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Modern Perspectives in Nutrition Science

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PREFACE

Nutrition science, encompassing both human and animal domains, plays a pivotal role in shaping health, productivity, and sustainability. In today's rapidly evolving world, the intersection of these two fields offers unique opportunities to address global challenges, including food security, environmental sustainability, and the health of all living beings. This book, Modern Perspectives in Nutrition Science, explores the latest advancements, research, and applications in human and animal nutrition, fostering a holistic understanding of this interconnected discipline.

The book is a collective effort to bridge the gap between human and animal nutrition, emphasizing the shared principles and distinct requirements of both fields. It delves into topics such as nutrient metabolism, dietary interventions, precision nutrition, and the role of microbiomes in health and productivity. On the human side, it addresses issues like malnutrition, obesity, and the impact of dietary choices on chronic diseases. For animals, it focuses on innovative feed formulations, the use of alternative feed resources, and strategies to enhance productivity while minimizing environmental impact.

By integrating perspectives from both realms, this volume underscores the importance of sustainable practices and the interconnectedness of human and animal health. It is particularly relevant in the context of the "One Health" approach, which recognizes the interdependence of human, animal, and environmental well-being.

This book is designed to benefit a diverse audience, including researchers, educators, healthcare professionals, veterinarians, and students. It aims to inspire collaboration across disciplines, driving innovation and practical solutions that advance the science of nutrition.

We extend our sincere gratitude to the contributors, whose expertise and dedication have made this book a comprehensive and insightful resource. Their efforts reflect the dynamic nature of nutrition science and its potential to transform lives.

It is our hope that Modern Perspectives in Nutrition Science serves as both a foundational text and a catalyst for further exploration, contributing to a healthier and more sustainable future for all.

- Editors

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AFLATOXIN CONTAMINATION IN PLANT-BASED AQUACULTURE FEEDS AND ITS IMPACT ON AQUACULTURE SPECIES HEALTH AND PRODUCTION

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Introduction:

The rapid expansion of aquaculture has led to a rising demand for formulated feed, and due to increasing feed costs, the industry has recently shifted from fish meal to plant-based ingredients. While this shift supports sustainable feed practices, it also introduces a greater susceptibility to fungal contamination in plant-sourced feeds under favorable environmental conditions. A key challenge lies in reducing animal-derived feed components while increasing the use of plant ingredients, which can sometimes contain aflatoxins and other anti-nutritional factors detrimental to the health and productivity of aquaculture species (Mendes, 2019). Aflatoxins are potent mycotoxins produced by toxigenic fungi such as *Aspergillus spp.* (Popescu, 2022), can contaminate feed ingredients directly through fungal infection or indirectly over inappropriate storage and handling. These toxins can impair growth performance, immune function, and overall well-being in cultured species, potentially leading to physiological and behavioral disorders, thereby affecting aquaculture systems overall productivity and economic viability.

Aflatoxin is known to be carcinogenic and mutagenic, and it is produced by several fungal species, notably *Aspergillus bombycis*, *A. ochraceoroseus*, *A. tamarri, Emericella stellata*, *A. pseudotamari*, *A. flavus*, and *A. parasitica*. Among these, *A. flavus* and *A. parasitica* are the primary contributors to aflatoxin contamination in aquaculture, as noted by multiple studies (Windham *et al.,* 2010; Hathout and Aly, 2014; Deepa Bhatt and Abhed Pandey, 2022). Ingredients commonly used in aquafeeds, such as maize grains, wheat, rice, sunflower seeds, cottonseed, millet, peanuts, sesame seeds, and various other types, along with poor hygiene practices in stored animal feed, pose significant risks. The first report of aflatoxin contamination was documented by Blout in 1961 concerning turkeys, which were found to be affected by cottonseed and peanut meal in formulated rainbow trout feed. Subsequent studies by Halver in 1965 and Rucker *et al.* in 2002 indicated that *A. flavus* and

A. parasitica produce mycotoxins in environments with temperatures between 24–35°C and humidity levels of 7–10%.

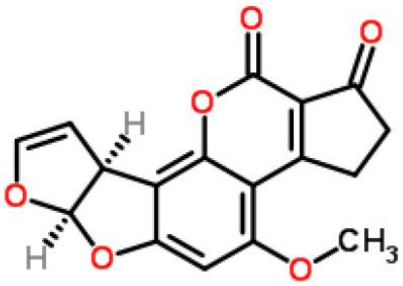
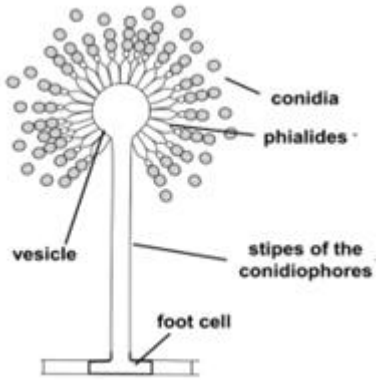
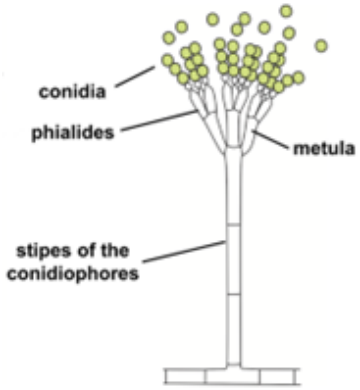
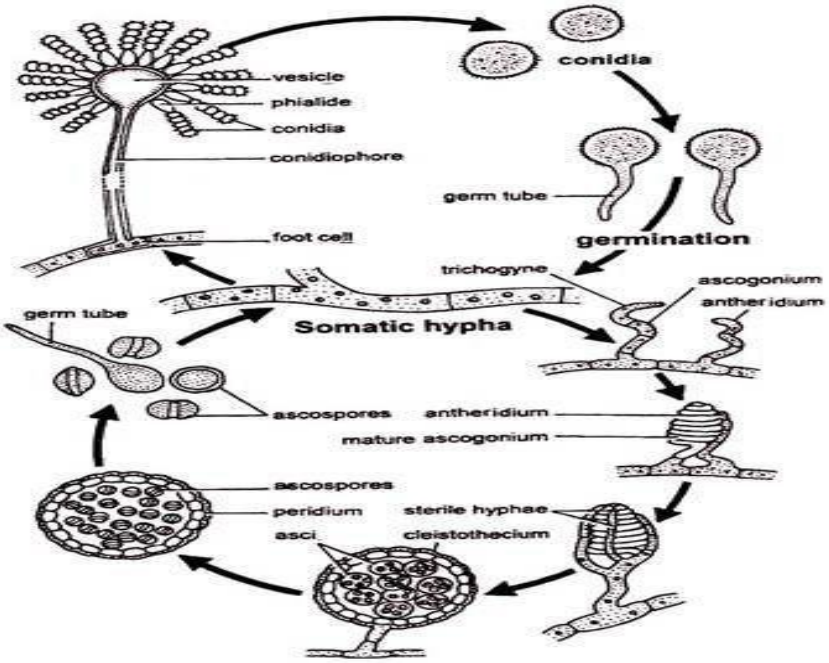


Fig. 1: Chemical structure of Aflatoxin B1 ($C_{17}H_{12}O_6$) (Ahmed *et al.*, 2015)

Table 1: Difference between the *Aspergillus* and *Penicillium*

Characters	*Aspergillus sp.*	*Penicillium sp.*
		
Conidiophore	Large vesicle with straight ending	Branched
Mould color	Green to black color	Blue in color
Definition	A genus of ascomycetes fungi with branched, radiate sporophores	Blue mold is most commonly found in food
Producing material	Aflatoxin is toxic	Penicillin acts as an antibiotic.
Causes	Aspergillosis in lungs and liver carcinogen	Penicillin is effective against Gram-positive bacteria

- Aspergillus can reproduce sexually or asexually.
- In the sexual cycle, the mycelium produces a fruiting body (Cleistothecium), which holds the ascospores; it is released into the environment and can form many new mycelium.
- Spores are produced in the form of conidia in the environment asexually. The conidia are largely found in the air; when moisture and nutrients are available, the conidia germinate from hyphae, and later, they develop into fungal mycelium.

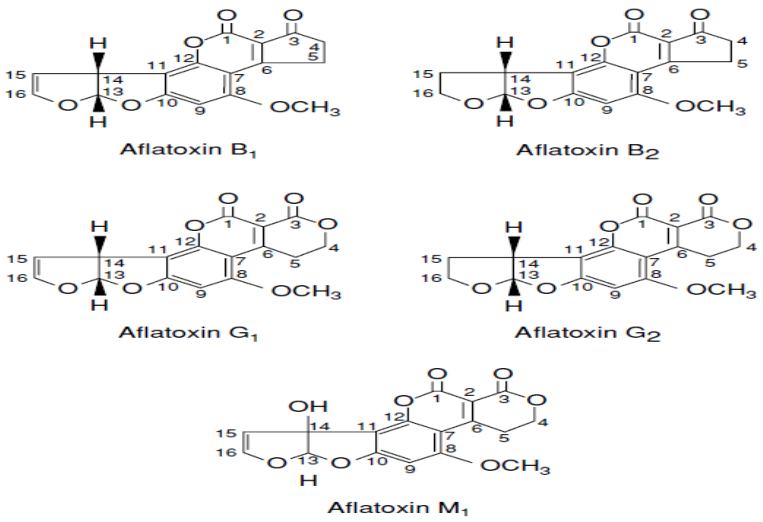


The life cycle of *Aspergillus sp.*

Types of Aflatoxin

Six forms of aflatoxin B1, B2, G1 and G2 are commonly present in plant-based foods and M1(Metabolites of B1) & M2 are found in animal food origin Oxidative metabolic product of the mycotoxin aflatoxin B_2 (Feddern *et al.,* 2013; Vijaya Kumar 2018 and Bbosa *et al.,* 2013) B1 and B2 aflatoxin are produced by *A. flavus,* and G1 and G2 originate from the *A. parasitica*.

- Aflatoxin B (blue in color) and G (yellow, green florescent color) toxins, due to their hetero-cyclic chemical structure, glow in thin layer chromatography although UV light is exposed.



Chemical structure of Aflatoxin B_1, B_2, G_1, G_2, M_1 (Popescu, 2022).

Table 2: Physical properties of aflatoxins (Deepa *et al.,* 2022)

Types of Aflatoxin	Molecular weight (g /mol)	Melting point (^{0}C)	Fluorescence emission (nm)	Reference	Disturbing organ
B_1 ($C_{17}H_{12}O_6$)	312	268 - 269	425	Vijaya Kumar, 2018	Hepatotoxicity (liver damage) Bile-duct hyperplasia Hemorrhage: Intestinal tract and Kidneys Carcinogenesis (liver tumors)
B_2 ($C_{17}H_{14}O_6$)	314	286-289	425		
G_1($C_{17}H_{12}O_7$)	328	244-246	450	Wu *et al.,* 2011	
G_2 ($C_{17}H_{14}O_7$)	330	237- 240	450		
M_1($C_{17}H_{12}O_7$)	328	299	435	Behfar, 2012 and Lee *et al.,* 2015	
M_2($C_{17}H_{14}O_7$)	330	293	450		

Characteristics of Aflatoxin

- Aflatoxin is colorless to pale yellow crystals (Okoth, 2016).
- Dissolve in Chloroform, Methanol, and Dimethyl sulfoxide (DMSO).
- They are unstable in UV light due to the presence of O_2 and pH below 3 and above 10 (Sargeant *et al.,* 1963).
- Aflatoxin B1 & B2 and G1 & G2 are produced by *A. flavus* and *A. parasitica* respectively. (Bennett *et al.,*2007, Wacoo *et al.,* 2014).
- The B & G letters stand in blue and yellow-green fluorescent colors.

Aflatoxin: Adverse Effects on Fish Species

Nile tilapia (*Oreochromis niloticus*)

Several researchers have investigated the impact of aflatoxin on fish growth, survival rates, mortality, and immune function. In their studies on *Oreochromis niloticus* (Nile tilapia), El-Bana *et al.* (1992) conducted incorporating 200mg/kg of aflatoxin, which resulted in a mortality rate of 16.7% along with growth reduction and low survival rates. In a different study, Tuan *et al.* (2002) reported that incorporating 100 mg/kg of aflatoxin into feed caused severe hepatic necrosis and resulted in a 60% mortality rate in Nile tilapia. Caganuan *et al.* (2014) recommended a range of 5 to 38.62mg/kg of aflatoxin-contaminated feed, demonstrating a commendable survival rate of up to 67% in tilapia culture.

Pacific white shrimp (*Litopenaeus vannamei)*

Yilong Wang *et al.* (2018), investigated the effects of Aflatoxin B1 (AFB1) on Pacific white shrimp (*L. vannamei)* intestinal health, the antioxidant system, and the dynamic changes in the intestinal microbiota of these shrimp over different days of AFB1 exposure. The researchers measured the activities of key antioxidant enzymes, including catalase (CAT), superoxide dismutase (SOD), glutathione peroxidase (GPX), and malondialdehyde (MDA) in both the intestines and hepatopancreas of the shrimp. The findings revealed that the control treatment had a greater abundance of microbiota at both the phyla and genera levels than the experimental treatment. At the phyla level, there was an increase in the abundance of Proteobacteria, Vibrio, Photobacterium, and Firmicutes in the experimental group as the culture days progressed; conversely, the numbers of Bacteroidetes, *Flavobacterium sp.*, and *Tenacibaculum sp.* decreased. Additionally, the activities of GPX, CAT, and SOD in both the intestines and hepatopancreas were higher in the experimental tanks than in the control tanks, indicating notable changes in the intestinal activity of the shrimp.

Rohu (*Labeo rohita*)

In *Labeo rohita*, a dosage of 12-13.3mg/kg of aflatoxin leads to haemorrhage and fusion, accompanied by epithelial cell oedema and lamellar hyperplasia (Sahoo *et al.,* 2003). Mohapatra *et al.* (2011) tested doses of 10, 20, and 40 ppm of aflatoxin in rohu culture. These doses decreased the total leukocyte count, erythrocyte count, and haemoglobin level in the fish's blood. As a result, the fish become more susceptible to pathogens. In 2001, Sahoo and Mukherjee fed rohu different doses of aflatoxin 1.25mg/kg, 2.5mg/kg, and 5mg/kg, which led to reductions in protein and globulin levels in the fish's blood.

Other fish Species

At a dosage of 0.18 mg/kg of aflatoxin mixed into the feed, Asian seabass (*Lates calcarifer*) exhibited rapid operculum movement, loss of equilibrium, and hemorrhage on the dorsal side of the body (Ec-sayed & Khalil, 2009). Zeng *et al.* (2019) conducted a study on the effects of dietary aflatoxin B1 on growth performance and its impact on the integrity of immune organs in juvenile grass carp (*Ctenopharyngodon idella*) at various concentrations.

Problems of Aflatoxin in the fish feed:

Aflatoxins are effective mycotoxins that pose significant risks to the health and performance of fish species, impacting various physiological systems. These toxins suppress immune responses, making fish more susceptible to contagions and diseases (Mohsenzadeh *et al.,* 2016). Furthermore, aflatoxins persuade mutagenesis by causing genetic alterations, which can lead to long-term impacts on fish health and population dynamics (Kim *et al.,* 2016). Hepatotoxicity is another life-threatening alarm, as aflatoxins damage liver tissues, impairing metabolic functions essential for survival (Rotimi *et al.,* 2017).

Chronic exposure to aflatoxins also stunts growth in fish by interfering with nutrient metabolism and energy allocation (Chen *et al.,* 2018). Furthermore, aflatoxins are recognized as carcinogens, promoting tumor development in various tissues, which can severely affect aquaculture productivity (Sirma *et al.,* 2019). Beyond these effects, aflatoxins exhibit epigenetic toxicity, altering gene expression patterns and causing reproductive dysfunction, thereby compromising reproductive success and offspring viability (Ferreira *et al.,* 2019). Neurotoxicity is another significant impact, as aflatoxins can impair nervous system function, leading to behavioral and physiological deficits in fish (Mahlouz *et al.,* 2020).

Consequence of aflatoxin in the aquaculture industry:

Alsayyah *et al.,*2019 & Wangia *et al.,* 2019 mentioned that cottonseed meal is no longer a major ingredient in aquaculture feed formulation due to its aflatoxin contamination, less availability and poor storage of feed ingredients. Rainbow trout (O*nchrochunus mykiss*) feed with 0.0004 mg/kg of aflatoxin in feed for 15 months of trial. It shows the risk of 14% developing tumours in the trout body. FDA enforces strict regulations about aflatoxin screening in oil seeds like cottonseed meal, lean seed meal, sesame meal and other feed ingredients also. In the late 1960s, the 1st aflatoxicosis case was documented in the rainbow trout. Farmers, without knowing, use aflatoxin-contaminated feed to feed. It started developing liver tumours in fish. Around 85% of trout fish die in the hatcheries.

Long-term aflatoxin exposure (Chronic aflatoxins) causes carcinogenicity, genotoxic, tumorigenic and humoral or neurotoxic effects in fish and other animals like rabbits, chicks, and ducks. Due to chronic aflatoxins in fish, the immune system's performance and stock quality gradually decrease (Santacroce *et al.,* 2008, 2011). Acute aflatoxicosis is a

short-term reaction; it causes fish poor health, poor fertility, decreased productivity, and weight gain, and the immune system is also superseded. Agag 2004 and Mahafouz & Sherif 2015 also requested to avoid aflatoxin toxicity in feed used in aquaculture, because it leads to low production, high mortality, morbidity and poor quality of fish and fishery products. It also causes huge economic losses in the aquaculture industry. The presence of aflatoxin in feed and fish tissue reduces the nutritional value of fish and causes health risks in humans, respectively. So, the quality of fish meat is not good enough, and this creates a bad impression about fish products (Puschhner, 2002; Meissonnier *et al.,* 2007; Tacon & Metian, 2008; Naylor *et al.,* 2009 and Hassan *et al.,* 2010).

Regulation and limits for controlling the aflatoxin in feed and food:

The WHO and FAO collaboration defines the safety level of food and feed. Since the aflatoxicosis was documented, a joint FAO / WHO expert committee on feed additives (JECFA 2002) developing the toxicological measurement test and dietary exposure assessments are taken. The organization also mentioned that aflatoxin levels in various grains, dried figs, nuts, and milk ranged from 0.5-15ig/kg. The tolerable daily intake of AFB1 stipulated in fish feed by the Food and Drug Administration (FDA) is 5 mg/kg (FDA, 2015). Aflatoxin human consumption ranges from 4-30ig/kg depending on the food variety (Mahato *et al.,* 2019) and 20 micrograms/kg of aflatoxin in the United States (Wu, 2006; FAOSTAT,2020).

In the United States, FDA - requested a total amount of 20ng/g in livestock feed and 0.5g/kg or 50n/g per litter (Ellis *et al.,* 1995). Creepy, 2002 mentioned that about 0.005mg/kg of aflatoxin M1 is permitted in European countries. The level of aflatoxin in food varies in different countries; it depends on countries' economic and developing status (Galvano *et al.,* 1996).

Detoxification of aflatoxin:

Some molds and mold spores have been observed to partially transform aflatoxin B1 into new fluorescing compounds. Notably, only one bacterium, *Flavobacterium aurantiacum* NRRL B-184, effectively removed aflatoxin from the solution (Line & Brackett, 1995). Both actively growing and resting cells of B-184 irreversibly absorbed the toxin. Aflatoxin-contaminated milk, oil, peanut butter, peanuts, and corn experienced complete detoxification when treated with B-184, while contaminated soybean was partially detoxified. Duckling assays confirmed that the detoxification of aflatoxin solutions by B-184 was thorough, with no new toxic byproducts formed.

In a study by Elsanhoty *et al.* 2014, five strains of lactic acid bacteria (LAB) were evaluated for their potential to remove aflatoxin M1 (AFM1) from yogurt. Probiotics such as lactic acid bacteria are widely utilized in food fermentation and preservation processes. Among the strains tested, *L. plantrium* exhibited the highest reduction of AFM1 levels during the yogurt storage period. The findings indicated certain LAB strains' efficacy in detoxifying AFM1-contaminated foods. Additionally, Inan *et al.* (2007) explored the use of ozone for detoxifying aflatoxin B1 in red pepper, yielding promising results.

Conclusion:

The occurrence of aflatoxins in aquaculture feed poses significant health risks to fish and other aquaculture species, eventually affecting growth, immunity, and survival rates. The carcinogenic, mutagenic, and hepatotoxic properties of aflatoxins and addressing contamination are crucial to maintaining the optimum level of aflatoxin in aquaculture systems to achieve high productivity and economic viability. Improved feed storage practices, using plant-based ingredients with lower contamination risks, and stringent regulatory measures can support and alleviate the impact of aflatoxins. Additionally, advances in detoxification techniques, such as probiotic applications and ozone treatment, offer promising solutions for reducing aflatoxin levels in aquafeeds and ensuring safe and supportable fish production.

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THE ESSENTIAL ROLE OF A BALANCED DIET FOR HEALTH AND WELL-BEING

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Introduction:

A balanced diet is crucial for maintaining good health and overall well-being. It provides the body with all the necessary nutrients, vitamins, and minerals it needs to function properly. A well-balanced diet includes a variety of foods in the right proportions, ensuring that the body receives the essential nutrients for energy, growth, repair, and maintenance of all bodily functions. This article delves into the importance of a balanced diet and the key elements that contribute to health.

Understanding a Balanced Diet

A balanced diet is composed of a variety of foods from all the essential food groups in the correct amounts. These groups include:

1. **Carbohydrates** – The body's primary energy source. These can be found in foods such as bread, pasta, rice, and fruits (Slavin, 2013; Hu, 2011).
2. **Proteins** – Vital for building and repairing tissues. They are found in meats, fish, eggs, legumes, and nuts (Chin *et al.,* 2019; Fulgoni *et al.,* 2011).
3. **Fats** – Necessary for energy storage and the proper functioning of cells. Healthy fats are abundant in foods like avocados, olive oil, and nuts (Micha *et al.,* 2017; Mozaffarian *et al.,* 2006).
4. **Vitamins and Minerals** – These micronutrients are essential for immune function, bone health, and energy production. Fruits, vegetables, dairy products, and fortified foods are rich sources (Micha *et al.,* 2017; Holick, 2007).
5. **Fiber** – Plays a critical role in digestion and regulating blood sugar levels. It is found in whole grains, vegetables, and fruits (Slavin, 2013).
6. **Water** – Supports all bodily functions, including digestion, temperature regulation, and waste elimination (Popkin *et al.,* 2010).

Each of these food groups provides the body with specific nutrients that work together to maintain health and promote well-being.

The Role of Carbohydrates

Carbohydrates are the body's primary energy source. They are broken down into glucose, which fuels muscles, the brain, and other vital organs (Slavin, 2013). Carbohydrates are categorized into simple and complex forms. While simple carbohydrates, like sugars, provide quick energy, complex carbohydrates, such as whole grains and vegetables, provide more sustained energy and are rich in fiber. Fiber not only aids in digestion but also helps lower cholesterol and control blood sugar levels (Micha *et al.,* 2017).

Studies show that complex carbohydrates help maintain steady energy levels and prevent the sharp fluctuations that can occur with refined sugar consumption (Kurl *et al.,* 2016). Excessive sugar intake has been linked to an increased risk of type 2 diabetes and other chronic conditions (Hu, 2011). Opting for whole grains over processed foods can help improve overall health and reduce the risk of developing cardiovascular disease (Krebs-Smith *et al.,* 2018).

Proteins: Essential for Tissue Repair

Proteins are composed of amino acids, which are essential for the building and repair of tissues. They also help produce hormones and enzymes that regulate various bodily functions (Chin *et al.,* 2019). A balanced diet includes proteins from both animal and plant sources, such as lean meats, fish, eggs, beans, lentils, and nuts. For vegetarians and vegans, plant-based proteins like quinoa, tofu, and tempeh are excellent alternatives (Fulgoni *et al.,* 2011).

Animal proteins contain all nine essential amino acids, but plant proteins also offer unique health benefits. Research suggests that plant-based proteins, when consumed as part of a healthy diet, may lower the risk of heart disease and certain cancers (Le & Sabaté, 2014). Thus, including a variety of protein sources is important for overall health.

Healthy Fats: Vital for Optimal Functioning

Not all fats are bad. In fact, healthy fats play an essential role in maintaining good health. These fats, found in sources like avocados, olive oil, and nuts, are important for brain function, hormone production, and cell structure. They also help the body absorb fat-soluble vitamins, such as A, D, E, and K (Micha *et al.,* 2017). Moreover, healthy fats have anti-inflammatory properties that can protect the heart and reduce the risk of cardiovascular disease (Mozaffarian *et al.,* 2006).

On the other hand, trans fats and excessive saturated fats, often found in processed foods and fried items, can lead to increased cholesterol levels and a higher risk of heart disease. It is therefore crucial to limit the intake of unhealthy fats while focusing on sources of healthy fats like omega-3 fatty acids, which are beneficial for heart health and reducing inflammation (Kris-Etherton *et al.,* 2002).

Vitamins and Minerals: Micronutrients That Make a Big Difference

Vitamins and minerals are essential for various bodily functions, including supporting the immune system, strengthening bones, and regulating energy production. Vitamin C, for instance, boosts immunity and enhances skin health, while vitamin D is crucial for bone strength (Holick, 2007). Minerals like calcium and iron play vital roles in maintaining bone health and oxygen transport in the body (Micha *et al.,* 2017).

For example, a deficiency in vitamin D has been associated with an increased risk of osteoporosis, cardiovascular diseases, and some cancers (Holick, 2007). Adequate intake of calcium and iron is important for preventing bone disorders and maintaining proper oxygen circulation throughout the body (Micha *et al.,* 2017).

The Importance of Fiber

Fiber is a critical yet often overlooked component of a healthy diet. It helps regulate digestion, control blood sugar levels, and lower cholesterol (Slavin, 2013). Fiber is abundant in fruits, vegetables, whole grains, and legumes. In addition to supporting digestive health, fiber helps maintain weight by promoting feelings of fullness and reducing calorie intake. It is recommended that adults consume at least 25-30 grams of fiber daily (Slavin, 2013).

Research has shown that high-fiber diets can lower the risk of developing conditions like type 2 diabetes, heart disease, and colorectal cancer (Bijkerk *et al.,* 2004). Increasing fiber intake, particularly from whole plant foods, is an effective way to improve overall health and well-being.

Hydration: Essential for Life

Water is fundamental to nearly every bodily function. It aids in digestion, nutrient absorption, temperature regulation, and waste elimination (Popkin *et al.,* 2010). Staying hydrated is crucial for maintaining energy, cognitive function, and healthy skin. It is recommended to drink sufficient water throughout the day, especially during exercise or in hot weather. In addition to drinking water, other fluids like herbal teas and consuming

water-rich foods, such as fruits and vegetables, can also contribute to hydration (Popkin *et al.,* 2010).

Even mild dehydration can impair physical performance, cognitive function, and mood. Studies indicate that dehydration can lead to decreased focus, memory issues, and physical fatigue (Armstrong *et al.,* 2012). Therefore, regular hydration is essential for maintaining good health.

Benefits of a Balanced Diet

1. **Steady Energy Levels**: A balanced diet ensures that the body receives a steady supply of nutrients, preventing fatigue and promoting sustained energy throughout the day (Slavin, 2013).
2. **Effective Weight Management**: A diet rich in whole, nutrient-dense foods, and low in processed items, helps maintain a healthy weight and reduces the risk of obesity (Micha *et al.,* 2017).
3. **Stronger Immune System**: Proper nutrition supports the immune system, helping the body defend against infections and diseases (Holick, 2007).
4. **Reduced Risk of Chronic Diseases**: A well-balanced diet helps prevent the development of chronic conditions like heart disease, diabetes, and high blood pressure (Micha *et al.,* 2017).
5. **Enhanced Mental Health**: Nutrients such as omega-3 fatty acids and certain vitamins contribute to brain health and emotional well-being (Fulgoni *et al.,* 2011).

Conclusion:

A balanced diet is a cornerstone of good health, and it should be a priority in daily life. By ensuring that the body receives the right combination of carbohydrates, proteins, fats, vitamins, minerals, fiber, and water, individuals can improve their overall health, maintain a healthy weight, and reduce the risk of chronic diseases. Achieving this balance is key to supporting the body's functions and ensuring a long, healthy life.

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NUTRITIONAL ATTRIBUTES OF *ARTOCARPUS GOMEZIANUS* WALL. EX TRECUL

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Abstract:

The fruits of *Artocarpus gomezianus* Wall.ex.trecul var.lakoocha Roxb.(Monkey jack) were collected from different altitudes of Central Western Ghats of Karnataka. The region is differing in their topography, vegetation and social cultural and food habits of the local people. An attempt has been made to determine proximate, nutritive value, elemental composition and heavy metal content of the fruits of monkey jack from different regions of Western Ghats. The macronutrients studies of fruit reveals that nitrogen is the dominate element and phosphorus or calcium or magnesium is the lowest element in their concentration. The micronutrients zinc, copper and iron are rich in fruit samples of coastal regions, whereas manganese is rich in fruit samples of higher altitudes. In contrast to proximate, macro and microelements, the heavy metals lead and cadmium are more in fruit samples of middle and higher altitudes. However, their percentage values are very low. When the recorded values are compared with RDA values all the macronutrients are rich in fruits of monkey jack. Similar to macronutrients, micronutrients and two heavy metals which are also essential at low concentration are also found in fruits of monkey jack. The components of proximates (Percentage of ash, moisture, fibre, protein and carbohydrates) are also rich in fruit of monkey jack. Therefore, fruits of monkey jack are nutritionally rich underutilized. The fruits not only sources of nutrients supplements but also one of the important resources for income generation at middle regions of Western Ghats. Further, the raw and processed products, is one of the important traditional ingredients for the preparation of local dishes. The importance of monkey jack for the future potential uses is also discussed for the middle regions of Western Ghats.

Keywords: *Artocarpus gomezianus* Wall.ex.trecul, Nutritional Value, RDA Value, Western Ghats.

Introduction:

The wild fruits are important sources of food, nutrition, medicine and also income generation to the people of Western Ghats. The Western Ghats is one of the 34 hot spots of biodiversity in the world (Chandrashekar Reddy, 2007) and is home for several plant species which yield fruits and vegetables. A few wild fruits are important sources of minerals, fiber, vitamins, carbohydrates, oils, protein, ascorbic acid and the antioxidant. The protein malnutrition is a major public health problem and can be solved by edible wild fruits (Aberoumand Ali and Deokule, 2009). Majority of fruits are anti-nutrition and diminish nutrient bioavailability (Spiller, 2001). The wild edible fruits agreed the characteristic feature of underutilized species (Gruere, 2003). The Western Ghats is one of the regions of wild edible fruits of India. Natural products derived from plants are focused in search of new drugs by indicating new modes of pharmacological action. The bioactive constituents of the plant are many, a large number of plant species have been screened for their pharmacological and chemotherapitic properties and still a vast wealth of edible medicinal plants have to be exploited for their edible and medicinal properties. 75% to 80% of the world population depends on the crude plant drugs problems and it is due to their poor economic conditions (Sukh Dev, 1997). At least 25% of the perception drugs issued in the USA and Canada contained bioactive compounds which are derived from plants (Vimalavady and Kadavul, 2012). The wild edible medicinal plants not only sources of nutrition and medicine but also generate income to the local people of Western Ghats. Number of investigators-initiated studies on documentation of harvesting, processing, preservation and marketing of wild edible medicinal plants. Kumar *et al.* (2012) documented Chironoji nut (*Buchania lanzan*) for its uses with reference to kernel, nut oil and nut and their products. The detail harvesting and processing of traditional methods have been documented. Sharma *et al.* (2012) recorded traditional processing of shotti (*Curcuma angustifolia* Roxb.) a rhizome based ethnic weaning food. It is also well known that knowledge is confined to native people especially to the women of ethnic groups. The wild edible and underutilized fruits attracted government to earn foreign exchange and also to establish industries which provide employment and to generate revenue to the local communities. In recent years, number of workers initiated to develop model for the utility of underutilized fruits. The protocol of Froukje Krujjssen and Sudha (2012) have outlined the model and marketing link for *Garcinia indica* in the Western Ghat region of Karnataka and Maharastra. Froukje Krujjssen and Sudha (2012) developed model to the marketing of kokum tree in the Western Ghats of India with reference to Karnataka and Maharashtra.

However, there are no published reports with respect to nutritional attributes, utility, harvesting and traditional uses and also medicinal importance of fruits of the Western Ghats, Karnataka, India. In addition, the studies of wild edibles in India and neighboring countries revealed that the proximate, nutrients, elemental composition and raw edible sources are resources for establishment of cottage industries. It also revealed that uses and preparation of value added products strangely related to the culture and tradition which influence the uses of raw and prepared products of wild edible medicinal plants. The studies initiated at Northeastern part and western parts of Indian emphasis the importance of alternative nutrition, conservation of tradition and knowledge and biodiversity.

Accordingly, a study is undertaken to study distribution, determination of nutritive value (based on proximate, elemental composition), medicinal uses and harvesting, processing and preservation of monkey jack of Western Ghats. In the present study, an attempt is made to study the nutritional attributes of underutilized fruits, monkey jack (*Artocarpus gomezianus* Wall. ex Tecul Var, Lakoocha) of Shimoga, Chikamagalure, Udupi, Dhakshnia Kannada, North Canara districts of Karnataka, with respective to nutritive value, utility and marketing.

Monkey Jack (*A. gomezianus*)

A. gomezianus commonly known as monkey jack belongs to the family Moraceae is regionally known by different traditional names all over world. The genus *Artocarpus* consist of 50 species found in tropical and subtropical Asia and specific islands. The plants of *Artocarpus* are reported from sub Himalayan regions and Western Ghats of India, China, Bangladesh and Srilanka. The distribution of monkey jack (*A. gomezianus*) is studied at different regions of Karnataka along with their uses (Gamble, 1921; Uppina, 1974; Nadakarni, 1976; Ramaswamy *et al.,* 2001; Bhat Vinayaka and Abbi Anil, 2007). Of the 50 species, 3 species, *A. integrifolia*, *A. hirsuta* and *A. gomezianus* are commonly found in Western Ghats of Karnataka between sea level and 2000-meter altitudes (Thunberg, 2003).

The plant is an evergreen, tall and valuable timber yielding and it is a valuable tropical tree species, native to India and used for fruit, furniture, timber and feed. The fruits are generally eaten fresh and the edible pulp is believed to act as tonic for the liver. The fruits are used in place of tamarind by local inhabitant at middle and lower higher altitudes of Western Ghats. The different parts of the plant have been being used for the preparation of herbal formulations. The bark when applied externally, draws out purulent matter, heals boils, cracked skin and pimples. Seed are purgative, haemagglutinating, stem is vermifug.

The stem bark contains oxyresveratrol used for tapeworm. The lakoocha fruits are generally eaten fresh. The edible fruit pulp is believed to act as a tonic for the liver. The raw fruits and male flowers spikes are utilized in pickles and chutney. The brown powder called Pug-Haad in Thailand is a product of the aqueous extraction of monkey jack (*A. gomezianus*) prepared by boiling the wood chips and then evaporating water away. This preparation has been used as a traditional anthelmintic drug for treatment of tapeworm infection in Thailand. The wood is a valuable timber and the leaves are used as fodder. The entire plant is also studied with references to food value and fodder value in the neighbouring countries of Bagaldesh and Nepal (Joshee *et al.,* 2002; Shajib *et al.,* 2012; Panday and Nosberger, 2004; Hossain *et al.,* 2010; Sritularak *et al.,* 2010; Puntumchai *et al.,* 2009; Likhitwitayawuid *et al.,* 2009). Hence the present paper deals with nutritional attributes of monkey jack.

a. View of tree of Monkey jack (*Artocarpus gomezianus* Wall.ex Trecul)

b. View of branch of unripe fruits c. View of branch of ripen fruits

Figure 1: Different parts of the plant *Artocarpus gomezianus* Wall.ex Trecul

Banajalaya

Padubidare

Navanagere

Ashwatpura

Gubburu

Etinala

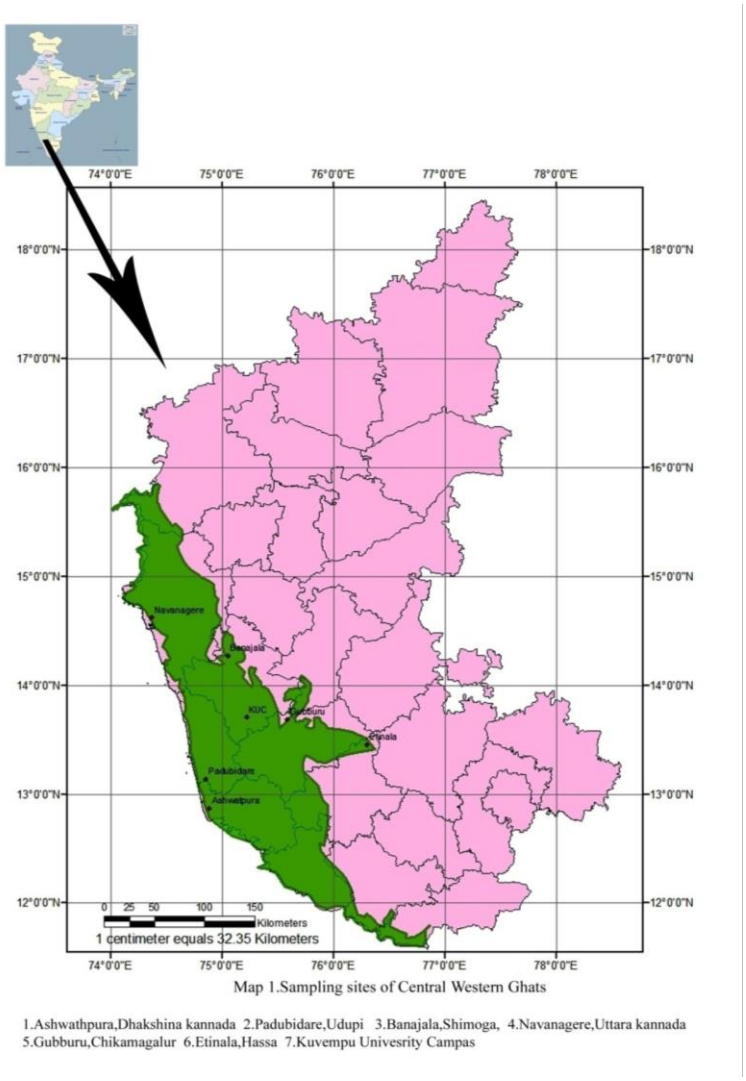
Figure 2: Variation in morphology of fruits of monkey jack (*Artocarpus gomezianus* Wall.ex Trecul)

Methodology

Study Area

The study area lies on the south western parts of Karnataka. The area is known as Western Ghats. The Western Ghats run parallel to the West Coast of India. The average elevation of Ghats ranges between 900 and 1500 meter and some place go behind 2000 meter (Menon and Bawa, 1997). The area harboured rich flora and fauna. The natural vegetation is interrupted by plantations of areca, coffee and paddy fields. The area receives maximum rainfall during south western monsoon.

To survey and documentation of wild edible fruits, six places are selected at different region between 20 and 2000 meter of altitude (Map 1). Ashwatpura and Padubidare come under coastal region, Banajalaya, Navanagere, Gubburu and Etinala come under middle and higher altitudes. The coastal region is densely populated and plants are found in the cultivated and disturbed forests, whereas the plants in the middle and higher altitudes are found in the semi evergreen and the evergreen forests which are not disturbed or less disturbed.



Map 1: Sampling sites of Central Western Ghats

Morphological Study

A total of 15 fruits are randomly selected from each place. The longitudinal and horizontal diameters are measured by using Digital Vernier Caliper. The fruit are weighed and the colour of the fruits is observed (Deepak Dhyani *et al.,* 2007 and 2011) Fig 2.

Powder Yield

The randomly selected 15 fruits are sliced and dried. The seeds are removed and pounded into powder along with 2 to 3 per cent of cooking salt. The weight of the powder is recorded (Kumar *et al.,* 2010) Fig 3.

Fruit Juice Yield

A total of 15 fruits which are randomly selected are subjected for juice extraction. The juice yield is measured and the weight of the pulp is recorded (Deeepak Dhyani *et al.,* 2007) Fig 4.

Drying of fruits in laboratory

Slices removed seeds drying in laboratory

Powder of monkey jack in polythene bags

Figure 3: A Detail of harvesting, processing and preservation

A view of halved fruits

Papad of monkey jack

Juice of monkey jack

Figure 4: Preparation of juice and papad from the fruit sample of monkey jack

Preparation of fruit sample for analysis

The collected fruit samples are carried to the laboratory as quickly as possible using polythene bags. The samples are washed with the help of camel hairbrush and sponging with a piece of cotton wool in a 0.1% detergent solution or dilute (0.1% N) HCl to remove the adherent dust particles, then it was rinsed with distilled water and to remove the excess of water, the fruit samples are rolled on blotting paper or ordinary filter paper. The fruits samples of monkey jack are cut in to small half moon shaped slices or pieces and

shade dried. The dried samples are made into powder used for analysis and extraction. In case of sweet jujube, the pulp and seeds are separated, shade dried and powdered. The powder is used for further analysis and extraction (Fig 5). The analysis was made at department of Applied Botany, Kuvempu University, Shankaraghatta and the Central Coffee Research Institute (CCRI) Balehonnur, Chikamagalure district of Karnataka, India.

Manually harvesting

Harvested fruits

Graded fruits

Halving of fruits

Halved & half moon shape

Slices drying

Drying of fruits in laboratory

Slices removed seeds drying in laboratory

Powder of monkey jack in polythene bags

Figure 5: A Detail of harvesting, processing and preservation

Analytical Method

The morphology and fruit yield were studied**.** The fruit materials were prepared for analysis. The components of proximates (Percentage of ash, moisture, fat, fiber, protein and

carbohydrates) and nutritive value are determined. The mineral components (macro, micro and heavy metals) have been determined using AAS and flame photometer in the laboratory of department of Applied Botany, Kuvempu University, Shankaraghatta and at the Central Coffee Research Institute (CCRI) Balehonnur, Chikamagalure district of Karnataka, India. The values of proximate and macronutrients are expressed in percentage and micro and also heavy metals are expressed in ppm and the nutritive values are compared with RDA values.

Recommended Dietary Allowance (RDA Value)

The proximate, nutritive value and elemental components of fruits of monkey jack and sweet jujube are compared with RDA values. The variations and the importance of proximate, nutritive value, elemental components are also discussed (Food and Nutrition 1945; Wayne *et al.,* 2003; Krishnamurthy and Sarala, 2012).

Results and Discussion:

Preparation of Powder

The processed or preserved slices are pounded for fine powder along with 2 to 3% of cooking salt. The product is known as Vatte pudi or Esluli pudi. The powder is used instated of tamarind (*Tamarindus indica* L.) to prepare curry and other dishes by the local inhabitants of Banajala of Shimoga, Gubburu of Chikmagalur and Navanagere of Uttra Kannada districts respectively (Fig 3).

Preparation of Juice

The known quantity of deseeded and epicarp removed pulp is mixed with equal amount of water and grinded in a mixer along with a known quantity of sugar. The slurry is filter and a pinch of cardamom (*Elettaria cardamomum* (L.) Maton) and black pepper (Piper nigrum L.) are added. The preparation is used as juice (Fig 4).

Monkey jack *(A. gomezianus*)

Having determined, proximate, nutritive value and elemental components of monkey jack at various altitudes for the two years, the observations are discussed. The two yearly average values of elemental components (micro, macro and heavy metals), proximate and nutritive values at different regions (altitudes).

Elemental Composition

Macronutrients

The macronutrients can be arranged on the basis of the concentration at different region/place (Table 1).

Place/region Concentration

- Ashwatpura (altitude 22 meter) nitrogen> potassium> sodium> calcium> phosphorus> magnesium.
- Padubidare (altitude 147 meter) nitrogen > potassium > phosphorus > sodium > magnesium > calcium.
- Banajalaya (altitude 579 meter) nitrogen > potassium > sodium > phosphorus > magnesium > calcium.
- Navanagere (altitude 590 meter) nitrogen > potassium > sodium > magnesium > calcium > phosphorus.
- Gubburu (altitude 763 meter) nitrogen > potassium > sodium > magnesium > calcium > phosphorus.
- Etinala (altitude 949 meter) nitrogen > potassium > sodium > calcium > phosphorus > magnesium.

Nitrogen is the dominate element and phosphorus or calcium or magnesium is the lowest element in their concentration. The position of the element various at different regions except nitrogen and potassium. Of the six elements, potassium, phosphorus, calcium and magnesium are higher in the coastal region except nitrogen and sodium which are highest in the middle regions of Western Ghats. At the same time, the macronutrients are rich in the fruit samples of coastal region.

The sequence of macro elements at different places on the basis of their concentration can be arranged as:

Macro elements	**:**	**Sequence of sampling region**
Sodium (Na)	:	Banajalaya>Etinala>Ashwatpura>Gubburu>Navanagere> Padubidare
Potassium (K)	:	Ashwatpura>Banajalaya>Etinala>Navanagere>Gubburu> Padubidare
Phosphorus (P)	:	Padubidare>Ashwatpura>Etinala>Banajalaya>Navanagere> Gubburu
Calcium (Ca)	:	Ashwatpura>Etinala>Navanagere>Gubburu>Banajalaya> Padubidare
Magnesium (Mg)	:	Gubburu>Ashwatpura≥Navanagere>Etinala>Banajalaya> Padubidare
Nitrogen (N)	:	Banajalaya>Gubburu>Padubidare>Navanagere>Etinala> Ashwatpura.

Among the six macronutrients, the values of sodium ranged between 0.24 ± 0.10 and 0.68 ± 0.52 the minimum and maximum values were recorded at coastal and middle altitudes. The potassium values ranged between 0.76 ± 0.58 and 1.47 ± 0.17, both minimum and maximum values recorded in the coastal region. The phosphorus value ranged between 0.10 ± 0.009 and 0.26 ± 0.04. The minimum and maximum values were recorded in the higher and lower altitudes. The calcium values ranged between 0.10 ± 0.07 and 0.26 ± 0.04 at the middle and coastal region. The magnesium value ranged between 0.098 ± 0.066 and 0.18 ± 0.01 at coastal and higher altitudes. The highest percentage of 23.48 ± 0.69 and lowest percentage of 19.24 ± 0.046 of nitrogen were recorded in middle and lower altitudes.

Micronutrients

Among the micronutrients iron is the dominant which is followed by manganese, zinc and copper. The sequence is same for all the places of sampling sites. The highest values of 802.01 ± 375.28 and minimum 284.95 ± 48.39 ppm of iron is recorded at Padubidare (Coastal region) and Etinala (higher mountain regions) respectively. The manganese value ranged between 34.14 ± 6.93 and 103.49 ± 6.62 ppm at Banajalaya (middle region) and Gubburu (higher mountain). The zinc value ranged between 19.82 ± 8.89 and 24.92 ± 10.24 ppm at Banajalaya (middle region) and Padubidare (coastal region) respectively. The range between minimum and maximum values of zinc and copper is narrow, whereas iron and manganese are wide.

Heavy metals

Between the two heavy metals, lead is dominant which is followed by cadmium at all the sampling stations. The high values of lead ranged between 29.76 ± 42.78 and 44.48 ± 30.90 ppm at Ashwatpura (coastal region). The highest values of 3.01±0.93 of cadmium at Navanagere (middle region) and minimum value of 1.81±1.39 ppm at Padubidare (coastal region) respectively.

Proximates and Nutritive value

The proximates values ranged in the following order at different regions.

Place/region Proximates

Ashwatpura (altitude 22 meter) : Moisture> fat> fibre> carbohydrates> ash> protein
Padubidare (altitude 147 meter) : Moisture>fibre>carbohydrates>ash>fat> protein
Banajalaya (altitude 579 meter) : Moisture>fat>fibre>carbohydrates >ash> protein
Navanagere (altitude 590 meter): Moisture>fat>ash>carbohydrates > fibre > protein
Gubburu (altitude 763 meter) : Moisture>fat>ash>fibre>carbohydrates > protein

Etinala (altitude 949 meter) : Moisture>fat>fibre>carbohydrates > ash > protein

The sequence of proximates at different places on the basis of their concentration can be arranged as:

Proximates: Sequence of sampling region

Ash : Navanagere>Gubburu>Padubidare>Ashwatpura>Etinala>Banajalaya

Moisture : Gubburu>Ashwatpura>Etinala>Navanagere>Padubidare>Banajalaya

Fat : Ashwatpura>Navanagere>Banajalaya>Gubburu>Etinala> Padubidare

Fibre : Padubidare> Ashwatpura> Banajalaya> Etinala> Navanagere> Gubburu

Protein : Padubidare> Etinala> Gubburu> Navanagere> Banajalaya> Ashwatpura

Carbohydrates: Ashwatpura> Padubidare> Etinala> Banajalaya> Navanagere> Gubburu

Among the proximates, ash values ranged between 1.50 ±0.5 and 5.33 ± 0.94 percent at Banajalaya and Navanagere (middle region) respectively. The highest value of moisture of 87.78 ± 1.44 and lowest value of moisture of 81.32 ± 4.47 percent are recorded at Gubburu (higher region) and Banajalaya (middle region) respectively. The lowest values of 3.17 ± 1.49 and higher values of 15.00 ± 5 .00 percent of fat are recorded at Padubidare and Ashwatpura (coastal region). The fiber values ranged between 1.84 ± 0.36 and 10.21 ± 1.72 percent at Gubburu (higher region) and Padubidare (coastal region). The highest and lowest values of 0.51 ± 0.10 and 0.12 ± 0.10 percent of protein are recorded at Padubidare and Ashwatpura (coastal region). The carbohydrates values ranged between 1.36 ± 0.93 and 8.62 ± 4.93 percent at Gubburu (higher region) and Ashwatpura (coastal region) respectively. The minimum and maximum values of all the proximate except moisture are wide. In case of moisture the range values are narrow.

The two yearly average value of nutrition can be arranged in the following sequence. Nutritive value Ashwatpura > Banajalaya > Navanagere > Gubburu > Etinala > Padubidare.

Both minimum of 72.53 ± 26.59 and 169.96 ± 11.14 cal/100 gm of nutritive value recorded at Padubidare and Ashwatpura (coastal region) respectively.

Therefore, the concentration of proximates, nutritive value and elemental components various from places to places and also different year /year of the same places. The variation of different chemical components may influenced by number of factors which include entire plant and their organs and also environmental factors which include soil, water, rainfall, temperature etc.

RDA Value and Nutrition Attributes

When the recorded values are compared with RDA (Recomded Diatry Allowences) values all the macronutrients except nitrogen is rich in fruits of monkey jack (*A. gomezianus*) . Similar to macronutrients, micronutrients and two heavy metals which are also essential at low concentration are found in fruits of monkey jack (*A. gomezianus)* (Wayne Chris Hawkes, 2003 and Food and Nutrition Board, 1945). Therefore, the fruits of monkey jack are the source of proximate, nutritive value and elemental components. Through, the values of proximate, nutritive and elemental components various at different regions, the fruits of monkey jack are the potential sources of nutrition (Table 2).

The proximates, nutritive value and elemental composition of monkey jack (*A. gomeziznus*) fruits collected from different altitudes are determined. The fruits are collected from three individual of population at each places ranging from coastal to high mountains of Western Ghats. Ashwatpura and Padubidare being located at coastal region recorded high values of nutritive value (169.96 cal/100 gm), fat (15.00%), carbohydrates (8.62%), fibre (10.21%), protein (0.51%), potassium (1.47%), phosphorus (0.26%), calcium (0.083%), magnesium (0.15%), zinc (24.52 ppm) and iron (802.01ppm). The Banajalaya and Navanagere being located in the middle region of the Western Ghats recorded high values of ash (5.33 %), nitrogen (23.48%), zinc (20.86 ppm) and cadmium (3.01 ppm). Gubburu and Etinala which are located in the higher altitude recorded high amount of moisture (85.22%), manganese (64.30 ppm) and cadmium (3.01ppm).

The comparatively the coastal region fruits, through small in size yield high amount of proximate and elemental components with high nutritive value, the middle altitudinal regions contain high amount of ash associated with maximum local utility which is revealed by the preparation of maximum value added products. The fruits of higher altitudes through rich in moisture and manganese content, they are inferior in their proximates and nutritive value. When compared the average values of proximate, nutritive value and elemental components with RDA values, the fruits of monkey jack is one of the potential substitutes of food in the middle regions of the Western Ghats. The fruits of middle region having moderate values of nutrients with comparatively high values of protein, ash and fibre being used not only as raw but also as processed products. The fruits replace the tamarind in cooking. It is one of the important ingredients in the number of value added products. The study also revealed that monkey jack an underutilized fruits of Western Ghats not only supplement of food but also generate income through raw and processed products.

The average, minimum, maximum and range values of proximate, nutritive value and elemental components emphasis the importance of monkey jack and sweet jujube fruits of Western Ghats. The number of investigations are initiated the studies on wild edible in India. Indrayan *et al.* (2005) analyzed mineral composition and nutritive value of medicinally valued plants of *Nelumbo nucifera*, *Embelia ribes*, *Eugenia jambolana* and leaves of *Artocarpus heterophyllus* of Uttaranchal and they reported that sodium (7.88%) was highest in *A. heterophyllus* leaves, contained less potassium (3.32%), whereas in the other three plants materials potassium was significant.

The calcium was highest in the seed of (922.10%) *Nelumbo nucifera* but negligible in *E. jambolans* seeds. Magnesium was moderate in all materials, except *Artocarpus heterophyllus* leaves. Copper (0.0463) and Zinc (0.0840) were sufficient in seeds of *Nelumbo nucifera,* moderate in seeds of *E. ribes* but low in the other two materials. The nutritive values of seeds of *Emblica ribes* was maximum followed by seeds of *Nelumbo nucifera* and *E. jambolans*. Leaves of *A. heterphyllus* were found to be less nutritive value, but on dry matter (DM) basis (Moisture 57.9%) they too have good nutritive values, which support their use as fodder for livestock. The *Nelumbo nucifera* seeds have good protein (10.6%) and high carbohydrates (72.17%). The nutritional and energy values of wild edible fruits, berries, nut root and spices consumed by Kashi tribes are studied by A. They are analyzed 8 fruits, *Solanum indicum* is rich in calcium, phosphorus and magnesium, iron is more in *Prunus nepalensis*, manganese in *Vibrnum corylifolia, Solanum xanthocarpum* contain higher amount of sodium and copper. *Vangeria spinosa* is higher in Zinc, *Gomphogyne cissiformis* is rich in potassium. Deepak Dhyani *et al.* (2007) worked on biochemical composition of fruit pulp of *Hippophae rhamnoides* populations, sample from different valleys of Uttarakhand Himalaya. The study revealed that fruit berries and seeds of Seabuckthorn are important source of valuable nutrients, minerals and several other bioactive substances for the local population. Among the different populations studied, the one at Gangotri valley seems to have slightly higher nutritive value and is rich in mineral content followed by those at Mana, Yammunotri, Bhyundar and Niti valley. Biochemical analysis of fruit and seed samples collected from different populations revealed that the fruit and seed of Gangotri populations contain good quality of fat (10.33 ± 0.88), protein (7.13 ± 0.64), carbohydrates (0.40 ± 0.01), reducing sugar (6.0 ± 0.03) and lignins (21.33 ± 0.67), whereas starch and acidity content were found higher in Gangotri population is also rich in macro and micronutrients composition, i.e., iron (0.81 ± 0.090), potassium (14.84 ± 0.2), nitrogen (1.14 ±0.10), phosphorus (0.63 ± 0.07) and arsenic (0.231 ± 0.012) in both

fruit pulp and seeds compared to the other populations. Singh *et al.* (2010) carried out the nutritive values of adult-juvenile foliage of *Celtis australis* a promising fodder tree and they reported that nutritive value of *Celtis foliage* was strongly influenced by altitudinal gradient. The dry matter, phosphorus, potassium and calcium contents showed strong inverse correlation ($P < 0.05$) with altitude whereas phosphorus, potassium and calcium contents showed strong positive correlation ($P < 0.01$) with elevation range of foliage. Crude protein in adult foliage also showed strong positive correlation with altitude ($P < 0.01$). A significantly higher ($P < 0.01$) dry matter, ash, crude protein, and starch was recorded in adult compared to juvenile foliage of *C. australis*. The study suggests that altitude influenced significantly the chemical composition of *Celtis foliage*. Strong correlation was also recorded for chemical composition of adult and juvenile foliage. On average, high altitude foliage (Badiyargon Population, 1980, MSL) exhibited comparatively higher values for crude protein, calcium and potassium whereas; the foliages of low altitude (550 MSL) revealed higher values for phosphorus, soluble sugar and dry matter. Valvi and Rathod (2011) were studied the mineral composition of some wild edible fruits from Kolhapur district. The study reveals that, the higher values of nitrogen, phosphorus and magnesium was observed in a *Grewia tiltifolia* fruits, calcium, sodium and potassium in *Ficus racemosa* fruits respectively and microelements found like iron, which is higher in *Megra lasifora* fruits, Zinc in *Elaeagnus conferta* fruits, while copper and manganese are present abundant in *Flacourtia indica* fruits. Maikhuri Rakesh and Dhyani Deepak (2012) studied on nutritional and energy value of an underutilized wild edible *Viburnum mullaha.* Vitamin analysis conformed that the fruit contain high amount of vitamin C (122.27 mg/100 gm), vitamin B_2 (0.14 mg/g) and vitamin E (13.47 mg/g), macronutrients profile revealed that *Viburnum mullaha* is a rich source of carbohydrates (184.4 g/100 gm), protein (11.3 g/100 gm) and lipids (18.4 g/100 g). It was calculated that 100 gm of fruit berries can provide an average of 284.4 Kcal (1185.7 KJ) energy. Shajib *et al.* (2012) analyzed the mineral composition and nutritive value of *Artcoarpus lakoocha*. The study revealed that the fruits are rich in micronutrients, macronutrients, vitamins. These fruits are economically viable nutrients source in rural people of Bangladesh. Investigation of Blan Mary Mandari and Joshi (2013) explained the nutritional content of traditional recipes consumed by ethnic communities of Meghalaya India.

Among the proximates, protein is one of the important parts of human nutrition; it is not only supporting growth but also important for maintenance and repair of body tissues. The total daily protein intake is based on growth needs and desirable weight of an

individual. The protein recommended for a healthy adult is set at 0.8 gm protein per kilogram of body weight (Suitor and Crowley, 1984). The plant stored or deposits protein in lipids (Jain Ashok and Tiwari Preeti, 2012). Fibre is only found in fruits that come from plants and they are two types of fibres. It is required between 25 and 30 gm a day. The main function of the fibre is kept the digestive system healthy and function properly. fat services as concentrated sources of energy (Agrahar-Murugkar and Subbulakshmi, 2005). Ash is the name given to all non-aqueous residues that remains after a sample is burned, and consists mostly of metal oxides (http/www.en.wikipedia.org/wiki/ash). The ash is the total mineral content of the fragile or diet (Agrahar-Murugkar and Subbulakshmi, 2005). The percentage of moisture is dependent on the pulpiness of the fruits and the wide variations in the moisture content. Water content or moisture content is the quantity of water contained in a material (http/www.en.wikipedia.org/wiki/ moisture). Carbohydrates are the organic compound which has the empirical formula $C_m(H_2O)_n$; that is consists only of carbon, hydrogen and oxygen, with a hydrogen and oxygen, with a hydrogen atom ratio of 2:1. The carbohydrates are divided into four chemical groupings: monosaccharide, disaccharides, oligosaccharides and polysaccharides. Carbohydrates perform numerous roles in living things. The nutritive value or energy is calculated on the basis of the following formulae

Nutritive value/Energy= 4 x percentage of protein + 9 x percentage of fat + 4 × percentage of carbohydrate (Sadasivam and Manickam, 1997).

The nutritive value depends on the quality and quantity of the products. The variation of their value is influenced by many factors which include region, altitude and other factors.

Of the six macronutrients which are studied sodium plays on important role in the transport of metabolites, because of the solubility of salts. Na and K take part in ionic balance of the human body and maintain tissue excitability. Potassium is of important as diuretic. Calcium constituents a large proportion of the bone, human blood and extracellular fluid; it is necessary for the normal blood and extracellular fluid; it is also necessary for the normal functioning of cardiac muscles, blood coagulation and milk clotting, and the regulation of cell permeability. It also plays an important part in nerve-impulse transmission and the mechanism of neuromuscular system. Magnesium is required in the plasma and extracellular fluid, where it helps to maintain osmotic equilibrium. It is required in many enzyme-catalyzed reactions, especially those in which nucleotides participate where the reactive species is the magnesium salt, e.g., $MgATP^{2-}$.

Lack of Mg is associated with abnormal irritability of muscle and convulsions and excess Mg with depression of the central nervous system (Indrayan *et al.,* 2005). Nitrogen is essential for structural proteins (Krishnamurthy and Sarala, 2010). Phosphorus is a major mineral and most of it is stored in bones, lesser amount of phosphorus are found in teeth, DNA, and cell membranes. Phosphorus is necessary for building strong bones and is important for many biochemical reactions such as converting the foods into the energy. Phosphorus also helps with muscle contraction, nerve conduction and normal kidney function (http/www.en.wikipedia.org/wiki/phosphorus). Iron deficiency causes poor growth, impaired immune function and delayed mental development. The poor absorption of iron by the humans significantly limits effectiveness of these supplements which are found in neutraceuticals (Jian Zhao, 2007). Copper is also a component of many enzyme systems such as cytochrome oxidase, lysyl oxidase and ceruloplasmin, an iron-oxidizing enzyme in blood (Mills, 1981). The observation of anemia in copper deficiency may probably be related to its role into haemoglobin (FAO/WHO Hand Book on Human Nutritional, 1974). Zinc is a component of many metalloenzymes, including some enzymes which play a central role in nucleic acid metabolism (Atukorala and Waidyanatha, 1987). In addition, zinc is a membrane stabilizer and a stimulator of immune response (Hamdidge, 1978). Zinc deficiency leads to impaired growth and malnutrition (Prasad, 1981). Cu plays an important role in enzymatic catalysis and are crucial to virtually all biochemical and physicochemical process (Saiqa Saiqa *et al.,* 2008). Manganese is another microelement essential for human nutrition; it acts as activator of many enzymes (Hassan and Umar, 2006). Lead is the most ubiquitous toxic metal in the environment and in many countries the intake from the diet can approach or exceed the PIWI (Caldas and Machado, 2004). Cadmium is accumulating in various parts of the body (liver, pancreas, kidney etc.) and is known to cause painful bone disease called itai-itai (Trivedy and Goel, 1986).

The average, minimum, maximum and range values of proximate, nutritive value and elemental components emphasis the importance of monkey jack fruits of Central Western Ghats. The number of investigations have initiated the studies on wild edible in India. The famine edible fruit and medicinal plant *Z. rugosa* in Western Ghats, provides proximate, nutrition and elements (Krishnamurthy and Sarala, 2012). The investigation of Dhyani *et al.* (2007) explained the importance of wild bio-resources to solve unemployment problem in the rural sector and to improve social-economic and environmental balance.

Table 1: Elemental components (macro elements in percentage, micro elements and heavy metal in ppm), Proximates (percentage), nutritive value (cal/100 gm) of *Artocarpus gomezianus* Wall.ex Trecul

Sl. No.	**Factors**	***Artocarpus gomezianus* Wall.ex Trecul**					
		Gubburu	**Ashwatpura**	**Padubidare**	**Banajalaya**	**Navanagere**	**Gubburu**
I	**Macronutrients**						
	Sodium (Na)	0.32±0.19	0.55±0.44	0.24±0.10	0.68±0.52	0.28±0.15	0.32±0.19
	Potassium (K)	0.85±0.47	1.47±0.17	0.76±0.58	1.45±0.07	0.87±0.55	0.85±0.47
	Phosphorus (P)	0.10±0.009	0.22±0.02	0.26±0.04	0.13±0.02	0.10±0.02	0.10±0.009
	Calcium (Ca)	0.123±0.075	0.26±0.04	0.083±0.069	0.10±0.07	0.14±0.04	0.123±0.075
	Magnesium (Mg)	0.18±0.01	0.15±0.055	0.098±0.066	0.11±0.04	0.15±0.03	0.18±0.01
	Nitrogen (N)	21.86±2.31	19.24±0.046	21.48±0.69	23.48±1.00	21.25±0.00	21.86±2.31
II	**Micronutrients**						
	Zinc (Zn)	20.29±7.83	24.52±5.37	24.92±10.24	19.82±8.89	20.86±9.61	20.29±7.83
	Copper (Cu)	9.85±3.95	9.76±4.71	12.84±3.57	10.06±2.47	9.36±2.61	9.85±3.95
	Manganese (Mn)	321.66±6.46	46.81±5.22	802.01±375.28	355.30±145.84	622.98±368.86	321.66±6.46
	Fe (Iron)	103.49±6.62	531.74±240.77	95.29±20.85	34.14±6.93	64.30±9.04	103.49±6.62
III	**Lead and Cadmium**						
	Lead (Pb)	-		-	-	-	-
	Cadmium(Cd)	-		-	-	-	-
	'+' indicates traces, '-' indicates not detected						

IV	**Proximates and nutritive value**						
	Ash	3.83±0.37	2.83±1.21	3.25±0.38	1.50±0.50	5.33±0.94	3.83±0.37
	Moisture	87.78±1.44	86.95±2.56	84.33±1.43	81.32±4.47	85.22±2.74	87.78±1.44
	Fat	9.00±0.50	15.00±5	3.17±1.49	10.58±0.34	11.50±2.08	9.00±0.50
	Fibre	1.84±0.36	10.00±0.00	10.21±1.72	8.43±1.28	2.53±0.48	1.84±0.36
	Protein	0.28±0.23	0.12±0.10	0.51±0.10	0.14±0.10	0.24±0.24	0.28±0.23
	Carbohydrates	1.36±0.93	8.62±4.93	7.57±3.14	6.54±4.69	3.17±3.47	1.36±0.93
	Nutritive value	85.57±13.17	169.96 ±11.14	72.53±26.59	121.53±20.37	95.30±11.78	85.57±13.17

$$\frac{\text{Graph ppm}}{10^6} \text{ X Dilution Factor x } \frac{\text{Volume of plat digestion made}}{\text{Weight of the plant sample}} \text{ X } 10000$$

Table 2: Comparison of Recommended Dietary Allowances (RDA) with Proximate, nutritive value and elemental composition of *A. gomezianus* (Krishnamurthy and Sarala, 2012)

Factors	22/A	147/P	579/B	590/N	763/G	949/E	Recommended Dietary Allowances					
							Females			Male		
							9-13 years	14-18 years	19-30 years	9-13 years	14-18 years	19-30 years
I. Macronutrients (mg/1gm)												
Sodium (Na)	55	24	68	28	32	63	250mg/d					
Potassium (K)	14.7	76	14.5	8.7	8.5	14.4	250mg/d					
Calcium (Ca)	26	83	10	14	12.3	19	1.250 mg	1.250 mg	700 mg	1.250 mg	1.250 mg	700 mg
Magnesium (Mg)	15	9.8	11	15	18	12	1.300 mg	1.300 mg	1.00 mg	1.300 mg	1.300 mg	1.00 mg
Nitrogen (N)	-	-	-	-	-	-	-	-	-	-	-	-
II. Micronutrients (mg/1gm)												
Zinc (Zn)	0.24	0.24	0.19	0.20	0.20	0.24	8 mg/d	9 mg/d	8 mg/d	8 mg/d	8 mg/d	11 mg/d
Copper (Cu)	0.9	0.12	0.10	0.93	0.98	0.78	700 mg/d	890 mg/d	900 mg/d	700 mg/d	890 mg/d	900 mg/d

Manganese (Mn)	0.53	0.80	0.35	0.62	0.32	0.28	1.6 mg/d	1.6 mg/d	1.8 mg/d	1.9 mg/d	2.2 mg/d	2.3 mg/d
Irone (Fe)	0.46	0.95	0.34	0.64	0.10	0.36	8 mg/d	15 mg/d	18 mg/d	8 mg/d	11 mg/d	8 mg/d
III.Heavy metals(mg or %/1gm)												
Lead (pb)	0.29	0.40	0.39	0.43	0.44	0.43	5.4%					
Cadmium (cd)	0.21	0.18	0.19	0.30	0.19	0.20	2.9%					
IV. Proximate (mg or %/1gm)												
Ash	2.83	3.25	1.50	5.33	3.83	1.83	NA					
Moisture	86.95	84.33	81.32	85.22	87.78	86.38	NA					
Fat	15.00	3.17	10.58	11.50	9.00	7.92	NA					
Fibere	0.10	0.10	0.84	0.25	0.18	0.74	25 to 30gm					
Protien	0.12	0.51	0.14	0.24	0.28	0.36	44 to 58 gm.					
Carbohydates	8.62	7.57	6.54	3.17	1.36	6.65	55 to 60%.					
Nutritive Value (Cal/100gm)	114.87	72.53	121.53	95.30	85.57	78.86	NA					

Conclusion:

Wild edible are the important resources to provide nutrients supplements and to generate income. The majority of the NTFPs have come to near extension, because of unsustainable marketing and demand. The monkey jack an underutilized fruits of Western Ghats is a potential sources for proximate, nutrients and elemental components. The entire plant is used one or the other way the plant is also a medicine not only in India but also in other tropical countries. The traditional systems of medicine reveal that all the parts of the plants have medicinal uses. The present investigation reveals that monkey jack is one of the important wild edible and medicinal plants. The traditional knowledge for processing, preservation and value added products are closely related with social and cultural status of the local people. The study is useful not only to known the various aspects of monkey jack but also useful in conservation of biodiversity and traditional knowledge.

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FERMENTED BAMBOO SHOOTS: AN OVERVIEW

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Abstract:

Fermented bamboo shoots (Bambusa sp.), mostly used in traditional cuisines, have been known to host a wide range of nutrients and phytonutrients that have been associated with numerous health benefits. They are a storehouse of probiotic microorganisms, including members of lactic acid bacteria (LAB) and yeasts, justifying their use as functional foods. Indeed, the available fermented bamboo shoot products, including soibum, lung-siej, mesu, ekung, soidon, hirring, and eup have been noted to be a valuable reservoir of proteins, carbohydrates, dietary fibres, minerals, and vitamins such as thiamine, niacin, vitamin A, vitamin B6, and vitamin E, with the content dependent on the process of fermentation and type of starter culture employed. These fermented shoots also contain significant amounts of plant-based polyphenols as well as sterols, which together with the nutrient content, portray health advantages, mainly alleviation of cardiovascular disorders, obesity, gastrointestinal discomfort, urinary tract infection, depression, cancers, and allergies mediated through their antioxidant and anti-inflammatory potentials. Nonetheless, cyanogenic glycosides in the bamboo shoots have been observed to raise safety concerns, which can be mitigated through the incorporation of recommended cooking and fermentation procedures. Hence, increased awareness and utilization of fermented bamboo shoots may be beneficial not only for maintaining nutritional status but also for promoting good health.

Keywords: Bamboo, Fermentation, Food, Health, Nutrients, Phytonutrients

1. Introduction:

Bamboo (*Bambusa sp.*) shoots, a versatile forest tree grass, are recognized for their health benefits and use in traditional cuisines. Fermented bamboo shoots contain microorganisms that offer anti-cancer, anti-oxidant, anti-aging, cardioprotective, anti-obesity, and anti-allergic properties. These nutrient-rich foods are also significant industrial and economic resources. Known as "green gold" in India, they are a valuable resource not only in tribal areas but also in the global markets (Joshi *et al.,* 2023).

Fermented bamboo shoots offer numerous health benefits as well as high medicinal and food value. Despite their pungent odor and bitter acidic taste, they are rich in essential microorganisms, particularly lactic acid bacteria (LAB) and yeast strains, giving food products color, fragrance, flavor, taste, and texture (Nongdam *et al.,* 2014). Moreover, these probiotics qualify them as functional foods. Local tribes in northeastern India produce various fermented bamboo shoot-based culinary products such as soidon, soibum, mesu, ekung, lung-siej, hirring, and eup. These products are important for their high dietary fiber, minerals, and low fat content, as well as their therapeutic potential (Bajwa *et al.,* 2020).

2. Microflora of Fermented Bamboo Shoots

Lactobacillus sp. ferments bamboo shoots to produce commodities like soidon, soibum, soidon, lung-siej, and bamboo shoot pickles. These foods serve as reservoirs of LAB, which enhance the flavor, fragrance, and sour taste of the same. LAB is crucial in research due to its fermentation and bio-preservation capabilities. They are also cell factories for the manufacture of metabolites, including B vitamins. Selecting suitable LAB strains as starter cultures is crucial as they determine the characteristics of the fermented products (Behara *et al.,* 2021).

3. Fermented Bamboo Shoot Products

Numerous food products derived through LAB-mediated fermentation of bamboo shoots are popular, specially produced and consumed by the local tribes of northeast India.

3.1. Soibum

Manipur is a hub for fermented food products, particularly those made by the Meiteis tribe. Soibum, a unique fermented bamboo stalk, is made from delicate bamboo shoots like *Bambusa tulda* and *Bambusa balcona* that is fermented for 3-12 months. The Meitei tribe eats it with steamed rice. Soibum is sold by Meitei women in Manipur and contains various microbes and yeasts, including *Lactobacillus plantatum*, *L.brevis*, *L. coryniformis, L. delbrueckii, L. mesenteroides, Leuconostoc fallax, Lactococcus lactis, Streptococcus lactis, Enterococcus durans, Bacillus subtilis, Candida, and Saccharomyces* (Acharya *et al.,* 2023).

3.2. Lung-Siej

Lung-siej is a traditional Meghalayan fermented bamboo shoot dish made from various bamboo species, where the shoots are sliced and placed in bamboo cylinders or glass bottles. Glass bottles are popularly used as fermentation containers that contain sliced bamboo shoots soaked in water and sealed for one month. Notably, lung-siej in glass

bottles has a longer shelf life (up to 12 months) compared to those in bamboo cylinders (1-2 months). Lung-siej is often served as a curry with fish and meat and is mainly developed through fermentation by LAB like *Leuconostoc fallax*, *L. mesenteroides*, *Lactobacillus brevis*, *L. curvatus*, and *Lactococcus lactis* (Behara *et al.,* 2021).

3.3. Mesu

Mesu made from edible bamboo shoots like karati bans, choya bans, and bhalu bans is commonly consumed by the Gorkha tribe of Sikkim. The shoots are defoliated, cut, and pushed into a bamboo stem, wrapped in leaves, and fermented naturally for 7-15 days. Mesu is primarily consumed as a pickle, with a typical flavor and taste. Made by Nepalese Limboo women, it is sold in green bamboo cups during the rainy season in local markets (Bawaik *et al.,* 2014).

3.4. Ekung

Ekung is an ethnic fermented bamboo shoot product from Arunachal Pradesh, made by slicing and washing the bamboo shoots in a trench near a water body. The pieces are then placed in a bamboo basket, covered with leaves, and sealed. The water is drained, and the shoots are fermented for 1-3 months, which can be stored in airtight jars for up to a year. Ekung microbes, including *Lactobacillus plantarum*, L. casei, L. brevis, and *Tetragenococcus halophilus* offer antifungal and antibacterial properties to these foods (Nongdam, 2015).

3.5. Soidon

Soidon is a popular fermented Manipur food made from ripe bamboo stalk tips. The tips are submerged in water in an earthen pot, and a previous batch's sour liquid is added as a starter. Fermentation by *Leuconostoc fallax, L. brevis*, and *Lactococcus lactis* takes place at room temperature for 3-7 days, with *Garcinia pedunculata* Roxb., also known as heibungin, added to improve the flavor. After 3-7 days, soidon is withdrawn and stored at room temperature. (Tamang *et al.,* 2009).

3.6. Hirring

Hirring is a fermented bamboo stalk product from Arunachal Pradesh, made by slicing or crushing bamboo shoots and placing them in bamboo baskets with leaves. Fermented for 1-3 months, it can be eaten as a curry and contains *Lactobacillus plantarum* and *Lactococcus lactis* (Acharya *et al.,* 2023).

3.7. Eup

Eup is a dry fermented bamboo shoot from Arunachal Pradesh, made from chopped bamboo shoots that are sun-dried for 5-10 days until they turn chocolate brown. These are usually consumed as a curry with vegetables, fish, or meat and can be stored for up to two years. Common microbes used in its production are *Lactobacillus fermentum* and *Lactobacillus plantarum* (Tamang *et al.,* 2009).

4. Nutritional and Phytonutrient Content of Bamboo Shoots

Bamboo shoots have a lot of potential as a health food because they constitute a significant source of nutrients, including proteins, carbohydrates, dietary fibre, minerals, and vitamins. These shoots have been characterized to be high in thiamine, niacin, vitamin A, vitamin B6, and vitamin E. Bamboo shoots often contain tyrosine, arginine, histidine, and leucine. The nutrient profile of fermented bamboo shoots might vary depending on the type of bamboo, the fermentation procedure, and the preparation methods. Following is a summary of the nutritive components found in fermented bamboo shoots:

4.1. Macronutrients and Fibre

4.1.1. Proteins

During the fermentation process, bamboo shoots experience changes in their protein composition. Because of enzymatic activity during fermentation, the proteins in bamboo shoots are broken down into smaller peptides and amino acids, enhancing their digestibility and bioavailability. Protein hydrolysis also yields bioactive peptides that have positive impacts on health, including antioxidant, antihypertensive, or antibacterial properties (Daliri *et al.,* 2017). Hence the amino acid and protein content result in the improvement of the nutritional quality of these food products.

4.1.2. Fat

During the fermentation process, bamboo shoots have been noted to experience changes in their fat composition. Fermentation-related microorganisms create lipolytic enzymes, which break down triglycerides into glycerol and fatty acids. Lipolysis alters the fatty acid content of fermented bamboo shoots, leading to a change in fatty acid composition and proportion. Fermentation also results in the production of some advantageous short-chain fatty acids (SCFAs) (Chongtham *et al.,* 2020). The degree of lipolysis and alterations in the fatty acid composition has an impact on the nutritional value of fermented bamboo shoots.

4.1.3. Carbohydrates

Fermented bamboo shoots can experience considerable changes in their carbohydrate characteristics, which are frequently employed in Asian cuisines. During fermentation, the starch content of bamboo shoots tends to decline. Microbial enzymes convert starch into less complex carbohydrates like maltose and glucose. Bamboo shoots' sugar content may rise as a result of fermentation. Lactic acid is one of the organic acids that may be produced during fermentation by LAB that result in a tangy flavour. Fermentation has the potential to alter the dietary fibre composition as well. Bamboo stalks that have been fermented can provide a valuable source of prebiotics that encourage the proliferation of probiotics (Li *et al.,* 2016).

4.1.4. Dietary fibres

Dietary fibre is naturally abundant in bamboo stalks. The bamboo species, processing techniques, and fermentation conditions affect the dietary fibre characteristics of fermented bamboo shoots. While water-soluble fibres have positive effects on blood sugar control and cholesterol levels, insoluble fibres provide bulk to food and promote normal digestion. The ratio of soluble to insoluble fibres in fermented bamboo shoots varies depending on the bamboo species and the fermenting method. Notably, certain dietary fibres found in bamboo shoots, namely fructans of the inulins, have prebiotic qualities (Li *et al.,* 2016). Prebiotic fibres nourish the probiotics, enhancing gut health and digestion. Improved digestive health, weight control, and a potential decrease in the risk of chronic illnesses like heart disease and type 2 diabetes are among the health advantages of dietary fibres derived from the above.

4.2. Micronutrients

4.2.1. Vitamins

Bamboo shoots are a good source of several vitamins, such as vitamins B, C, A, and K. Fermentation has been shown to influence the vitamin composition of these shoots. B vitamins including thiamin (B1), riboflavin (B2), and niacin (B3), increase in concentration depending on the bacteria engaged in fermentation. These vitamins can be produced by the fermenting microbes, including LAB, with the levels dependent on the conditions and type of starter culture (Nongdam *et al.,* 2014). Folic acid has been particularly found to be elevated in fermented bamboo shoots compared to their non-fermented counterparts, thereby increasing their nutritional value. Moreover, fermented bamboo shoots have been shown to contain significant amounts of vitamin K that are produced by the microbes. This process has also been reported to convert provitamin A to vitamin A, hence enhancing the

concentration of this micronutrient in fermented products. Nonetheless, fermentation has been shown to dramatically reduce the vitamin C content of bamboo shoots, mostly because of changes in pH, oxygen concentration, and temperatures (Singhal *et al.,* 2021).

4.2.2. Minerals

Although fermentation has been reported to lower the content of certain minerals, fermented bamboo shoots are a good source of calcium, iron, sodium, potassium, zinc, copper, and manganese. The fermentation procedure and conditions have been shown to affect the mineral characteristics of the final product, mainly due to the utilization of brine in the process. During fermentation, the calcium content of bamboo shoots stays unchanged. Similar to calcium, the magnesium concentration has also been noted to stay constant or undergo slight fluctuations. Fermentation improves the bioavailability of iron because of a reduction in anti-nutritional elements like phytates. The fermentation process also affects the amounts of dietary sodium and potassium. Fermented bamboo shoots also contain minimal amounts of phosphorus, zinc, copper, and manganese. Additionally, the soil quality used for the cultivation of bamboo impacts the mineral content of bamboo shoots (Chongtham *et al.,* 2021).

4.3. Phytonutrients

Phytonutrients, commonly referred to as phytochemicals, are organic substances present in plants that have a range of health-improving qualities. The bamboo variety, processing conditions, and the fermentation method affect the amount and quantity of phytonutrients in fermented bamboo shoots (Bajwa *et al.,* 2020). The antioxidant activity of fermented bamboo shoots may be influenced by their phytonutrient content. Bamboo shoot-derived phytonutrients provide a range of health advantages, including immune system support, cancer prevention, and protection against cardiovascular disease through their antioxidant and anti-inflammatory properties conferred by the phytonutrients, mainly phenolic compounds. Moreover, bamboo shoot-based diets are high in phytosterols, which lower cholesterol levels, making them a popular health food.

4.3.1. Phenolic compounds

The functional and sensory qualities of fermented bamboo shoots are mostly influenced by the phenolic constituents. Phenolic compounds are a family of bioactive phytochemicals that are present in a variety of plant-based diets and serve several crucial purposes owing to their antioxidant and other therapeutic capacities. Numerous phenolic compounds, such as flavonoids and alkaloids that are found in bamboo shoots contribute to health advantages, including improved immune function, cancer prevention, and

cardiovascular health. Fermented bamboo shoots' phenolic compounds assist in scavenging free radicals, lowering oxidative stress and the danger of developing chronic illnesses (Knez *et al.,* 2023). Notably, bamboo shoot (*Chimonobambusa quadrangularis*) contains fructans that resemble inulin (Chen *et al.,* 2020). These prebiotic fibres foster the development of advantageous gut flora, enhancing digestion and gut health.

4.3.2. Sterols

The precise composition and concentration of sterols in fermented bamboo shoots can vary depending on the species of bamboo, the growth conditions, and the fermentation method. Bamboo shoots, like many plant-based meals, contain modest levels of plant sterols, notably β-sitosterol, campesterol, and stigmasterol. These phytosterols, which resemble cholesterol structurally, are known to provide a variety of health advantages, including the ability to decrease cholesterol levels in the blood. The sterol content of bamboo shoots, though not significantly elevated by fermentation, is dependent on the microbial activity and the fermentation conditions (Sarangthem *et al.,* 2003).

Because of their high protein, amino acid, mineral, fibre, carbohydrate, and low-fat content, bamboo shoots are usually regarded as nutrient-dense foods. The presence of phytosterols in young shoots also bestows enhanced vitality and lifespan upon consumption. The rich nutritional and functional profile of fermented bamboo shoots has boosted their commercial value. Also, bamboo shoots can be utilized to make functional xylooligosaccharides, which can be used in food, biodegradable polymers or nanoparticles, and pharmaceuticals.

4.4. Effect of Fermentation on the Nutritional and Phytochemical Content of Bamboo Shoots

Studies have observed the fermentation of bamboo shoots to modulate their nutrient composition compared to their non-fermented counterparts. Although fermentation marginally reduces the mineral content manifested by the ash percentage, an increase has been observed in the protein content, mainly the soluble proteins. This may be due to the proteolytic activity displayed by probiotic microbes that are involved in fermentation (Thakur *et al.,* 2018). Elements including calcium, magnesium, phosphorus, potassium, and sodium are reduced post-fermentation. Moreover, fermentation reduces the content of total carbohydrates, including both soluble and non-soluble sugars, because of their utilization by the microbes during fermentation. The fat level of fermented bamboo shoots has been reported to be significantly low, demonstrating that fermented shoots are an appropriate nutraceutical meal with high protein and low-fat content (Nirmala *et al*,

2008). Fermentation has also been observed to limit the vitamin C content of bamboo shoots. Fermented bamboo has been associated with a significant content of polyphenols and flavonoids, mostly integrated with iron in the form of complexones. Furthermore, fermentation has been noted to elevate the phenolic content, such as procatechuic acid, p-hydroxybenzoic acid, and syringic acid, owing to microbial activity causing hydrolysis of glycosidic bonds in phenolic compounds, resulting in the liberation or synthesis of numerous bioactive chemicals. Fermented bamboo products have also displayed heightened antioxidant potential, most of which has been attributed to its phenolic percentage (Singhal *et al.,* 2021).

5. Health Benefits of Bamboo Shoots

Bamboo shoots have enormous promise as a vital health food. Because of the interests of numerous research groups promoting its nutritional values and health features, the usefulness of bamboo shoots as a health food has recently been recognized. Fermented bamboo shoots portray several beneficial effects fostered by their biochemical content and probiotic properties. The phenolic content of fermented bamboo shoots has been observed to assist in free radical mitigation and cardio-protection through reduced inflammation and oxidative stress (Joshi *et al.,* 2023). Moreover, this property has also been proven useful for protection against cancers. Additionally, the above protection is also mediated by the probiotic action that stimulates immunological defenses and up-regulates anti-inflammatory cascades. Fermented bamboo has been observed to promote the reduction of pro-inflammatory cytokines, depletion of serum cholesterol, improvement of glucose and lipid metabolism, and curtailment of carcinogenesis during all stages of development (initiation, promotion, and progression) (Badwaik *et al.,* 2021). The phytosterols present in these products have also been recognized in cancer and cardiovascular disease prevention and protection. Furthermore, the amino acid profile of these products assists in stabilizing hormonal levels and supporting optimum metabolism. In fact, tyrosine, a precursor for adrenaline, has been reported to regulate body metabolic activities and play a key part in the function of the thyroid and pituitary glands (Nongdam *et al.,* 2014).

The dietary fibre content equips this fermented product with properties of improved digestibility, enhanced heart health, and reduction of constipation and obesity. Indeed, the phytosterol and dietary fibres present in the shoots have been correlated with cholesterol, and fat-lowering properties. Moreover, the mineral and phytonutrient composition of the above also enables them to reduce hypertension (Awol, 2015). Fermented bamboo shoots have been employed for the treatment of piles and urination

issues in traditional medicine, which may be attributable to the anti-inflammatory effects delivered by phenols, phytosterols as well as vitamins C and E. Additionally, these fermented commodities have been used for the alleviation of respiratory disorders (Chongtham *et al.,* 2011). The protease activity of the same bestows it with digestion improvement and curing of maggot-infected wounds. These products have also found insight into anti-aging strategies and have been found useful for the elimination of heavy metals (Massoud *et al.,* 2019). Consumption of fermented bamboo has also been associated with weight management owing to the reduction of the amount of food required by the body due to prolonged digestion and metabolism of these products (Zhou *et al.,* 2023). Most of the above-mentioned benefits have been reported to be delivered through bioactive compounds found in fermented bamboo shoots, such as phenolics, flavonoids, phytosterols, and crude fibre along with the prebiotic-mediated effects.

5.1 Probiotic Property

Fermented bamboo shoots such as soidon, lung-siej, ekung, soibum, and mesu are high in probiotic microbes. Hence most of the health benefits shown by these food products might be attributed to the probiotic effects displayed by members of the LAB, such as *Lactobacillus plantarum* (Figure 1). Many members, especially *L. brevis,* display high hydrophobicity that allows them to successfully colonize the host gut through effective attachment to the epithelial cells. Being considered GRAS (Generally Recognized as Safe), these products have no side effects even in immunocompromised people. Additionally, they have been reported to promote immune-modulation effects with enhanced healing of damaged mucosa apart from regulating over-stimulated immune and inflammatory responses (Thakur *et al.,* 2018). Moreover, they have also been correlated with antagonistic effects against pathogenic microorganisms due to the secretion of antibiotic-like factors and degradation of toxin receptors. Indeed, *L. plantarum* has been documented to limit pathogen adhesion to the gastrointestinal system or urinary tract, hence preventing infection along with maintaining the balance of gut microbiota because of its probiotic nature. Furthermore, the GABA (gamma-aminobutyric acid) produced by LAB, mainly *L. brevis*, renders antidepressant properties (Alizadeh Behbahani *et al.,* 2020). The beneficial bacteria in these products have also been observed to help in the inhibition of auto-aggressive and allergic reactions via the expansion of mucosal regulatory cells.

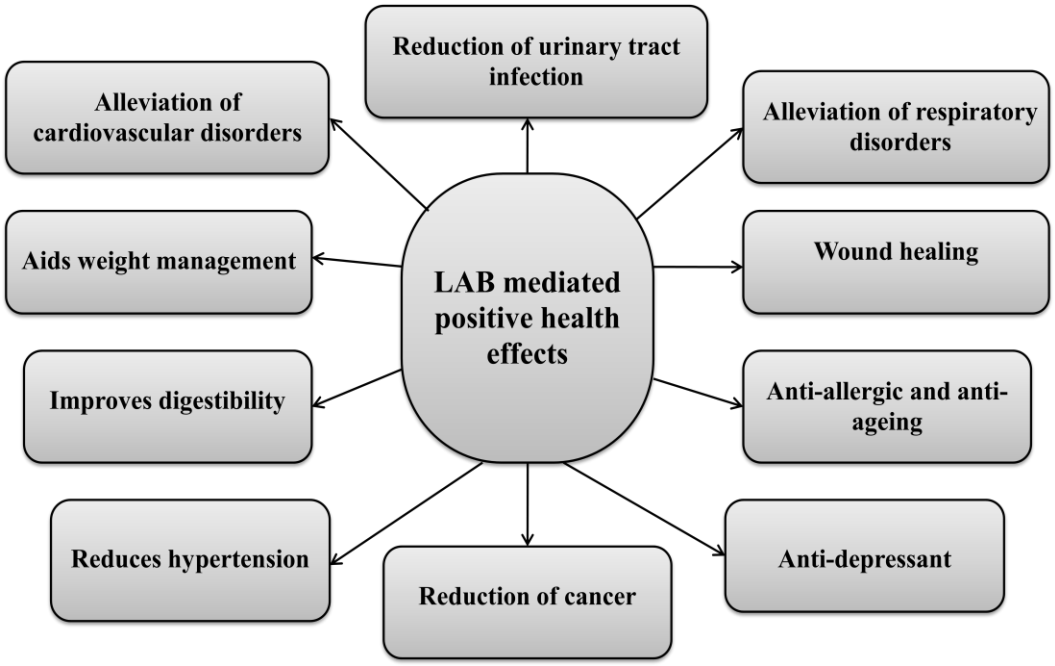

Figure 1: Health benefits of fermented bamboo shoots

6. Demerits of Fermented Bamboo Shoots

Consumption of fermented bamboo stalks may occasionally result in poisoning. Taxiphyllin, a cyanogenic glycoside found in bamboo shoots, can cause cyanide poisoning. A dosage of 0.5-3.5 mg/Kg body weight is considered unacceptable and may cause major health problems. When a cyanogenic plant is consumed, β-glycosidase is generated during digestion and remains active until deactivated by the stomach's low pH. This enzyme will hydrolyze the cyanogenic glycoside and release hydrogen cyanide gas, which can lead to adverse health consequences by affecting the central nervous system and leading to cardiovascular instability (Rawat *et al.,* 2015). Most edible bamboo shoots contain a high quantity of cyanogenic glycoside, with the highest concentration seen at the shoot tip. Nonetheless, bamboo shoots with high levels of cyanogenic chemicals can be made completely edible by cooking in water for around 2 hours. Importantly, fermentation has been observed to reduce the content of these glycosides, thereby rendering them safe for consumption. On the contrary, consumption of incorrectly prepared bamboo shoots may be harmful and has been noted to cause symptoms such as fast breathing, low blood pressure, dizziness, stomach pains, headache, vomiting convulsion, and coma (Nyirenda, 2019). Its effect on respiration has been attributed to the inactivation of cytochrome oxidase. Apart from the disadvantages mediated by cyanogenic glycosides, bamboo-based fermented meals necessitate a vast body of water for preparation and fermentation. Additionally, chopping and slicing of large quantities of bamboo shoots results in deforestation. However, when the benefits of fermented bamboo shoots are weighed against the

drawbacks, the former exceeds the latter in qualifying as a rich source of nutrition, functional effects, and therapeutic value.

Conclusion:

Fermented bamboo shoots are a reservoir of microorganisms, many of which are natural probiotics belonging to the LAB group. These are mostly prepared and consumed in northeast India and are available in several preparations, including soibum, lung-siej, mesu, ekung, soidon, hirring, and eup. These products have been noted to portray numerous benefits, including antioxidant, anti-cancer, blood pressure reduction, cardiovascular disease prevention, anti-obesity, and weight loss. Being a rich source of several nutrients and phytochemicals such as carbohydrates, proteins, minerals, vitamins, phytosterol, and phenolics, these have been recognized to be useful for maintaining nutritional status along with good health in individuals. Indeed, these have been documented to be commercially important, especially in the food and pharmaceutical industries. Although associated with certain demerits conferred by cyanogenic glycosides and environmental issues related to the requirement of enormous volumes of water and deforestation, the benefits outweigh the drawbacks. Therefore, fermented bamboo shoots qualify as promising targets in the international market in terms of nutrition, health, and therapeutic properties.

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THE GUT MICROBIOME: A CORNERSTONE OF HUMAN HEALTH

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Abstract:

The gut microbiological system is a complex ecosystem of trillions of microorganisms residing in the gastrointestinal tract which plays an important role in human health and disease. This diverse microbial community influences on physiological functions like immune modulation, digestion, metabolism and even brain function through the gut brain axis. Recent advancements in metagenomics and sequencing technologies have revealed the major impact on health with alterations in microbial composition being connected to many disease conditions like diabetes, obesity, cardiovascular disease and mental health disorders. The microbiota role extends beyond digestion. It modulates immune responses, aids in nutrient synthesis, and affects metabolic pathways by fermenting dietary fibers into essential short chain fatty acids. The therapeutic potential of microbiome modulation through prebiotic, probiotic and fecal microbiota transplantation gaining significant interest as an avenue for treating diseases associated with dysbiosis. The growing recognition of the gut microbiological system as a cornerstone of human health has led to a paradigm shift in both medical research and clinical practice, with an increasing focus on microbiome-based interventions for personalized healthcare. This abstract provides an overview of the gut microbiological system, its impact on health its impact on human health and the therapeutic strategies being explored to modulate the microbiota for health benefits.

Keywords: Microbiome, Probiotics, Prebiotics, Dysbiosis, Dietary Fiber, Human Health, Clinical Practice

Introduction:

The gut microbiome is the complex community of trillions of microbes inhabiting the human gastrointestinal tract has emerged as a human health in recent years. The human gut microbiota is composed of fungi, viruses, bacteria and other microorganisms that work together in a highly coordinated manner, influencing a range of many

physiological processes like immunity, digestion, metabolism and cognitive functions. The gut microbiome and human health has symbiotic relationship. Recent scientific research shown that the gut microbiome plays a critical role in regulating gut health influencing immune function, and even contributing to mental health through gut brain axis. The microbiota is involved in the metabolism of dietary components, such as lipid, protein and carbohydrate and has a role in the synthesis of vital nutrients like short chain fatty acids and vitamins which have anti-inflammatory properties. Disruptions to the microbiome, whether through poor diet, use of antibiotics, other factors which leads to imbalances (dysbiosis) that contribute to many health conditions. The gut microbiological ecosystem comprising a wide variety of microorganisms like bacteria, fungi, viruses, archaea is one of the most intricate and dynamic ecosystems in the human body. Over the past two decades research showed the major impact of the gut microbiota on the human health which influences various physiological functions and it contributes to the metabolism, immune responses and even brain activity. Each human body hosts approximately 100 trillion microbial cells, which collectively outnumber human cells by factor of 10and it contains over 3 million genes, far outpacing the human genome. These microbes are essential for digestion, synthesizing vitamins and essential nutrients and fermenting dietary fibers into short chain fatty acids that enhances gut health and systemic wellbeing. [1]

The gut microorganism's role extends far beyond simple digestion. Emerging research suggest that the gut microbiome is a critical determinant of metabolic homeostasis, immune system function, and disease susceptibility. Disruptions to this delicate microbial balance, termed dysbiosis. A pivotal breakthrough in microbiome research has been the discovery of the gut brain axis which underscores the connection between brain function and gut microbiome. Through biochemical signals, such as neurotransmitters and SCFAs, the gut microbiome influences mood, cognition, and emotional behavior, suggesting its potential involvement in psychiatric and neurological conditions like depression, anxiety, and autism. This intricate interplay between gut and brain is one of the most exciting areas of current research, with promising implications for treatments targeting both mental health and gut health. Moreover, it regulates and develops the immune system to distinguish between harmful pathogens and harmless substances, ensuring an appropriate immune response. An imbalance in the gut microbiological ecosystem has been associated with diseases such as rheumatoid arthritis, multiple sclerosis, and allergic asthma. [2]

This extended introduction emphasizes the diverse and critical roles well as the emerging research exploring therapeutic strategies to leverage the microbiome for disease prevention and treatment. It sets the stage for a deeper understanding of how gut microbiota affects various factors of physiology, immune function mental health and metabolism reinforcing the importance of this microbial community in maintaining health.

Key Functions of the Gut Microbiome in Human Health

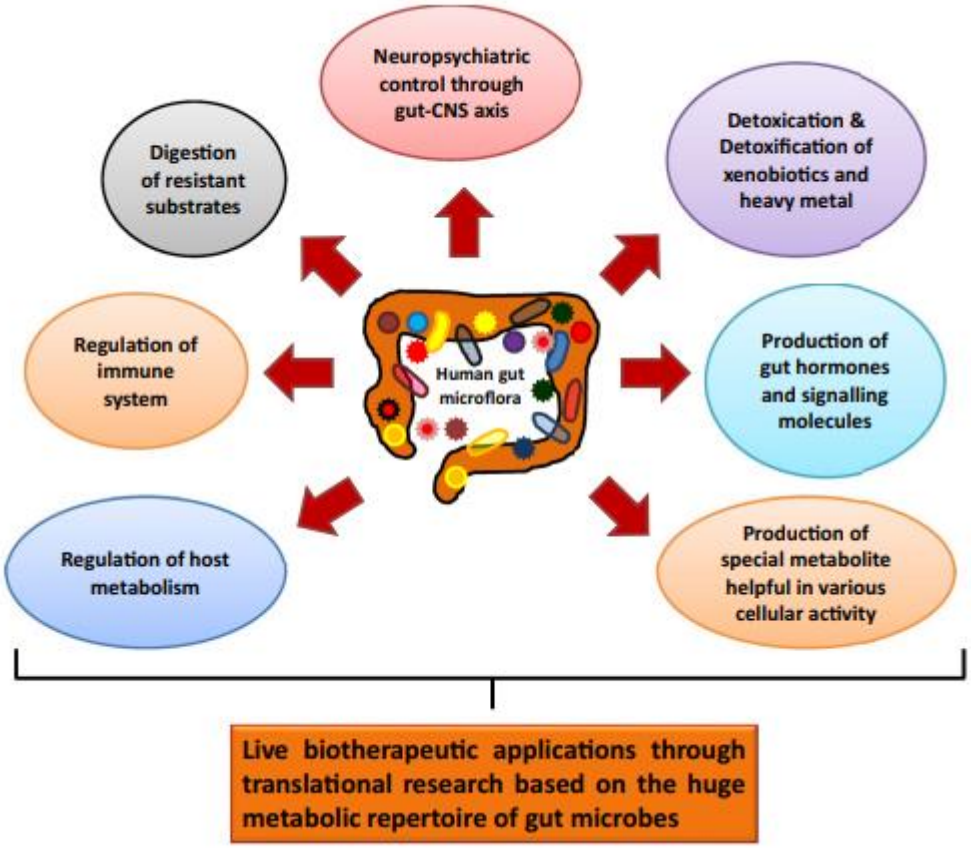

Figure 1: Diagrammatic representation of human gut microbiome

The functions of the gut microbiome extend far beyond digestion, influencing immune function, metabolism, development of chronic diseases and neurological health. Below we explore some key functions in detail:

1. Digestive Health and Nutrient Absorption

The gut microbiome is crucial for the breakdown of many dietary components that are indigestible by human enzymes. Specifically, many carbohydrates, such as dietary fiber, are fermented by gut bacteria into SCFAs which include propionate, acetate, butyrate. These short chain fatty acids serve as energy source for the cells lining the colon (colonocytes) and have numerous beneficial effects like anti-inflammatory properties, maintenance of gut barrier integrity.

- **Fiber Fermentation**: Many dietary fibers are not digested by human enzymes but can be fermented by gut microbiota. The production of SCFAs from this fermentation provides significant energy to the host, particularly in the colon, and helps maintain healthy gut motility. [3]
- **Nutrient Synthesis**: The gut microbiota also synthesizes essential nutrients like vitamins and amino acids that human body cannot produce on its own. For instance, certain gut bacteria produce vitamin B12 and biotin, which are important for metabolic processes. [4]
- **Gut Barrier Function**: The gut microbiome helps to maintain the integrity of the intestinal barrier preventing the leakage of harmful pathogens and toxins into the bloodstream. SCFAs, especially butyrate, are critical for strengthening tight bond between intestinal epithelial cells which helps protect against intestinal permeability. [5]

2. Immune System Modulation

It plays the fundamental role in maturation, development and function of the immune system. In fact, a main portion of the human immune system lives in the gut specifically in gut associated lymphoid tissue.

- **Immune Tolerance**: One of the microbiome's key functions is to educate the immune ecosystem help it to differentiate between beneficial and harmful stimuli. A healthy microbiome promotes immune tolerance, reducing the likelihood of allergies and autoimmune diseases. [6]
- **Anti-inflammatory Effects**: SCFAs mainly butyrate act as anti-inflammatory mediators influencing both the local gut immune system and systemic immunity. They can regulate the production of cytokines, suppress the activation of inflammatory pathways and promote the differentiation of regulatory T-cells which help dampen overactive immune responses. [7]
- **Pathogen Defense**: The gut microbiome also provides a first line of defense against pathogens. Beneficial microbes compete with harmful pathogens for nutrients and space, preventing their colonization (competitive exclusion). In addition, certain gut bacteria produce antimicrobial peptides and metabolites that directly inhibit the growth of pathogenic microorganisms. [8]

3. Metabolism and Weight Regulation

The gut microbiota plays a crucial role in regulating host metabolism, including digestion of food, energy harvest, and the regulation of fat storage. It also influences on how the body metabolizes food, impacting energy balance and the development of metabolic disorders like obesity, diabetes, and cardiovascular disease.

- **Energy Harvest**: The microbiome contributes to the digestion of otherwise indigestible carbohydrates. By fermenting these carbohydrates, gut bacteria help extract additional calories from the food consumed, which can contribute to weight gain if energy extraction is excessive. Certain microbial communities, particularly those that break down polysaccharides, have been found to be more abundant in obese individuals.
- **Insulin Sensitivity**: The microbiome influences insulin sensitivity and glucose metabolism. Studies show that individuals with a healthy gut microbiome are more likely to maintain proper insulin regulation, while those with dysbiosis may develop insulin resistance, a precursor to type 2 diabetes. [1]
- **Fat Storage and Lipid Metabolism**: Gut bacteria affect lipid metabolism by influencing the production of bile acids, which in turn affect the absorption of dietary fats and cholesterol. Some gut microbes may promote fat storage by altering metabolic pathways, while others may support fat burning. [9]

4. Gut-Brain Axis and Mental Health

It is one of the most intriguing discoveries in recent years which refers to the bidirectional communication between the gut microbiome and the brain. Through metabolic products such as SCFAs, signaling molecules like neurotransmitters, the gut microbiome influences mental health and cognition. Conversely anxiety, stress, depression can affect gut health, creating a feedback loop that may worsen mental health symptoms.

- **Neurotransmitter Production**: Gut bacteria synthesize several important neurotransmitters like serotonin, dopamine and GABA which play crucial roles in mood regulation anxiety and sleep. In fact, up to 80-90% of the body's serotonin is produced in the gut and certain microbes have been linked to the production of these mood-regulating molecules.
- **Stress Response**: The microbiome has been shown to influence the hypothalamic pituitary adrenal axis which is body's central stress response system. Studies

indicate that gut bacteria can affect the stress hormone, production of cortisol and modulate the body's overall responses to stress.

- **Mental Health Disorders**: Dysbiosis has been associated with a variety of psychiatric and neurological conditions like depression, anxiety, and even autism spectrum disorders. The therapeutic potential of microbiome modulation through dietary interventions or probiotics to treat these conditions is a rapidly growing area of research. [10]

5. Protection Against Pathogens and Immune Function

These microbial communities interact with the host's immune system to regulate inflammation, pathogen resistance, and overall immune balance. [11,12]

a. Barrier Function and Protection Against Pathogens

Physical Barrier: The epithelial cells lining the intestines are connected by tight junctions which help to prevent harmful microorganisms, toxins fron entering the bloodstream. A healthy microbiome strengthens these barriers, while an imbalance (dysbiosis) can lead to a leaky gut, increasing the risk of pathogen invasion and systemic inflammation.

Competitive Exclusion: The microbiota helps prevent pathogenic bacteria from colonizing the intestines through a mechanism known as competitive exclusion. By occupying available niches and consuming available nutrients, beneficial microbes limit the growth of harmful pathogens.

Production of Antimicrobial Substances: the gut microbiota produces the antimicrobial compounds that inhibit the growth of pathogenic microbes. SCFAs, like butyrate, acetate, and propionate, are particularly effective in lowering the pH of the gut, making it an unfavorable environment for many pathogens.

b. Immune System Modulation

Regulation of Immune Cells: the gut microbiological ecosystem interacts with the intestinal associated with lymphoid tissue which comprises of about 70 to 80% of body's immune system. Through this interaction the microbiota educates immune cells to distinguish between harmless antigen and harmful pathogens, thereby preventing excessive inflammation and immune responses.

Induction of Tolerant Responses: The gut microbiota contributes to immune tolerance by promoting the the development of regulatory T cells which suppress

overactive immune responses. This is crucial for preventing autoimmune diseases where the immune system mistakenly targets the bodys own tissues.

Th1/Th2 Balance: Imbalances in this system can contribute to conditions like allergies and inflammatory bowel diseases (IBD).

c. Inflammation and Immune Defense:

Pro-inflammatory and Anti-inflammatory Effects: The gut microbiome influences the production of cytokines signaling molecules that regulate inflammation. A balanced microbiome promotes the production of anti-inflammatory cytokines which reduce chronic inflammation. In contrast dysbiosis can lead to an increase in proinflammatory cytokines, contributes to the conditions like allergies, autoimmune disorders and inflammatory bowel disease.

Gut-Associated Immune Cells: Gut-resident immune cells such as neutrophils and macrophages play an essential role in defending against pathogens. They communicate with the gut microbiota to enhance pathogen clearance and tissue repair. This interaction is essential in preventing infection and maintaining gut health.

Cross-talk Between Gut Microbiome and Systemic Immunity: recent findings shows that the gut microbiome does not only affect local immunity in the intestines but also modulates systemic immune responses. Dysbiosis can lead to systemic immune activation, potentially contributing to systemic inflammatory conditions or autoimmune diseases.

d. Role of Gut Microbiome in Immune Function During Aging

Aging and Immunity: the composition of gut microbiome changes with and this can influence the immune system's ability to protect against pathogens. Older people tend to have a less diverse gut microbiome, which may lead to immune dysregulation and an increased susceptibility to infections. Maintaining a healthy gut microbiome through diet or probiotics has been shown to help modulate immune responses and improve immune defense in the elderly.

Disruptions to the Gut Microbiome: Dysbiosis and Disease

A balanced gut microbiota is essential for maintaining proper immune function, protecting against pathogens, and supporting various physiological functions such as digestion and metabolism. However, disruptions to this microbial community, a condition known as dysbiosis can lead to a wide range of health issues like metabolic diseases,

autoimmune conditions, gastrointestinal disorders, mental health problems and even neurological health issues. Dysbiosis refers to imbalance or disruption in the gut microbiota composition where the beneficial microorganisms are reduced, and potentially harmful microbes overgrow. This imbalance can arise from various factors like poor diet, infections, stress, antibiotic use and environmental toxins. Dysbiosis can lead to and alterations in the production of metabolites essential for health. Addressing dysbiosis through dietary interventions, probiotics, prebiotics, and appropriate use of antibiotics is essential to restore balance in the gut microbiome and reduce the risk of disease. [13]

Therapeutic Potential of Gut Microbiome Modulation

The gut microbiome is a diverse and dynamic community of microorganisms residing in the gastrointestinal tract plays an important role in maintaining human health. Disruptions to this ecosystem known as dysbiosis have been associated with a range of diseases.

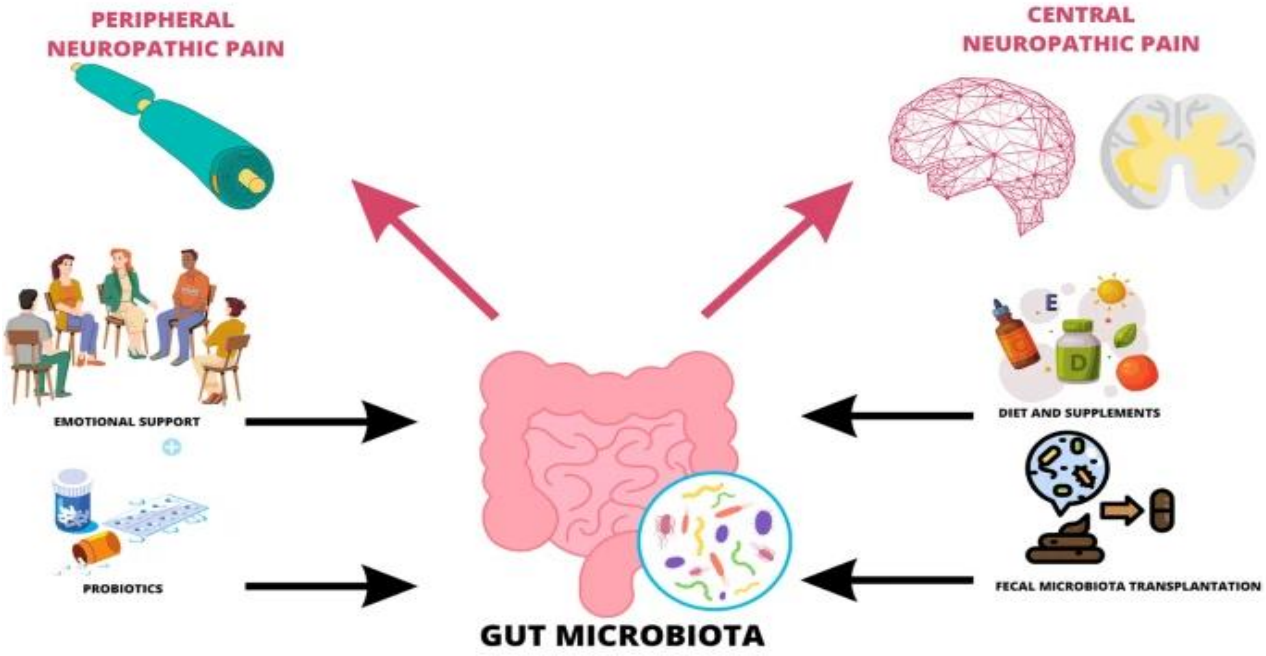

Figure 2: Potential therapeutic strategies for gut microbiota modulation

A. **Probiotics and Prebiotics**: Probiotics are living microorganisms that when consumed in required amount provide health benefits to the host. Prebiotics are the compounds that are selectively promote the growth of beneficial microbes in the gut. Together these these interventions show effect like promote healthy gut microbiome, alleviating symptoms of IBS, and improving immune function. [14]

B. **Fecal Microbiota Transplantation (FMT):** It has revolutionary treatment for individuals suffering from recurrent C. difficile infections. By restoring a healthy microbiome, FMT has been shown to cure many cases that do not respond to antibiotics. [15] Ongoing research is exploring its application for other diseases associated with dysbiosis, including IBD and metabolic syndrome.

C. **Dietary Modifications**: Diet has a major impact on the composition and diversity of the gut microbiome. A diet rich fiber, fermented food, polyphenols A diet rich in fiber**,** polyphenols and fermented foods supports the growth of important microbes and enhances microbiome health. Key dietary strategies include:

i. Fiber-rich diets: fruits, vegetables, whole grains provide the necessary substrates for beneficial gut bacteria, promoting microbial diversity and the production of SCFAs.

ii. Polyphenols: Found in foods like berries, tea, and red wine, polyphenols have anti-inflammatory and antioxidant effects and promote the growth of important gut microbiome.

iii. Microbiome-Targeted Drugs: The development of drugs targeting the microbiome is an emerging field in therapeutic research. These drugs aim to selectively modulate microbial populations or enhance the production of beneficial metabolites. Some potential therapeutic strategies include:

- Bacteriophage therapy: Bacteriophages, viruses that target specific bacteria, may be used to selectively eliminate pathogenic bacteria in the gut while preserving beneficial microbiota.
- Microbiome-based small molecules: The development of small molecules that influence microbial metabolism and immune signaling pathways is an area of active research. For example, drugs that mimic SCFAs or enhance their production could have therapeutic benefits for conditions like metabolic disorders like IBD, obesity.

Conclusion:

The gut microbiome is an intricate ecosystem of microorganisms that plays an important role in maintaining human health, it supports body functions like digestion, metabolism nutrient absorption, immune regulation and mental health. A healthy gut microbiome helps in the breakdown of food, production of vital nutrients, protection against pathogens and modulation of inflammation. It also influences weight regulation,

metabolism and even mental well being through gut brain axis. Dysbiosis lead to many health issues like obesity, digestive disorders, autoimmune diseases, and mental health conditions. Maintaining a balanced microbiome through a healthy diet, lifestyle and reduced dose of antibiotic is important for promoting long term health.

As research into the gut microbiome continues to grow, it holds great promise for personalized medicine, offering insights into how we can optimize our microbiomes to prevent or manage various health conditions. Thus, understanding and nurturing the gut microbiome is fundamental to achieving optimal health and well-being.

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HEALTH AND HYGIENE OF STREET FOOD VENDORS IN INDIA

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Introduction:

For millions of people in India, selling and buying street foods has become a every-day practice. They may fall under formal or informal vendors, ready to eat, processed and fresh foods and beverages fall under formal setting whereas small mobile or permanent stalls come under informal category of vendors. Regardless of the circumstances, the health and hygiene of these vendors remain the top priority. "Street-vended foods" or "street foods" are defined as food and beverages that are prepared and/or sold by vendors in public spaces and street food hubs, intended for immediate consumption or for later consumption. These street foods often showcase a variety of traditional dishes with diverse tastes and flavors, and are readily available and accessible at nearly every corner of the city.

Given the anticipated substantial economic growth between 2011 and 2030, coupled with population growth and urbanization, household incomes are projected to rise due to increased factor incomes, such as land rents and wages. This will likely result in a higher demand for food, particularly fruits, vegetables, and meat, contributing to a significant increase in foodborne diseases (FBDs). The incidence of FBDs is expected to rise from 100 million cases in 2011 to between 150 million and 177 million cases by 2030. This implies that by 2030, approximately one in nine individuals will contract foodborne illnesses, compared to one in twelve in 2011. However, affluent rural and urban populations are predicted to experience a disproportionate burden, with one in three individuals potentially affected by FBDs. It is also important to note that the projected increase in FBDs may be even higher, as the current FBD burden is likely underreported.

Bhowmik (2005) estimates that 2.5% of India's urban population is involved in street vending, providing food and other consumable goods to city residents. The urban poor, living in illegal slums or at their places of work, face constraints in terms of infrastructure and time to cook meals at home. As a result, they largely depend on street food vendors and curbside food stalls to fulfill their daily food requirements. Despite the

significant contributions of the informal sector to the economy, employment, and food security, workers in this sector remain marginalized. Street food vendors, in particular, are often forced to operate on the social, legal, and economic fringes of society, as policymakers tend to view them as both a nuisance and a safety risk. Their presence on busy streets is blamed for traffic congestion, while their food offerings are criticized for contributing to disease outbreaks.

The Ministry of Urban Development and Poverty Alleviation has recently finalized the draft National Policy on Street Vendors. This policy was developed by the National Task Force for Street Vendors, which was appointed by the Ministry of Urban Development and Poverty Alleviation and chaired by the Minister of State for Urban Development and Poverty Alleviation. The primary goal of the policy is to "create and foster a supportive environment that enables street vendors to earn their livelihoods, while also ensuring the prevention of congestion and the upkeep of hygiene in public spaces and streets."

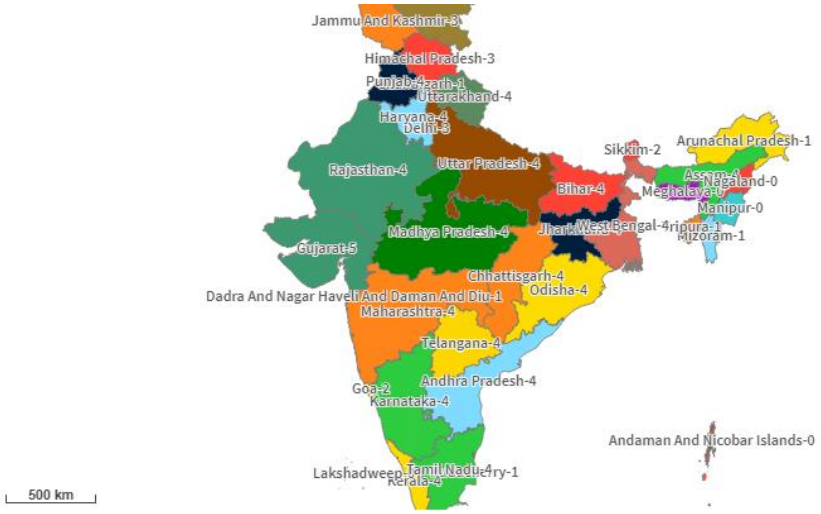
A case study of street food vendors in Madurai, Tamil Nadu, India, highlighted several key issues related to health and hygiene, which are presented below. Nearly half of all street food consumers included in the study clearly recalled negative health effects, such as indigestion or upset stomach, jaundice, ulcers, and fever, which they experienced from eating street food. Many respondents also listed specific types of street food that they would never eat, including non-vegetarian dishes, foods cooked in oil, spicy foods, sliced fruits, and boiled yams. This demonstrates that the urban poor, while thought to be illiterate and unconcerned with food safety and public health, have significant knowledge and ability to employ discretion when choosing among various street foods. Street vendors understand that their customers have preferences related to quality and health, and do their best to ensure that their products are perceived as healthy, safe, and nutritious. Vendors also mentioned that they tried to keep their dishes, utensils, products, and serving area clean. They stressed that their products were high quality, nutritious, and made with a personal touch. No extra fillers or additives were used to stretch staple ingredients, and no old or leftover food was sold. Despite their best intentions to be hygienic, vendors were constrained by limited access to clean vending sites and sanitation infrastructure such as clean running water and waste disposal facilities. Due to a limited supply of water, washing of dishes was commonly done in dirty dishwater without soap, and vending surfaces were not always wiped down. Few vendors had waste bins and most threw their waste in piles around their carts. Of course, this disparity between street vendors' health awareness and

their vending practices is not irrational. In the absence of any efforts from the state, consumer protection groups, or development organizations, the cost associated with increasing health and safety measures will be imposed on the few individual street vendors who take initiative. When the profit margin is so slim due to the fierce competition in the food vending business, it is unlikely that poor vendors will be motivated to take the initiative. Unless some kind of governance structure led by street vendors is established to ensure fair distribution of costs related to additional food safety and health measures, the gap between the health claims of vendors and their actual practices will continue to prevail.

As per the Section 31(1) and 31(2) of Food safety and standard Act 2006, Food Business Operator in the country is required to be licensed/registered. The licensing and registration procedure and requirements are regulated by Food Safety and Standards Regulations,2011. Registration is meant for petty food manufacturers that includes petty retailer, hawker, itinerant vendor or a temporary stall holder or small cottage scale industry having annual turnover up to 12 lacks. All food business having income more than this limit are required to take license.

Healthy and Hygienic Food Streets (HHFS) – FSSAI Initiative under Eat Right Movement

A press release was made by Ministry of Health and Family Welfare dated 20th April 2023 declaring this initiative. This initiative plans to develop 100 food streets in 100 districts across the country. This is being started at a pilot scale to create an example for other such food streets to come up across the country to ensure hygienic and safe food practices. Among the 100 cities selected, there are 4 cities from Karnataka namely Bengaluru Urban, Mysore, Vijayanagar and Udupi.



Vision: Source: https://eatrightindia.gov.in/100hhfs/index.php

To raise the food safety and hygiene standards of India's street vended food to global benchmarks.

Objectives:

- Uplift safety and hygiene standards of selected street vended foods.
- Ensure proper regulatory oversight on street food vendors.
- Training and capacity building of street food vendors on Food Safety & Hygiene under schedule IV of FSS Act, 2006.
- To engage local municipality bodies for infrastructure and facility development near the site of food vending.
- Building trust among consumers in local eating.
- To give recognition to street food clusters and boost livelihood of vendors.

Implementation Plan

To operationalize food streets, the National Health Mission (NHM) of the Ministry of Family and Health Welfare (MoFHW) will provide financial assistance of Rs. 1 crore for each food street in a district as part of a pilot project. This initiative aims to support 100 food streets in various locations across the country. The grant will be allocated through NHM with a funding ratio of 60:40 (Centre: State) for general category states, or 90:10 (Centre: State) for special category states. It is required that the branding of these food streets complies with the guidelines set by FSSAI.

Steps involved in implementation Plan

1. Creation of State Committee
2. Identification of Food streets/hubs in the state
3. Proposal Development and Submission of approval to Central Level Committee
4. Approval and Sanction of Funds by NHM
5. Upgradation of Infrastructure and FoSTaC Training of Street Food Vendors
6. Final Assessment
7. Declaration of Healthy and Hygienic Food Street

Personal Hygiene

Street vendors selling food are often from disadvantaged backgrounds, with limited education and training. They frequently lack knowledge about food hygiene, which encompasses the necessary practices and conditions to ensure food safety from production to consumption. Inadequate food hygiene can result in foodborne illnesses due to improper handling, and in severe cases, may even lead to customer fatalities.

Those involved in street food vending during conduct of business should maintain a high level of personal hygiene.

They should not handle food if they are suffering from infectious diseases such as jaundice, diarrhea, vomiting, fever, cough, skin lesions (including boils/cuts), discharge from nose and eye, frequent and rapid coughing, visibly infected skin lesions (boils, cuts, etc.)

They should cover any non-infected cuts and wounds completely by a waterproof dressing that is firmly secured and routinely changed. The vendors should be inoculated against the enteric group of diseases as per recommended schedule of the vaccine including bi-annually de-worming.

They should wear clean clothes, disposable gloves, hair net and avoid wearing jewellery, ornaments etc. during food preparation.

Finger nails should be kept short and clean at all times and they should wash hands thoroughly with soap and clean water before and after handling food, after using the toilets, after activity like sneezing, touching any surface.

The vendors should avoid eating, chewing, smoking and nose blowing while handling food and should refrain from any unhygienic practices such as spitting, cleaning nose, ears or any other body orifice, touching any body part, touching mobile phone, currency etc. while handling food, and sneezing or coughing over or onto the food. They should preferably wear mask, head cap, gloves etc.

Despite the existence of food safety standards and regulations, food hygiene remains inadequate in certain developing countries, including India. While there has been some progress in food security across various nations, including India, food safety continues to be a prominent issue, often dominating public discourse due to the health risks posed by food-borne diseases. In India, food safety has become a critical concern, particularly in relation to the quality assurance offered to consumers. (Das *et al.,* 2018).

While food safety risks can arise at any stage of the food supply chain, the majority of food safety incidents typically occur during food retail and vending, handling, preparation, storage, waste disposal, or as a result of using substandard ingredients in food production. (Chen *et al.,* 2018). There are around 10 million street vendors in India, of which about 20% are exclusively street-food vendors of low socioeconomic status, who operate on pavements or on the roadside in busy places. According to the FAO, food handlers require the knowledge and skills necessary to manage food hygienically in order

to foster sustainable employment, combat poverty, and support affordable urban living. However, maintaining food hygiene at the street level is challenging, and even when this knowledge is available, its implementation is often hindered by the lack of essential facilities, such as clean water and sanitation, which contribute to the spread of diarrheal and other food-borne diseases. Foods sold on the road side may become contaminated either by spoilage or by pathogenic microorganisms, and the street foods have been exposed as epidemiological links to disease outbreaks, with potential for serious food poisoning outbreaks.

The education of street-food vendors is crucial for raising awareness about the importance of food safety practices. It also encourages the registration of vending businesses and the implementation of basic hygiene practices, such as hand washing. However, the use of hand gloves and aprons is almost nonexistent. A concerning observation is that the majority of street-food vendors handle both food and cash with the same hands, which constitutes a significant source of contamination. According to street food vendor survey, 81% overall cleaned food with fresh water, while less than 17% did not clean food and cooked it straight away.

Several studies have shown that street-food vendors are capable of producing relatively safe food, it provided with proper hygienic conditions and access to basic sanitary facilities. Despite this, street food remains a source of health problems. Few selected studies carried out at different area in India are discussed in detail in this chapter.

A pilot study was done to study the impact of health education intervention on food safety and hygiene of street vendors of an urban slum Wanowrie, Pune. Health education intervention was carried out in two phases. In the first phase, two sessions of one-to-one counselling was carried out to suit the requirements od each vendor. Whereas in the second phase, laminated posters in Hindi on do's and don'ts of food safety were displayed. BIS guidelines for street vendors were converted into a score-based questionnaire. End line data were collected on same tool after 4 weeks. None of them had registered with FSSAI. Majority of them (87.1%) were following incorrect food handling practices. One-third of them received poor ratings due to factors such as the poor condition of the vending cart, suboptimal location, inadequate personal hygiene, and improper and unsafe food handling practices. After intervention, it was observed that there was no significant improvement on overall score of vendors. But specifically mean scores in domains of personal habits, hygiene and food handling practices improved significantly after intervention. There was

no noticeable improvement in the overall compliance of vendors with BIS standards, as health education alone is insufficient to enhance food safety. Addressing this issue requires a multi-sectoral approach and a collaborative effort, with the Municipal Corporation playing a central role. (Singh, A. K. *et al.,* 2016).

Epidemiological investigations can reveal statistical associations between foods consumed and illness, existing data indicates that food from animal source are important causes of food borne diseases. Meat consumption is a strong predictor of foodborne mortality. A cross-country study estimated that for every additional metric ton of meat consumed per 100 people, foodborne disease mortality increased by 6%. (Kristkova, Z.,2017).

The present study was conducted on 200 street food vendors, randomly selected from the New Okhla Industrial Development Authority (NOIDA) in Gautam Buddh Nagar district, Uttar Pradesh, to assess food safety and hygienic practices. Data were collected using a questionnaire and site observations, and analyzed using MS Excel. The findings indicated that the majority of respondents (42.5%) were aged between 15 and 30 years, with 85% being male. Of the total respondents, 35% had attained a primary education level, while 24% were illiterate. Approximately 60% of vendors reported a monthly income of Rs. 10,000 or more. Additionally, 45% of respondents were not permanent residents of Uttar Pradesh, having migrated from other Indian states such as Bihar, Madhya Pradesh, and West Bengal. Only 5% of the vendors were registered. Most vendors (88%) operated from mobile carts, and 62.5% prepared their food at the marketplace, with half of them preparing food both in the morning and during sales. A majority (85%) used tap water for food preparation, and 60% washed their utensils in cold water, either in a bucket or directly from the tap. Over 61% of vendors did not cover their food items, and more than 80% of the stalls were exposed to flies. A significant proportion (74%) of vendors did not use serving utensils such as forks or spoons, and 98% served food with bare hands. Furthermore, 98% of vendors sold food without wearing gloves, 79.6% did not cover their heads, and 76.8% did not wear aprons. Less than half of the food handlers washed their hands before food preparation and after using the toilet. (Singh, A. K *et al.,* 2018).

Health care settings in Indian cities are supported by numerous street food vendors who provide services to patients, visitors, doctors, medical students, and staff. Ensuring proper food hygiene among these vendors is crucial. A cross-sectional study was conducted involving 106 street food vendors in the vicinity of a tertiary care hospital in Kolkata. A

predesigned, pretested schedule was employed to collect data on the socio-demographic profile, knowledge, and attitudes towards food hygiene through interviews, with observations of food handling practices. The median attitude score regarding food hygiene was 9.5, with a significant ($p<0.05$) association found with age, gender, and education. Fewer than one-third of the vendors demonstrated acceptable hygiene practices, with significant ($p<0.05$) associations observed between hygiene practices and factors such as education, marital status, and type of food vendor. While the vendors displayed awareness and positive attitudes towards food hygiene, these were not reflected in their actual practices. This study highlights the factors influencing food hygiene practices and can inform the development of targeted food hygiene training programs (Mukherjee, S.,2018).

The study was conducted to evaluate the hygienic practices of street food vendors in Allahabad City and assess the bacteriological safety of the water and food items sold, focusing on Coliform and Salmonella contamination, between March and May 2010. A total of 30 street food vendors were interviewed to collect data on personal hygiene and food handling practices. Fifty-two food items, including cooked and raw foods, unpasteurized fruit juices, and raw salads, along with 20 water samples, were analyzed. The highest Salmonella contamination was found in sugarcane juice (83.3%) and sweet lime juice (66.6%). The contamination was primarily attributed to unhygienic conditions, inadequate maintenance of premises, poor personal hygiene, and the presence of slime on poorly cleaned utensils. The highest occurrence of Salmonella was observed in cucumber (100%), followed by kakadi (66.6%) and arhar dal (50%). Additionally, 85% of the water samples tested positive for coliform bacteria. To ensure safe street food production, critical control points were identified, and appropriate control measures were recommended. Health risks could be significantly reduced by adhering to Good Manufacturing Practices (GMPs) and operating in sanitary environments.

This study evaluated the food safety standards adhered to by street food vendors in two major Indian cities, Hyderabad and Delhi, in 2017, following the introduction of the Food Safety and Standards Rules. A survey was conducted among 200 street food vendors across various socioeconomic groups to assess their compliance with food safety standards. The findings revealed that only about one-third of the vendors were registered to operate food vending businesses. Additionally, many vendors did not follow basic food safety practices, such as wearing aprons, providing access to tap water, using soap for utensil cleaning, or having refrigerators for food storage. The results indicated that vendors

in higher-income areas, with higher education levels and proper registration, were more likely to adhere to food safety standards. From a policy standpoint, the study suggests that while India's food safety standards align with those of many developed nations, their practical implementation by street food vendors remains inadequate. To address this issue, fostering an exchange of experiences between street food vendors and consumers should be encouraged. Initiatives like "Clean Street-Food Clubs" should be promoted to address the needs of street vendors, allowing them to better understand consumer demands and enhance their awareness of food safety standards. (Reddy, A. A., 2020).

The present study conducted a survey in Guwahati city to assess the socio-economic status and food safety knowledge of street food vendors. Data on the socio-economic and business profiles of 80 vendors were collected using three standardized proformas. Additionally, the study examined the vendors' knowledge of food safety and hygiene practices, as well as their methods of sourcing raw materials. The study also evaluated the relationship between vendors' knowledge and procurement practices and various socio-economic factors. The findings revealed that the majority of street food vendors were mobile vendors (54%), with the remainder operating small restaurants or working as food handlers. Most vendors were local to Guwahati (93%). The average daily income of mobile food vendors ranged from Rs. 200 to Rs. 600. It was noted that only 30% to 37% of vendors were aware of hygienic food handling practices, and a mere 8% to 11% had knowledge of biological sources of food contamination. The study concluded that there was a significant association between procurement practices and factors such as vendor type, ownership status, and average income. However, no strong association was found between socio-economic factors and the vendors' knowledge of food hygiene. The overall street food situation in the city was found to be concerning and requires strict measures to improve food safety standards.

Based on a survey of 49 street food vendors in the Indian cities of New Delhi and Coimbatore, this study highlights the significant role of informal learning as a form of vocational education and training. The vendors do not typically acquire their skills through formal vocational education and training (VET) programs; instead, on-the-job learning, often within family businesses or informal employment, plays a crucial role. Contrary to other studies, the findings reveal that street food vendors possess a diverse array of specialized knowledge, skills, and expertise essential for running their businesses profitably. These skills extend beyond food preparation and sales, encompassing areas

such as pricing and marketing. All the vendors interviewed expressed a strong identification with their occupation and pride in their work. (Pilz, M.,2015).

A total of 130 vendors were included in the study through convenient sampling. Data were collected using face-to-face interviews with a questionnaire. The study found that the personal hygiene of street food vendors was inadequate, with only 10.8% using gloves and 3.8% using aprons. Additionally, environmental hazards such as exposure to dust (80%) and flies (71.5%) were prevalent. Out of 130 vendors Three-fourths were literate, most of the vendors (85.5%) originally belonged to states other than Delhi. Most common structure used for vending the food was cart, used by 53.1% vendors. It was found that majority of the vendors were having dust (80%) and vehicular pollution (86.2%) in the surrounding environment. Majority of the vendors had kept dustbins for garbage disposal but rest of the vendors were throwing their garbage on roads. Out of 113 vendors who had dustbins, 74.7% had covered dustbins, which was a good practice. Head and hair were covered by only 3.1% (4) vendors. Rest of the vendors did not cover their hair and head while handling food. There was no wound in hands of 90% vendors. Less than half of the vendors were found to clean their hands with soap and water. About 22% vendors were using dish towel to clean their hands. More than half of the vendors (52.3%) were serving food with bare hands. Only 3.8% vendors were wearing aprons. 65.4% had slippers in their feet, 31.5% had shoes and 3.1% were barefoot. Street food vendors face both personal and environmental hazards, and the lack of any formal training on food hygiene and safety is a significant drawback. The findings highlight the need for regulatory measures, including mandatory certification for these vendors. (Kumari, S. *et al.,* 2017).

The bacteriology of Panipuri was investigated, and the antibacterial effects of eight essential oils (EOs) on pathogens found in the dish were evaluated. Samples were collected from twelve street food vendors in different locations of Baripada city, Orissa. The samples were divided into two parts: khatta pani (spiced water) and smashed potato masala. Total plate count and pathogenic bacterial isolation were performed using both basal and selective media. Coliforms were initially detected by presumptive testing and confirmed using Eosin Methylene Blue (EMB) Agar. Selected colonies were purified and identified through staining and a series of biochemical tests. The antibiotic susceptibility profile of the pathogens was determined, and their resistance to eight different EOs was assessed. The antibacterial efficacy of four EOs was tested on food samples. The aerobic bacterial load in solid samples was higher than in liquid samples, with 80.33% of the samples testing

positive for coliforms. Pathogenic bacteria identified included *Escherichia coli*, *Klebsiella sp.*, *Enterobacter sp.*, *Bacillus sp.*, *Enterococcus sp.*, *Micrococcus tetragens*, *Salmonella paratyphi*, *Shigella dysenteriae*, and *Vibrio sp.* Antibiogram studies revealed that the multiple antibiotic resistance index (MRI%) ranged from 15 to 92%. Among the EOs tested, cinnamon and clove oils exhibited the highest antibacterial activity. The antibacterial efficacy of clove and cinnamon oils was found to be superior to that of turmeric leaf and Japanese mint oils in combating foodborne pathogens. Although preliminary, this study provides important insights into the role of pathogenic microorganisms in street food and the potential use of EOs as both antibacterial agents and food preservatives.

Health risks associated with street food vending can be mitigated by enhancing the capacity of vendors in the areas of food handling, preparation, storage, and disposal. Systems should be established to ensure that food handlers are consistently aware of the necessary procedures for maintaining food safety and quality. The "Clean Street Food Hub" initiative is a promising approach that integrates food heritage with safety standards and cultural values. Given the rapid expansion of street food vending in major urban centers across India, the active participation of vendors in self-regulating associations is crucial to ensuring adherence to food safety standards. The FSSAI, street food vendor associations, and local authorities should collaborate on registration processes, and basic facilities should be provided to street vendors to help them improve their knowledge of and compliance with proper food hygiene practices.

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NUTRITIONAL EVALUATION OF *GLIRICIDIA MACULATA* LEAF MEAL ON GROWTH PERFORMANCE, FEED UTILIZATION, AND DIGESTIVE ENZYME ACTIVITY IN *CIRRHINUS MRIGALA* (HAMILTON)

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Abstract:

The present study was aimed to assess the impact of replacing fish meal with varying levels of *Gliricidia maculata* plant leaf protein on growth performance, feed utilization, and digestive enzyme activity in freshwater fish, *Cirrhinus mrigala*. Seven experimental diets were used, each containing different levels of *G. maculata* protein source. The proportions of plant leaf powder used were 0, 20, 30, 40, 50, 60, and 70%. *C. mrigala*, with a mean initial weight of 2.3 ± 0.05 g, were fed the experimental diets for 120 days. The findings indicate that 40% replacement of fish meal with *G. maculata* plant protein resulted in the highest growth performance. 40% diet showed relatively better growth, feed utilization and digestive enzyme activity than other diets. However, replacing 70% of fish meal significantly decreased growth, feed utilization, and digestive enzyme activity in comparison to the control.

Keywords: Plant Protein Source; Fish Feed Replacement; Growth; Feed Utilization; Digestive Enzyme Activity; *Gliricidia maculata*; *Cirrhinus mrigala*.

Introduction:

Fishmeal is a valuable but limited resource for aquaculture, and its long-term sustainability is a serious concern. To promote sustainable development of aquaculture, many researchers have explored the possibility of replacing fishmeal with plant feedstuffs (Benedito-Palos *et al.,* 2007). However, the scarcity of fishmeal poses significant challenges to the aquaculture industry, and there is a need to find alternative protein sources that can reduce feed cost and satisfy the protein requirement of fish (Teves and Ragaza, 2016). It

has been generally demonstrated that up to 50% fishmeal protein can be substituted by plant proteins in fish diets without compromising growth or fish welfare outcomes. Plant proteins are the most prevalent alternatives for fishmeal in aquafeeds (Collins *et al.,* 2013).

In the past two decades, several studies have investigated various alternative protein sources for replacing fishmeal (Dossou *et al.,* 2018; Inanan and Acar, 2019). These studies have demonstrated that plant ingredients can partially replace dietary fishmeal in many cultured species. Partial replacement of fishmeal with plant protein sources for *Oreochromis niloticus* (Ahmad *et al.,* 2020; Ismail *et al.,* 2020), *Cyprinus carpio* (Wang *et al.,* 2020), *Ctenopharyngodon idella* (Jiang *et al.,* 2016) showed positive growth results.

Dietary nutrient composition has been found to affect the activity of digestive enzymes (Castro *et al.,* 2013). In order to understand the feeding habits of fish, it is important to consider the enzymatic ability to digest various types of food. The digestive structure of fish reflects their natural resource utilization, including enzyme composition, distribution, amount and specific activities. The knowledge of digestive enzyme activities helps in selecting the right ingredient for feed formulation for a species. Variations in fishmeal composition probably put impact on different types of enzymes for its digestion (Kamalam and Medale, 2017; Thobaitia *et al.,* 2018; Weinrauch *et al.,* 2019; Carneiro *et al.,* 2020).

The objective of this research work was to evaluate the impacts of various replacement rates of fishmeal with *Gliricidia maculata* in the diet on the growth performance, feed efficiency and digestive enzyme activity of *Cirrhinus mrigala*.

Material and Methods:

The fingerlings of *Cirrhinus mrigala* were used for the feeding experiment. The feeding experiment was conducted for 120 days in triplicates. Each aquarium of size 36" X 12" X 12" size was stocked with 10 fingerlings of almost of uniform size and weight. Seven diets were formulated using various proportions of *Gliricidia* as shown in table. Fishes were fed formulated diet at the rate of 5% to body weight daily. At fortnightly intervals a minimum of 50% of fishes were sampled to record the growth in terms of weight.

Growth performance of experimental fish were determined in terms of final individual fish weight (g), specific growth rate (SGR, % per day), protein efficiency ratio (PER) and net protein retention (NPR) at the end of the feeding experiment (Hopkins, 1992; Lugert *et al.,* 2016).

After the completion of feeding trial period, the fishes were sacrificed and whole intestine removed. It was homogenized in 0.9% NaCl solution so as to prepare homogenate. The homogenate was centrifuged at 5000 rpm, supernatant was collected, frozen in sample vials and stored in refrigerator until assayed for the digestive enzymes. The estimation of lipase was carried out as per the method of Hayase and Tappel (1970), protease by Ishaya *et al.* (1971) and amylase and invertase by the method of Bernfeld (1955). Statistical analysis was performed using ANOVA.

Table 1: Formulation and proximate composition of fish diets containing increased levels of *Gliricidia maculata* leaf meal

	Diet						
	0 (Control)	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**
Ingredients (%)							
Groundnut oilcake	43	33	27	22	17	11	6
Rice bran	36	26	22	17	12	8	3
Fishmeal	10	10	10	10	10	10	10
Guar gum binder	10	10	10	10	10	10	10
Mineral –vitamin mixture	01	01	01	01	01	01	01
***G. maculata* leaf powder**	00	20	30	40	50	60	70
Nutrient content (%)							
Moisture	7.05	6.32	6.93	7.27	7.75	8.18	8.65
Total Ash	12.13	12.26	11.59	11.38	10.89	10.62	10.02
Protein	26.24	28.30	29.93	30.42	31.10	31.16	30.38
Fat	3.81	7.33	6.40	6.26	5.56	5.02	5.89
Fibre	10.54	9.21	10.78	11.76	11.60	12.02	14.31

Results and Discussion:

The chemical analyses of formulated diets were carried out according to the procedures of the AOAC, (1990) (Table 1). The growth performance and feed utilization indices such as body weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER) of *Cirrhinus mrigala* fed with different levels of *G. maculata* are presented in table 2 and figure 1.

Fishes fed with 40% *Gliricidia* diet showed better growth performance as compared to other diets. The final body weight (29.96 ± 0.86) gm, weight gain (27.66 ± 0.79) gm and SGR (1.17 ± 0.03) were highest in 40% diet group, whereas FCR was highest in control and 20% diet group (2.49 ± 0.07) % day $^{-1}$ and PER in 50% diet group (0.71 ± 0.02). The lowest weight gain was reported in control diet (12.54 ± 0.36) gm. The least SGR (0.89 ± 0.02) % day $^{-1}$ was found in control while 70% diet showed lowest FCR (1.35 ± 0.03) and PER (0.46 ± 0.01).

Table 2: Growth performance and feed utilization in *Cirrhinus mrigala* fed diets containing *Gliricidia maculata* leaf meal

	0 (Control)	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**
Initial body weight (gm)	2.1 ± 0.05	2.4 ± 0.02	2.3 ± 0.06	2.3 ± 0.05	2.1 ± 0.04	2.2 ± 0.05	2.2 ± 0.05
Final body weight (gm)	14.64 ± 0.42	17.04 ± 0.49 NS	22.85 ± 0.65 ***	29.96 ± 0.86 ***	26.56 ± 0.76 ***	20.44 ± 0.59 ***	17.66 ± 0.50 NS
Weight gain (gm)	12.54 ± 0.36	14.64 ± 0.42 NS	20.55 ± 0.59 ***	27.66 ± 0.79 ***	24.46 ± 0.70 ***	18.24 ± 0.52 ***	15.46 ± 0.44 *
Specific growth rate (SGR) % day $^{-1}$	0.89 ± 0.02	0.91 ± 0.02 NS	1.05 ± 0.03 *	1.17 ± 0.03 ***	1.15 ± 0.03 ***	1.02 ± 0.02 NS	0.96 ± 0.02 NS
Food conversion ratio (FCR)	2.49 ± 0.07	2.49 ± 0.07 NS	1.98 ± 0.05 ***	1.58 ± 0.04 ***	1.36 ± 0.03 ***	1.43 ± 0.04 ***	1.35 ± 0.03 ***
Protein efficiency ratio (PER)	0.65 ± 0.01	0.48 ± 0.01 ***	0.66 ± 0.01 NS	0.85 ± 0.02 ***	0.71 ± 0.02 NS	0.55 ± 0.01 *	0.46 ± 0.01 ***

(Value expressed is mean of n (n=3); ±: SE) *P<0.05, **P< 0.01, ***P< 0.001, NS – Non Significant

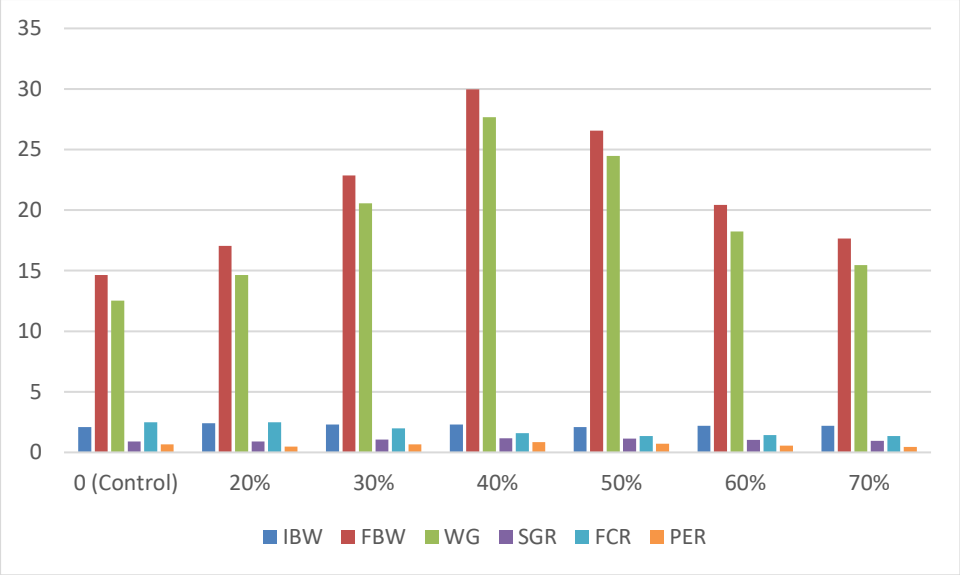

Figure 1: Growth performance and feed utilization in *Cirrhinus mrigala* fed diets containing *Gliricidia maculata* leaf meal

Table 3: Digestive enzyme activity in *C. mrigala* fed with different levels of *G. maculata* diets:

Enzyme	Control	20%	30%	40%	50%	60%	70%
Lipase	3.721 ± 0.04	4.237 ± 0.17**	4.666 ± 0.06***	4.847 ± 0.06***	3.890 ± 0.03 NS	3.570 ± 0.01 NS	3.361 ± 0.01 NS
Protease	16.766 ± 0.31	17.404 ± 0.12 NS	18.660 ± 0.34**	20.490 ± 0.46***	22.349 ± 0.35***	17.594 ± 0.24 NS	14.328 ± 0.09***
Amylase	28.060 ± 0.46	29.479 ± 0.25 NS	31.651 ± 0.43**	34.971 ± 0.13***	34.137 ± 0.29***	31.437 ± 0.13***	28.364 ± 0.27 NS

(Value expressed in mg palmitic acid/gm protein/hr for lipase; mg tyrosine/gm protein/hr for protease and mg maltose/gm protein/hr for amylase; ±: SE; *P<0.05, **P< 0.01, ***P< 0.001, NS – Non Significant)

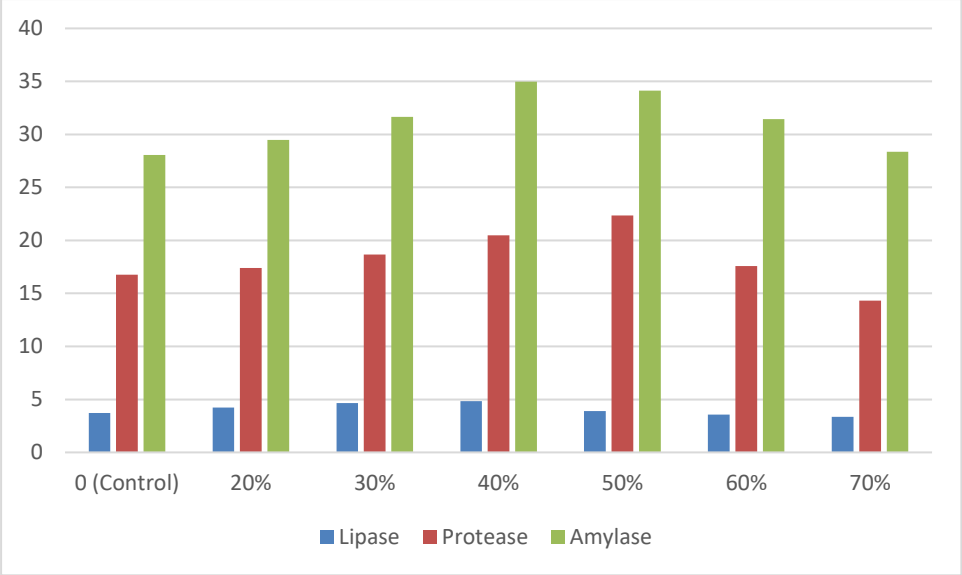

Figure 2: Digestive enzyme activity in *C. mrigala* fed with different levels of *G. maculata* diets

The results of the present study showed that *Gliricidia* leaf meal can be used in the diet of fish up to 40% inclusion level. Higher inclusion of plant protein in formulated diet of fish, hampers the growth and feed utilization. It results in retarded growth. In the present study, it was observed that incorporation of *Gliricidia* above 40% impaired the overall growth of experimental fish, *C. mrigala*. The data of the present study agree with the finding of Xu *et al.* (2012), who reported that significant decreases were found for both, growth and feed utilization with the highest replacement levels of dietary fish meal with plant proteins for gilthead sea bream. The results of the present study are similar with the results of Zhou and Yue (2010), Mahboob (2014) and Ahmad *et al.* (2020) who reported that fish meal could be partially substituted with other ingredients in feeds prepared for *O. niloticus*. Wang *et al.* (2020) also reported the similar results in the fish *Cyprinus carpio*.

The digestive enzymes activity (Lipase, Protease and Amylase) of fish, *C. mrigala* was recorded in table 3 and figure 2. The 40% diet showed higher lipase (4.847 ± 0.06 mg palmitic acid/gm protein/hr) and amylase (34.971 ± 0.13 mg maltose/gm protein/hr) activity as compared to all other diets. Protease activity was higher in 50% diet (22.349 ± 0.35 mg tyrosine/gm protein/hr).

The current investigation revealed that the level of plant product in the diet impacts the digestive enzyme activity. Additionally, the activity of lipase is reliant on the lipid content and digestibility of the diet. The *Gliricidia* diet demonstrated the highest activity at

40% and 50% inclusion levels. However, the lipase activity decreased as the level of plant protein in the diet increased. A decrease in intestinal lipase activity was observed at higher levels of spirulina supplementation in the diet of common carp, *Cyprinus carpio* (Nandeesha *et al.,* 1998). Previous studies on lipase activity in fish fed with plant proteins have indicated that the activity of lipase is directly linked with the lipid content of feed, feed ingredients, and apparent protein digestibility of feed (Lopez-Lopez *et al.,* 2005; Pavasovic *et al.,* 2007; Castro *et al.,* 2013).

According to the digestive enzyme activity analysis conducted in this study, an increase in dietary protein level led to an increase in protease activity. Additionally, both amylase and protease activity increased with an increase in dietary carbohydrate or protein. Thus, the amylase/protease (A/P) ratio can serve as an indicator of the effect of diet composition on enzymatic activities. However, when the dietary level of carbohydrate and protein exceeds the optimal level, the activities of enzymes responsible for their breakdown start to decline (Ceccaldi, 1997; Pérez-Jiménez *et al.,* 2009; Castro *et al.,* 2015; Carneiro *et al.,* 2020).

In the present study, amylase activity changes significantly with the incorporation of plant proteins in the diet. The highest amylase activity was found in the 40% plant based diet. Amylase activity was found to increase in rainbow trout (*Oncorhynchus mykiss*) fed diets containing increasing rates of dietary protein. However, an opposite response was reported in grass carp, *Ctenopharyngodon idella* (Das and Tripathi, 1991). Cahu and Zambonino Infante (1994) reported that diet influences the amylase activity in sea bass, *Dicentrarchus labrax* larvae. The increased plant protein percentage in diet affects the amylase activity (Weinrauch *et al.,* 2019; Carneiro *et al.,* 2020).

Conclusion:

Based on the results obtained from present study it was concluded that supplementation of 40% to 50% fish meal with combination of plant proteins (*G. maculata* leaf meal) improves growth, feed utilization and enzymatic activity as high as control diet. However, inability of *C. mrigala* to use higher levels of plant protein in their diet could be due to scarcity of some essential amino acids and low alkaline protease enzyme activity.

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INTEGRATING TRADITIONAL REMEDIES: MEDICINAL PLANTS IN THE TREATMENT OF DIABETIC MELLITUS

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Introduction:

Diabetes mellitus is a metabolic illness with numerous etiologies that is characterized by a loss of glucose homeostasis and disturbances of protein, lipid, and carbohydrate metabolism due to abnormalities in insulin production and/or insulin action. It is one of the major global public health problems. [1]. An increasing global burden on public health is caused by adult-onset diabetes mellitus. According to predictions, the countries with the highest rates of diabetes by 2030 will be China, India, and the United States [2]. Diabetes mellitus is characterized by a series of metabolic abnormalities, one of which is hyperglycemia, which can be brought on by anomalies in insulin secretion, action, or both. Type I and Type II are the two types that make up this entity. Only 5% of people with diabetes have type I diabetes, often known as juvenile diabetes, which is insulin-dependent. Adults over 40 years of age typically develop Type II, which is not insulin dependent [3]. The blood sugar is taken up by muscle, red blood cells, and fat cells and used in various metabolic processes that bring blood sugar levels back to normal [4].

In the small intestine's epithelium is intestinal α-glucosidase, an enzyme essential to the digestion of carbohydrates. As the first metabolic anomaly to manifest in type 2 diabetes mellitus, postprandial hyperglycemia has been identified as a therapeutic target for α-glucosidase regulation [5]. India has become known for its riches in herbs. Studies have been conducted on the use of medicinal herbs, such as T*rigonella foenum graucum, Allium sativum, Gymnema slyvestre, and Syzigium cumini,* to treat diabetes mellitus [6]. The duration and effectiveness of the disease's management may have an impact on the degree of harm that hyperglycemia causes to the individual organ systems. Diabetes also has other side effects, including thirst, polyuria, blurred eyesight, and weight loss. [7]

Etiology

Type 1 Diabetes mellitus:

An absolute deficiency of insulin results from the autoimmune disease's death of the pancreatic beta cells that generate the hormone. Most commonly, children and teenagers are seen with this illness. A kind of autoimmune diabetes called T1DM, which is caused by the loss of pancreatic beta cells, affects 90% of people. Strong genetic vulnerability exists for both the antigens of human leukocytes (HLA) and the majority histology complex (MHC). Genetic markers and autoimmune pathologic processes help identify type I diabetes as the condition is characterized with a total shortage in insulin production.

Type 2 Diabetes mellitus:

Diabetes mellitus (T2DM), a condition that causes insulin resistance, accounts for 90% of diabetes cases. It is typically seen in those who are older than 45. In children, adolescents, and young adults, obesity is becoming more prevalent due to calorie-dense meals, physical inactivity, and obesity. The primary causes of type 2 diabetes are inadequate pancreatic insulin production and insulin resistance in the liver, muscle, and fat cells. Insufficient insulin secretory response and resistance to insulin action can induce silent hyperglycemia without any clinical symptoms in people with type 2 diabetes [8]

Epidemiology

In 2011, an estimated 366 million individuals were predicted that they had insulin; by the year 2030, the number would have risen to 552 million. Each nation is seeing a rise in the number people with diabetes of type 2, with low- and middle-income nations housing 80% of the people infected. In 2011, 4.6 million deaths were attributed to DM.

By 2030, 439 million individuals are expected to develop diabetes of type 2. Because of environmental and lifestyle risk factors, the incidence of diabetes type 2 varies greatly between areas of the world. [9]

Through 2030, 439 million of people are predicted to be diagnosed with diabetes of the type 2 kind. Type 2 diabetes is a condition where the incidence varies greatly between geographical regions due to personal and risk factors related to the environment.

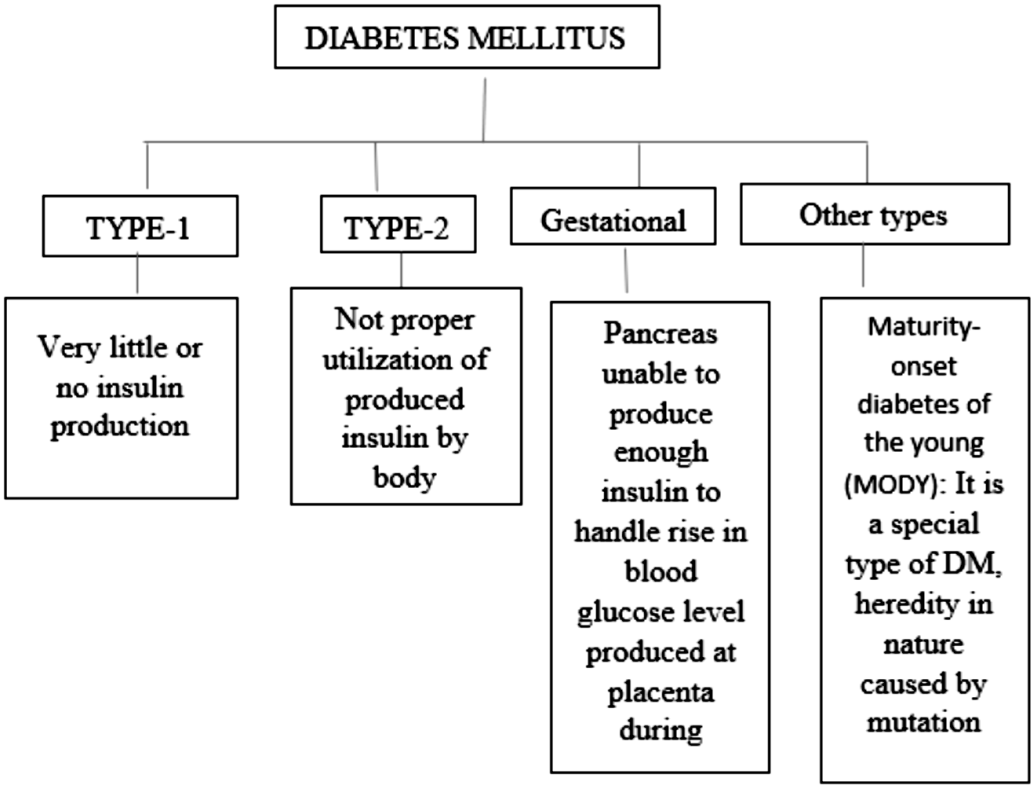
The next 20 years, individuals will be more likely to have diabetes, with type 2 diabetes becoming more common. A large portion of this growth will take place in the developing world, when more than half of those with diabetes are around aged of 45 to 64. [10]

Pathophysiology

Given diabetes mellitus (DM) has a complex pathophysiology and a wide range of presentations, any classification of the disorder is subjective but nonetheless helpful, and it is frequently impacted by the physiological parameters that exist at the time of assessment and diagnosis. The current classification scheme is helpful in determining the necessary therapy and is based on both the pathophysiology and the etiology of the condition. [11]

As the concentration of glucose in the blood increases, pancreatic β-cells release more insulin. As opposed to second-phase insulin release, which is more slow and reaches a steady state 2-3 hours after the initial rise in arterial levels of glucose, first-phase insulin release peaks 2-4 minutes after the initial rise in glucose levels in the blood and reduces abruptly by 10-15 minutes. Normal insulin sensitivity does not trigger β-cells to release as much insulin as insulin resistance does. [12]

Types of Diabetic mellitus



Clinical Features [13]

- Inhibition of digestive enzyme, i.e., pancreatic lipase, cholesterol esterase, pancreatic α- amylase, intestinal α-glucosidase.
- Adipocyte differentiation.
- Influence on the appetite.

- Regulation of lipid metabolic: improvement of lipid profile.
- Improving the oxidative status of the organism.

1.7. MANAGEMENT OF DIABETIC MELLITUS [14,15]

- Communication and education
- Pharmacological management
    - Hypertension
    - Atherosclerotic Cardiovascular disease(ASCVD)
    - Dyslipidemia
    - Hyper coagulopathy
    - Endothelial cell dysfunction
    - Nephropathy
    - Retinopathy
- Surgical procedures
- Rehabilitation management

Drug Therapy [16]

Due to the relatively complex pathogenesis of diabetes mellitus, the key to managing and treating the condition is to combine medication treatment, appropriate exercise, diet modification, close monitoring of blood sugar, mood assessment, and self-management with the unique circumstances of each patient. Anti-diabetic medications for treatment mostly include insulin, insulin analogs, and non-insulin hypoglycemic medications made up of glucose regulators, gene therapy, insulin secretagogues, and insulin sensitizers. This essay examines current viewpoints regarding popular anti-diabetic medications.

A. Insulin and insulin Analogs:

One of the most essential exogenous medicines used to treat diabetes is insulin, which is secreted by patients with type 1 diabetes and severe type 2 diabetes. Insulin and its analogs' primary physiological roles include controlling in vivo protein, lipid, and sugar metabolism and preserving appropriate blood glucose levels. By promoting the membranes of target cell carriers in adipose and muscle tissue, they can carry insulin in plasma into tissue. They can also quicken the synthesis of glycogen in muscle and liver cells, prevent glycogen breakdown, and prevent the production of PEP carboxykinase.

B. Non- Insulin Hypoglycemic Agent:

Non-insulin hypoglycemic medications are the first choice for patients who find it difficult to control their blood sugar levels with diet changes and light exercise alone. Many other forms of these medications are currently available for purchase, including glinide, biguanide, thiazolidinedione, sulfonylurea and biguanide. Medicines that include sodium-glucose cotransport protein 2 inhibitors, glucagon-like peptide 1 receptor agonists, and dipeptidylpeptidase-4 (DPP-4) inhibitors.

Medications Used to Treat Diabetes Mellitus [17]

The diabetic mellitus disease is associated problem can be treated with the following kinds of medications Table 1.

Table 1: Allopathic Treatment for Diabetic Mellitus

S. No.	Class of Drug	Drug Name	Brand Name
1.	Insulin	NPH insulin, Aspart insulin	Humulin, Novo Log
2.	Dipeptidyl peptidase 4 inhibitors	Sitagliptin, Linagliptin, Vildaglptin	Januvia, Tradjenta, Galvus
3.	Sulphonylureas	Glimepiride, Gliclazide, Glibenclamide	Amaryl, Glucotrol, Glynase
4.	Biguanide	Metformin	Glucophage
5.	α- glucosidase inhibitors	Acarbose	Precose
6.	Meglitinides	Nateglinide	Prandin, Starlix
7.	GLP-1 receptor agonists	Liraglutide	victoza
8.	Thiazolidinediones	Pioglitazone	Actos, Avandia

Table 2: List of medicinal plants for Diabetic Mellitus

S.No	Scientific Name	Common Name	Family	Parts	Medicinal uses	Mechanism of action	Ref
1.	*Acacia arabica*	Babhul	Fabaceae	Seed	Anti – diabetic	Secretagouge to release Insulin	18
2.	*Aegle marmelos*	Bengal Quince	Rutaceae	Leaves	Hypoglycemic	Improves digestion and reduces blood sugar	18
3.	*Allium cepa*	Onion	Amaryllidaceae	Bulb	Hypolipidaemic	Glucose 6-phosphatase and HMG Co A reductase	18
4.	*Allium sativum*	Garlic	Amaryllidaceae	Bulb	Hypoglycemic	Increased insulin release from pancreatic beta cells	18
5.	*Aloe barbadensis*	Aloe vera	Asphodelaceae	Leaves	Hypoglycemic	Release of insulin from pancreatic beta cells	18
6.	*Azadirachta indica*	Neem	Mahogany	Leaves	Anti-bacterial, Anti-malarial, Anti-oxidant.	Inhibition of NF-κB	18
7.	*Caesalpinia bonducella*	Gray Nicker	Fabaceae	Seed	Anti-hyperglycemic, Anti-hypolipidemic	Insulin Secretagogue	18
8.	*Capparis decidua*	Kerda	Capparaceae	Fruit	Hypolipidemic	Inhibition of lipid absorption	18
9.	*Cinnamomum verum*	Cinnamon tree	Lauraceae	bark	Anti-cancer, Anti-oxidant, Anti-diabetic	Glucose levels, lipid metabolism, and beta cell	19
10.	*Coccinia indica*	Ivy gourd	Cucurbitaceae	Leaves	Hypoglycemia	Glucose-6phosphatase and lactate dehydrogenase	18

11.	*Coriandrum sativum*	Coriander	Apiaceae	Leaves	Hypoglycemic, Hypolipidemic	Capacity of beta cells of pancreatic islets	19
12.	*Eugenia jambolana*	Jamun fruit	Myrtaceae	Fruit	Hyperglycemic	Increased release of insulin from existing β-cells	19
13.	*Mangifera indica*	Mango	Anacardiaceae	Leaves	Hypoglycemic	Stimulation of β-cells to release insulin	18
14.	*Momordica charantia*	Bitter gourd	Cucurbitaceae	Leaves	Hypoglycemic	Glucose-6-phosphatase besides fructose-1, 6biphosphatase in the liver	18
15.	*Murraya koenigii*	Curry leaves	Rutaceae	Leaves	Hypolipidemic, Hypoglycemic	Decrease of the generation of superoxide radicals	19
16.	*Ocimum tenuiflorum*	Holy basil	Lamiaceae	Leaves	Anti-fungal, Anti-bacterial, Anti-ulcer	Lipid lowering action	18
17.	*Phyllanthus amarus*	Bhuiawala	Euphorbiaceae	Leaves	Anti-inflammatory, Anti-cancer	Inhibiting phagocytosis process of the neutrophils and monocytes	18
18.	*Pterocarpus marsupium*	Malabar kino	Fabaceae	Leaves	Hypoglycemia	Cytokinines, TNF-C	19
19.	*Trigonella foenum graecum*	Fenugreek	Fabaceae	Seed	Anti-oxidant	Renal glucose-6-phosphatase and fructose –1,6-biphosphatase	18
20.	*Tinospora cordifolia*	Guduchi	Menispermaceae	Fruit	Anti-diabetic	Increase in glucose metabolism	19
21.	*Gymnema sylvestre*	Gurmar	Asclepiadaceae	Leaves	Anti-diabetic, Anti-infammatory	Inhibit glucose absorption from the intestine	19

Drawbacks in Current Modern Treatment [20,21]

- Diabetes patients have long been treated with herbal remedies, which are now recognized as an additional form of treatment for the disease.
- The main mechanism of action of this antihyperglycemic drug is to increase peripheral glucose uptake and utilization while reducing intestinal and hepatic glucose absorption.
- According to those without diabetes, those with diabetes have a 2-4 times higher risk of developing coronary heart disease and stroke. Additionally, poorly managed diabetes can make pregnancy more difficult since babies born to diabetic mothers are more likely to have congenital defects.
- Along with other adverse effects, these medications can cause Diabetic ketoacidosis, acute kidney damage, fungal infection and toe amputation.
- One of the least important things that diabetics must do is monitor their blood sugar. The primary methods used by antidiabetic medications involve stimulating pancreatic β-cells to lower blood sugar, blocking other hormones that raise blood sugar, and improving insulin receptor sensitivity.

Hence the current study intends to find a plant that is widely available in India that may have anti – diabetic properties for the purpose of treating diabetes, taking into account the significance of alternative medicine in the management of Diabetic mellitus.

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