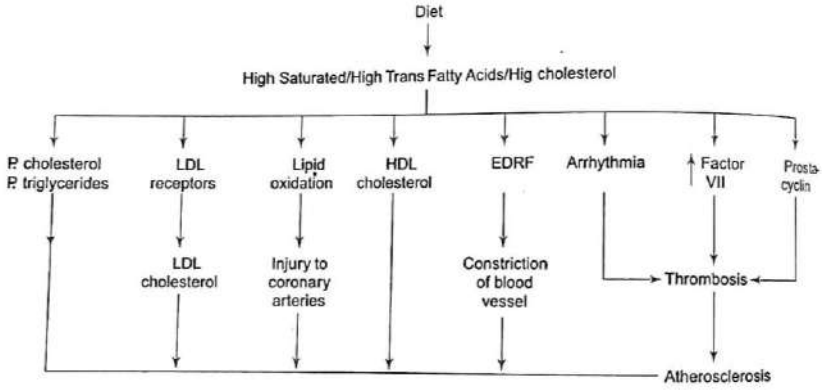
Cardiovascular Disease (CVD)

Heart disease continues to be a major contributor to global illness and mortality. Nevertheless, evidence shows that appropriate nutrition and lifestyle changes can greatly lower the risk and improve prognosis. Diet influences cholesterol, blood pressure, vessel health and inflammatory processes, all of which determine cardiovascular outcomes.

Fat and Fatty Acids

Omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) found in oily fish, provide strong protective benefits for the cardiovascular system. They improve the functioning of blood vessel linings and help to lower the resting heart rate. Their anti-inflammatory properties reduce the release of harmful mediators and decrease platelet stickiness. Regular intake lowers the likelihood of irregular heart rhythms and the development of atherosclerotic plaques. Plant-derived sources such as flaxseed, canola oil and walnuts supply alpha-linolenic acid, which is also beneficial but not as effective as marine-derived omega-3s.

Monounsaturated fatty acids, which are present in oils such as olive, almond and peanut, contribute positively to heart health. They help in lowering harmful low-density lipoprotein (LDL) cholesterol while maintaining beneficial high-density lipoprotein (HDL) cholesterol levels. In addition, they provide anti-inflammatory effects that protect blood vessels. In contrast, saturated fats from sources like butter, coconut oil and palm oil, along with industrially produced trans fats, are harmful because they elevate LDL cholesterol and accelerate the formation of arterial plaques which can lead to atherosclerosis. Dietary patterns such as the Mediterranean diet, which emphasize the use of monounsaturated fats along with fruits, vegetables, legumes and whole grains, have consistently demonstrated protective benefits against cardiovascular disease.



Source: B Srilakshmi, 2024, Dietetics, New Age International Publisher, 332

Fig. 1.

Carbohydrates, Fibre and Micronutrients

Carbohydrates should be chosen wisely, with focus on their quality rather than just their quantity.

- Diets high in refined sugars reduce HDL cholesterol and increase triglycerides.
- Complex carbohydrates and foods with a low glycemic index promote better blood sugar regulation and lipid balance.
- Soluble fibres such as oats, psyllium and pectin lower LDL cholesterol, improve blood pressure control and support overall heart function.
- It is advisable to consume at least twenty-five grams of dietary fibre daily from natural sources including fruits, vegetables, cereals and legumes.

Micronutrients and functional foods provide additional cardioprotective effects:

- **Niacin** is effective in improving lipid balance as it raises levels of high-density lipoprotein cholesterol and lowers triglycerides.
- **Vitamin C** strengthens blood vessels, while **vitamin E** helps protect low-density lipoprotein cholesterol from oxidative damage.
- **Selenium**, commonly present in foods like cereals and legumes, reduces oxidative stress and supports antioxidant defense.

- **Soy protein** has cholesterol-lowering effects and plays a role in maintaining the integrity of arterial walls.
- **Garlic** is known to reduce total cholesterol and triglycerides and it also decreases platelet aggregation.
- **Nuts** and **green tea** supply a variety of antioxidants that promote vascular health and reduce cardiovascular risk.
- Foods rich in **flavonoids**, such as turmeric, fenugreek, berries and green leafy vegetables, help lower inflammation and provide additional protection for the heart.

Nutrition in Specific Conditions

Post Myocardial Infarction

Start with small, soft and easily digestible meals served frequently to reduce strain on the heart. Avoid foods that are very hot or cold. Gradually increase calories based on body weight, blood sugar and cholesterol levels. Limit sodium to about two grams per day and reduce foods high in saturated fat and cholesterol. Include lean proteins, fish, fresh fruits and vegetables and low-fat dairy in the diet.

Hypertension

According to B Srilakshmi "Reduce sodium intake to two to three grams per day, lowering it gradually for better tolerance. Ensure sufficient intake of potassium, calcium and magnesium, as these minerals help control blood pressure. A daily protein intake of around sixty grams is generally recommended, with temporary adjustments if kidney function is affected. Focus on healthy fats, such as vegetable oils and omega-3 fatty acids. The DASH (Dietary Approaches to Stop Hypertension) diet, rich in fruits, vegetables, lean proteins and low-fat dairy, is especially beneficial."

Hypercholesterolemia

Limit foods high in saturated and trans fats. Replace them with healthier fat sources, such as nuts, seeds, olive oil and other plant-based oils. Individuals with familial hypercholesterolemia require stricter dietary management and often need medications to maintain healthy cholesterol levels.

Heart Failure

Sodium intake should generally be restricted to 1.5–2 grams per day. Fluid consumption may also need to be limited to 1.5–2 liters daily. Ensure

adequate calories and protein to prevent muscle loss. Regular monitoring of body weight can help detect early fluid retention.

Obesity and Metabolic Syndrome

"According to F.P Antia and Philip Abraham, Obesity is a condition marked by an excessive accumulation of body fat. Unlike carbohydrate and protein reserves, which are limited in the body, fat intake does not automatically trigger its breakdown. Over time, this imbalance—where fat consumption exceeds fat utilization—leads to obesity. Fat-rich foods are often overconsumed because they are highly palatable and energy-dense, providing a large amount of calories in relatively small portions."

Pathophysiology and Metabolic Alterations

The distribution of adipose tissue plays a critical role in disease risk. Visceral or upper-body obesity (abdominal, truncal fat) is strongly associated with insulin resistance, type 2 diabetes, dyslipidemia and cardiovascular disease. Peripheral or lower-body obesity (hips, thighs, buttocks) carries less metabolic risk but is associated with difficulty in weight reduction. The waist-to-hip ratio is often used to assess fat distribution, with higher values correlating with increased cardiometabolic risk.

Metabolic alterations in obesity include impaired insulin signaling, chronic low-grade inflammation, increased free fatty acid flux and altered hormone regulation involving leptin, adiponectin and ghrelin. These disturbances contribute to complications such as hypertension, dyslipidemia, sleep apnea, gallstone disease, osteoarthritis and various cancers.

Nutrition and Lifestyle Interventions

The primary approach to managing obesity involves reducing calorie intake while simultaneously increasing physical activity. Creating a moderate energy deficit of about 500–750 kcal per day, adjusted to an individual's needs, supports steady and maintainable weight reduction. Diets that focus on whole grains, fruits, vegetables, legumes and lean protein sources are recommended, as opposed to restrictive fad diets, which are often linked to repeated weight regain and unfavorable long-term results.

Macronutrient Adjustments Are Important:

- **Fat intake** should be limited, prioritizing unsaturated vegetable oils over saturated fats.

- **Protein** intake of around 1 g/kg body weight supports satiety and lean mass preservation.
- **Complex carbohydrates and dietary fiber** help regulate appetite and improve glycemic control.

Lifestyle modification is equally critical. Regular aerobic and resistance exercise enhances fat oxidation, preserves muscle mass and reduces cardiometabolic risk. Behavioral strategies — such as self-monitoring, portion control and reducing sedentary activities (e.g., television viewing) — improve adherence. Long-term weight maintenance requires ongoing reinforcement, as relapse and weight regain are common.

Pharmacological agents and bariatric surgery may be considered for severe or refractory cases, but these are adjuncts to, not replacements for, nutrition and lifestyle measures.

Metabolic Syndrome: Dietary Management

Metabolic syndrome refers to the concurrence of abdominal obesity, impaired insulin action, abnormal lipid levels and elevated blood pressure, all of which collectively heighten the likelihood of type 2 diabetes and cardiovascular complications.

Table 1: Diagnosis of metabolic syndrome

Risk factor		*Defining level*
Abdominal obesity		
	Men	> 102 cm
	Women	> 88 cm
Triglyceride		≥ 150 mg/dl
High density lipoprotein cholesterol		
	Men	< 42 mg/dl
	Women	< 50 mg/dl
Blood pressure		≥ 130/≥ 85 mm Hg
Fasting glucose		≥ 110 mg/dl

Source: B Srilakshmi, 2024, Dietetics, New Age International Publisher, 298

Dietary strategies are directed at reversing these metabolic alterations: Achieving even a modest weight reduction of 5–10% can significantly improve glucose regulation and lipid balance. Adopting a Mediterranean-style eating pattern—rich in monounsaturated fats, nuts, fish and plant-based fiber—has been shown to lower cardiometabolic risk. Selecting carbohydrates with a low glycemic index helps stabilize blood glucose and reduce postprandial spikes. Restricting sodium while ensuring sufficient intake of

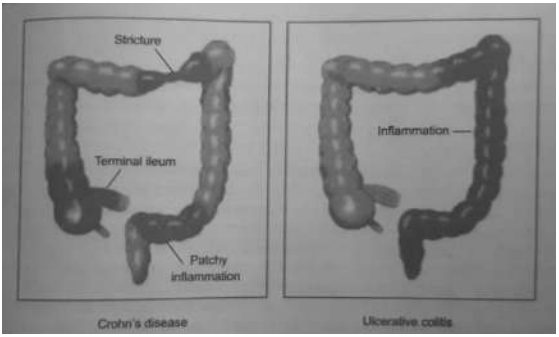
potassium, calcium and magnesium contributes to blood pressure and vascular health. Minimizing consumption of alcohol and processed foods curtails excess energy intake and improves overall metabolic function. In practice, the most sustainable management combines nutritional modification with regular physical activity and behavioral support, offering the greatest benefit for individuals with obesity and metabolic syndrome.

Nutrition in Gastrointestinal and Liver Disorder

Inflamatory Bowel Disease

Chronic Inflammation and Nutrient Absorption

Chronic intestinal inflammation in Crohn's disease and ulcerative colitis impairs the ability of the gut to absorb nutrients effectively. Damage to the mucosa, increased intestinal permeability, diarrhea and protein loss through the inflamed bowel contribute to poor nutritional status. At the same time, inflammation elevates metabolic needs, creating a mismatch between intake and requirement.



Source: B Srilakshmi, 2024, Dietetics, New Age International Publisher, 383.

Fig. 3

Key effects:

- Increased nutrient losses via diarrhea, bleeding and protein leakage.
- Higher energy and protein needs due to inflammatory stress.
- Reduced absorption efficiency because of mucosal damage.

Common Nutrient Deficiencies

Patients with IBD are vulnerable to several specific deficiencies, many of which worsen clinical outcomes if left uncorrected.

- **Protein–energy malnutrition**: caused by anorexia, malabsorption and increased catabolism.
- **Vitamin B12**: frequently deficient in Crohn's disease involving the ileum.
- **Folate**: reduced absorption or drug-related depletion (e.g., sulfasalazine).
- **Iron**: chronic blood loss leading to microcytic anemia.
- **Vitamin D and calcium**: low levels contributing to bone demineralization and osteoporosis risk.
- **Zinc**: losses through diarrhea; deficiency impairs healing and immunity.

Nutritional Role in Management

Nutrition is a cornerstone of supportive therapy in IBD, complementing medical treatment. The aim is to improve nutritional status, minimize symptoms and maintain remission.

- **Individualized diet plans**: tailored to disease location, symptom triggers and tolerance.
- **Enteral nutrition**: preferred in severe disease or malnutrition; maintains gut integrity and may reduce inflammation.
- **Avoidance of trigger foods**:
  - Low-fibre diet in cases of strictures or obstruction.
  - Limiting lactose, gluten or wheat if intolerance is suspected.
- **Supplementation**:
  - Iron, folate, B12, vitamin D, calcium and zinc as required.
  - Antioxidants and omega-3 fatty acids may support inflammation control.
- **Dietary strategies**:
  - Small, frequent meals are often better tolerated than large ones.
  - MCTs (medium-chain triglycerides) can be useful in fat malabsorption.
  - Probiotics may help in maintaining remission, especially in ulcerative colitis.

Fatty Liver

According to F.P Antia and Philip Abraham, Hepatic steatosis, commonly termed fatty liver, is a condition in which triglycerides accumulate abnormally within the liver tissue. Although minimal fat storage is normal, excessive deposition interferes with metabolism and, if prolonged, can progress to fibrosis or cirrhosis.

Causes

- **Nutritional factors**: Seen in malnourished or protein-deficient individuals (e.g., kwashiorkor).
- **Alcohol use**: Chronic alcohol consumption is a major cause, even in the absence of protein deficiency.
- **Metabolic and systemic conditions**: Diabetes mellitus, obesity, ulcerative colitis.
- **Medical interventions**: Long-term parenteral nutrition without adequate choline, massive small bowel resection, intestinal bypass surgery.
- **Pregnancy**: Acute fatty liver may occur, often mistaken for hepatitis.
- **Other associations**: Certain toxins, viral infections and rare metabolic disorders.

Pathogenesis and Mechanisms

- **Nutrient deficiencies**: Lack of lipotropic factors (methionine, choline) reduces fat export from the liver.
- **Protein deficiency**: Limits lipoprotein formation, impairing fat transport.
- **Alcohol**: Increases fat synthesis, reduces oxidation and mobilizes fatty acids to the liver.
- **Starvation or high-carbohydrate diets**: Promote fatty acid mobilization or synthesis.
- **Overall outcome**: Accumulated triglycerides lead to hepatocellular steatosis; recovery is possible if the underlying cause is removed.

Clinical Features

- Often **asymptomatic**, detected incidentally on imaging.

- In malnourished patients: ascites, leg edema, pallor, poor nutrition, fine skin scaling.
- Liver: enlarged, soft and palpable below the costal margin.
- Spleen: usually not enlarged.
- Laboratory: mild anemia, hypoalbuminemia, minimal changes in liver enzymes.
- Alcoholic fatty liver: usually less edema/ascites, better nutrition, but risk of progression to fibrosis/cirrhosis.

Pathology

- Gross: enlarged, smooth, soft liver.
- Microscopic: hepatocytes filled with fat; sometimes coalescing into cyst-like spaces.
- Reversibility: With adequate nutrition or alcohol abstinence, fatty changes resolve within weeks, although established fibrosis or cirrhosis persists.

Treatment and Nutritional Management

- **Energy**: 2000–2500 kcal/day depending on needs.
- **Protein**: 75–100 g/day from eggs, fish, meat, milk, pulses, legumes, groundnuts.
- **Fat**: About 60 g/day; restriction unnecessary if protein intake is adequate.
- **Micronutrients**: Iron, folate, vitamin B1 and multivitamin supplementation when indicated.
- **Alcohol abstinence**: Essential in alcoholic fatty liver.
- **Complications**: Diuretics (e.g., frusemide) for ascites.
- **Prognosis**: Usually reversible with dietary management and elimination of the causative factor, though progression to cirrhosis may occur if injury persists.

Special Situations

- **Reye's syndrome**: Acute fatty liver with encephalopathy, often following viral illness and aspirin intake in children; requires supportive care (glucose, fluids, electrolytes, vitamin K, frusemide for cerebral edema).

- **Fatty Liver in Pregnancy**: Acute fatty liver during late pregnancy can mimic viral hepatitis; early diagnosis and termination of pregnancy can be life-saving.

Cancer

Cancer is a broad term describing malignant growths that originate from abnormal cells. These cells lose normal regulatory control, enabling them to multiply uncontrollably, infiltrate nearby tissues and potentially spread to distant sites through metastasis. Unlike benign tumors that remain confined, malignancies disrupt organ structure and impair systemic function. The disease results from a gradual build-up of genetic mutations, often influenced by environmental and lifestyle factors, which alter normal processes such as cell division, DNA repair and programmed cell death

Etiology and Risk Factors:

The development of cancer is multifactorial, involving both **genetic** and **environmental influences** are

- **Genetic factors**: Family history can increase susceptibility, as inherited mutations in key regulatory genes (e.g., BRCA mutations in breast and ovarian cancers) lower the threshold for malignant transformation.
- **Environmental factors**: Exposure to ionizing radiation, carcinogenic chemicals (such as benzene, asbestos), tobacco smoke, alcohol and oncogenic viruses (HPV, hepatitis B) play a major role in cancer initiation.
- **Lifestyle influences**: Physical inactivity, stress, obesity and unhealthy dietary patterns further amplify risk.

Among all risk factors, **tobacco use remains the leading preventable cause of cancer**, accounting for a substantial share of oral, lung, esophageal and bladder cancers. Alcohol acts synergistically with tobacco, especially in cancers of the head and neck.

Dietary components increasing cancer risk:

- **Red and processed meats**: Associated with colon, gastric and prostate cancers, particularly when cooked at high temperatures (barbecuing, frying) which generates carcinogenic compounds.
- **High-fat diets**: Excess animal fat and omega-6 fatty acids are linked

with breast, colon and pancreatic cancers.

- **Sugars and refined starches**: Diets with a high glycemic index contribute to insulin resistance and increase risk of colon and breast cancers.
- **Alcohol**: Strongly linked with cancers of the liver oral cavity, pharynx, esophagus and breast.
- **Food contaminants**: Aflatoxins from moldy cereals and groundnuts, nitrosamines from processed meats and chemical preservatives can act as potent carcinogens.

Dietary elements that may support health:

- **Fruits and vegetables:** Packed with nutrients, fiber and natural compounds, they help protect cells from damage and reduce inflammation.
- **Whole grains and legumes:** Containing fiber and plant-based estrogen-like compounds, they can lower the likelihood of developing colorectal and breast cancers.
- **Omega-3 fats:** Present in fish, nuts and flaxseeds, these fats aid in controlling inflammation and promoting proper cell communication.
- **Key vitamins and minerals:** Nutrients such as vitamin C, vitamin E, folate, selenium and zinc are important for repairing DNA, strengthening immunity and minimizing oxidative stress.

Nutritional Consequences of Cancer and Its Therapy

Cancer and its treatments (surgery, chemotherapy, radiotherapy) often produce a wide range of metabolic and nutritional disturbances:

Cancer Cachexia

A complex metabolic syndrome seen in many cancer patients, characterized by involuntary weight loss, muscle wasting and loss of fat tissue, often despite adequate nutritional intake.

- **Mechanism:** Driven by tumor-induced inflammatory cytokines, altered metabolism, insulin resistance and protein-energy malnutrition.
- **Clinical impact:** Leads to reduced physical function, poorer tolerance to therapy and decreased survival.

- **Nutritional considerations:** Focus on maintaining lean body mass, providing adequate calories and protein and possibly using supplements like branched-chain amino acids or high-calorie liquid nutrition.

Metabolic changes:

- Increased gluconeogenesis, insulin resistance, higher fat oxidation and protein catabolism lead to negative nitrogen balance.

Treatment-related issues:

- Surgery can impair digestion and absorption, especially with gastrointestinal resections.
- Radiotherapy often causes mucositis, dysphagia, diarrhea or malabsorption.
- Chemotherapy is associated with nausea, vomiting, altered taste and reduced appetite.

Principles of Nutritional Management in Cancer

The goals of dietary intervention are to **maintain nutritional status, minimize treatment side effects and improve quality of life**.

Key dietary guidelines include:

- Provide **high-energy, nutrient-dense meals** to meet increased metabolic demands.
- Ensure **adequate protein intake** (1.5–2.5 g/kg/day in catabolic states) to prevent muscle wasting.
- Incorporate **frequent, small meals** that are easy to digest and appealing in flavor and aroma.
- Emphasize **fruits, vegetables, whole grains, legumes, milk and fish**, while limiting refined sugars, red meats and processed foods.
- Use **medium-chain triglycerides** (MCTs) when fat absorption is impaired.
- Encourage **hydration** to prevent dehydration and aid in toxin elimination.
- Consider **oral supplements, enteral nutrition or parenteral feeding** if oral intake is insufficient.

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7
CHAPTER

Public Health Nutrition

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Abstract

Public health nutrition is critical role in promoting health and preventing disease by addressing nutritional needs at the population level. This chapter comprehensively covers major health concerns and nutritional challenges, especially those prevalent in India, while examining the essential functions of public health in this context. It highlights community-based nutrition programs designed to combat malnutrition and related diseases, describes methods of nutritional assessment and discusses the impactful roles of national and international agencies in advancing nutrition goals. Emphasizing the importance of nutrition education, the chapter effectively integrates theory with practical applications, providing valuable insights to improve public health outcomes and address nutrition-related challenges at both community and national levels.

Keywords: Public health, malnutrition, nutrition education, assessment method and protein energy malnutrition.

Introduction

Nutrition

According to "B. Sri Lakshmi", it is the science of foods, the nutrients and other substances therein, their action, interaction and balance in

relationship to health and disease; the processes by which the organism ingests, digests, absorbs, transports and utilizes nutrients and disposes the end products. In addition, nutrition is concerned with social, economic, cultural and psychological implications of food and eating. In short, nutrition science is the area of knowledge regarding food's role in maintaining health. Good nutrition is the foundation of health.

Health:

Health is defined by the **World Health Organisation** as the "state of complete physical, mental and social well-being and not merely the absence of disease and infirmity".

Public Health Nutrition

"Barrie M. Margetts" States that public health nutrition promotes good nutrition and prevents diet - related diseases across populations. It uses science, epidemiology and health promotion to support overall well-being. Public health is society's effort to prevent illness and improve health for everyone.

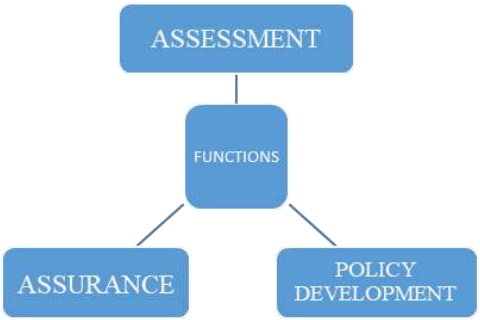
Significance of Public Health Nutrition

- It evaluates food systems, meals, nutrients and their interaction with social and environmental factors.
- The first international congress of public health nutrition (Barcelona, 2006) highlighted the role of nutrition in promoting population health and well-being.
- A population-based approachs requires public awareness, education and strong nutrition policies.
- Public awareness plays a vital role in improving dietary habits and preventing diseases like diabetes and cardiovascular disorders.
- It aims to protect and improve the health of people and communities through various strategies, such as promoting health behaviors, preventing and controlling diseases, conducting research and influencing policies.
- Public health is especially valuable in a country like India, which faces a double burden of communicable and non-communicable diseases, health disparities and challenges.

Major Issues of Public Health

- Public health deals with a various range of problems such as infectious diseases, chronic diseases, environmental health hazards and mental health disorders.
- It involves health and hygiene practices that prevent the spread of diseases and infections and promote a clean and healthy environment.
- It also addresses various public health issues, such as health disparities and inequities, health communication and education.

Core Functions of Public Health



Assessment

- It is defined as collecting and analysing information about health problems.
- Public health professionals study health conditions, risks and resources in communities.
- As cited by the Centres for Disease Control and Prevention, the essential services of this function are to:
    1. Monitor environmental and health status, to further identify and resolve health problems.
    2. Identify and investigate environmental health problems and health hazards in communities.

Policy Development

- It will start after gathering health information from the assessment.
- It involves the process of information sharing, consulting and involving citizens in decision making.

- The essential functions of public health policy developers are to
    1. Inform, educate and empower people about environmental health issues.
    2. Mobilise community partnerships and actions to identify and solve health problems.
    3. Develop policies that support individual and community environmental health efforts.

Assurance

- The third core function of public health is assurance; it means that communities are healthy and protected.
- It is also involved in the promotion and protection of public health through dedicated programs, events, campaigns and other strategies to safeguard health and wellness across populations.
- The essential functions of assurance are
    1. Enforces policies that protect environmental health and ensure safety.
    2. Assure a competent environmental health workforce to help communities.
    3. Evaluate the effectiveness, accessibility and quality of health services.

Nutritional Problems in India

Protein energy malnutrition (PEM), vitamin A deficiency (VAD), IDA and IDDs and B complex deficiencies are the most common nutritional problems in India.

Protein Energy Malnutrition

Protein energy malnutrition is an important nutritional problem affecting infants and children. Severe protein-energy malnutrition affects not only physical growth but also mental development. The most important characteristic of protein energy malnutrition is underweighted for age. The primary cause of protein-energy malnutrition is inadequate intake of food due to poverty. Infections like diarrhea, respiratory disease, measles and worm infestations often precipitate PEM. Integrated Child Development Services (ICDS) scheme of the Government of India and the Tamil Nadu Integrated Nutrition Project are being implemented with the aim to control PEM.

Vitamin A Deficiency

Vitamin A Deficiency is one of the highest in the world especially among preschool children. Clinically this may manifest as the earliest Conjunctival Xerosis to the most severe from Keratomalacia. The Primary cause of Vitamin A Deficiency is inadequate intake of vitamin A rich foods such as milk, eggs and vegetables containing β-carotene. Vitamin A Deficiency is often seen in PEM cases.

Nutritional Anemia

Anemia can arise due to deficiency of different kinds of nutrients. The most common nutrition deficiency for anemia in India is iron. Anemia is caused due to inadequate intake of iron containing foods in our habitual diets. Rural people are found to suffer from anemia more than urban. Anemia impairs cellular immunity, causes significant morbidity and mortality in pregnancy and also affects the working capacity. In children, anemia is found to affect their scholastic performance.

Deficiency of B-Group Vitamins

Rice and wheat are the staples of many populations of the world. Processes such as excessive refining and polishing of cereals remove considerable proportions of B-group vitamins from these cereals. Cereal food used in emergency situations are not fortified with micronutrients. Pregnant and lactating women, infants and children are at high risk of developing deficiency.

Community Nutrition Programs

Balwadi Nutrition Program

- The Balwadi nutrition program was started in the year 1970-1971.
- Under this program, food supplement will provide 300kcal of energy and 10g of protein per child is being supplied to children in the age group of 3-5 years through balwadies established in rural areas for 270 days in a year.
- The Department of Social Welfare is responsible for the implementation of the program.
- In this program children will get pre-primary education.

Mid-Day Meal Program for School Children

Fig. 1.1

- It comes under the Ministry of Human Resource development.
- Started on 15th August 1995 on the recommendation of the National School Health Committee.
- The Government of India pays 40% of expenditure and 60% is borne by the states. It covers all children up to the age of 15 years.
- It is world's largest school feeding programme.
- Provides free mid-day meal for 200 days/year.
- Government of India supplies: 100g of wheat/rice, 15g dal, 1g oil and 20 paise worth of vegetables.
- Meals based on cereals, pulses, leafy vegetables; eggs given thrice a week.
- It aims to improve nutrition, reduce deficiencies and promote weight gain.
- A variety of meals includes khichdi, rice-sambar and roti-vegetables.
- Some states are making this mid-day meal better by contributing their own funds to this programme.

Tamil Nadu Integrated Nutrition Project

The Tamil Nadu Integrated Nutrition Project was started in 1980 by targeting 6-36 months old children and pregnant and lactating women.

Objectives

- To reduce malnutrition among children under 4 years of age.

- To reduce Vitamin A Deficiency in children under 5 years old.
- To reduce anemia in pregnant women.

Components

1. Nutrition services.
2. Health services.
3. Communication.
4. Monitoring and evaluation.

Under this scheme, the children who failed to gain weight will receive supplementary feeding and pregnant women also receive supplements. Health services are also provided to antenatal women and children in collaboration with primary health care and subcenters.

Integrated Child Development Services Scheme

This scheme was launched on 2nd October, 1975. The primary responsibility for the implementation of the program is with the Department of Women and Child Development, Ministry of Human Resources Development at the centre and the nodal departments at the state, which may be social welfare, rural development and Women and Child Development.

Beneficiaries

Children below 6 years, pregnant and lactating women, women in the age group of 15-44 years and adolescent girls in selected blocks are the beneficiaries.

Objectives

1. Improving the nutrition and health status of the children in the age group of 0-6 years.
2. Laying the foundation for proper psychological, physical and social development of the child.
3. Enhancing the capability of the mother to look after the normal health and nutrition needs through proper nutrition and health education.

The package of services provided:

- Supplementary foods, Vitamin A, iron and folic acid tablets.
- Frequent health checkups
- Nutrition and health education for women.

An Anganwadi worker is the key person who is responsible for all the activities of the centre.

Assessment of Nutritional Status

Definition

The nutritional assessment is a systematic process in which the state of nutrition and health of an individual or a group of individuals is determined.

Objectives of Nutritional Assessment

- To find out the severity of malnutrition and where it occurs.
- To recognise people or groups who are at risk of poor nutrition.
- To study the different environmental and social factors causing malnutrition.
- To plan suitable actions or health programs to solve the problem.
- To give clear evidence about the malnutrition to authorities so they understand its seriousness.
- To check how well nutrition programs are working.

Methods of Nutritional Assessment

There are two types of methods.

1. **Direct method**
   - Anthropometry
   - Biochemical and laboratory estimation
   - Clinical examination
   - Diet survey
2. **Indirect method**
   - Vital statistics.
   - Ecological factors assessment.

Anthropometry

Height, weight, skin fold thickness and midarm circumference of people in general and children in particular indicate their nutritional status. Anthropometric measurements can help in the assessment of sub clinical forms of malnutrition and has been recognized as a reliable tool to identify at-risk groups.

Common anthropometric measurements

- Body mass
- Linear dimension
- Body composition and reserves of energy and protein

Circumference of head and chest is also included in some surveys covering children under five. For adiposity assessment, waist and hip circumference are also used along with the fat fold thickness measurement.

Biochemical Assessment

Tests like hemoglobin estimation, serum levels of albumin, proteins and vitamins are useful to detect subclinical deficiency early, before they become clinical.

Limitations of Biochemical Assessment

1. The tests are time-consuming and expensive.
2. They cannot be applied to a large group of population.
3. Most biochemical tests reveal the current nutritional status only and are useful to identify mild deficiency.

Clinical Assessment

It is a simple and practical method of assessing the nutritional status of groups of individuals. Clinical signs associated with specific nutrient deficiency, such as angular stomatitis in riboflavin deficiency, conjunctival xerosis in VAD, etc., are looked for and assessed. Head to foot is examined for deficiency features in clinical examinations.

Diet Survey

It is a vital part in determining the health and nutritional status of an individual. The dietary habits of individuals, families or communities vary according to the socio-economic factors and regional cultural factors. So, a diet survey provides a record of person's food habits and food intake and can thus help to identify possible nutritional imbalance in a community.

Purpose of the diet survey

- Diet survey is a systematic enquiry into the food supplies and food consumption of individuals and population groups is made through this method of nutritional assessment.
- Diet assessment is also an important aspect of the survey of the nutritional status of population group.

- It is an important part of nutritional assessment, but it cannot be used alone to make a diagnosis of nutritional health.
- The methods used in their instance must be appropriate for the purpose intended.

  There are three methods by which diet consumption pattern can be assessed

1. Weighment of Raw Foods

This is considered as the most practical and commonly used technique. The raw food items that are to be cooked in a household for a given day are carefully weighed. The total amount is then divided by the number of family members, including any guests, to calculate the average per capita consumption. Ideally, such surveys should be carried out for 21 consecutive days; however, in practice, they are often limited to 7 days. The National Institute of Nutrition (NIN), Hyderabad, for routine purposes, generally conducts surveys for 3 consecutive days.

2. Weighment of Cooked Foods

This method is regarded as more accurate since it involves weighing foods after cooking. However, it is not widely adopted because many individuals are reluctant to allow their cooked foods to be weighed.

3. Oral Questionnaire Method

This method is especially useful for large-scale diet surveys. Respondents are asked to recall and provide information about the food consumed during the previous 24 hours. When conducted systematically and with care, this method can yield fairly reliable results.

Indirect Methods

1. Vital Statistics

Morbidity and mortality statistics may also indirectly indicate the nutritional status of populations.

2. Assessment of Ecological Factors

To evaluate the nutritional status of a population, it is essential to study various ecological factors. These include details on food production, per capita availability of food, family size and occupational patterns. In addition, customs and cultural practices that influence nutrition, the healthcare facilities accessible in the community and the prevalence of infections and worm

infestations are also significant considerations. Together, these factors provide a clear understanding of the influences on the nutrition and health of the people.

Agencies and Organizations to Combat Malnutrition

Agencies are organizations established to delivered specific services, often involving professionals from diverse fields who work together on community-oriented projects. Their activities commonly focus on health, nutrition and the overall development of communities at local, national and global levels. Such organizations are collectively known as health agencies.

Based on their authority and scope of services, health agencies can be broadly classified into the following categories:

- International agencies.
- National agencies.

International Agencies

World Health Organization

Origin:

In April 1945, at the conference of United Nations at San Fransico, the Brazil and China proposed that an international organization should be established.

In 1946, a constitution was drafted by "technical preparatory committee" under the chairmanship of Rene Sand. The constitution came into force 7th April 1948 which is celebrated every year as World Health Day. The theme for "World Health Day" is chosen every year to focus attention on a specific aspect of public health.

Objectives of Who:

- Act as directing and co – ordinating authority on international health activities.
- Promote medical research and improve the under developed countries.
- Bring the health status to international level.
- Collaborate the member states and other agencies in planning and carrying one health programs.

Head Quarters

The headquarters of WHO is at Geneva, Switzerland.

Organization

The WHO is unique among the United Nations Specialized Agencies in the specialty that, WHO has its:

- Own constitution.
- Own governing bodies.
- Own membership.
- Own budget.

Functions of Who

- WHO works in collaboration with specialists, volunteer groups, policy makers and government bodies to establish and maintain global standards.
- It prioritizes continuous research and ensures that scientific advancements are utilized for the benefit of public health.
- One of its major responsibilities is to set international standards for the formulation, control and implementation of global health policies and programs.

Food and Agricultural Organization

It was established in 1945. It is one of the largest specialized agencies within the United Nations System. Its primary mandate is to enhance nutrition levels and living standards by improving agricultural productivity and the conditions of rural populations.

Aims

- To help nations raise living standard.
- To improve nutrition of the people of all countries.
- To increase the efficiency of farming, forestry, fishes.
- To improve the condition of rural people.
- To widen the opportunity of all people for productive work.

Functions

- Promotion of scientific, technological, social and economic research related to nutrition, food and agriculture at the national and international level.

- Conservation of natural resources and adoption of improved methods in the cultivation and production of agricultural goods.
- Development of international policies addressing agricultural commodity arrangements.
- Provision of technical assistance to governments upon request in matters related to food, nutrition and agriculture.

United Nations Children's Fund

UNICEF is a United Nations agency responsible for promoting and protecting children worldwide. It was established in 1946 to provide emergency food and healthcare to children in countries.

Headquarters

The headquarters of UNICEF is in New York City, United States. It acts as the organisation's worldwide operations hub, including programme development, fundraising and collaboration with partners and stakeholders.

Functions of UNICEF

- Providing immunisations and disease prevention.
- Treating children and mothers with HIV.
- It improves childhood and maternal nutrition.
- It supports child health and nutrition.
- It creates safe and inclusive environments for children with disabilities.
- It gives quality education and skill-building.

National Agencies

Indian Council of Medical Research (ICMR)

Established in 1911 and headquartered in New Delhi, ICMR is among the oldest biomedical research organizations worldwide. Its primary focus is to advance biomedical research in India.

Objectives of ICMR

- Promote research activities.
- Develop health-related policies.
- Monitor and control diseases.
- Facilitate capacity building and training.
- Ensure standardization and maintain quality assurance.

Functions of ICMR

- Prioritizes control of communicable diseases.
- Emphasizes fertility regulation as a crucial health area.
- Focuses on improving maternal and child health.
- Pays significant attention to controlling nutritional disorders.
- Supports research on communicable diseases including cancer, cardiovascular diseases, diabetes and metabolic disorders.
- Advances drug research, including studies on traditional medicines.
- Promotes extramural research through centers for advanced investigations.

Indian Council of Agricultural Research (ICAR)

ICAR operates autonomously under the Department of Agricultural Research and Education, Ministry of Agriculture, Government of India. It is pivotal in developing agricultural technologies and scientific expertise to achieve food self-reliance.

Origin

Originally established on 16th July 1929 as the Imperial Council of Agricultural Research under the Societies Regulation Act, 1860, following the Royal Commission on Agriculture report.

Objectives

- Promote and coordinate education and research in agriculture, agroforestry, animal husbandry, fisheries, home science and allied disciplines.
- Serve as the central agency for collection, publication and dissemination of research and information, fostering technology transfer.
- Provide consultancy in education, research, training and information dissemination related to agriculture and allied sectors.
- Address rural development including post-harvest technology through collaborative programs with organizations such as the Indian Council of Social Science Research and the Bhaba Atomic Research Centre.
- Take necessary measures for achieving society objectives effectively.

Functions of ICAR

ICAR works through eight subject matter divisions:

- Crop Science
- Horticulture
- Soil Agronomy and Agroforestry
- Agricultural Engineering
- Fisheries
- Animal Sciences
- Agricultural Extension
- Agricultural Education

Council of Scientific and Industrial Research (CSIR)

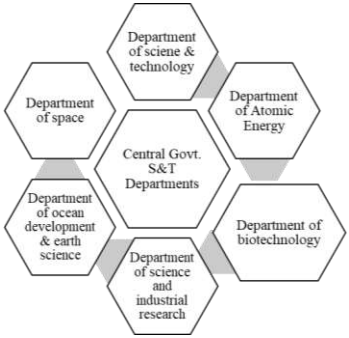
Founded in 1942, CSIR is one of India's largest and most respected R&D organizations, fostering innovation to support industrial growth and enhance scientific research.

Mission and Objectives of CSIR

- Provide scientific and industrial research and development maximizing economic, environmental and societal benefits.
- Promote trans-disciplinary research and development of advanced technologies.

Organization Structure

- Comprises 37 laboratories and 39 field stations/extension centers across India.
- Employs thousands of scientists, researchers and technical personnel.



Source: Textbook of Community Nutrition Dr. Suryatapa Das

Functions of CSIR

1. Provide indigenous technologies, consultancy, computational support and documentation.
2. Generates revenue through sponsored projects, consultancy and licensing to industries.
3. Supports decentralized employment, conserving energy through improved techniques.
4. Offers fellowships, emeritus scientist programs and manages multiple research schemes.
5. Publishes several scientific periodicals and journals in multiple languages, covering major scientific fields.

National Institute of Nutrition (NIN)

Establishment & History

Founded in 1918 by Sir Robert McCarrison as the Beri-Beri Enquiry Unit at the Pasteur Institute, Coonoor, it evolved into the Nutrition Research Laboratories in 1928 and was renamed National Institute of Nutrition in 1969, relocating to Hyderabad in 1958.

Vision

To eradicate all forms of malnutrition in India through healthy, sustainable and eco-friendly diets and lifestyles.

Objectives

1. Identify dietary and nutritional problems across populations.
2. Continuously monitor the nutritional status of the nation.
3. Develop strategies for prevention and treatment of nutritional disorders.
4. Conduct operational research supporting national nutrition programs.
5. Integrate nutrition research with broader health initiatives.
6. Promote human resource development in nutrition.
7. Disseminate nutrition-related information.
8. Advise governments and organizations on nutrition issues.

Functions & Activities

- Conduct research on dietary patterns, nutrient intake, maternal and

child nutrition, non-communicable diseases, environmental toxins and nutrient-immune interactions.

- Develop and issue RDAs, dietary guidelines and condition-specific diet recommendations.
- Influence and support national nutrition programs like ICDS, Mid-Day Meal Scheme and micronutrient supplementation protocols.
- Generate public awareness through campaigns, e-learning, mobile applications and outreach programs focusing on balanced diets and disease prevention.
- Facilitate human resource development through postgraduate and specialized training programs.
- Provide rapid technical support during health emergencies such as disease outbreaks and nutritional crises.

Central Food Technological Research Institute (CFTRI)

CFTRI, located in Mysore, is a constituent of CSIR laboratory established in 1950 focused on food science and technology research.

Aims and Objectives

- Develop low-cost and eco-friendly food technologies using indigenous raw materials.
- Emphasize integrated food technology, safety, health and nutrition for diverse populations.
- Generate and apply scientific knowledge for optimizing national food resource use.
- Integrate scientific advances into traditional food systems considering local contexts.
- Add value to agro-resources through R&D for sustainable food security.
- Promote development of the food industry through interdisciplinary innovation.
- Set national food quality standards.
- Maintain leadership in strategic research and technology development.
- Optimize food supply chains to benefit cultivators and consumers at affordable costs.

- Foster multi-level human resource development.
- Continuously develop new knowledge to address emerging challenges and emergencies.

Headquarters and Regional Centres

Headquartered in Mysore, Karnataka, with regional centers at Bombay, Hyderabad, Lucknow, Ludhiana, Mangalore and Nagpur.

Activities

CFTRI operates 15 R&D divisions excelling in food science and technology, offering technical assistance, technology transfer, quality certification and manpower training.

Human Resource Development & Education

Offers a two-year M.Sc. in Food Technology affiliated with the University of Mysore and publishes a range of scholarly and reference materials.

Definition of Nutrition Education:

Nutrition education refers to a set of communication efforts designed to encourage voluntary modifications in behaviors that influence the nutritional health of a community. The ultimate aim is to enhance the nutritional well-being of the population.

Importance of Nutrition Education:

- Nutrition education improves understanding and corrects misconceptions about nutrition.
- It plays a crucial role in controlling malnutrition.
- It conveys preventive measures against diseases related to overnutrition, such as obesity, cancer, heart disease, diabetes and hypertension.
- It helps identify and address the prevalent nutritional disorders within communities using scientific and organized methods.
- It assists policymakers in creating programs related to agriculture, rural development and education.
- It motivates and guides people toward adopting healthier habits concerning food, nutrition and hygiene.

Thus, nutrition education is recognized as a vital tool for the advancement of maternal and child nutrition care.

Objectives of Nutrition Education:

- To encourage changes in dietary habits that promote nutritional health.
- To emphasize factors hindering food consumption and nutrient utilization.
- To facilitate the distribution of vitamin and mineral supplements from national and international organizations.
- To provide education to mothers visiting maternal and child health centers.
- To promote and protect breastfeeding and guide the introduction of supplementary and weaning foods.
- To teach about food hygiene, sanitation and the use of locally available foods.
- To educate about family planning and birth spacing methods.

Principles of Conducting Nutrition Education:

1. Begin by observing and questioning to understand cultural, dietary habits and available foods.
2. Introduce new dietary ideas gradually, aligning them with local culture.
3. Demonstrate the importance of good nutrition, for example, in child growth and academic performance.
4. Use local language for effective communication.
5. Prioritize teaching with original, especially home-based, food products.
6. Employ diverse educational tools such as posters, flashcards, puppet shows, role plays and dramas.
7. Encourage questions and discussions; allow sharing of successful experiences.
8. Connect nutrition education to maternal and child health and other health education activities.
9. Avoid recommending foods or practices that are not feasible or affordable for the community.
10. Follow up to ensure positive changes in food habits, using feedback to adapt teaching methods.

Opportunities for Conducting Nutrition Education:

- Visiting families directly.
- Organizing nutrition education sessions for various groups.
- Conducting programs in schools linked to mid-day meal initiatives.
- Health workers educating at Balwadi and Anganwadi centers.
- Teaching mothers in nutrition rehabilitation centers about better child feeding practices.

Steps for Planning Nutrition Education:

Source: Textbook of Community Nutrition Dr Suryatapa Das

1. Identification of the Problem to be tackled:

Analyze the community situation by asking:

- What is the community's age and gender distribution?
- What are the morbidity and mortality rates?
- Which illnesses are common and what causes them?
- How do behaviors influence disease spread?
- Who are the most vulnerable groups and priority targets for education?
- What health facilities exist?
- Who influences health and nutrition decisions (e.g., traditional healers, religious leaders)?

2. Discussion with Community Members:

Assess knowledge, attitudes and practices. Identify key influencers and target groups for behavior change.

3. Assessment of Resources:

Evaluate available resources such as funds, time, manpower (including local health guides, teachers, Anganwadi workers) and facilities.

4. Establishment of Nutrition Education Objectives:

Set clear, actionable educational goals. Plan where and how the program will be delivered, expected achievements and reach.

5. Development of a Detailed Action Plan:

Define the communication content, target audience, educational channels (hospitals, schools, clubs, exhibitions, group discussions) and methods/tools to be used.

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8
CHAPTER

Food Safety and Hygiene

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Abstract

Ensuring food safety and maintaining proper hygiene are essential for protecting public health and guaranteeing that the food consumed is nutritious, safe and free from harmful contaminants. The food supply chain faces numerous risks, including biological, chemical and physical hazards, which can lead to foodborne illnesses if not properly managed. Implementing systematic safety measures, such as Good Hygiene Practices (GHP), Sanitation Standard Operating Procedures (SSOPs) and Hazard Analysis and Critical Control Points (HACCP), is critical for preventing contamination throughout all stages of food production and handling. Key aspects of these measures include safe food handling, preventing cross-contamination, maintaining appropriate storage and cooking temperatures and ensuring that all equipment and surfaces are thoroughly cleaned and sanitized. Providing proper training and guidance to food handlers significantly improves their knowledge and encourages safe food handling practices, reducing the likelihood of foodborne outbreaks. Public health strategies, such as routine inspections and educational campaigns, are especially important for protecting high-risk groups, including children, the elderly, pregnant women and immunocompromised individuals. Enhancing hygiene practices through ongoing training, sufficient resources and promoting a strong culture of food

safety helps ensure compliance with safety standards. Regular monitoring and adherence to regulatory requirements maintain the quality and safety of food products. Together, these measures strengthen consumer confidence, safeguard public health and support a reliable and resilient food system. Food safety management is therefore not only a regulatory obligation but also a societal responsibility that protects communities from preventable illnesses.

Keywords: Food Safety, Hygiene Practices, Foodborne Illness, Good Hygiene Practices (GHP), Sanitation Standard Operating Procedures (SSOPs), Hazard Analysis and Critical Control Points (HACCP), Cross-Contamination Prevention, Food Handler Training, Public Health

Introduction

Food safety and hygiene are essential to ensure that food remains safe, nutritious and free from harmful pathogens. Contaminated food may carry biological, chemical or physical hazards, leading to foodborne diseases and posing serious public health risks. Hygiene measures are required at every stage of the food supply chain, including production, storage, processing, transportation and handling. Following Good Hygiene Practices (GHP), such as proper sanitation of equipment and maintaining personal hygiene of food handlers, is critical to prevent contamination. Potential food safety hazards can be systematically identified, evaluated and managed through the implementation of Hazard Analysis and Critical Control Points (**HACCP**). Sanitation Standard Operating Procedures (**SSOPs**) play a key role in maintaining clean and safe food processing environments. Ensuring food safety also involves proper control of temperature, preventing cross-contamination and providing access to safe water. Educating food handlers and conducting awareness programs significantly reduce the risk of foodborne diseases. Effective management of food safety not only protects public health but also enhances consumer trust. Many instances of food contamination are still linked to insufficient knowledge and unsafe practices among food handlers. Continuous monitoring, adherence to safety regulations and regular training are essential to minimize potential food hazards.

Food Chain Risks:

The food supply chain is prone to a variety of hazards that threaten food safety and human health. Usually, these risks fall into one of three primary categories: physical, chemical or biological.

Biological Hazards

Microorganisms that might cause foodborne illnesses, including bacteria, viruses and parasites, are known as biological hazards. From production to consumption, contamination may occur at any point in the food chain. For example, raw meat and poultry items are frequently caused by diseases such as Salmonella, Campylobacter and E. coli. If the food is stored improperly, these germs can multiply and cause foodborne illness outbreaks.

Chemical Hazards

Chemical hazards in food involve substances such as heavy metals, industrial chemicals, pesticides and food additives that may contaminate the food supply. These toxins can enter the food chain through farming practices, food processing methods or environmental pollution. Prolonged exposure to certain chemicals, like lead or mercury can result in chronic health issues, including neurological disorders and increased risk of cancer

Physicial Hazars

Physical hazards consist of foreign objects like glass fragments, metal pieces or plastic particles that can accidentally contaminate food during processing or packaging. Such contaminants pose immediate risks to consumers, potentially causing injuries, triggering product recalls and damaging consumer confidence.

Pathway of Contamination

Contamination can occur through several pathways, including improper handling by food workers, direct contact with contaminated surfaces and cross-contamination between raw and cooked foods. Additionally, hazards can be introduced into the food chain through vectors such as pests or unsafe water sources.

Good Hygiene Practice

Good Hygiene Practices are critical for maintaining food safety and minimizing the risk of foodborne illnesses. These practices involve a set of procedures designed to ensure cleanliness and prevent contamination at every stage of food production and handling.

Key Elements of Good Hygiene Practices

- To ensure food safety and reduce the risk of foodborne illnesses, maintaining proper cleanliness is essential.

- Food handlers should maintain personal hygiene by washing their hands frequently, dressing in clean clothes and refraining from handling food when sick.
- Equipment, utensils and preparation surfaces must be cleaned and sanitized on a regular basis to remove residues and hazardous microorganisms.
- It is crucial to properly manage physical, chemical and biological risks, including controlling temperature, preventing cross-contamination and using water safely.
- Food workers should get ongoing training and education to emphasize good hygiene and safe

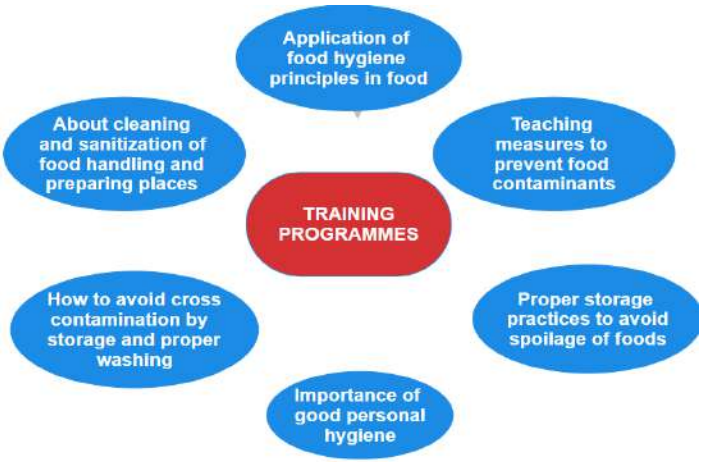

Fig. 1

Standard Operating Procedures for Sanitation (SSOPS)

Sanitation Standard Operating Procedures (SSOPs) are essential elements of a food safety management system. They consist of documented instructions that outline the steps required to clean and sanitize utensils, equipment and food-contact surfaces in a food processing facility. The primary purpose of SSOPs is to maintain all equipment and work areas in a hygienic condition, thereby preventing contamination or adulteration of food products.

Importance of SSOPs

Preventing Foodborne Illnesses: Implementing SSOPs ensures that equipment, surfaces and utensils remain clean, minimizing the presence of harmful bacteria and lowering the likelihood of foodborne diseases.

Meeting Regulatory Standards: Adherence to SSOPs helps food businesses comply with safety regulations and guidelines, such as those established by the Food Safety and Standards Authority of India (FSSAI).

Enhancing Consumer Trust: Consistent sanitation practices signal a commitment to food safety, fostering greater confidence and trust among consumers in the quality of the products.

Improving Operational Workflow: Well-defined cleaning procedures contribute to smoother operations in food processing facilities, reducing downtime and improving overall efficiency.

HACCP: Managing Food Hazards

Hazard Analysis and Critical Control Point (**HACCP**) is recognized as a preventive and science-based strategy for maintaining food safety, which is central to protecting public health. Unlike traditional methods that mainly rely on testing finished products, this system focuses on anticipating risks in advance. It ensures that potential biological, chemical and physical hazards are carefully managed at every stage of the food chain—beginning with raw material sourcing, continuing through processing and storage and extending up to distribution and consumption (Awuchi *et al*., 2023). By incorporating HACCP into food manufacturing, firms can implement preventive steps to limit the likelihood of infection. Monitoring cooking temperatures, for example, prevents bacteria such as Salmonella from surviving and good sanitation practices reduce cross-contamination between raw and processed food.

Cross Contamination Prevention

Defenition

Cross-contamination prevention means placing to use specific precautions and hygiene practices to prevent hazardous microbes, chemicals or foreign particles from being transferred from one food item, surface or utensil to another, especially from raw foods to ready-to-eat goods. According to de Jong *et al*. (2008), these preventative measures are essential for reducing foodborne diseases and preserving the food supply's safety and quality.

Common Sources

Kitchen surfaces, knives, cutting boards, raw foods and food handlers' hands are the main places where cross-contamination occurs. Pathogens can spread from raw components to foods that are ready to eat due to even simple hygiene mistakes.

Prevention Measures

Food Segregation: Use distinct cutting boards and utensils for raw and prepared meals to keep them apart.

Hand hygiene: After handling raw materials, properly wash your hands with warm water and soap.

Cleaning & Sanitization: To lower microbial survivability, wash blades, utensils and surfaces with hot water and disinfectants.

Drying: To stop bacteria from growing, pat dry work surfaces and utensils after washing.

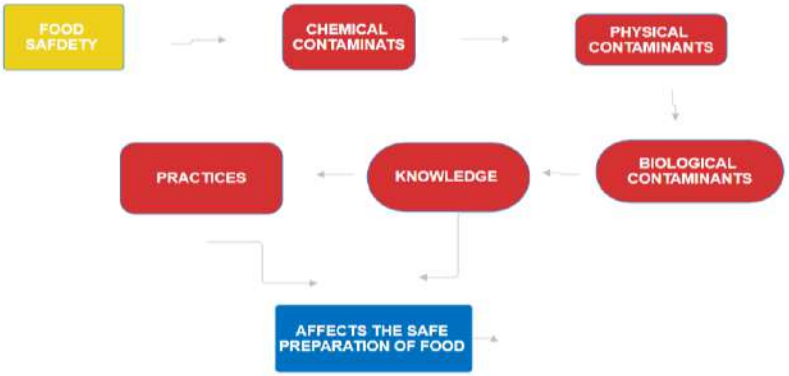

Fig. 2

Importance in Food Safety

Cross-contamination prevention is an important step toward ensuring food safety and public health. If proper sanitation precautions are not taken, foodborne pathogens including Salmonella, E. coli and Campylobacter can readily spread from raw materials, contaminated surfaces or utensils to foods that are ready to eat. Foodborne illness outbreaks may result from this transfer, which can take place in homes, eateries or places that process food.

The risk of contamination is considerably decreased by regularly putting

hygiene procedures into effect, such as adequate handwashing, separating raw and cooked meals, utilizing different cutting boards and thoroughly cleaning and sanitizing utensils and work surfaces. In addition to shielding customers against illnesses, routine monitoring and adherence to these procedures improve the general quality and dependability of the food supply.

Food Handling Training

Food handler training is an important aspect of guaranteeing food safety in various food operations. Food handlers who receive the right training are better prepared to avoid foodborne illnesses by following safe food handling procedures. Research has indicated that properly designed training programs can greatly increase food handlers' understanding of food safety, resulting in better hygiene habits and fewer outbreaks of foodborne illness.

Components of successful food safety training programs are

- Teaching food handlers about prevalent foodborne infections and how they spread is part of understanding foodborne diseases.
- Personal Hygiene Practices: Emphasizing the need of handwashing, appropriate dress and personal hygiene.
- Prevention of Cross-Contamination: Instruction on how to stop dangerous microbes from moving from raw to cooked food.
- Temperature Control: Giving advice on the ideal cooking and storage temperatures to prevent the growth of bacteria.
- Cleaning and Sanitization: Offering instructions on how to properly clean and sanitize surfaces and equipment.

Impact on Knowledge and Practices

Providing structured food safety training greatly improves the understanding and behave or of food handlers in daily operations. Studies, including **Insfran-Rivarola *et al.* (2020),** have found that such training enhances awareness about proper hygiene, safe food handling and contamination prevention. Trained staff are more likely to follow correct procedures, reduce errors and maintain safe food preparation practices. The research also emphasizes that one-time training is not enough—regular refresher courses and reinforcement activities are necessary to sustain good practices and ensure long-term improvements in food safety standards.

Impact on Public Health

Global Burden If Foodborne Illness

Foodborne illnesses are a major public health concern worldwide. The World Health Organization (WHO) reports that approximately 600 million people—almost one in ten—fall ill each year due to consumption of contaminated food. These illnesses are responsible for more than 420,000 deaths annually, with children under five years of age being particularly vulnerable. In the United States alone, foodborne diseases lead to an estimated 48 million cases of illness, 128,000 hospitalizations and around 3,000 deaths each year.

Vulnerable Population

Some groups of people are particularly at risk for severe outcomes from foodborne illnesses. Children under five, older adults, pregnant women and individuals with weakened immune systems are more likely to experience serious complications or even death if they consume contaminated food. According to the World Health Organization (WHO), nearly 30% of deaths from foodborne diseases occur in children under five years of age. These vulnerable populations require special attention, including targeted food safety interventions, education on safe food handling and stricter hygiene practices. Protecting these groups is crucial to reducing overall morbidity and mortality associated with foodborne infections.

Public Health Interventions

Implementing public health interventions plays a critical role in reducing the occurrence of foodborne illnesses. Regular inspections of food service establishments help ensure that hygiene and safety standards are maintained, identifying potential hazards before they cause outbreaks. Research has shown that such inspections are effective in lowering the risk of contamination and promoting safer food practices. In addition, targeted health education programs for food handlers enhance their knowledge of proper food handling, personal hygiene and cross-contamination prevention. These educational initiatives improve adherence to food safety protocols and reduce unsafe practices. Together, routine monitoring and ongoing training form a comprehensive approach to safeguarding public health and preventing foodborne diseases.

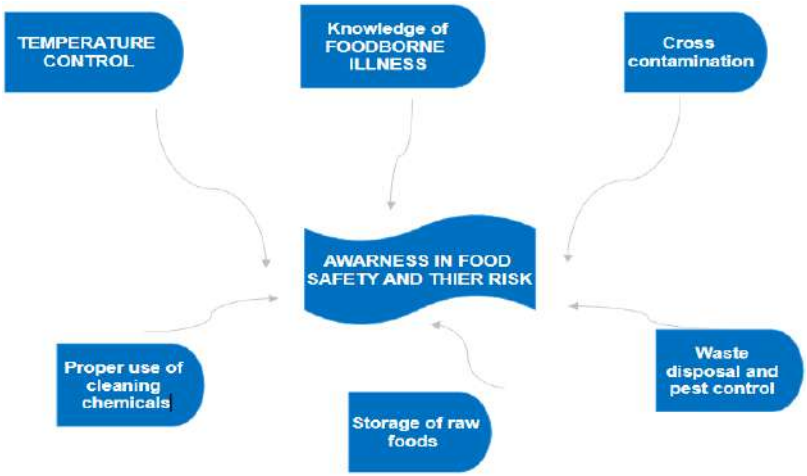

Fig. 3

Challenges in Hygiene Practices

The hygiene practices of food handlers are influenced by a variety of factors. Limited training and insufficient knowledge about proper food safety procedures can lead to unsafe handling practices. A lack of necessary resources, such as cleaning supplies or protective equipment, further hinders the ability to maintain high hygiene standards. Cultural beliefs and attitudes toward food preparation may also affect adherence to recommended practices. Addressing these challenges through education, provision of resources and awareness programs is essential to improve hygiene compliance in food establishments (Mphasha, 2024).

Strategies for Improvement

To address the challenges faced by food handlers, Mphasha (2024) emphasizes the importance of well-structured and continuous training programs that cover all aspects of food safety and personal hygiene. Providing adequate resources, such as cleaning supplies, protective gear and properly maintained equipment, is essential to support these practices. Additionally, cultivating a workplace culture that prioritizes food safety encourages consistent adherence to hygiene standards. Regular monitoring and reinforcement of proper practices strengthen compliance. By combining education, resources and a supportive environment, food establishments can significantly improve hygiene practices. These strategies ultimately help reduce the risk of foodborne illnesses and protect public health.

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9
CHAPTER

Therapeutic Potential and Medicinal Applications of *Punica granatum L.*: A Comprehensive Review

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Abstract

Punica granatum L. (pomegranate) is a phytochemical-rich medicinal plant used in Ayurveda, Unani and Persian medicine for treating gastrointestinal, metabolic, inflammatory and infectious disorders. Its major constituents punicalagin, ellagitannins, anthocyanins, flavonoids, punicic acid and phenolic acids exhibit wide pharmacological properties including antioxidant, anti-inflammatory, antimicrobial, antidiabetic, cardioprotective, anticancer, neuroprotective and wound-healing activities. Recent research demonstrates that pomegranate's biological effects result from modulation of oxidative pathways, inflammatory cascades, apoptotic signaling and metabolic enzymes. This review provides an expanded scientific evaluation of the medicinal potential of P. granatum, integrating preclinical and clinical findings.

1. Introduction

Punica granatum L. (Family: Lythraceae) is cultivated widely across India, Iran, the Mediterranean region and Southeast Asia. Historically, its fruit rind, seeds, flowers and bark have been used in traditional medicine for digestive disorders, helminth infections, inflammation and cardiovascular ailments [1].

In the last decade, research has focused extensively on the biologically active polyphenols—particularly punicalagin and ellagic acid—due to their strong antioxidant and therapeutic potential [2]. Increasing evidence supports the plant's role in preventing or managing chronic diseases such as diabetes, cancer, hypertension and metabolic syndrome [4].

2. Phytochemical Composition of *Punica granatum*

The therapeutic value of pomegranate arises from its structurally diverse phytochemicals, which vary across different plant parts.

2.1. Fruit Peel

The peel contains a high concentration of ellagitannins (punicalagin, punicalin), phenolic acids, catechins and flavonoids [3]. Studies show the peel possesses significantly higher antioxidant activity than the juice [7].

2.2. Seeds

Pomegranate seeds are rich in punicic acid—an omega-5 conjugated fatty acid with anti-inflammatory and anticancer potential [8]. Seed oil also contains sterols and tocopherols.

2.3. Juice

The juice contains anthocyanins (delphinidin, cyanidin derivatives), vitamin C and organic acids. High antioxidant capacity of juice correlates with its phenolic profile [7].

2.4. Leaves, Flowers and Bark

These plant parts contain alkaloids (pelletierine), gallic acid and tannins, which contribute to antimicrobial and antiparasitic activities [2].

3. Pharmacological Activities

3.1. Antioxidant Activity

Pomegranate exhibits exceptionally strong antioxidant activity due to punicalagin, ellagic acid and anthocyanins [3]. These compounds suppress reactive oxygen species (ROS), inhibit lipid peroxidation and enhance endogenous antioxidant enzymes (SOD, CAT, GPx) [7].

3.2. Anti-inflammatory Activity

Pomegranate extracts inhibit inflammatory pathways by downregulating NF-κB, COX-2, TNF-α, IL-1β and IL-6 [1, 2]. Clinical studies demonstrate decreased inflammatory biomarkers after regular pomegranate juice intake [9].

3.3. Antimicrobial Activity

Peel extracts show strong antimicrobial effects against S. aureus, E. coli, P. aeruginosa and Streptococcus mutans due to tannin-mediated cell wall disruption [3]. Antifungal activity is reported against Candida albicans and various dermatophytes [1].

3.4. Antiparasitic Activity

Bark alkaloids such as pelletierine show potent anthelmintic activity against Giardia lamblia, Entamoeba histolytica and tapeworms [1, 2].

3.5. Antidiabetic and Metabolic Activity

Pomegranate peel and juice extracts inhibit α-amylase and α-glucosidase enzymes, enhance insulin sensitivity and protect β-cells from oxidative damage [4]. Clinical trials report improvements in fasting glucose and lipid profile [9].

3.6. Cardioprotective Effects

Studies indicate that pomegranate juice reduces LDL oxidation, improves endothelial nitric oxide availability, lowers blood pressure and inhibits atherosclerotic plaque formation [4, 9].

3.7. Anticancer Activity

Pomegranate extracts show anticancer effects against breast, prostate, colon, lung and bladder cancers.

Mechanisms include:

- inhibition of PI3K/Akt and MAPK pathways
- suppression of angiogenesis
- induction of apoptosis
- reduction in metastasis

Ellagitannins and punicic acid are primarily responsible for anticancer effects [2, 5, 10].

3.8. Neuroprotective Effects

Studies show protective effects against neuroinflammation and oxidative stress associated with Alzheimer's and Parkinson's diseases [4]. Ellagic acid reduces amyloid-β plaque accumulation [2].

3.9. Hepatoprotective Effects

Pomegranate reduces liver enzyme elevation (ALT, AST), prevents lipid peroxidation and protects hepatocytes from toxic damage [4].

3.10. Anti-obesity Activity

Seed oil supplementation reduces adipogenesis by modulating lipid metabolism and inhibiting triglyceride accumulation [8].

3.11. Dermatoprotective and Wound-Healing Effects

Topical pomegranate formulations enhance collagen synthesis, accelerate wound closure and protect against UV damage due to ellagic acid's photoprotective properties [5].

4. Traditional Uses

Ayurvedic texts describe P. granatum as astringent, digestive and antihelmintic [1]. Unani medicine uses it for heart and stomach health, whereas Persian medicine regards it as a tonic for inflammation and infections [2].

5. Clinical Evidence

Human studies indicate:

- Significant reduction in systolic blood pressure after daily juice intake [9]
- Lower oxidative stress and improved lipid profile [9]
- Slower progression of prostate cancer in men consuming pomegranate extract [5]
- Reduced arthritis biomarkers in inflammatory disorders [4]

These findings support therapeutic use but require larger trials.

6. Safety and Toxicity

Pomegranate is generally safe; fruit and juice show no toxicity [1]. High-dose extracts may cause mild gastrointestinal discomfort. Possible interactions with antihypertensives and anticoagulants require caution [2].

7. Future Prospects

Future directions include nanoformulation of ellagitannins for enhanced bioavailability, development of standardized extract-based medicines and deeper evaluation in metabolic, neurodegenerative and oncological conditions [4, 5].

8. Conclusion

Punica granatum L. is a scientifically validated medicinal plant with broad pharmacological potential. The strong antioxidant and anti-inflammatory profile supports traditional uses and modern clinical interest. Although promising, standardized clinical studies are needed to translate its phytochemicals into pharmaceutical-grade therapies.

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