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Recent Trends and Innovations in Food Science, Food Technology & Nutrition explores cutting-edge developments in the fields of food production, preservation, and nutritional science. The book delves into advanced technologies such as nanotechnology, biotechnology, and smart packaging, offering insights into their applications for enhancing food quality, safety, and shelf life. It also addresses emerging challenges, such as climate change impacts on food security and the demand for sustainable and plant-based food systems. With contributions from experts, it highlights innovative solutions, including functional foods, alternative proteins, and nutrigenomics, providing a comprehensive resource for researchers, industry professionals, and students. This text serves as a critical guide to understanding the dynamic advancements shaping the future of food science and nutrition.

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Recent Trends and Innovations in Food Science, Food Technology & Nutrition

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Chapter - 1

A Comprehensive Review on Emerging Therapeutic Potential of Banana Flower

Sohini Guha Thakurata and Moumita Das

Abstract

The banana plant (*Musa sp.*) is a prominent tropical crop found in various countries. India stands at a leading global production of 29 million tonnes annually. Despite the widespread cultivation of bananas, the banana flower or blossom, or inflorescence, remains underutilized, even though it possesses notable nutritional and therapeutic benefits. This paper aims to summarize crucial health-promoting properties of banana blossoms and also focuses on various bioactive compounds such as alkaloids, tannins, flavonoids, and phenolic compounds with significant antioxidant, anti-microbial, and anti-diabetic effects. Furthermore, traditional Indian and Asian cuisines incorporating banana blossoms are explored, emphasizing the need to raise global awareness of these nutrient-dense dishes. By advocating the inclusion of banana blossoms in food product development, this review underscores their potential to improve nutritional value and foster the development of health-conscious diets.

Keywords: Banana flower, bioactive compound, therapeutic potential, innovative food products.

Introduction

The global population increase has significantly driven the demand for conventional food products, particularly by-products of fruits and vegetables. Often discarded as waste, these by-products are rich in nutrients and bioactive compounds, including potent antioxidants that help combat oxidative stress within the body. One notable example is the banana (*Musa*), part of the Musaceae family and the world's fourth-largest food crop, trailing only wheat, rice, and maize. The banana (*Musa paradisiaca*) thrives in tropical, humid climates, ideally at daytime temperatures around 27°C, with a minimum of 13°C at night. India leads global banana production, generating 14.20 million tons annually, and cultivation spans nearly every state. Tamil Nadu ranks first in banana production, with an area of 118.04 hectares dedicated to cultivation during the 2013-2014 crop year. Banana farming generates an estimated 220 tons of plant mass by-products per hectare.

Though cultivated primarily for its fruit, banana cultivation also produces large amounts of waste and underutilized by-products. Typically, agricultural by-products are discarded or repurposed for non-edible uses such as packaging. However, with the global shift towards sustainability, researchers are increasingly exploring the nutritional and health potential of these by-products to reduce agricultural waste. In this regard, the banana plant stands out as a zero-waste crop, with nearly every part of the tree having a functional use. This review specifically examines the traditional use of the banana plant's edible inflorescence (flower) in Indian ethnic cuisine, as well as its health benefits.

The banana flower, often large, pointed, and crimson-colored with yellow or pink hues, has a crunchy, nutty, and starchy taste. Its color varies from orange to purple, with inner florets colour appearing white or pale yellow. Although banana flowers are generally considered as waste during crop production but they possess a rich nutritional profile. In several Asian countries, like Sri Lanka, Malaysia, Indonesia, and the Philippines, the banana flower (Musa acuminata Colla) is commonly consumed as a vegetable.

Nutrient profile

The nutritional composition of banana flower, is excellent for its high content of bioactive compounds and nutrients making it a highly nutritious edible flower which has been recognized for various nutritional components worldwide. Here are some key points regarding to the nutritional profile:

1) **High nutrient content:** Banana flowers are known for its excellent nutrient content, which includes vitamins, minerals, and dietary fiber. The chemical composition of banana fiber are cellulose, hemicelluloses, and lignin, which makes them a valuable addition to the diet, especially in regions where they traditionally consume it.

2) **Bioactive compounds:** The nutritional profile of banana flower consist various bioactive substances like alkaloids, flavonoids, tannins and saponins. These compounds are well-known for their antioxidant, anti-diabetic and anti-microbial properties, contributing to our overall health and wellness. Table 1 consist the nutritional composition of banana flower.

Table 1: Nutritional composition of banana flower

Nutrients /100g of banana flower	Quantity
Energy (kcal)	51.00
Carbohydrates (g)	9.90
Proteins (g)	1.60
Fats (g)	0.60
Dietary Fiber (mg)	5.70
Calcium (mg)	56.00
Phosphorus (mg)	73.30
Iron (mg)	56.40
Copper (mg)	13.00
Potassium (mg)	553.3
Magnesium (mg)	48.7

Health benefits

Antidiabetic properties

Diabetes mellitus is a chronic metabolic disorder which is caused due to insulin deficiency or resistance. Insulin is essential for maintaining the blood glucose levels and regulating carbohydrate metabolism. Insulin receptor (IR) is a tetrameric protein that activates tyrosine kinase beta subunit, which leads to impaired insulin signaling and hyperglycemia. Bio-flavonoids, including flavonoids present in plants like Musa sapientum, are known for their effective anti-diabetic efficacy. Flavonoids can act as insulin secretagogues or mimetics, influencing pleiotropic mechanisms. Banana flower extracts have been found to promote glucose uptake into cells, potentially replacing some insulin for diabetes mellitus. Studies on the anti-diabetic properties of banana blossom have shown that a balanced intake can reduce blood sugar levels and increase hemoglobin levels. The extracts have been found to stimulate glucose uptake in tumor cells and have antihyperglycemic effects in rats. Bioactive compounds like umbelliferone and lupeol have also been isolated for their anti-diabetic properties. Ramith *et al*. (2014) found that antidiabetic effects occur by inhibiting alpha-glucosidases in the intestine, which in turn suppresses carbohydrate absorption into the bloodstream.

Antioxidant properties

Studies show that the concentration of polyphenols and flavanols in banana flower has antioxidant properties, which can reduce the risk of diabetes, cancer, oxidative stress, and cardiovascular diseases. The phenolic content in banana inflorescences may depend on the banana species, with

Musa spp. shows significant flavonoid and phenolic content, which contributes to health maintenance among the locals. The antioxidant properties of banana inflorescences are due to methanol extracts, which reduce free radical activity. Consuming banana's edible flower can also help treat aging and cancer.

Anti-inflammatory properties

The banana inflorescence also has an anti-inflammatory property, which prevents swelling or inflammations in various parts and organs. This property has significant potential to work as a natural immune booster if focused on food value addition and fortification with its immune-enhancing bioactive components. Gallic acid, quercetin, and epicatechin are few of them which are identified as responsible for the anti-inflammatory activity, which suppresses the COX-2 and 5-LOX activities.

Anti-microbial properties

A study from Ramu *et al*. (2015) found that banana flower extract is a rich in source of saponins, terpernoids, coumarins, flavanoids cardiac glycosides, and steroids. It also has antimicrobial activity which makes it a potential source of nutraceutical. The research suggested that certain bioactive compounds particularly malic acid from banana blossoms contains antibacterial activity against the bacteria bacillus. The extract is also useful for healing wounds, especially in children, and preventing malarial parasites.

Effect on gastrointestinal tract

Banana flowers and their parts are rich in fiber, which helps to reduce ulcers and improve bowel movements and maintaining gut health. They are rich in minerals like potassium, sodium, phosphorous, and calcium, and have significant level of antibacterial and antioxidant properties. Banana flowers are also loaded with phytochemicals such as vitamins, flavonoids, and protein, making them suitable for treating bronchitis, constipation, and peptic ulcers. The antioxidant property scavenges free radicals and controls cell and tissue damage. Banana flower helps to maintain good gastrointestinal health and manage ulcers by neutralizing gastric juice.

Effects on woman health

Banana flower is good source of fiber and iron, which helps in the production of red blood cells and helps maintain menstrual cycle. Consuming banana blossom regularly for about a month can reduce blood sugar levels and raise hemoglobin levels, due it is rich in necessary nutrients. It can also help lower menstrual bleeding, which can cause pain in many women, especially those suffering from severe PMS symptoms or excessive bleeding. Banana blossom also reduces muscle cramps and regulates the progesterone hormone, reducing painful bleeding. It also boosts milk production in lactating mothers by stimulating the production of **prolactin**, the hormone responsible for milk synthesis.

Culinary significance

The global cultivation of bananas occurs on large scale, resulting to an increased production of banana flowers. These flowers are accessible at low cost due to their underutilization. Owing to their highly commendable nutritional composition, banana flowers are now being employed in formulation of various food products.

Rich in iron and fiber, banana flowers, accompanied with gooseberries, have been utilized in the creation of a product called "humus" (Anand *et al*., 2019), while biscuits have been produced through dehydration of banana flowers (Elaveniya *et al*., 2014). Additionally, a dish known as banana flower "sisig" was developed by combination of banana flowers with coconut powder, onion, ginger, and salt (Salvador, 2012), and also dark chocolate incorporating with banana flower was developed and evaluated by Sharmila *et al*. (2013). Dried slices, flour, and ready-to-cook (RTC) products have been developed by using three varieties of banana flower, namely Nendran, Rasakadali, and Palayankodan (Mahendran, 2014). Zehla (2018) developed a laddu by using banana flower, while Komal (2019) created a value-added product which integrated nut chocolate with banana flower. Given the low cost and favorable nutritional properties, banana flowers hold potential for developing of diverse novel food products and dehydrated powders, which may assist in resolving various health disorders.

There are numerous dishes are crafted from banana blossom in the eastern regions (West Bengal, Assam, Tripura) and southern parts of India (Kerala and Tamil Nadu). One such dish is the named as Banana Flower Cutlet, also referred to as fritters (Mochar Chop/Vazhaipoo Vadai). This dish is a traditional and widely consumed as snack among Bengali and Tamil communities, where banana flower and potatoes considered as the primary ingredients.

Another ethnic curry featuring the banana flower, which is originated from West Bengal, is the Banana Flower Curry (Mochar Ghonto). This dish is characterized as a dry curry and is frequently accompanied by steamed rice. In "Mochar Ghonto," banana flowers are prepared with potatoes and an array of aromatic spices, imparting a delicious flavor.

The Banana Flower Poriyal (Vazhaipoo Podimas) has its origins from Tamil Nadu, South India. This traditional dish is made of banana flowers and yogurt, establishing itself as an ideal complement to an Indian lunch, particularly for individuals suffering with diabetes.

Banana flower chutney (Vazhaipoo Thogayal or Thuvaiyal) is primarily rooted in Kerala and Tamil Nadu. It is typically enjoyed by combining it with rice, accompanied with a drizzle of either ghee or gingelly oil. These traditional dishes may be proposed as superfoods for the future generations (Sharma *et al*., 2020).

The incorporation of fiber-rich banana flower into a diverse range of foods and beverages contributes to generation of functional and value added foods that cater to the increasing demand of dietary fiber supplements (Begum and Deka, 2019). A discussion on some of the value-added products derived from banana flower is presented below:

1) **Banana flower pickle:** A pickle comprising banana flower fermented or preserved with spices, oil and vinegar or lemon juice.
2) **Banana flower flour:** After sun drying, grinding banana flowers into gluten free flour can be used in baking and as a thickening agent for soups and smoothies.
3) **Banana flower chips:** Banana flower slices are either sun dried or fried to make crispy and crunchy pakodas. The chips are seasoned with various spices like salt, pepper etc.
4) **Banana flower juice/extract:** This can be used as a medicinal health drink to control your blood sugar levels and digestion due to its exceptional flavonoid content.
5) **Banana flower curry:** Using this in dishes will enhance the flavor and you get a long lasting product.
6) **Canned or frozen banana flower:** The canned/frozen varieties are processed and packed for preservation which ensures that this healthy banana flower can be used over time even at areas where fresh banana flowers cannot reach.
7) **Banana flower tea:** Tea can be made by drying banana flower petals, not only to a calming tea but also high in fibre and good for diabetes.

These are products that not only enhance the shelf life of banana flowers but also offer health-oriented solutions for consumers. Banana flower is a rich source of dietary fibers and can be effectively used for the production of value-added products which in turn helps to minimize food waste created in large scale banana cultivation by enhancing the economic value.

Conclusion

Due to the global production and consumption of bananas, the banana flowers is often produced in large quantities as a by-product. The banana flower is also called as the banana blossom or banana heart, an underutilized yet highly nutritious part of the banana plant. Its impressive nutritional profile and therapeutic properties holds a position as a key player in the development of innovative food products which can be designed to mitigate the risks of several health conditions. Packed with essential phytochemicals such as vitamins, flavonoids, proteins, and antioxidants, it offers numerous health benefits, particularly in enhancing the body's immunity against various diseases. High in dietary fiber, the banana flower offers various health benefits, including reducing constipation, cholesterol levels, controlling blood sugar, supporting weight management, and promoting optimal gut health as a prebiotic. So rather than discarding as agricultural waste, this nutrient-rich flower has the potential to be repurposed as a valuable ingredient in wide range of food products. Banana flower could emerge as a noble component in enhancing both nutritional quality and overall health outcomes in our modern diet.

Future prospect

Banana flowers, despite being highly nutritious, affordable, and easy to find, are often overlooked and discarded, mainly because people are not aware of its benefits or how to use them effectively. This gap in knowledge shows the need for more studies and awareness to help people to see the potential of banana flower and how they can be better incorporated into our food systems. Bananas, as a tropical plant, are mostly grown in low-income countries where there are limited access to the modern resources and knowledge leading to the wastage of banana flowers. This lack of awareness is one of the main reasons that they remain underused. The wealthier nations can make a big difference by sharing research, technology, and investment with these regions and helping to turn banana flower into valuable products. Future studies and research should also look into affordable ways to extract the health-boosting compounds present in banana flowers, as they offer many medicinal properties that could tackle various health problems. With more global cooperation and creative solutions, banana flowers could be fully utilized, for their nutritional benefits and for potential therapeutic uses.

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Chapter - 2
Prevalence of Work-Related Health Hazard among Loco Pilots

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Chapter - 2

Prevalence of Work-Related Health Hazard among Loco Pilots

Priyanka Paul, Madhumita Ghosh and Jagannath Ghosh

Abstract

Indian Railway Drivers (Loco Pilots) work in an environment where they have no control and an atmosphere that destroys their schedules, interferes with their home life, and makes it difficult to plan social activities and regular rest breaks. The moderating effects of personality traits between job demands and its various health effects also reveal sleep problems, exhaustion, stress, and depressive symptoms. The purpose of this paper is to find out the stress level of locomotive pilots (train drivers) in India. The work of railway conductors is considered very stressful, and this article discusses the factors that lead to stress and fatigue and therefore a high probability of accidents. The purpose of this study is to focus on the various influences affecting the health of railway drivers (locomotive pilots) in India.

Keyword: Railway driver, working condition, health risk, occupational stress.

Introduction

A locomotive pilot, often referred to as a "loco pilot", is the person responsible for operating and controlling a locomotive in a train. They are skilled professionals trained to ensure the safe and efficient movement of trains, following established railway regulations and protocols. The job of a railway driver entails facing a challenging psychosocial work environment, characterized by solitary work conditions, minimal social interactions, and significant responsibility for safely operating the train. (In terms of both safety and adhering to the timetable) (Ranjan and Prasad, 2013). The job of a railway driver is perceived as very stressful, and stress is here the result of conflict demands on the driver, and low level of control by the driver on these demands and circumstances, for example, time pressure, long shifts, responsibility for security of passengers for instance (Dorn, 2003).

The work of Indian railways‟ drivers is considered extremely stressful. Railway drivers struggle to fulfil work and family responsibilities. This struggle is due to long hours, irregular and inflexible work schedules, and heavy workloads (Ranjan and Prasad, 2013).

Occupational stress

Occupational stress is the inability to cope with the pressures of a job (Rees, 1997), because of a poor fit between someone's abilities and his/her work requirements and conditions (Holmlund- Rytkonen and Strandvik, 2005).

These are the following sources of occupational stress:

i) Poor physical work environment.

ii) Work overload.

iii) Time pressures.

iv) Physical danger.

v) Responsibility for people.

vi) Little or no participation in decision-making.

vii) Family problems etc. (Nina Pološki Vokić and Ana Bogdanic, 2007).

Consequences of occupational stress

Stress produces a range of undesirable, expensive, and debilitating consequences (Ross, 2005), which affect both individuals and organizations.

On the individual level, there are three main subgroups of strains:

a) Unwanted feelings and behaviours – such as job dissatisfaction, lower motivation, low employee morale, less organizational commitment, lowered overall quality of work life, absenteeism, turnover, intention to leave the job, lower productivity, decreased quantity and quality of work, inability to make sound decisions, sabotage and work stoppage, occupational burnout, alienation, and increased smoking and alcohol intake.

b) Physiological diseases (poor physical health) – such as increased blood pressure and pulse rate, cardiovascular diseases, high cholesterol, high blood Report: The review on Loco Pilot Page 6 of 12 Report was generated on Tuesday, Feb 13, 2024, 10:49 PM sugar, insomnia, headaches, infections, skin problems, suppressed immune system, injuries, and fatigue.

c) Psychological diseases (poor emotional (mental) health) - psychological distress, depression, anxiousness, passiveness/ aggressiveness, boredom, loss of self-confidence and self-esteem, loss of concentration, feelings of futility, impulsiveness, and disregarding of social norms and values, dissatisfaction with the job (Giovanni Costa, 1995).

On the organizational level, the consequences of occupational stress can be grouped into two major subgroups:

a) Organizational symptoms - such as discontent and poor morale among the workforce, performance/productivity losses, low-quality products and services, poorer relationships with clients, suppliers, partners, and regulatory authorities, losing customers, bad publicity, damage to the corporate image and reputation, missed opportunities, disruption to production, high accident and mistake rates, high labour turnover, loss of valuable staff, increased sick-leave, permanent vacancies, premature retirement, diminished cooperation, poor internal communications, more internal conflicts, and dysfunctional workplace climate.

b) Organizational costs - such as costs of reduced performance/ productivity (lack of added value to product and/or service), high replacement costs in connection with labour turnover

(Increase in recruitment, training, and retraining costs), increased sick pay, increased health-care costs and disability payments, higher grievance, and litigation/compensation costs, as well as costs associated with equipment damage, can significantly impact financial expenditures. (Nina Poloski Vokic and Ana Bogdanic, 2007).

Health status of Railway drivers (loco pilot)

The health and fitness of railway drivers is an important issue when considering how to manage the risk of fatigue. It directly affects a railway driver's ability to deal with the stresses and demands of the job (WorkSafe, Department of Consumer and Employment Protection, 2013).

When speaking about railway drivers and how they must fight with stress and workload, we should consider how the job influences their health conditions. The fact that railway drivers are exposed to everyday whole-body vibration, diesel exhaust (in diesel locomotives), and noise, leads to increased health risks. According to Evans and Johansson (1998) and their report in the Journal Occupational Health Psychology, epidemiological data from several different countries consistently find drivers among the unhealthiest of occupational groups, particularly concerning cardiovascular, gastrointestinal, and musculoskeletal disorders. (Bigert, 2003).

Some of the common health hazard among loco pilots

i) **Obesity and heart disease:** Being overweight or obese is strongly related to high levels in the blood and high blood pressure. Both factors greatly increase the risks of having a heart attack (McDonald, 1984).

- They suffer 2 to 5 times the rate of stomach disorders.
- They are 40% more likely to suffer from cardiovascular disease.
- They suffer from peptic ulcers at an earlier age.
- They suffer more from anxiety and depression.
- They are more likely to die younger.

ii) **Diabetes:** Diabetes is a condition characterized by uncontrolled blood sugar levels, leading to fatigue if left unmanaged. Factors such as being overweight, and lack of physical activity significantly contribute to its development (FIRE Quartly Magazine, 2012).

iii) **Sleeping problems:** Sleep disorders like sleep-disordered breathing or apnea pose serious health risks, particularly for individuals who snore. These conditions involve the collapse of the windpipe during sleep, resulting in inadequate airflow to the lungs, frequent awakenings, and disrupted sleep patterns for both the affected individual and their sleep partner (WorkSafe, Department of Consumer and Employment Protection, 2013).

iv) **Muscular:** Musculoskeletal disorders (MSDs) are prevalent worldwide and a leading cause of workforce disability. Assessing exposure levels to MSD risk factors is crucial for planning and implementing ergonomic interventions in the workplace. Locomotive pilots are particularly susceptible to MSDs due to factors such as exposure to vibration, noise, magnetic radiation, varying climatic conditions, driving posture, and irregular job conditions, all of which can impact their health status.

v) Stomach and intestinal disorders (Kompier, 1996).

vi) **Psychological problems:**

- **Fatigue:** Fatigue is a particular problem for railway drivers. Numerous research studies have established that long and irregular work hours for drivers lead to fatigue, reduced alertness, and impaired coordination (Belzer, 2002). The other factor of fatigue can be driving at night, since the nighttime driving is different for driving in daytime: a driver requires greater concentration because of visibility limitations. Lack of visibility may increase driver´s drowsiness and fatigue (McDonald, 1984).

- Tension, mental overload.
  - Irregular and night work is a further stress factor for the loco-pilots due to its negative effects on various aspects of their lives, as concerns:

vii) Disturbances of the normal biological rhythms, beginning with the sleep/wake cycle.

viii) Negative effects on health and well-being, including troubles with the digestive function, nervous system (sleep deficit, anxiety, depression), cardiovascular systems (heart diseases).

ix) Social problems, resulting from difficulties in maintaining the usual relationships both at the family and social levels (Jorn Bakker, 2013).

Extended working hours and health

Research has shown that unusual and extended working hours, in particular night work can have negative effects on the health, safety, and well-being of workers. (US Congress OTA, 1991 Waterhouse, 1992)

This is both in the short and long term.

- **Short term:** Effects can include disturbed sleep, stress, fatigue, irritability, psychosomatic illnesses, family problems and accidents.
- **Long term:** Increased risk of gastrointestinal, cardiovascular, and psychoneurotic diseases and women shift workers can experience adverse effects on their hormonal and reproductive functions and family roles.

Conclusion

This research has the potential to contribute to a better understanding of the challenges faced by railway drivers in India and inform interventions to improve their work environment and health. By identifying the link between working hours and stress levels, the study can provide valuable insights for policymakers and railway companies to develop effective strategies for improving the well-being of their employees.

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Chapter - 3
An Overview of the Impact of Caffeine and Creatine on Sports Performance

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Chapter - 3

An Overview of the Impact of Caffeine and Creatine on Sports Performance

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Abstract

Creatine and caffeine are among the most popular and commonly consumed dietary supplements throughout the sports and fitness industry. Creatine and caffeine are the substances about which certain physiological features and applications can be mentioned. It is astonishing that creatine is a substance that exist naturally in muscles. In one word creatine has been used most notably to enhance muscle mass power and also power which is in activities with short duration but with high intensity through charging of phosphocreatine which charges ATP. Instead, caffeine used to function as central nervous system stimulant. Caffeine has some significant role like; increases wakefulness, concentration specifically in aerobic activity. They are all good on their own but collectively they will significantly improve the effort being invested in the care of the heart. Caffeine and creatine monohydrate especially when in combination has an effect which may improve or decline performance. Thus, negative effects are relative to time, dosage, and types of activities out there causing harm. Creatine and caffeine are two legal substances that have received attention in the last decade by coaches and athletes this paper aims to review the literature on creatine and caffeine, as well as their ergogenic benefits in sport.

Keywords: Creatine, caffeine, supplements, ATP, stimulant, aerobic activities

Introduction

There is a growing interest in the use of dietary supplements by athletes and fitness enthusiasts. Two of the most researched ergogenic aids are caffeine and creatine. Caffeine is one of the most widely used central nervous system stimulants consumed globally, and its popularity among athletes is due to its availability. Initially, it was thought that the actions of caffeine were due to its fat-burning properties. Creatine is considered one of the most researched supplements in the sporting world. Its popularity among athletes is due to its well-documented ergogenic effects in short, high-intensity activities. To update the current evidence, the purpose of this mini-review is to discuss caffeine and creatine on anaerobic sports performance and the safety of acute and chronic supplementation. (Elosegui *et al.*, 2022) (Marinho *et al.*, 2023) (Valiño-Marques *et al*., 2024)

To maintain a competitive edge, scientists and practitioners seek to identify compounds and make recommendations regarding nutrients and dietary supplements that can influence and enhance sports performance, as well as recommend nutrients that have no effect or even a negative effect on sports performance, which could lead to poor health outcomes. Investigating ergogenic substances in isolation is crucial, but it is just as important to study the effects of combining ergogenic aids because athletes use combination ergogenic aids without checking whether they are safe to consume together or whether the combination of the two substances can enhance physical performance. (Drobnic *et al*.,2022) (Khoramipour *et al*.,2022)

Background and Significance

Both caffeine and creatine supplementation have been used as ergogenic aids by athletes for many years. Historically, caffeine was consumed in the form of coffee, spurring the use of caffeine hydrate capsules to improve the precision of dosing. In fact, it has been recorded that winning athlete in the 19th and 20th centuries used caffeine as a performance enhancer to fuel their doping practices, a belief that was adopted by many military groups worldwide. Subsequently, the World Anti-Doping Agency banned excess caffeine intake during competitions until 2004. Though largely unregulated, caffeine is still regarded as one of the most effective and common ergogenic aids, used by many sports enthusiasts and studied widely within the scientific community. Creatine first gained prominence as a research topic in the early 1990s, yielding neutral to positive ergogenic effects in a number of sports. Believed to serve as a phosphate buffer to phosphocreatine, creatine ingestion is purported to increase power and strength.

Both caffeine and creatine have rewarded practitioners and researchers alike by earning 'classic' status in exercise physiology and sports science. Creatinergic and adenosinergic pathways may be closely allied. Since the initial isolation of caffeine, along with the precursor xanthine base, in 1820 by doctor Friedrich Ferdinand Runge, augmented in 1827 by Johann Wolfgang Dober. (Elosegui *et al*., 2022) (Marinho *et al*., 2023) (Huerta Ojeda & Jorquera-Aguilera, 2024)

Caffeine

Caffeine is probably the most common psychoactive substance, classified as a central nervous system stimulant. Its use for research was registered in 1819; its chemical composition was later explained in 1895, and it was recommended as a guard against depression. It arouses much interest for its possible ergogenic effects on sports performance, not only at the amateur level but also among professionals. The non-application of some positive doping tests throughout a variety of sports has even motivated the World Anti-Doping Agency to place caffeine on its list, although, as a result, its use continues without restrictions. However, its legal status must be taken into account, as well as the possible adverse effects on health, which, if not controlled, may represent an infringement of the principles of good clinical practice. Many specialists, when reviewing nutritional supplements and ergogenic aids, state that caffeine, when using moderate doses, should not be considered a nutritional supplement, as it does not bring specific nutrients, but neither should it be treated as a true ergogenic aid, such as gaining muscle mass, improving healing, or increasing strength.

In recent years, a number of possible cellular mechanisms of action have been proposed to explain the beneficial effects of caffeine on sports performance. Despite numerous scientific publications on the topic, another explanation would be of a psychological nature because caffeine can act on the central nervous system. Indeed, caffeine can influence the dopaminergic system, fostering the sensation of well-being and happiness. Furthermore, alertness and a more optimistic perception of fatigue positively ameliorate adherence to recovery strategies, enhanced not only by caffeine's biochemical properties but also by its sensory and limbic system-mediated action of relaxation generally facilitated by a good drink. Many are the benefits, not only for those who run, cycle, or practice popular marathons on weekends, but also for professional ultra-cyclists, tennis champions, and long-distance swimmers. (Diaz-Lara *et al*., 2024) (Jodra *et al*.,2020) (Delleli *et al*., 2022)

Mechanism of Action

Have you ever found yourself pondering the reasons behind that delightful feeling you get from your morning cup of coffee? Or perhaps you've considered why that caffeine pill seems to give you the energy boost you need to power through a long, late-night cram session filled with studying? Caffeine is a naturally occurring compound that can be found in various sources such as coffee, tea, chocolate, and even in many sports drinks, pre-workout supplements, and fat-burning products. This remarkable compound is recognized as the most commonly consumed psychoactive substance across the globe. The purpose of this section is to delve into and explain how caffeine can significantly enhance physical performance and cognitive function. If you are not particularly concerned about the somewhat ironic and frustrating idea of adhering to a keto diet while potentially missing out on the full benefits of your regimen due to caffeine consumption, you may choose to bypass the scientific details that follow. However, for those who are keen to understand, whether it is about reducing the perception of effort and pain or increasing the duration during which you are capable of performing high-intensity activities and resisting feelings of fatigue, caffeine is known to be ergogenic for a vast majority of athletic events and workouts. It has been mentioned in various discussions that because of caffeine's ubiquitous presence and usage, it is less prone to being abused compared to other substances. Nevertheless, it still incites quite a bit of controversy among those who impose strict bans on its use and those who fight for the right to consume it legally without restrictions. (Lara *et al.,* 2020) (Grgic *et al.,* 2021)

Although more practical knowledge than scientific research exists, theoretically caffeine’s obvious finish is via calcium and increased epinephrine/norepinephrine availability. Widespread physiological effects occur due to caffeine being an adenosine receptor antagonist. This adenosine confrontation causes found receptors in the heart, vascular smooth muscle, and fat cells to act directly, releasing neurotransmitters such as dopamine and norepinephrine in the brain through a different mechanism, suggesting at least a portion of the ergogenic response to caffeine is also psychological. Simulating the central nervous system has led to similar conclusions drawn after specifically determining its effects on neurotransmitters in the brain. Psychological effects manifest due to the increased availability of dopamine and norepinephrine, as those are known to heighten mood, improve glucose metabolism, and permit wakefulness and training motivation/resilience.

Effects on endurance performance

Caffeine has been shown to positively influence endurance performance in trained individuals. The magnitude of the beneficial effect depends on individual responsiveness, exercise protocol, and dosage, and it has been hypothesized to be stronger in women. Caffeine is effective in subjects able to improve performance with the onset of caffeine effects and for exercises that are limited not by the cardiovascular system, but by the provision of glucose. Additionally, caffeine could reduce the rating of perceived exertion immediately after supplementation. Whether caffeine influences the hormonal and psychological responses to exercise is still unclear. Chronic coffee consumption does not modify caffeine's ergogenicity. Several studies have attempted to identify the mechanisms that underpin the ergogenic effects of caffeine. Based on both in vitro and animal research, it is thought that caffeine can stimulate lipolysis, allowing muscles to use free fatty acids as fuel so that intramuscular glycogen can be spared. (Filip-Stachnik *et al.*, 2020) (Ferreira *et al.* 2021)

Moreover, caffeine's stimulant effect on the central nervous system is thought to reduce perceived effort and fatigue, increase motor unit recruitment and muscle function, which can delay fatigue further by altering the central determinants of fatigue. However, not all aspects of caffeine's ergogenicity are fully understood. There is a large variation in the metabolic and performance responses to caffeine, making it difficult to understand how to optimize caffeine supplementation strategies. For example, there is not a clear dose-response relationship between caffeine and motor performance or metabolic rate; that is, while there are numerous studies showing a performance-enhancing effect of caffeine, between-study results are not always consistent. Factors contributing to the lack of a clear dose-response relationship are likely related to differences in the timing of caffeine intake, the type of exercise protocol, or the mode of caffeine administration across studies. Despite this, there is evidence available from ongoing meta-analyses supporting the ergogenic potential of acute caffeine intake on endurance performance. A moderate enhancement is observed in time-trial and time-to-exhaustion exercises, mainly in running and cycling. (Wang *et al.,* 2022) (Harty *et al,*. 2020) (Chen *et al.,* 2024)

Effects on Strength and Power Performance

Aside from endurance, the effects of both caffeine and creatine on more general forms of performance, including strength and high-intensity power-related performance, are well documented and have warranted many reviews alone on these areas. In strength and power, many forms of activity can be utilized to develop a sizeable workload throughout a rehabilitation program as well as in performance, and the neuromuscular properties required for success in strength and power can differ between sports and athletes.

Pre-workout caffeine intake combined with regular resistance training can elicit an increase in overall strength, so it should be highlighted in this section. Recent research indicates that caffeine ingested at doses can elicit improvements in both 1 repetition maximum (1RM) and in 3RM in recreationally active men with regular weight training experience, therefore demonstrating caffeine to be effective in prolonged, strength-based exercise in these individuals. Though optimal repetition ranges for strength development are much lower compared to endurance repetitions, no research has explored the effects of caffeine in lower repetition training in controlled settings. Despite this, many other studies have highlighted chronic changes to certain variables that are essential for strength development; testosterone and cortisol are indicative hormones that are responsible for adaptations to resistance training, glycogen uptake following resistance exercise can differ depending on caffeine intake, caffeine doses can lead to significant improvements in relative lean mass, and caffeine doses have also been reported to increase velocity output in some trained strength populations. The increase in load volume due to caffeine can also be beneficial to strength improvements; it was reported that a caffeine dose was able to increase rated perceived exertion (RPE) during leg press at 80% 1RM in highly trained basketball players, suggesting a greater volume load can be completed at intensities conducted in strength-based workouts. Whether caffeine can increase volume load at an intensity close to 1RM has not been researched, but the aforementioned study reports greater muscle hypertrophy completed in these trained individuals consuming caffeine 1 hour prior to exercise, therefore such studies can display increases in muscle adaptations due to caffeine. The increase in volume appears to be greater at these higher intensities compared to lower, as it failed to demonstrate any beneficial effects of caffeine doses above on a leg press repetition-to-failure test at 50 or 67% 1RM compared to placebo. Caffeine increases training intensity, and greater training intensity increases the potential to increase safe muscle hypertrophic growth in the trained masses. Despite this, individual variation is still observed with showing no apparent response to caffeine compared to placebo, and therefore, very cautious supplementation advice should be provided. Not only is a person's personal mindset required prior to caffeine supplementation, but also a tolerance to the potential side effects, which reported jitteriness in some of the individuals supplemented with caffeine. Maintaining a tight goal focus and tolerance to the stimulatory effect was also more prominent in those showing a physiological response. Moreover, in the same study, a percentage of individuals reported an adverse event following all doses of caffeine, and therefore a cautious approach should be applied in order to develop an individualized caffeine dose, particularly among strength and conditioning practitioners and the general population. More research is warranted on the individual response to caffeine and the effects on strength as well as potential injuries caused by this ergogenic aid. (Grgic, 2021) (Grgic, 2022) (Wilk *et al*., 2020).

Creatine

Creatine is effectively the most researched supplement used by athletes and is used by a variety of athletes seeking performance enhancement. Creatine is a non-protein, nitrogenous compound that is biosynthesized at a rate of 1.7 g/day in the human body, mainly in the liver and kidneys, by the methylation of guanidinoacetate using the amino acid glycine to produce 1 g/day of creatine and by the body through the consumption of creatine-rich dietary sources. Approximately 95% of the body's total creatine stores are located in skeletal muscle, bound to a phosphoryl group in a compound called phosphocreatine, with approximately 5% found in the testes, brain, heart, kidney, and liver. The role of creatine phosphate in energy metabolism is to donate a phosphate moiety to adenosine diphosphate (ADP) to restore its high-energy phosphoanhydride bond for the resynthesis of adenosine triphosphate (ATP) when ATP is being rapidly metabolized for energy during "fast" activities.

The phosphocreatine (PCr) stored in this muscle is used to rephosphorylate adenosine diphosphate (ADP) because ATP is broken down in the muscle and only a limited amount of it can be stored. It is therefore the mean average rate at which new ATP can be made available that determines the rate at which "fast" activities can be performed. Since the creatine supplementation significantly increases the PCr content in both type I and II muscle fibers, an increase in the PCr/ATP ratio will allow more of this fast energy reserve backup. Few clinical trials have been conducted in which creatine has increased performance in weight lifting. Moreover, creatine supplementation has improved performance in single and repetitive sprint tasks. Since these initial trials, many clinical trials have found improvements in various respects compared to a placebo after creatine supplementation. Biochemical experiments show that creatine can be safely fed over long periods of time if the appropriate dose is followed. Potential side effects of the use of creatine are discussed. It has never been shown that creatine supplementation in the long-term leads to dehydration when a person is fully hydrated by his or her usual intake of food and beverages. Identical to caffeine, creatine enhances the effect of caffeine during dehydration, so creatine and caffeine must be cycled simultaneously. Creatine as a dietary supplement is considerably different from other substances such as anabolic steroids. It is an essential ergogenic aid for sports and can play an important role in the everyday program of competitive athletes. (Hall *et al.,* 2021) (Fazio *et al.,* 2022) (Wax *et al.,* 2021)

Mechanism of Action

Creatine

Phosphocreatine (PCr) is a naturally occurring molecule that is stored in the muscle and facilitates ATP re-synthesis via its action as an ATP spec courier. The ATP-PCr energy system is anaerobic and alactic and is capable of supporting high-intensity exercise lasting approximately 10-15 seconds. A supplementary effect of this process of energy re-synthesis is the 'mopping up' of hydrogen ions that are released during the high-energy phosphate breakdown. This role can delay the onset of intramuscular acidosis. Furthermore, because creatine generally 'tugs' water into the muscle cell, it may have a 'cell-hydrating' or 'cell-volumizing' effect, whereby the muscle looks and feels fuller and may take on a small amount of water weight. Over time, if creatine supplementation results in muscle cell swelling, its effects may 'spill over' and aid in muscle rebuilding and repair, such as by augmenting the action of human growth hormone and insulin-like growth factor-1, the anabolic hormones.

There are several cellular uptake mechanisms for creatine with an insatiable cell infatuation for the muscle cell. Large tissue stores of creatine can be achieved with the oral ingestion of three to five daily doses for 3-6 days of 20 grams per day. Due to the speed of the 'creatine-loading' phase, an increase in the 'total creatine' or 'creatine plus creatine phosphate' pool can be observed within a few days of commencing supplementation. A further increase of muscle PCr stores may arise after a prolonged supplementation period of 6-12 weeks, though this effect tends to be less dominant, possibly because an indirect rate-limiting factor kicks in, such as the level of the enzymes involved in creatine synthesis and degradation. Called an 'indirect' ergogenic aid, the overall effect of creatine may be to quicken the time to recovery from a workout and the time to recovery gating and the rebound of anaerobic power output in the short term, and to increase training volume and augment training adaptations in the long term. Given the uniqueness of the metabolic system, creatine may produce unique outcomes in different athletes, with large ergogenic effects generally seen in power and strength trained athletes and smaller or unclear responses in endurance or team sport athletes. A diverse range of positive performance outcomes are now reported with creatine supplementation across a range of sports, such as American football, baseball, basketball, military-based and short-distance running events, field sports, rugby, soccer, squash, and tennis. (Wax *et al*., 2021) (Forbes *et al.*, 2023) (Hall *et al*., 2021)

Effects on Endurance Performance

According to the simplistic conceptualization of "creatine = weightlifting and strength training supplement," it is accepted among part of the lay public that creatine does not play a part in activities characterized by long-duration exercise, little recovery, high oxygen costs, and large reliance on oxidative metabolism. Creatine, in this school of thought, is supposed to aid in improving "limit-strength performance," which is the maximum amount of force that can be produced in one moment. Anything beyond a few minutes would have to fall into "endurance training." Based on the misconception that "creatine supplementation = weightlifting, ergo, if you don't do weightlifting, you don't need creatine," a large portion of the endurance sports population engaged in continual strength and conditioning and metcon work have neglected supplementing creatine.

It is noted that "intense physical exercise can only be maintained for a limited duration of time." A properly fueled body "burns a mixture of carbohydrate and fat." Fat is the preferential energy source at low intensities, and carbohydrates are the limiting energy source at high intensities. The problem is that the maximal amount of carbohydrate stored in the body is 1500 kcal (most of that in fat). This means that during glycogenolysis, the primary energy system for short-term anaerobic exercise of 1 second up to 2 minutes rapidly depletes, and the body is left with just whatever remains in the bloodstream or liver glycogen. Between these two is oxidative phosphorylation, a system that can utilize fats or carbohydrates (aerobic), but only a third as quickly or less. If one can better recover the energy sources for both glycolysis and oxidative phosphorylation, one would have better sustained performance in "high-intensity" activities "longer than 2 minutes." These would be things like rowing hundreds of meters or sprinting for extended periods, as well as engaging in a sport modality that blends continuous and varied movement or changing modality every 30-120 seconds, such as the high-medium intensity exertions with multiple loaded objects or the constantly varied, high-intensity "athletic ability" competitions or "ergathons." There are other less direct effects as well, but these would be the most applicable to most athletes. Anecdotally, a number of endurance athletes who do not come to The Lab use creatine for that very purpose, and others use alkaline creatine with the same dosage and rationale. (Hall *et al.,* 2021) (Wax *et al.*, 2021) (Forbes *et al.*, 2023)

Effects on Strength and Power Performance

One of the most studied ergogenic aids is creatine. Improved swimming performance has been reported after creatine supplementation, with a decreased race time of 100 m by 0.4%. However, in relation to creatine, the majority of studies have been conducted to examine its effects on strength and power performance. Creatine can improve maximal strength, mainly during repeated bouts of high-intensity, short-duration activities, by increasing the buffering of hydrogen ions due to the increased buffer capacity in the muscle. The benefits of increased muscle creatine content and subsequent performance enhancement have been demonstrated using a variety of different forms of creatine, ranging in dose from a large acute ingestion of approximately 200 to 225 g, and supplementation for as little as 3 to 6 $s \cdot d^{-1}$ and as long as 3 to 5 years. It is apparent that creatine is effective in increasing the creatine content of muscles, which facilitates the phosphocreatine system, leading to an increased ability to rapidly regenerate adenosine triphosphate exclusively.

While only a few research studies have failed to show that creatine can enhance performance, the majority have reported improvements in maximal strength, power, sprint speed, and power endurance, as well as single sprint performance. For instance, creatine supplementation has improved maximal strength, power, and sprint speed in male rugby players, elite American football players, female volleyball players, as well as men and women of a variety of other sports. The long-term use of creatine is the most effective way of increasing creatine storage and improving performance. Typically, a common way for athletes to achieve supranormal creatine stores within the muscle is by a period of daily ingestion of 4 × 5 g creatine, usually for 10 to 14 days; this is known as the loading phase. Alternatively, a smaller load, 3 × 5 g for example, has been utilized. However, these relatively large dosages for short periods can result in stomach upset, so a lower dosage might be a more appropriate and practical option. Long-term maintenance of a high creatine storage level can be achieved through ongoing consumption of between 0.03 to 0.06 g of creatine for every kg of body weight per day, a dose that is almost certainly practical for all athletes. It has been shown that a typical serving size of a creatine-containing supplement of 5 g would maintain a sitting but not an exercising blood creatine level in the range of approximately 132 to 137 mM. With only slight digestive upset, ingestion of 5 g creatine for every 10 kg-bw can also be used to aid in maintaining muscle mass, phosphocreatine, and strength while injured or immobilized. A short-term consumption of a typical 5g dose of creatine may substantially improve intermittent running performance in effort-related team sports but not in skill-based sports.

The benefits of creatine may vary from individual to individual, depending on initial muscle creatine content, body composition, dietary intake, physical condition, and training; for example, there is some evidence that vegetarians may respond better than meat eaters. The improvements in performance with the use of creatine positively influence the physiological response. Mechanistically, it is now generally agreed that creatine exerts some or all of its effects due to several possible means: a) increase the total phosphocreatine content leading to an increased temporal and/or quantitative phosphate supply for the re-phosphorylation of adenosine diphosphate; b) deactivation of myosin ATPase; c) possible action via increased glycogen storage. Creatine ingestion, however, does not result in increases in fat mass, although several kilograms of body weight can be gained due to increased muscle girth and water retention. (Wax *et al.*, 2021) (Bogdanis *et al.*, 2022) (Forbes *et al.*, 2023)

Combined Effects of Caffeine and Creatine

Recent years have seen the explosion of caffeine and creatine supplements, among the most widely used throughout sports nutrition and an area of great interest for sports science. Yet few studies have evaluated the potential synergistic effect of their combined use on sports performance. To date, solo studies addressing possible interactions yield contradictory results due to differing research protocols. This section critically evaluates the benefits of taking caffeine and creatine together.

Caffeine supplementation during creatine usage has been shown to positively impact time to exhaustive exercise in the heat among rugby players. In addition, effects on acute and chronic strength and cognitive functioning have been evaluated using varying research methodologies. For instance, some literature suggests that the contrasting mechanisms of action of these two supplements might account for different results. One study reported different mechanisms of action: caffeine enhances peak power through central mechanisms of arousal, while creatine seems to aid with the maintenance of power output by increasing the stores of phosphocreatine.

Information limited to effects of the combined use of caffeine and creatine only in doses in excess of 3 g and separated by 5–6 hours can be found. Both prior and acute caffeine use on the same day as creatine supplementation in doses varying from 3 to 6 mg/kg show an interaction that may lead to a positive influence on physical performance; yet in some circumstances, it may promote side effects. Studies have since found that during pre-season, caffeine has been shown to enhance the effect of maintaining creatine phosphate, resulting in improved recovery and time to fatigue. Evidence has suggested that the increase in creatine phosphate stores has a preferential effect on type II muscle fibers, which may help explain the larger caffeine effect in type II muscle fiber-dependent acute and chronic training studies. By understanding the combined effect of creatine phosphate availability and increased metabolism of fat, carbohydrate intake, and potential increase in fatty acid oxidation, athletes could find the right diet to support this metabolism improvement, further increasing adaptation and the rate of improvement in their training regime. Long-term studies of 12 to 24 weeks have found an increase in resting metabolic rate from creatine use, and the oxidation of substrates may also influence the use of energy from phosphagen systems when they are required. (Mabrey *et al.*, 2024) (Moesgaard *et al.*, 2024) (Stratton *et al.*, 2022)

Practical Applications and Recommendations

Undeniably, creatine and caffeine supplementation can improve individual exercise performance. Ingestion of low to moderate dosages of caffeine 30–60 minutes prior to exercise can enhance performance in single exhaustive sprints, time trials, multiple sprint exercises, and high-intensity resistance exercise. Acute supplementation of creatine per day improves intermittent high-intensity activities such as sprinting, resistance exercise, and muscular endurance. Caffeine enhances strength-power performance when it is either combined with creatine or consumed post-exercise, while creatine accelerates muscle tissue recovery following maximum voluntary contractions in a cumulative dose-response manner with no relation to the timing of creatine ingestion.

Aerobic and anaerobic performance outcomes of large male cohorts show marked variation in both caffeine and creatine responses, which emphasizes the need for individualized supplementation strategies. In order to improve athlete performance, research providing specific evidence to the individual who will directly benefit is urgently needed to develop, interpret, and promulgate. However, due to the large number of athletes manifesting non-response to ergogenic aids, it is crucial to individualize supplementation strategies according to the athlete's background, associated risks, performance goals, and other performance-related aspects such as nutrition and hydration, in order to optimize any potential benefit. The ergogenic properties of any substance need to be carefully outlined before providing practical guidelines. Typically, these include dosages, timing, and driving ergogenic potential. However, following the development of such evidence-based guidelines, the potential of an ergogenic substance to become widely accepted relies on the practical implications for its use. Ergogenic aids have also been shown to unlock the process to improved physiological well-being, as caffeine for 8 weeks increased quality of life in relation to mental and physical well-being.

Caffeine has been found to enhance strength-power in combination with creatine supplementation. However, creatine has been stated to not contribute to an acute strength effect beside one-repetition maximum. Tolerance towards caffeine has been demonstrated in relation to the anaerobic strength effect, following the use of caffeine for 14 days. Overall, caffeine is described to have poor beneficial effects towards elite rugby league game movements, match-based performance measures, and CNS response. (Wang *et al.*, 2020) (Lima-Silva *et al.*,2021) (Karayigit *et al.*,2021)

Conclusion

In conclusion, there is a complex interaction of many factors that contribute to an athlete's potential for performance improvement. Among these factors are neural drive to muscles, concentration, maximum motor unit recruitment, and the frequency and regimen of training. The use of nutritional ergogenic aids is another factor that needs to be given consideration. The use of caffeine in supplement form can effectively enhance endurance performance. These ergogenic effects are observed at moderate dosages, and the effect is not altered in habitual users. Side effects are mild, and no serious risks to health have been documented. In supplement form, caffeine is almost completely banned. It is recommended that the dietary intake of creatine be increased in order to obtain the reported ergogenic effects on high-intensity activities. Side effects have been associated with very high supplemental dosages. For sports requiring bursts of power lasting up to 30 seconds, such as sprinting and Olympic weightlifting, creatine supplementation is still recommended even at a higher quality accomplished in training.

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Chapter - 4
Exploring the Preventative Potential of Kiwi: A Critical Review Concerning the Anti-Carcinogenic Benefits of Kiwi Fruit

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Chapter - 4

Exploring the Preventative Potential of Kiwi: A Critical Review Concerning the Anti-Carcinogenic Benefits of Kiwi Fruit

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Abstract

This thorough analysis delves into the intriguing field of kiwi fruit consumption's anti-carcinogenic benefits. In spite of its rich nutrient profile, kiwi fruit stands out as a prospective choice for helping people comprehend the potential impact of dietary interventions, as the prevalence of cancer remains a global health concern. The nutritional makeup of kiwi fruit, emphasising how abundant it is in important vitamins, minerals, dietary fibres, and special phytochemicals. The research looks at how important bioactive substances like vitamins C and E, polyphenols, and carotenoids contributes to the fruit's anti-inflammatory and antioxidant qualities, which lay the groundwork for the fruit's possible anti-carcinogenic benefits.kiwi fruit appears out as a potential option for educating people about the possible effects of dietary modifications despite its excellent nutritional profile.The kiwi fruit's nutritional composition is examined in the first section of the study, which highlights the fruit's high content of vital vitamins, minerals, dietary fibre, and unique phytochemicals. The study examines the role that significant bioactive component such as carotenoids, polyphenols, and vitamins C and E play in the fruit's antioxidant and anti-inflammatory properties, which set the stage for potential anti-carcinogenic effects.Dosage, frequency, and possible interactions with additional nutritional elements are taken into account, offering useful information to those who want to take advantage of the anti-carcinogenic properties of kiwi fruit.

Keywords: Kiwi fruit, cytotoxicity, reactive oxygen species, melanoma, quercetin.

Introduction

The fruit produced by plants belonging to the genera Actinidia Lindl. Is commonly referred to as "kiwifruit." The majority of act inidia species are found in southwest China, yet a tiny number are also found in nations that border China (Ferguson and Huang, 2007). The majority of commercially available fruit comes from two varieties: A. deliciosa (A. Chev.) C.F. Liang and A.R. Ferguson, that produces green-fleshed fruit, and A. chinensis Planch, which primarily has yellow-fleshed fruit, occasionally with a red ring around the core. A. chinensis var. chinensis and A. chinensis var. deliciosa are closely related taxa that are increasingly considered to be variations of the same species (Li *et al*., 2007).

Additionally, they were used to treat a variety of tumours, particularly digestive system and breast cancer (Motohashi *et al*., 2002). According to Chang (2002), the polysaccharide content of kiwifruit (A. chinensis) may be responsible for some of the "anticancer" qualities identified in traditional Chinese medicine. The preservation of well-being and health is becoming more and more important as populations age, and there is growing interest in creating functional meals based on conventional therapy. Since kiwis have been utilised for for medicinal purposes in China, further research is warranted to see whether or not they may be used to advance modern medicine or otherwise improve health. Because of their high ascorbic acid (vitamin C) concentration, kiwifruit is frequently advocated, which likely accounts for some of the health advantages noted. The normal fresh weight concentration of A. deliciosa 'Hayward' is 85 mg/100g, and one fruit can meet the recommended daily allowance (RDI; Ferguson and Ferguson, 2003). Different Actinidia species have different quantities of vitamin C (Drummond., 2013; Huang *et al*., 2004). Antioxidant, antiatherogenic, anticarcinogenic, and immunomodulatory properties are among the health advantages linked to vitamin C (Vissers *et al*., 2013). Nonetheless, kiwifruit also have additional vitamins and minerals, such as dietary fibre, polyphenols, folate, potassium, and magnesium, that may add to potential health advantages (Ferguson & Ferguson, 2003; Drummond., 2013).

Defence of cells and antimutagenic properties

Reactive oxygen species (ROS) are generated during normal metabolism and are constantly present in cells due to many factors such as illness, smoking, alcohol intake, insufficient nutrition, and environmental pollution. ROS can also be formed at higher concentrations. ROS-mediated oxidative stress has the capacity to oxidatively damage proteins, lipids, and DNA, which can lead to inflammatory processes and the emergence of numerous diseases, including cancer. (Kryston *et al*., 2011) Kiwifruit has been shown to protect against reactive oxygen species (ROS) and oxidation; this effect has been linked to higher levels of circulating antioxidant species, especially vitamin C and vitamin E (Hunter *et al*., 2012; Chang and Liu, 2009; Brevik *et al*., 2011). However, it should not be assumed that kiwifruit consumption provides the only protection against oxidative stress.

Certain processes, such cell signalling, gene regulation, and enzyme activity, are modulated by phytochemicals in order to defend against oxidative stress and DNA damage (Collins, 2013; Stevenson, 2012). Kiwifruit is one example of a fruit that demonstrates this ability. A substantial increase of gene sets linked to immunological response, oxygen deprivation and apoptosis, and DNA repair (including nucleotide elimination repair, imbalance repair, and a double-strand break repair) was observed in healthy male smokers who provided three kiwifruits (the species and variety not defined) to their daily diet (Bohn *et al*., 2010). One indicator of mutagenicity susceptibility has been DNA repair (Collins and Gaivão, 2007).

The therapeutic advantages of kiwifruit:

Cytotoxic activity: The anticancer effect of the acetone extracted from kiwi peelings was investigated using cancers of the liver (HEPG-2) and breast (MCF-7) cells. In opposition to malignant cells of tumours, it functions as a cytotoxic substance without harming healthy bodily cells. Because of its high dietary fibre content, it reduces the chance of colon cancer. Hsieh, Moyad and Carroll state that cancer is a worldwide health problem with an elevated morbidity and mortality rate in addition to financial issues and psychological difficulties. Cancer cells have the ability to disperse across the stroma of their hosts (Ashizawa *et al*., 2006). Different types of epithelium dysplasia and unregulated crypt cell growth are characteristics of colon cancer. When neoplastic cells cross the muscularis mucosa and enter the submucosa, they are deemed malignant (Tanaka, 2009). According to research, kiwi extracts can stop oxidative DNA damage in cells and stop cancer cells from growing (YOU Y *et al*., 2012; H. B. Collins *et al*., 2001)

Immune system performance and defence against infectious diseases

Immune competence is significantly influenced by nutrient status. Vital nutrients for effective immune function include zinc, copper, iron, selenium, linolenic acid (LA), folic acid, essential amino acids, and vitamin A, B6, B12, C, and E (Calder and Kew., 2002). According to Ferguson and Ferguson (2003), kiwi fruit (A. deliciosa and A. chinensis) are an excellent source of vitamin C and an appropriate sources of copper, vitamin E, and folate (18%, 11%, and 10% U.S. RDI for A. deliciosa 'Hayward' and 19%, 11%, and 8% for A. chinensis 'Hort16A').Furthermore, kiwifruit are rich in phytochemicals, including carotenoids, and there is evidence linking a higher consumption of carotenoids to a lower risk of infection. (Cser *et al*., 2004; van der Horst-Graat *et al*., 2004)

Kiwi fruit in relation to Melanoma (Skin cancer)

Globally, malignancy of the skin is the most prevalent type of cancer. While making up just 1% of all occurrences of skin cancer, melanoma is primarily to blame for the bulk of skin cancer-related mortality [Siegel RL *et al*., 2020]. Melanoma incidence is rising faster than that of all other cancers. Despite improvements in identification and treatment, melanoma is still the 3rd most common disease to spread to the brain (Rainov NG *et al*., 1996). The bioactive antioxidant chemical polyphenol is one of the several components of kiwifruit extract (KE) (Lippi G *et al*., 2020). According to a study published by Lippi and Mattiuzzi, kiwifruits have significant antioxidant qualities. A few of these properties include a dose-dependent rise in DNA repair, a decrease in H2O2-induced DNA damage, and a decrease in cell viability in two cell lines of human lung and stomach cancer (Lippi G *et al*., 2020). Although no research has demonstrated that KE has antiproliferative effects on melanoma, earlier research has indicated that resveratrol, a phenol present in many plants, including kiwifruit, may have tumor-suppressive effects on melanoma cell lines. (Johnson GE *et al*., 2008)

Kiwi Fruit in Digestive Health

Actinidin, a proteolytic enzyme found in kiwi fruit, improves the digestion of proteins and aids in meal digestion by breaking down proteins. It also helps maintain smooth intestinal transit by containing bromelain and papain. By its effects, the fibre in kiwi fruit also contributes to the enhancement of this outcome. (Richardson *et al*., 2018)

Kiwi fruit in relation with Pancreatic Cancer

Reactive oxygen species (ROS) growth and unbalanced radical scavenging are the causes of macromolecular damage in many diseases, including Alzheimer's, inflammation, atherosclerosis, and different types of malignant neoplasms (Fan *et al*., 2020; García-Sánchez *et al*., 2020). According to Brindisi *et al*. (2020) and Zhang *et al*. (2020), high ROS concentrations can oxidise biomolecules such as DNA, proteins, and lipids, causing damage to tissues, death of cells, or degenerative processes. Because they play a critical role in scavenging and suppressing these radicals, it is essential to assess and categorise novel plant-based sources of antioxidants (Neha *et al*., 2019). Because of their critical role in both the prevention and treatment of various diseases, phytochemicals derived from natural sources like fruits and vegetables are frequently administered as possible antioxidant

(Sharifi-Rad *et al*., 2020). (Zhao *et al*., 2017). Numerous Actinidia family species produce edible kiwifruits. The most popular and widely accessible green kiwifruit in the market is the 'Hayward' cultivar, which is a member of the Actinidia deliciosa genus (Park *et al*., 2011). Following utilisation by solvents with different polarities, a wide range of phytochemicals, including phenolic compounds, flavonoids, carbohydrates, vitamins, folic acid, mineral substances, saponins, and tannin compounds, have been identified from kiwifruit extracts (Bae *et al*., 2012; D'evoli *et al*., 2015; Wang *et al*., 2018; Alim *et al*., 2019). Its abundance of antioxidant components makes it useful for treating and preventing a wide range of clinical illnesses, such as rheumatism, dyspepsia, cardiovascular diseases, and digestive disorders (Leontowicz *et al*., 2014; Podsedek *et al*., 2014; Peticila *et al*., 2015). Kiwi flesh exhibited stronger anti-pancreatic adenocarcinoma properties compared to its peel. This was closely linked to the phenolic profile of the flesh and the substances detected, including quercetin, caffeic acid, and syringic acids, which are mostly present in the flesh extract and absent from the peel. While caffeic and syringic acid have a limiting impact on various cancer cells proliferation, quercetin, a pleiotropic kinase inhibitor, has been shown to have an anti-pancreatic activity (Russo *et al*., 2014; Rajendra Prasad *et al*., 2011)

Conclusion

The kiwifruit's possible health advantages, especially its anticancer and antioxidant qualities. Given its Chinese origins and abundance of nutrients, such as vitamin C and polyphenols, kiwifruit has the potential to improve immune system performance, protect against oxidative stress, and support gut health. Additionally, the study raises the possibility of a role in treating pancreatic cancer and melanoma. In general, kiwifruit appears to be a potential candidate for enhancing well-being and preventing numerous diseases; however, more research is necessary to substantiate these findings.

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Chapter - 5
Anthocyanins and Its Role in Cancer Prevention

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Chapter - 5

Anthocyanins and Its Role in Cancer Prevention

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Abstract

Anthocyanins, a subgroup of flavonoids, are naturally occurring pigments abundant in various fruits, vegetables, and plants. Over the years, research has shed light on their potential health benefits, particularly in cancer prevention. Anthocyanins are water-soluble pigments of the phenolic group found in spanish marigold, purple cauliflower, white water lily, beet roots, blue wheat, and rush berry that comprise cyanidin, delphinidin, malvidin, peonidin, petunidin, and pelargonidin, these substances demonstrate antioxidative and antimicrobial properties, contributing to visual and neurological health and providing protection against communicable diseases. By examining the mechanisms underlying their anti-cancer properties, elucidating their effects on cancer cell proliferation, apoptosis, angiogenesis, and metastasis, this review synthesizes evidence from both in vitro and in vivo studies. Furthermore, it discusses the synergistic interactions between anthocyanins and other bioactive compounds, highlighting potential avenues for future research and therapeutic applications. Anthocyanins function as antioxidants by stabilizing molecules through electron donation, thereby mitigating the damaging effects of reactive oxygen species (ROS), with their effectiveness influenced by specific hydroxyl groups on the beta and C rings. Through an extensive analysis of scientific literature, this review aims to contribute to a deeper understanding of the promising role of anthocyanins in cancer prevention.

Keywords: Anthocyanins, cancer prevention, flavonoids, anti-cancer properties, mechanisms, therapeutic applications.

Introduction

Anthocyanins are water-soluble pigments synthesized through the phenylpropanoid pathway. They belong to the flavonoid family and are characterized by their polyphenolic structure, which consists of an anthocyanidin core attached to sugar molecules. Common anthocyanidins include cyanidin, delphinidin, pelargonidin, peonidin, petunidin, and malvidin. The glycosylation pattern and the number of sugar molecules attached to the anthocyanidin core determine the specific type of anthocyanin.

Cancer is an uncontrolled cell growth or hyper proliferative disease. Today one in six individuals have been diagnosed as cancer. Despite conventional cancer treatments like surgery, chemotherapy, and radiotherapy there is growing interest in the potential of naturally occurring substances like anthocyanin. These compounds are widely distributed in various plant-based foods, with berries (such as blueberries, strawberries, raspberries, and blackberries), grapes, red cabbage, eggplant, and purple sweet potatoes being particularly rich sources. The concentrations of anthocyanins vary depending on factors such as the plant species, cultivar, ripeness, and environmental conditions.

Numerous studies have investigated the anti-cancer properties of anthocyanins. Wang and Stoner (2008) highlighted the inhibitory effects of anthocyanins on cancer cell proliferation, angiogenesis, and metastasis. Sun *et al*. (2016) demonstrated the antimetastatic properties of anthocyanins from black rice in human oral cancer cells. Additionally, Yao *et al*. (2017) reported the induction of autophagy and apoptosis in tumor cells by anthocyanins from purple sweet potato. Aqil *et al*. (2009) revealed the antioxidant and antiproliferative activities of anthocyanin-enriched extracts from Syzygium cumini. These studies collectively suggest a promising role for anthocyanins in cancer prevention.

Chemical structure and Sources

Anthocyanins are water-soluble compounds synthesized through the phenylpropanoid pathway in plants. They consist of an anthocyanidin aglycone moiety, which is responsible for their color, attached to one or more sugar molecules. The most common anthocyanidins include cyanidin, delphinidin, pelargonidin, peonidin, petunidin, and malvidin. The type and position of sugar moieties attached to the anthocyanidin core determine the specific anthocyanin compound.

These compounds are abundantly found in various fruits such as berries (blueberries, strawberries, raspberries, blackberries), grapes, cherries, and vegetables like red cabbage, purple sweet potatoes, and eggplants. The concentration of anthocyanins in these foods can vary widely based on factors like the species, cultivar, ripeness, and environmental conditions.

Method of extraction

These blueberries have reached an 8-week fruit period, attaining maturity with a diameter ranging from 5 to 10 mm. Characterized by a purple-red hue and a moisture content of 88%, they belong to the half-height clumped blueberry variety. Fresh fruits are harvested and subsequently stored in a refrigerator at -20°C. For the experiment, the frozen fruits are retrieved from the -20°C storage and thawed in a refrigerator maintained at 4°C.

Enzymatic extraction: Adjusting the pH with a mixture of citric acid and sodium citrate, enzymatic extraction of blueberry anthocyanin was performed. 5 g of blueberry was crushed, and enzymolysis was carried out using 5 mg/g pectinase at 45°C, pH 4.5. The enzymatic hydrolysis process, with a material–liquid ratio of 1 g:8 mL, lasted for 60 min and 90 min. Following centrifugation at 2,000 rpm for 20 min, the resulting blueberry anthocyanin extract was collected (Li *et al.*, 2020).

Mechanisms of action in cancer prevention

Anthocyanins exert their anti-cancer effects through a variety of mechanisms, including antioxidant activity, anti-inflammatory effects, induction of apoptosis, inhibition of cancer cell proliferation, suppression of angiogenesis, and modulation of metastasis-related pathways.

Antioxidant activity: Anthocyanins possess potent antioxidant properties, which help to scavenge reactive oxygen species (ROS) and reduce oxidative stress. Oxidative stress can lead to DNA damage, mutation, and promotion of carcinogenesis, making antioxidants crucial in cancer prevention.

Anti-inflammatory effects: Chronic inflammation is closely associated with cancer development and progression. Anthocyanins exhibit anti-inflammatory effects by inhibiting pro-inflammatory mediators and signaling pathways, thereby suppressing tumor-promoting inflammation.

Induction of apoptosis: Apoptosis, or programmed cell death, is a vital mechanism for eliminating damaged or malignant cells. Anthocyanins have been shown to induce apoptosis in cancer cells through various pathways, including activation of caspases, modulation of Bcl-2 family proteins, and regulation of mitochondrial function.

Inhibition of cancer cell proliferation: Anthocyanins can inhibit the proliferation of cancer cells by arresting the cell cycle at different checkpoints, such as the G0/G1, S, or G2/M phases, thereby preventing uncontrolled cell division.

Suppression of angiogenesis: Angiogenesis, the formation of new blood vessels, is essential for tumor growth and metastasis. Anthocyanins have been reported to inhibit angiogenesis by targeting pro-angiogenic factors and signaling pathways, thus depriving tumors of nutrients and oxygen.

Modulation of Metastasis: Anthocyanins possess antimetastatic properties by inhibiting the migration, invasion, and adhesion of cancer cells, as well as by regulating epithelial-mesenchymal transition (EMT) and matrix metalloproteinases (MMPs).

Evidence from preclinical studies

Numerous preclinical studies have provided compelling evidence supporting the anti-cancer effects of anthocyanins. In vitro studies have demonstrated the ability of anthocyanin-rich extracts or pure anthocyanins to inhibit the growth and proliferation of various cancer cell lines, including breast, colon, prostate, lung, and leukemia. Additionally, animal studies have shown that dietary supplementation with anthocyanins can suppress tumor growth, reduce tumor incidence, and prolong survival in mouse models of cancer.

These findings collectively underscore the potential of anthocyanins as chemo preventive agents against a wide range of malignancies.

Clinical evidence and Epidemiological studies

While most evidence supporting the anti-cancer properties of anthocyanins comes from preclinical studies, some clinical trials and epidemiological studies have also provided promising results. For instance, a randomized controlled trial in patients with colorectal cancer found that supplementation with bilberry extract, a rich source of anthocyanins, led to a significant reduction in markers of oxidative stress and inflammation.

Similarly, several observational studies have reported an inverse association between the consumption of anthocyanin-rich foods or beverages and the risk of certain cancers, including breast, colorectal, and prostate cancer. However, more well-designed clinical trials are needed to confirm these findings and elucidate the optimal doses and formulations of anthocyanins for cancer prevention.

Synergistic interactions with other phytochemicals

Anthocyanins often act synergistically with other bioactive compounds present in fruits and vegetables, such as other flavonoids, phenolic acids, vitamins, and minerals. These synergistic interactions may enhance the overall anti-cancer efficacy of whole foods or plant extracts compared to isolated anthocyanins. For example, the combination of anthocyanins and resveratrol, a polyphenol found in grapes and red wine, has been shown to exert greater inhibitory effects on cancer cell proliferation and metastasis than either compound alone.

Thus, consuming a diverse and balanced diet rich in various phytochemicals may offer greater protection against cancer than relying on individual dietary supplements.

Challenges and Future directions

Despite the promising evidence supporting the role of anthocyanins in cancer prevention, several challenges remain. One major challenge is the limited bioavailability of anthocyanins, as they are subject to rapid metabolism and excretion in the body. Strategies to improve the bioavailability of anthocyanins, such as nanoencapsulation, complexation with stabilizing agents, or co-administration with absorption enhancers, warrant further investigation.

Moreover, additional mechanistic studies are needed to elucidate the specific molecular targets and signaling pathways through which anthocyanins exert their anti-cancer effects in different types of cancer. Furthermore, large-scale clinical trials are necessary to evaluate the long-term efficacy and safety of anthocyanin supplementation in diverse populations.

Conclusion

In conclusion, anthocyanins hold great promise as natural compounds with potential chemopreventive properties against cancer. Their diverse pharmacological effects make them attractive candidates for cancer prevention and therapy. However, more research is needed to overcome challenges related to bioavailability, dosing, and mechanistic understanding

Future scope

The role of anthocyanins in cancer prevention holds significant promise for future research and applications. As we delve deeper into understanding the mechanisms underlying their anticancer effects, several areas emerge as potential future directions.

Conflict of interest: There is no conflict Of interest between the authors in publication of this paper.

Author's contribution: Srijani Pal undertook the entire literature review responsible for creating all the figures and handling the references. Dr. Rupali Dhara Mitra conceptualized the idea and title of this paper and also provided comprehensive editing for the entire manuscript.

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Chapter - 6
Incidence of Salmonella Typhimurium, a Multi-Drug Resistant Pathogen Found In Spoiled Foods

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Chapter - 6

Incidence of *Salmonella Typhimurium*, a Multi-Drug Resistant Pathogen Found In Spoiled Foods

Sonia Biswas and Parul Thapar

Abstract

Antimicrobial resistance is when microorganisms, like bacteria, fungi, viruses, and parasites, develop the ability to resist the effects of antimicrobial drugs. This can happen after exposure to antibiotics, antifungals, antivirals, antimalarials, and anthelmintics. *Salmonella typhimurium* is a species that belongs to genera Salmonella. This species can show high levels of resistance to many antibiotics, including ampicillin, chloramphenicol, streptomycin, sulphonamides, and tetracycline. *Salmonella typhimurium* is a highly virulent and adaptable foodborne pathogen that continues to pose a significant threat to global public health. This multi-drug-resistant bacterium is frequently isolated from spoiled foods, particularly poultry, meat, and dairy products, highlighting the critical need for enhanced food safety measures. This study aims to investigate the incidence, antimicrobial resistance patterns, and molecular characteristics of *S. typhimurium* strains recovered from foodborne outbreaks.

Keywords: *Salmonella typhimurium*, foodborne pathogens, antimicrobial resistance, whole-genome sequencing, food safety.

Introduction

Salmonella typhimurium is a common pathogen that can cause foodborne illnesses. *Salmonella typhimurium* has multi-drug resistance and can naturally resist a variety of antibacterial drugs. The main mechanisms of drug resistance are decreased permeability of the outer membrane, changes in lactamase and penicillin-binding proteins, activation and production of efflux pumps. The rate of antibiotic resistance in *Salmonella typhimurium* has been increasing in recent years. Due to its increased antibiotic resistance, *Salmonella typhimurium* is one of the most common causes of human non-typhoidal salmonellosis (Figure 1). The most common resistance patterns are tetra-resistant (ASSuT) and penta-resistant (Papdemas, 2018).

Fig 1: Rod shaped Salmonella spp.

Prevalence of Antibiotic Resistance strains

The multidrug-resistant *Salmonella typhimurium* has caused outbreaks around the world. In China, Salmonella is the second most common bacteria that causes foodborne outbreaks. In September 2024**,** an outbreak linked to eggs occurred with sixty-five people reported infected in nine states. In 2021 outbreaks linked to salami sticks, seafood, onions, Italian-style meats, prepackaged salads, frozen cooked shrimp, raw frozen breaded stuffed chicken products, backyard poultry, Jule's Cashew Brie, ground turkey, wild songbirds, and small turtles In 2018, outbreaks linked to raw turkey products, ground beef, eggs, fast food, pre-cut melon, and frozen coconut. In 1985, an outbreak linked to 2% pasteurized milk in northern Illinois. The Centre of Disease Control and Prevention (CDC) estimates that Salmonella causes about 1.35 million illnesses, 26,500 hospitalizations, and 420 deaths in the United States each year. Salmonella outbreaks can be caused by a number of factors, including contaminated food and contact with infected animals (Bula, 2015).

Salmonella can be found in raw or undercooked meat, poultry, and seafood, as well as eggs, fruits, vegetables, unpasteurized milk or cheese, and untreated water. Salmonella can live in the guts of animals, including poultry, pigs, cattle, and reptiles. Salmonella can also be found on the skin, feathers, scales, fur, and poop of animals, as well as on surfaces touched by infected people (Kothari *et al*, 2008).

Transmission

Salmonella is a highly infectious bacteria that can be transmitted in several ways, including (Figure 2) (Zerva *et al*, 2019):

- **Food:** Salmonella can be found in contaminated food, especially raw or undercooked meat and eggs, raw milk, and unwashed fruits and vegetables.
- **Person-to-person:** Salmonella can be transmitted through contact with an infected person.
- **Animal-to-person:** Salmonella can be transmitted through contact with an infected animal, such as reptiles, baby chicks, or ducklings.

- **Vertical transmission:** Salmonella can be transmitted from a pregnant person to their foetus.

Fig 2: Transmission

Symptoms

The symptoms of salmonellosis infection include (Holschbach and Peek, 2018):

- Diarrhea.
- Stomach (abdominal) cramps.
- Fever.
- Nausea.
- Vomiting.
- Chills.
- Headache.
- Blood in the stool.

Salmonellosis can also cause more severe infections, such as:

- Infections in the blood, urine, bones, joints, or nervous system
- Reactive arthritis, which is joint pain
- Eye irritation
- Pain when urinating

Preventive measures of Salmonellosis

- **Personal hygiene:** Wash your hands with soap and water for at least 20 seconds before and after handling food, especially after handling raw or undercooked meat, poultry, eggs, or seafood.
- **Wash utensils and surfaces:** Wash cutting boards, dishes, countertops, and utensils with hot, soapy water after handling raw or undercooked meat, poultry, eggs, or seafood.
- **Cook and store food properly:** Cook and store food at the appropriate temperatures.

- **Keep food separate:** Keep raw meat and poultry separate from other foods and produce.
- **Avoid unpasteurized dairy:** Avoid unpasteurized or raw dairy products.
- **Avoid contact with reptiles and amphibians:** Don't kiss or hold reptiles or poultry close to your face. Don't let reptiles or poultry roam free in your home or where you store, prepare, or eat food.
- **Keep water clean:** Chlorination and purification of water is important to prevent contamination.
- **Refrigerate perishables:** Refrigerate or freeze perishables, prepared foods, and leftovers within 2 hours.
- **Soak produce:** Soak leafy greens, berries, and broccoli in clean cold water for a few minutes before eating.

Treatment

Salmonella infection can cause dehydration, treatment focuses on replacing lost fluids and electrolytes-minerals that balance the amount of water in the body (Jibril, 2021):

1) Fluid replacement

- Oral rehydration therapy
- Intravenous fluids to prevent dehydration.

2) Supportive care

- Rest
- Pain management
- Anti-diarrheal medications (if necessary)

Foods to be consumed

After food poisoning from salmonella, eat bland foods that are easy on your stomach. Some examples include:

- Bananas
- Cereal
- Egg whites
- Honey
- Jell-O
- Oatmeal

- Plain potatoes, including mashed potatoes
- Rice
- Saltines
- Toast

BRAT diet, which consists of bananas, rice, apples, and toast. Drink clear liquids and drinks that help you rehydrate, such as non-caffeinated sodas, decaffeinated tea, or chicken or vegetable broth.

Food to be avoided: To prevent salmonellosis, avoid eating raw or undercooked eggs, poultry, seafood, and meat. Also avoid eating or drinking anything that is unpasteurized, such as milk or juice.

Conclusion

Salmonella enterica serovar *typhimurium* is a primary enteric pathogen infecting both humans and animals. Infection begins with the ingestion of contaminated food or water so that salmonellae reach the intestinal epithelium and trigger gastrointestinal disease. Foods like raw or undercooked meat, poultry, eggs, and dairy products, as well as in fruits and vegetables. The incidence of *Salmonella typhimurium*, a multi-drug-resistant pathogen, in spoiled food poses a significant public health concern.

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Chapter - 7
Nutrigenomics: The Future of Personalized Nutrition

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Chapter - 7

Nutrigenomics: The Future of Personalized Nutrition

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Abstract

Personalized nutrition and nutrigenomics are emerging fields that aim to customize dietary recommendations based on an individual's genetic, metabolic, and phenotypic characteristics. By understanding gene-diet interactions, nutrigenomics seeks to identify how genetic variations affect nutrient metabolism and disease risk, offering the potential for precision nutrition interventions. This review explores the foundational principles of personalized nutrition, including gene-diet interactions, nutrient-gene expression, and epigenetics. It also highlights advancements in genomic testing, metabolomics, and microbiomics that have expanded the scope of personalized dietary strategies. Personalized nutrition has shown promise in improving health outcomes, particularly in the prevention and management of chronic diseases like obesity, cardiovascular diseases, diabetes, and cancer. Despite its potential, challenges related to scientific validation, ethical considerations, and accessibility must be addressed to integrate these approaches into clinical practice. As the field evolves, personalized nutrition may redefine public health strategies by offering more precise and individualized dietary interventions.

Keywords: Nutrigenomics, human health, diet, personalized nutrition, Epigenetics

1. Introduction

The idea of "one-size-fits-all" dietary guidelines has been increasingly challenged by advances in genetic research and technology. Personalized nutrition, grounded in the field of nutrigenomics, investigates how individual genetic variations influence the body's response to specific nutrients (Gibney & Walsh, 2013). Nutrigenomics focuses on understanding the interaction between diet and genes to predict disease susceptibility and optimize nutritional interventions (Ordovas *et al*., 2018). The concept of personalized nutrition has garnered significant interest due to its potential to enhance health outcomes and prevent chronic diseases through customized dietary recommendations.

1.1 Personalized Nutrition and Nutrigenomics

Personalized nutrition refers to dietary recommendations and interventions that are tailored to an individual’s unique biological makeup, including their genetic, phenotypic, and metabolic characteristics (de Toro-Martín *et al.*, 2017). Nutrigenomics, on the other hand, specifically examines the interactions between nutrients and genes, with the goal of identifying how genetic variability affects an individual's response to diet (Corella & Ordovas, 2015). The integration of nutrigenomics into personalized nutrition allows for more precise and effective nutritional interventions, potentially reducing the risk of diet-related diseases.

2. Key Concepts in Nutrigenomics

2.1 Gene-Diet Interactions

Nutrigenomics investigates how dietary components affect gene expression and how genetic variations affect the body's response to nutrients. Certain genetic polymorphisms can influence nutrient metabolism, absorption, and utilization, which in turn affect an individual's health (Kaput & Rodriguez, 2004). For example, individuals with variations in the *FTO* gene are more likely to experience obesity, particularly when consuming diets high in fat (Livingstone *et al.*, 2016).

2.2 Nutrient-Gene Expression

Diet can modulate gene expression by influencing signaling pathways that regulate metabolic processes. Nutrients like fatty acids, vitamins, and minerals act as signaling molecules, directly influencing gene expression by interacting with transcription factors (Zeisel, 2007). Understanding these nutrient-gene interactions is essential in formulating personalized nutrition strategies aimed at preventing or mitigating diseases such as diabetes, cardiovascular diseases, and cancer (Corella & Ordovas, 2015).

2.3 Epigenetics and Diet

Epigenetics refers to heritable changes in gene expression that do not involve alterations to the DNA sequence. These changes are often influenced by environmental factors, including diet (Van Camp & de Souza, 2016). Epigenetic mechanisms, such as DNA methylation and histone modification, can be modulated by nutrients, affecting disease susceptibility and progression. For instance, folate and B-vitamins are known to play a key role in DNA methylation, impacting cancer risk and other health conditions (Zeisel, 2007).

3. Technological advancements in personalized nutrition

3.1 Genomic testing

Advancements in genomic technologies, such as single nucleotide polymorphism (SNP) genotyping and next-generation sequencing, have enabled the identification of genetic variants associated with dietary responses (Celis-Morales *et al.*, 2015). These technologies allow researchers to analyze large datasets of genetic information and identify associations between genetic polymorphisms and individual nutrient needs or disease risks (de Toro-Martín *et al.*, 2017).

3.2 Metabolomics and Microbiomics

Beyond genetic testing, metabolomics and microbiomics are key components of personalized nutrition. Metabolomics involves the study of metabolites in biological samples, providing insights into an individual's metabolic state and response to diet (Zierer *et al.*, 2016). Microbiomics, the study of the gut microbiome, has also emerged as a critical factor in determining an individual's response to dietary interventions. Research has shown that the gut microbiota composition can influence metabolic health, weight management, and immune function (Turnbaugh *et al.*, 2009).

3.3 Digital health tools

The integration of digital health tools, such as wearable devices and mobile apps, has facilitated the implementation of personalized nutrition. These tools allow for real-time monitoring of dietary intake, physical activity, and metabolic markers, enabling more precise adjustments to individualized dietary plans (Ordovas *et al.*, 2018).

4. Potential health impacts

4.1 Disease prevention

Personalized nutrition has the potential to improve disease prevention by tailoring dietary interventions to individual genetic profiles. For instance, individuals with genetic predispositions to cardiovascular diseases may benefit from specific dietary interventions that target lipid metabolism and inflammation (Corella & Ordovas, 2015). Similarly, those with a higher risk of developing type 2 diabetes due to genetic factors may benefit from customized carbohydrate intake recommendations (Ordovas *et al.*, 2018).

4.2 Obesity and Weight management

Genetic variations in genes related to energy metabolism, such as *MC4R* and *FTO*, have been linked to obesity. Nutrigenomics-based interventions can offer personalized dietary recommendations that target these genetic predispositions, potentially leading to more effective weight management strategies (Livingstone *et al*., 2016).

4.3 Cancer prevention

Nutrigenomics has also shown promise in cancer prevention. For instance, folate and other B-vitamins play a critical role in DNA methylation, and deficiencies in these nutrients can contribute to carcinogenesis (Zeisel, 2007). Personalized nutrition strategies may focus on ensuring adequate intake of these nutrients for individuals at high risk of cancer due to genetic susceptibility.

5. Challenges and Ethical considerations

5.1 Scientific challenges

Despite the potential benefits, personalized nutrition faces several challenges. The complexity of gene-diet interactions and the influence of environmental factors make it difficult to establish clear guidelines for personalized interventions (Celis-Morales *et al*., 2015). Additionally, more research is needed to validate the long-term effectiveness of personalized nutrition in diverse populations.

5.2 Ethical and Privacy Concerns

Personalized nutrition raises ethical concerns, particularly regarding privacy and data security. Genetic data is sensitive, and individuals may be at risk of genetic discrimination if their information is not properly safeguarded (Ordovas *et al*., 2018). Furthermore, there are concerns about accessibility and equity, as personalized nutrition services may be cost-prohibitive for certain populations.

Table 1: Potential Health Impacts of Nutrigenomics

Health Impact	Description	Citation
Cardiovascular Health	Personalized dietary interventions based on genetic polymorphisms can reduce risk factors such as high cholesterol and hypertension.	Corella & Ordovas (2015)
Obesity and Weight Management	Nutrigenomics enables customized dietary strategies targeting genes like *FTO* and *MC4R*, which are linked to obesity, improving weight management outcomes.	Livingstone *et al*. (2016)
Diabetes Management	Genetic variants related to insulin sensitivity and glucose metabolism allow for tailored carbohydrate recommendations to prevent or manage type 2 diabetes.	Ordovas *et al*. (2018)

Cancer Prevention	Dietary modifications based on gene-diet interactions, such as ensuring adequate folate intake, can reduce cancer risk by influencing DNA methylation processes.	Zeisel (2007)
Metabolic Syndrome	Precision nutrition can manage and prevent metabolic syndrome by tailoring interventions according to genetic predispositions toward lipid and carbohydrate metabolism.	de Toro-Martín *et al*. (2017)
Bone Health	Nutrigenomics informs calcium and vitamin D recommendations based on genetic predispositions that affect bone density and osteoporosis risk.	Zierer *et al*. (2016)
Mental and Cognitive Health	Tailored nutritional interventions targeting genes involved in neuroprotection, such as *APOE*, can help reduce the risk of cognitive decline and Alzheimer's disease.	Ordovas *et al*. (2018)
Gut Health and Microbiome	Personalized diets based on individual gut microbiome compositions can improve gut health and overall metabolic function.	Turnbaugh *et al*. (2009)

Conclusion

Personalized nutrition and nutrigenomics represent promising approaches to improving health outcomes by tailoring dietary interventions to individual genetic profiles. The integration of genomics, metabolomics, and microbiomics into personalized nutrition has the potential to revolutionize disease prevention and management. However, the field faces significant scientific, ethical, and practical challenges that must be addressed before personalized nutrition can be widely implemented in clinical practice. As research progresses, personalized nutrition may become a key tool in precision medicine and public health nutrition.

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Chapter - 8
The Alleviating Effect of Soy Curd on Lactose Intolerance: A Systematic Review

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Chapter - 8

The Alleviating Effect of Soy Curd on Lactose Intolerance: A Systematic Review

Sovana Kotal and Paromita Mukherjee

Abstract

Lactose intolerance is a digestive disorder usually caused by a deficiency of an enzyme in the body called lactase. Persons who produce less amount of lactase enzyme in the body are does not digest lactose rich products and may contain several symptoms such as abdominal cramp, bloating, nausea, vomiting, gas, diarrhoea, etc. Tofu, generally called soy curd, is an outstandingly regarded food of plant starting with mind blowing dietary and clinical benefits. It is a fabulous wellspring of non-animal protein in the eating routine of veggie sweetheart. The dairy starter culture namely Streptococcus thermophilus and Lactobacillus bulgaricus are used to enhanced nutritional property of soy curd. Additionally soy curd is a lactose free product , so those people who are suffer from lactose intolerance can be consume it easily.

Keywords: Deficiency, lactase, abdominal cramp, digest, non-animal

Introduction

Lactose intolerance (LI) is the inadequate hydrolysis of lactose because of lactase lack, which might happen as an essential problem or optional to other digestive sickness (Usai-Satta *et al*., 2012). People with lactose narrow mindedness can't process huge measures of lactose in view of a hereditarily lacking measure of the catalyst lactase. Normal side effects incorporate stomach torment and swelling, over the top flatus, and watery stool following the ingestion of food varieties containing lactose (Swagerty Jr *et al*., 2002). Lactose malabsorption might happen optional and in this manner transiently to different etiologies like irresistible gastroenteritis, cow's milk sensitivity and celiac illness. Be that as it may, this substance just extraordinarily causes side effects before the age of 4-5 years. Side effects are stomach spasms, fart and watery, corrosive stools, and lessening the personal satisfaction (Vandenplas, 2015).

Tofu, otherwise called bean curd, is an exceptionally respected food of plant beginning with incredible dietary and medical advantages. It is a fantastic wellspring of nonanimal protein in the eating routine of veggie lover (Mahendra Pal *et al*., 2019). Soyabean curd is plentiful in fiber, fat, protein, nutrients, and minor components. It has potential for value-added handling and usage (Li *et al*., 2013).

Objective

- The motivation behind this study was to disengage soy curd framing bacterial strains (Kim *et al*., 2015).
- To decrease the allergic affect of lactose rich product for lactose intolerance patient.
- To decide if side effects that patients normally quality to lactose bigotry are equivalent to side effects incited by a controlled lactose challenge and whether these side effects are connected with lactose retention limit (Casellas *et al*., 2010).
- To assess the predominance of lactose maldigestion and lactose narrow mindedness in an example of everybody taken from a rustic place (Carroccio *et al*., 1998).

Health benefits

- Soymilk with beany flavor is viewed as negative, its satisfactoriness is improved by maturation (Fukuda *et al*.,2017).
- Soy curd truly do decrease the dangers of creating different age-related ongoing infections (Jooyandeh, 2011).
- Soy curd is rich in fiber, fat, protein, vitamins, and trace elements (Li *et al*., 2013).
- Microbial digestion is answerable for delivering the β-glucosidase chemical that changes over glycosidic isoflavones into aglycones with higher natural action in matured soy curd (Prado *et al*.,2022).

Nutritional value

Table 1: Nutritional content of soy curd (Sugano, 2005)

Components	Content (g/100g)
Energy (kcal)	417 (433)
Moisture	12.5 (11.7)
Protein	35.3 (33.0)
Carbohydrates	28.2 (30.8)

Dietary fibre	19.0 (21.7)
Water	15.3 (15.0)

Conclusion

The recurrence of lactose bigotry is a lot of lower than that of lactose intolerance. Gastrointestinal side effects after lactose load in self-revealed milk-intolerants are tracked down in just an extremely low number of people. Besides, in these subjects we noticed a superfluous decrease in milk utilization and a lacking dietary calcium admission (Carroccio *et al*., 1998). Tofu, a plant started food, is an extremely rich wellspring of protein, minerals and nutrients. It tends to be thought of as a decent other option to meat and fish. Tofu is consumed in a large number nations of the world including India. Researchers have perceived a few wellbeing advantages of tofu (Pal *et al*., 2019). Soybean germination increments protein content while bringing down fat and also, against nourishing elements, for example, lipoxygenase, urease action, oxalate, phytic corrosive, and trypsin inhibitor content. In the meantime growing is normal, non-synthetic and non-warm cycle, came about top notch handled soy items like tofu (Zinia *et al*., 2022).

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Chapter - 9
Association Between the use of Cannabis, Opioid and Postpartum Depression Outcomes in Relation to its Pharmacokinetics and Impact on Nutritional Health

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Chapter - 9

Association Between the use of Cannabis, Opioid and Postpartum Depression Outcomes in Relation to its Pharmacokinetics and Impact on Nutritional Health

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Abstract

Postpartum depression (PPD) is recognized as a global public health issue wherein baby blues severity emerges within the first 6 to 12 months postpartum, by extension 18% of postpartum women affliction with consequential morbidity and mortality rates being a stressor triggering the onset of chronic or recurrent depressive episodes. A large body of evidence underpins the positive link between cannabis and opioid use and depression, having both health promoting and nociceptive traits or consequent adverse pregnancy outcomes reinforcing deleterious impacts on mother-infant interaction in the spectrum of PPD altering sleep, appetite, mood and behavioral patterns. Opiates subsequently regulated obstetrical, biochemical, psychoneuro-immunological and neonatal outcomes during chronic use, and possessed pharmaco-therapeutical assays on pain, depression and inflammatory models. This comprehensive narrative is an attempt to epitomize PPD subject to the psychopharmacological effects of substance use disorders (medical cannabis and opioid) and explore up-to-date clinical and observational evidence on current intakes of these drugs and their concurrent effects on national profile. Relevant published articles were summarized by performing computerized literature searches of various authentic data bases using keywords. Potential studies with original data were selected and incorporated their important findings into conclusion regarding the current scenario on postpartum depression. The field of postpartum substance use lingers to be an esoteric domain which can be addressed effectively by a well-rounded diet rich in nutrients like vitamins, minerals and essential fatty acids which were vigorously correlated with reduced PPD symptomatology. Outreach and educational resources targeting pregnant and postpartum mothers and the poor counterparts sustaining below federal standards about the perils of substance use disorder may be notably instrumental in fostering community welfare.

Keywords: Cannabis, opioid, postpartum depression, pharmacokinetics, pharmacotherapeutics

Introduction

Postpartum depression (PPD) is a severe puerperal mood disorder of peripartum, posing a risk of recurrence and relapse later triggering tragic maternal and foetal consequences, amenable to medical treatment and interventions (Robertson *et al*., 2004). Some maternity care providers report that women habitually do not perceive the illicit substance cannabis to be a "drug" as a direct repercussion of the growing usage, global legalization movements of medicinal cannabis, the thriving trend concurrent with increased perception of cannabis safety and the pharmacological modulation of the ubiquitous natural, endogenous cannabinoid (eCB): Endocannabinoid System (ECS) distribution in the human physiology, thereby garnering attention from researchers in medicine, clinicians, funders and policy-makers throughout disciplines, allowing the drug discovery and development adept at affecting the downstream signalling pathways of the ECS (Pagano *et al*., 2022).

Current prevailing hypotheses propose that the heterogeneous pathoetiology of PPD may owe to the convolution between neurotransmitters, hormones and external milieu determinants affecting endocrine, mood and immune measures. Some contributing factors inculcate hypothalamic-pituitary-adrenal(HPA) axis disequilibrium, cancer, gut dysbiosis (microbiotic dysregulation), malnutrition (Vitamin D deficiency), neuropsychoendocrine features like rapid hormonal changes during post childbirth, circadian rhythm alterations, ECS disruption, biopterin/neopterin/leptin level alterations, emotional stress of nursing a neonate, lactation hurdles, iron-deficiency anemia, thyroid dysfunction and/or thyroid autoantibodies, neurodegenerative disorders, immunological imbalance, pathogens, proinflammation and inflammatory mechanisms, illicit drug abuse, chronic pain, chronic stress, trauma, conflict, death, genealogical records (found to agitate the susceptibility of puerperal episodes in women with bipolar disorder (Jones *et al*., 2001)), and prescription medications (Groer *et al*., 2007). Premenstrual syndrome, general biological depressive vulnerability (e.g.: serotonergic dysregulation), psychosocial support (e.g., social isolation), certain feasible hormonal etiology as the likes of Premenstrual Dysphoric Disorder (PMDD), psychological factors (e.g., coping mechanisms), third trimester and early postpartum mood symptoms or unplanned pregnancies foster exacerbating effects on fabricating PPD spectrum unaccounted hitherto (Bloch *et al*., 2006; Hyer *et al*., 2020).

Despite promulgation of exacerbating effects of their psychoactive substances, dose-dependent cannabis and opioid extracts have known pleiotropic therapeutic effects on depression prodromes (Feingold *et al*., 2021). Cannabis plant and opioid composites have demonstrable antioxidant, anti-microbial, anti-inflammatory, its purported anxiolytic, antiemetic, orexigenic, neuroprotective, acute psychosocial stress relief and analgesic effects. Firstline depression treatments remain cognitive behavioural therapy and pharmaceuticals including the most frequently prescribed pharmaceutical medications being antidepressants (e.g. monoamine oxidase inhibitors, tricyclic antidepressants, Selective Serotonin-Reuptake Inhibitors (SSRIs), sedatives (e.g. benzodiazepines), Selective Norepinephrine Reuptake Inhibitors (SNRIs), anticonvulsant medicines, and antihistamines- all having a low remission rate with umpteen adolescent and adult sufferers also beseeching repose through alcohol and illegitimate drugs, opening a window for the clinical depression treatment with MAGL inhibitors (Yin *et al*., 2018).

This umbrella review evaluates the efficacy of an array of preventive interventions aimed at abating the paramountcy of PPD episodes by encapsulating existing knowledge about the psychopharmacological effects of addictive drugs (cannabis and opioids) compared to placebo or low intakes, their apposite nutritional interventions used in this substance use disorders for postpartum women and to inform program development by maternity care and treatment providers.

Methodology

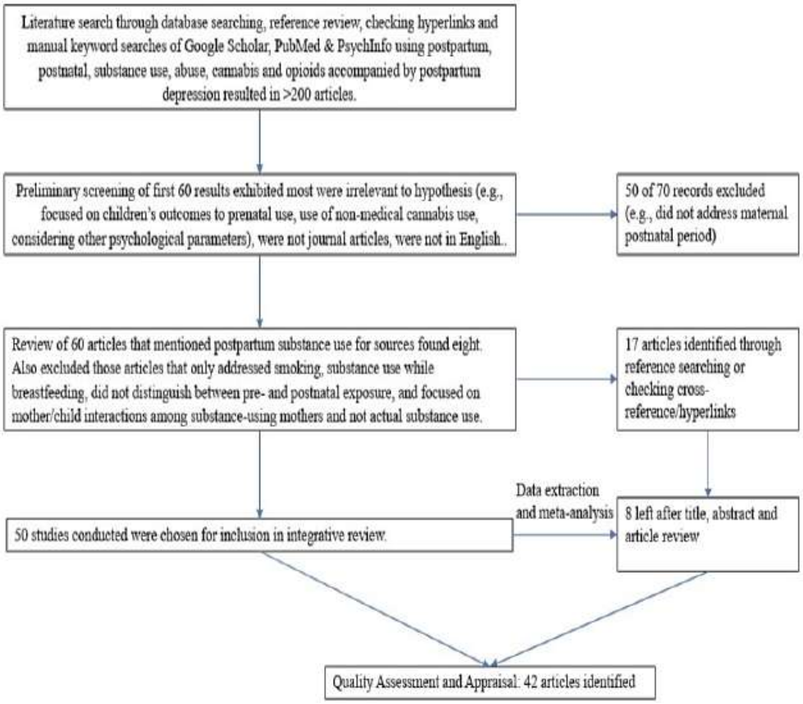

Fig 1: Flow diagram depicting detailed methodology applied in present review

Discussion

Pathophysiology of Postpartum Depression: A triad of symptoms inclusive of severe mood swings, energy changes, emptiness, extreme sadness, despondency, anhedonia, irritability, guilt, worthlessness, hopelessness, low self-esteem, excessive crying, anger, indifference, emotional lability, diminished concentration abilities likely crop up during PPD episodes. It may be plausible to infer that a background of depression was presaged to be a menacing facet for early postpartum mood symptomatology. As such, rudimentary postpartum symptoms may reflect vulnerability to subsequent PPD; it may be noteworthy to assess these looming criteria and mood promptly post parturition (Bloch *et al.*, 2006). Chronic SSRI citalopram exposure during postpartum everted the heightened depressive-like comportment and structural conversions in the basolateral amygdala and nucleus accumbens ensuing gestational stress ramifying depression susceptibility differentially with mitigated progesterone and allopregnanolone levels to be positively associated with higher PPD preponderance (Qiu *et al.*, 2020). Obstetrician-gynaecologists anticipated their belief that mental health providers are indisposed to prescribe antidepressants during pregnancy, hindering mental health care for gravidas while also studying antenatal cannabis use and PPD risk. Anecdotal claims of antidepressant medication and non-therapeutic interventions unveiled higher daytime sleepiness and more than double fatigue levels of depressed mothers compared to non-depressed counterparts, accounting for comprehensive care and maintenance programs like drug-free outpatient or residential program treatments (Eakley *et al*., 2022).

Pharmacokinetics and genetic epidemiology of Phytocannabinoids: The most eminent psychoactive substance in cannabis is Δ-9-tetrahydrocannabinol (THC) alongside less abundant Δ-8-THC while cannabinol (CBN) and cannabidiol (CBD) serves as the most prominent non-psychoactive elements besides other compounds like terpenes, flavonoids. They exert cognitive effects by G-protein coupled receptor binding, gene-encoded by chromosome 6, termed CB1 and CB2 cannabinol receptor (Chayasirisobhon, 2020). Cannabis is often designated as a 'gateway drug' straddled by precursory illicit and subsequent hard drug use (Agrawal *et al*., 2006). The ostensible difference between the THC response of depressed patients and that of normal subjects is similar to amphetamines and cocaine, which are stimulants and euphoriants for normal subjects but not for depressed patients having implications on psychobiological substrate of affective illness (Ablon *et al*., 1974). Cannabinoids undergo carboxylation to instigate its neutral configuration on plasma and tissue eCBs (abundantly distributed in the uterus and breastmilk for its reproductive functionality) illustrating reliable diagnostic biomarkers of reproduction and pregnancy outcomes (Onaivi, 2010).

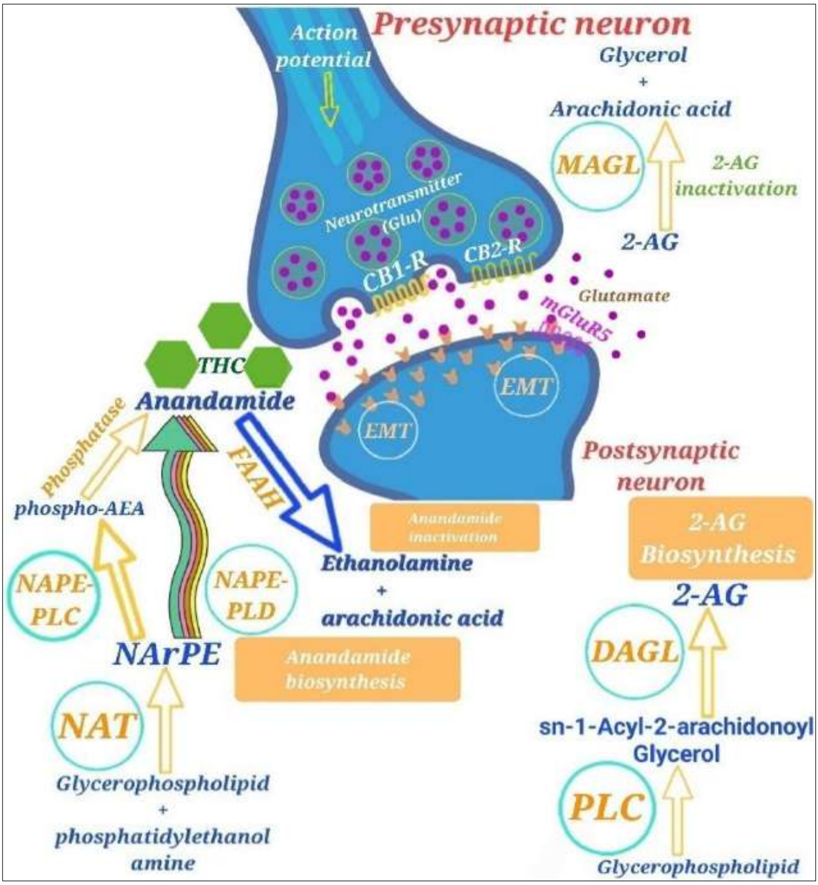

Fig 2: Schematic diagram representing the primary components of the Endocannabinoid System: Membrane phospholipids demand the biosynthesis of AEA and 2-AG by NAPE-PLDor calcium-dependent NAT and DAGL respectively. The reuptake of endocannabinoids into cells occurs across the cell membrane by putative EMT. On depolarization of the postsynaptic terminal, 2-AG is present at the postsynaptic terminal and synthesized “on-demand” by DAGL. AEA degradation is superintendented by FAAH enzyme, while 2-AG hydrolysis is governed by the key enzyme MAGL, releasing arachidonic acid. The various receptor targets of AEA and 2-AG on the plasma membrane are: CB1, CB2.

Abbreviations: NAT: N-acyltransferase; NArPE: N-arachidonoyl-phosphatidylethanolamine; NAPE-PLC (or PLD): N-Acylphosphatidylethanolamine phospholipase C (or D); FAAH: Fatty Acid amide hydrolase; 2-AG: 2-Arachidonoylglycerol; MAGL/DAGL: Mono (or di) acylglycerol lipase; EMT: Endocannabinoid Membrane Transporter; CB1-R/CB2-R: cannabinoid receptor 1 and 2.

Nociceptive traits of Cannabis extracts: Cannabigerol (CBG) activates TRPV1 receptor for its desensitization by blocking pain signal transmissions; β-endorphin release from human epidermal keratinocytes (HaCaT) cells promote mediation of CBG antinociception. Post nociceptive behavioural test of mice using a dynamic plantar tactile device was scrutinized by screening carrageenan-induced inflammatory pain models. Preliminary reports claim that CBG is safe and non-toxic with transdermal properties, promising for topical formulation development for pain management (Wen *et al.*, 2023). Gaoni and Mechoulam isolated cannabichromene (CBC) from cannabis in 1964 having minimized carrageenan-induced inflammatory and arthritic responses and lipopolysaccharide-induced inflammatory feedback in rats and mice respectively, modestly impeding thermal antinociception and enabling THC antinociception (Gaoni *et al.*, 1966).

Medical Cannabis: Integrating the Potential Therapeutic Use of Endocannabinoid signalling in Clinical Practice for the regulation of PPD symptomatology: Phytocannabinoid extracts is used medicinally and recreationally for millennia by Indian, Arab and Chinese pharmacologists, governing behavioural outputs as functional neuromodulators. Being extensively disseminated in the CNS with eCB-mediated control of relevant brain zones and their interregional connections, it generates neurogenesis and synaptic plasticity guiding multiple cell type activities (neuronal subtypes, astrocytes, microglia) as depressed patients have deplorable eCB levels (Yin *et al.*, 2018). With growing cannabinoid usage, an ECS pharmacogenomic and epigenetic test diagnoses if medical cannabis can be of salutary benefits. An apparent yin-yang relationship preponderance between the best-known eCB physiological ligands, anandamide (AEA) and 2-arachidonoyl glycerol (2-AG) acts as potential antidepressant candidates with bidirectional regulation: AEA facilitating the initiation and manifestation of stress effects (mediated by maximized AEA hydrolysis by FAAH) and 2-AG tempering and terminating the response (mediated by a monotonic acceleration in corticosterone levels) (Morena *et al.*, 2016; Dubreucq *et al.*, 2012; Yin *et al.*, 2018). Equivocal findings have been reported for synergistic activity of sublingual cannabis spray in aggrandizing neurogenic indications insensitive to standard treatments. (Wade *et al.*, 2003). Pharmacogenomics reveals that when admixed with sociodemographic forbidding criteria, postpartum phase is especially taxing for primigravidas.

a) **Anxiety:** GABAergic terminals and cortical glutamatergic both induces and ameliorates anxiety by anxiogenesis and anxiolysis in women with PPD, inferring that ECS is disrupted by stress.

b) **Sleep:** Documented expositions propound clinical insomnia, sleep pattern and psychomotor distress with wavering quotas of putative narcolepsy and restless leg syndrome, conjuring that THC has utility in aiding rapid eye movement suppression and upsurging slow-wave sleep, with nabilone guiding PTSD-related nightmares.

c) **Suicide, self-harm and homicidal ideation towards the baby:** Documented clinical and preclinical repository proposes epigenetic modulations inflicting suicidal tendencies like maternal suicide and infanticide, owing to cannabis-related psychosis, behavioural, neuropsychiatric, and executive incompetency of perinatal women.

d) **Appetite stimulation:** A paradox exists among cannabis users burgeoning an analeptic natural cannabis efficacy on hunger surveilling brain zones governing autonomic and GI diseases opposed to synthetic cannabinoids (Ayisire *et al*., 2022).

Psychopharmacology of Opioids: Observational and epidemiological studies indicate a positive long-term opioid effect available as codeine, heroin, fentanyl, morphine, pethidine, tramadol use on PPD course and outcome, alleviating pain perception and engendering euphoria, constipation, nausea, emesis, drowsiness. Research advances in opioids demonstrates physical opioid dependence shortly for 4-8 weeks (Sharma *et al*., 2016). There persist pockets of claims about illegitimate and prescription opioid abuse accounting 15.7% of females aged 15 or older using prescription opioids and upto 41% of adults in the age group of 20-50 years old are sustaining communal opioid agonist therapy, thus outreaching "epidemic" culminations (Ryan *et al*., 2017). By magnifying patient numbers, a physician can open newer avenues for treatments using buprenorphine, methadone or hydrocodone products. However, the expansion of buprenorphine prescribing privileges will have meagre impression on expecting mothers with OUD than for the natives since midwives/certified nurse will be ineligible for a waiver application (Terplan, 2017).

Opioids as an emerging target of pharmacotherapy: Buprenorphine administration treatment to inpatients with Opioid Use Disorder (OUD) and generalized anxiety disorder (32, 64, 96mg) espouses considerable PPD alleviation by day 3 on Beck Depression Inventory and almost complete anxiety symptom remission by day 7 on Hamilton Anxiety Rating Scale

(Ahmadi *et al.*, 2018). The corollary for OUD patients on methadone maintenance were severe anxiety tied to a 3.5-fold greater relapse risk and elevated anxiety/depression levels provoking more cannabis and benzodiazepine use (Richesson *et al.*, 2021). When mental health measures were annexed in the second model, while controlling for sociodemographics, women facing odds consistent with PPD and/or an anxiety disorder were 2.98 (95% CI 1.10−8.03) times more prospective to proclaim using opioids compared to their asymptomatic counterparts (Grywacheski *et al.*, 2021).Biochemical variables like thirst significance and leukocyte count growth ($P <$ or $= 0.05$) has also been noted (Knight *et al.*, 1994).

Drug nutrient interaction of Cannabis and Opioid on human health: Cannabis and opioid have deleterious effects on chronic usage, however is a rich resource of vitamins, minerals, fibres, essential amino acids and fatty acids. Escalated Total Cholesterol and High Density Lipoprotein (HDL), subsided triglycerides, serum glutamic-oxaloacetic transaminase (SGOT) and serum glutamic pyruvic transferase (SGPT) (in serum lipid profile and liver enzymes), elevated blood glucose levels in the CN1-treated trial group, decreased mRNA testimony of phosphoenolpyruvate carboxykinase (PEPCK) of gluconeogenesis hence affecting hepatic carbohydrate and lipid metabolism, higher Bacteroidetes to Firmicutes ratio of the gut microprofile (except CB1) were noted in high fat-cholesterol diet leading to amelioration of nonalcoholic fatty liver disease (NAFLD) in mice model afflicted with CN2 (THC-rich extract) thereby being propitious in statistically noteworthy improvement in the major NAFLD parameters (Assa-Glazer *et al.*, 2020).

Effects of Cannabis and Opioid on Drug Metabolizing Enzymes and Related Potential Drug Interactions: A study with 21 individuals ratified that vaporized cannabis enhanced opioids' analgesic effects without reorienting plasma opioid degrees (Abrams *et al.*, 2011). Additionally, IV drug use stimulates HIV infection. A non-controlled, presumptive open-label study with 274 participants found that medicinal cannabis pruned opioid consumption. A cocktail of medications administered to PPD patients is delineated by scattered bidirectional data to effectuate collateral administered determinants through affected membrane transporters (Glycoprotein p, multidrug resistance proteins, breast cancer resistance proteins) and metabolizing enzymes (UDP-glucuronosyltransferases and Cytochrome P450), MRP1 inhibition by CBD in vitro. Mounting evidence shows that medical cannabis use bolsters as an opioid substitute. A study in 32 adult cannabis smokers perceived that low-dose alcohol (approximately 0.065% peak breath alcohol concentration) amplified THC fractions, enunciating the execution depreciation discerned from a cannabis–alcohol amalgamation (Alsherbiny *et al*., 2018).

Maternal characteristics, obstetrical, perinatal and neonatal outcomes with relation to cannabis and opioid use: Certain challenging determinants often abets OUD like homelessness, job instability, poverty (which doubles PPD incidences), mental and physical ailments, addictions and domestic violence (a key risk factor of PPD often mediating cannabis use) rendering prenatal care onerous. Apprehending child's custody loss, statutory proceedings against women or irresolution to unveil drug abuse repudiates prenatal care (Cao *et al*., 2021). The unavailability of essential nutrients' supply for the foetus germane to compromised maternal nutritional status by alcohol and drugs is a harbinger of infectious pregnancy, miscarriage and foetal abnormalities like Intrauterine Growth Restriction (IUGR) or Foetal Alcohol Spectrum Disorder (FASD). It is exigent to strategize teratogenic effect mitigation (preterm birth, low birth weight and neurological impairment) concomitant of prenatal substance abuse subjection besides poor maternal nutrition. Maternal morbidities like interpersonal psychotherapy, proliferated prenatal nutrition interventions and depression surveillance on prenatal visits, postnatal check-up and paediatric visits is ergo warranted during the inchoate 6 months for primigravidas. Maternal depression and stress during peripartum may adversely affect obstetrical outcome and infant well-being like premature delivery, premature membrane rupture, stillbirths, offspring externalizing predicaments, raised neonatal mortality and neonatal opioid withdrawal (or neonatal abstinence syndrome (NAS)) affecting maternal and neonatal immunopathological pathways, which underscores the need to clarify the windows for heightened maternal mood monitoring (Stowe *et al*., 2005).

An overview of nutritional interventions in postpartum depression: Tryptophan and tyrosine involves monoamine oxidase A (MAO-A) activity maintenance in the brain. MAO-A levels augmented during postpartum period due to oestrogen level decline producing catalysation of brain's neurotransmitters (serotonin, norepinephrine, dopamine). These neurotransmitters' depletion catapults superfluous oxidative stress, allusively precipitating mood disorders. Hence, tryptophan and tyrosine supplementation in maternal diet was evinced to compensate excess neurotransmitter removal (Yahya *et al*., 2021). Women with OUD sustained specific undernutrition risks encompassing lower Body Mass Index (BMI), folate, vitamin B_{12}, and iron (Fe) deficiencies than their analogues (Nagarajan *et al*., 2019). Alcohol and drugs imbibition interferes with nutrient absorption, impairing the quality and quantity of nutrient and energy intake with 'empty-energy' cravings, declined haemoglobin and proteins, eliciting chronic malnutrition chiefly of micronutrients (vitamins, omega–3, folic acid, zinc, choline, iron, copper, selenium) as well as protein-energy malnutrition, anemia and chronic energy deficiencies (Sebastiani *et al*., 2018).

1) **Vitamin B complex:** The 8 water-soluble Vitamin B complex molecules are pivotal in integumentary, nervous and haematological systems by condensing homocysteine into a cysteine precursor for translation in protein synthesis with 'vascular hypothesis' of PPD claiming hyperhomocysteinaemia, destructing intracerebral and carotid arteries provoking prefrontal cortex hypoxia, thus causing vascular damage, chronic inflammation, reduced neurotransmitter secretion (noradrenaline, dopamine, serotonin) and PPD with atrocious mentation (Ellsworth-Bowers *et al*., 2012).
2) **Vitamin D:** In a longitudinal survey executed during the postnatal period, Murphy *et al*. elucidated a link between vitamin D levels <32 ng/ml quantified monthly for 7 months postpartum and depressive symptom scores at these concurrent points (Murphy *et al*., 2010). Plasma vitamin D levels measured in early and late pregnancy were a presage of PPD scoring at 3 time points during pregnancy and at 6–8 weeks postpartum; the levels being inversely related with BDI scores both at 12-20 and at 34–36 weeks' gestation, therefore monitoring the neuroimmunomodulation and neuroplasticity accordingly- a proposed mechanism for the mood effect during postpartum (Williams *et al*., 2016).
3) **Iron:** Iron deficiency is a plausible candidate for PPD since low Iron-PPD link was established in a population distressed by economic and political unrest with high incidence of food insecurity among women having PPD vs. without PPD, creating disproportionality in low and middle-income nations (Hameed *et al*., 2022).
4) **n-3 PUFA:** At 6-8 weeks postpartum, total monounsaturated fatty acid (MUFA) levels drastically lessened at risk women's PPD, while n-6 polyunsaturated fatty acid (PUFA) levels escalated the risk ensuing covariate adjustment (Lin *et al*., 2019). Clinical and epidemiological studies evinced that sparse docosahexaenoic acid (DHA) concentrations of mothers' milk, depletion of maternal n-3 long chain fatty acids and deprived seafood consumption were robustly conjoined with intensified PPD counts and less inter-partum intervals (Hibbeln, 2002).

A randomized, placebo-controlled, double-blind trial was designed and nested into a cohort study exemplifying daily dose use of n-3 PUFA dietary supplementation (fish oil) as mammals cannot synthesize it de novo with potential foetal growth during pregnancy and breastfeeding alongside foetal brain growth, subsequent cognitive and other neurodevelopmental benefits by high placental transfer of eicosapentaenoic acid (EPA) (20:5 n-3) and (DHA) (22:6 n-3) (Vaz *et al*., 2017).

5) **Trace minerals:** The neuronal postulations are based on scientific repertoires that synaptic vesicles of hippocampal glutamatergic neurons retain half of brain's free zinc. Zinc atrophy has been physiologically affiliated to mood disorders as normal zinc levels may tailor glutamate release from these neurons, protecting neuron health in a zone of the brain. Se and other antioxidants (vitamins A, C and E) governs dopamine metabolism, showing improvement in multiple subscales of mood and cognitive function measures by subsiding thyroid functions (Ellsworth-Bowers *et al*., 2012).

Conclusion

The topical cannabis and opioid epidemic perpetuate to affect millions of women encountering unique challenges in achieving balanced, nutrient rich diets preconceptually, as well as during pregnancy, lactation and postpartum periods, especially patients with psychiatric comorbidities. In order to subdue the limitation of lipophilic nature classed cannabinoids in diminished surfactant and delivery system usage to reinforce its solubility and bioavailability, nanoparticle formulations (i.e. allowing targeted delivery of cannabinoid formulations) may proffer an excellent alternative. By implementing nanotechnological advancements to nanomedicine, the cannabinoids may be 'packed' in endogenous nanoparticles, bestowing the opportune effective delivery of cannabis and cannabinoid formulations to the diseased sites, with the aptitude to ennoble their application to scientifically validated nontherapeutic services with growing maturation of the domain of cannabis nanoscience (Murillo-Rodriguez *et al*., 2021).

There lies a climacteric desideratum to structure target therapy, participant-driven curriculums, psychotherapies, experiential learnings and nutrition education schemes catering to medication side-effects, food insecurity, rebuttals, stigmatization, cost-benefit ratio and antipathetic use for PPD management which has sought researchers to delve in the pursuit of other feasible, effective and auxiliary management substitutes (Nagarajan *et al*., 2019; Ayisire *et al*., 2022). The postpartum period is subject to biological and lifestyle changes where addressing the women's mental and behavioural needs are imperative to build self-assurance, assimilate infant and early-childhood parent training juxtaposed to exhaustive cultural-specific neonatal interventions (Chapman *et al*., 2013). A paucity of the direct asseveration of these eCB signalling task in freely behaving animals challenged with distinct undertakings proselytizes the well-revealing ability to scout for causal linkages between the synaptic electrophysiological/plasticity modulations and behavioural denouements arbitrated by the eCB system. Future outlook for the advent of novel technological correspondences like viral tracing, calcium imaging techniques, designer receptor exclusively activated by designer drugs (DREADD) strategy and optogenetics based on Cre-loxP system to cell-specific modification of the eCB system will empower a direct evidence prospect for CB1-R to regulate discrete behaviour and circuits, becoming members of our therapeutic armamentarium (Yin *et al*., 2018).

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Chapter - 10
Isolation of Proteins from Various Plant Wastes and Their Uses in the Formulation of Food

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Chapter - 10

Isolation of Proteins from Various Plant Wastes and Their Uses in the Formulation of Food

Neha Das and Manisha Maity

Abstract

Protein is a vital component of our body, which is engaged in building our cells, muscle mass, hormones, hair and nails, plasma protein, and enzymes. In this growing population and changing eating patterns, young adults and children always tend to eat junk foods, carbonated beverages, sugary cakes, and pastries. But in some other parts of our country, people and children are suffering from malnutrition. Kwashiorkor, marasmus, early-age pregnancy, and PCOS (polycystic ovarian syndrome). This project aims to isolate protein from waste plant products. In local fruit and vegetable markets, many waste materials are produced, and they are rich in protein, carbs, vitamins, minerals, and fibers. As an alternative to animal protein with plant-based protein, many leafy vegetables are an excellent, ubiquitous source, which has become animal feed at last. There are several methods to extract the proteins from these plant sources. Every step should be carefully studied to facilitate the right conditions to prepare a sustainable food item out of agricultural and cultural food waste. If we isolate them and use this protein to produce a unique food item, it would be beneficial in diverse ways, like economic, nutritional, and waste management. This product will be at a low cost, which gives us beneficial health effects along with a good taste. Thus, from the waste food material, we can utilize its bioactive compounds.

Keywords: Protein, plant sources, isolation, waste management, food product development

1. Introduction

There are several macro- and micronutrients that are very essential for our body. Such nutrients are carbohydrates, proteins, and fats, as well as vitamins, minerals, and dietary fibres. Among them, protein is also a useful component that helps to build our body tissues, hormones, etc. They are referred to as the "building blocks of the body" (Kinsella, 1970). A diet rich in protein is immensely helpful for a person who wants to build muscle mass, who is severely injured, pregnant women, or lactating mothers. If the diet lacks carbs and fats, our body starts to break down protein to produce energy to meet our calorie requirements (Harmann, 2022). Due to the inadequacy of food, 820 million people in the overall world population suffer from hunger, which has become a serious threat to the modern era (FAOSTAT, 2019). They are also deficient in energy and other vital nutrients. For example, malnutrition is the state of inadequacy in protein and energy value in their daily diets. This situation could get worse if we do not increase the supply and distribution of protein-rich foods. We can use modern technologies to extract protein from plant sources and utilize them as an alternative source of protein (Kumar *et al.*, 2021).

Proteins have two main functions in agricultural raw materials: biological function and technological function. The biological functions of protein include its nutritional properties and physiological effects on our body. The technological functions include its biochemical properties, which affect the texture, appearance, and stability of food products by altering their solubility, emulsification nature, gelling ability, and fat absorption capacity (Panyam and Kilara, 1996). The increased demand for high-quality nutrients in the diet for better nourishment and proper growth of the body motivates researchers and nutritionists to develop some unique products that do not harm our nature and can be used without any adverse effect. This can be done by using alternative protein sources, which are extracted from plant waste or food waste. As animal sources of protein become limited nowadays, they are quite expensive, and for that reason, every person in society cannot afford them. Along with this, they are responsible for freshwater depletion, biodiversity loss, and associated diseases (Kumar *et al.*, 2021).

The study's key conclusions include:

- The list includes plant-based renewable protein sources from various plant wastes.
- The review focuses on environmentally friendly protein extraction technologies, which do not affect our health.
- Considering the tools or techniques used in the extraction, isolation, and characterization of proteins.
- Raising people’s awareness of the need to buy, eat and accept alternate protein sources in response to the growing need for protein.

Source of protein from vegetables

Plant proteins often have numerous benefits over animal proteins. They are often lower in saturated fats, cholesterol-free, and can help to promote a more sustainable and environmentally friendly diet. Plant proteins also contain important nutrients like fibre, antioxidants, and phytochemicals, which have been linked to a variety of health advantages. Furthermore, plant-based diets have been associated with lower rates of certain chronic diseases, such as heart disease and type 2 diabetes (Nasrabadi *et al*., 2021). Figure 1 shows diverse sources of protein from vegetables. We can extract these proteins from sustainable and inexpensive sources, like leftover vegetables after the local market has closed. These may assist in minimising food waste (Munialo, 2023). Vegetable proteins are derived from plant sources. Examples include legumes (beans and lentils), nuts, seeds, and grains. While individual veggies may not contain as much protein as animal products, but a well-balanced plant-based diet or food products made from different plants can provide all the essential amino acids required for protein synthesis in the body.

2. The Mechanism of extraction protein from vegetable wastes

In general, the processing and purchasing of vegetables generates a substantial number of byproducts and trash. They have many proteins, peptides, and amino acids. The choice of extraction process depends critically on the nature of the starting material. Plant-based protein extraction has major hurdles due to the large concentrations of lipids, polysaccharides, and polyphenols in plant tissues. These substances can cause alterations in the amino acid residues of proteins or interfere with protein separation (Luis *et al*., 2016).

Plant proteins are often recovered by a process called "Wet separation," which involves the use of solvents. Here a water film is applied to the system to prevent particulate matter from spreading. Nebulizers and filters that extract water vapour from the air supply the water film. The advantage of wet separation is, it is easier and reduces the deterioration of equipment. It helps to achieve more than 90% concentration of protein powders during isolation. Another extraction method called as “Dry separation,” is a solvent-free method for separating proteins. It does not require additional water. Milling breaks up the dried material, which is then mechanically separated using air classification or other processes (Pojić *et al*., 2018).

Extraction

The extraction technique is employed in laboratories for adjusting moisture content as well as pH, pulping, filtering, pressing cakes, and coagulating liquid (Ghaly and Alkoaik, 2010). It is done by some processes, including aqua aqua-based extraction, alkaline extraction, isoelectric precipitation, dry fractionation and inorganic and organic solvent and enzymatic extraction are often used in the extraction of natural proteins.

Aqua-based extraction - The process of aqueous extraction involves extracting ore using water or another liquid. Water is frequently employed to aid in the protein molecule's gravitational separation (Jin *et al*., 2023).

Alkaline extraction - Using this approach, the proteins are solubilized by changing a suspension of plant material to strongly alkaline conditions (pH 8-12). Filtration, centrifugation, or sedimentation can subsequently be used to get rid of the leftover insoluble material (Hadidi *et al*., 2023).

Salt extraction is another popular method for protein isolation, using plant-based sources. This approach utilizes the salting-in and salting-out phenomenon (Boye, Aksay *et al*., 2010). Salting-in increases the ionic strength of protein. By adding salt, it improves protein hydration due to greater protein-water interaction. Protein solubility rapidly increases under high salt concentrations. However, protein solubility reduced dramatically after salting out. It promotes precipitation and salting out (Zara and Pletch, 2010). The most often utilized salts in protein extraction are ammonium sulphate and sodium chloride (Sun and Arntfield, 2010).

Dry Fractionation - For plant-based protein extraction, dry fractionation is an additional technique that has been employed. Based on particle size and density, this method uses the effectiveness of milling to mechanically separate proteins and other biological constituents, such as starch (Schutyser *et al*., 2015). According to their sizes, the dissociated proteins can now be divided using an airstream (Assatory *et al*., 2019). The main benefits of the dry fractionation process include minimal impact on techno-functional qualities, loss of insoluble protein, low energy consumption, and no chemical residues left behind (Schutyser *et al*., 2015). The restricted application of the dry fractionation approach is attributed to the low yield of protein extraction, as noted by (Schutyser *et al*. 2015; Singhal *et al*. 2016).

Another method to get more pure protein extracts is to remove secondary metabolites. Low molecular weight molecules with about 50,000 structures are known as secondary metabolites (Thangaraj, 2019). The following are a few examples of secondary metabolites: tannins, phenols, flavonoids, lignin, and stilbenes (Smith, 2007). It is not an innovative idea to include these kinds of substances in food products, protein isolates, and other products because of their flavour, smell, look, and potential health risks. Organic solvents are utilized to clean the extract via TCA/acetone precipitation (Wang *et al*., 2008) Using aqueous buffers like EDTA, DTT, or 2-ME, a protease inhibitor cocktail, and polyvinyl Poly pyrrolidone (PVPP) to eliminate secondary metabolites during the extraction process is another tactic. Centrifuges can be used for PVP(P) compound cleaning. Unfortunately, organic solvents are not remarkably effective at eliminating co-precipitating pollutants. Thus, this approach is appropriate for easily removed tissues, such as young tissues (Wang *et al*., 2008).

The benefits of using traditional techniques to extract proteins: (I) This procedure does not call for complicated procedures or specific equipment; instead, it makes use of solvents that are widely available and utilized in laboratories. (II) Compared to certain contemporary alternatives, conventional protein extraction methods are less expensive. (III) Compared to some novel approaches, older procedures are comparatively faster (Yang *et al*., 2023). But there are a lot of problems with this technique, namely (I) faster protein denaturation that reduces the usefulness and quality of the proteins that are recovered. (II) The generation of massive effluent that endangers the environment (III) Organic solvents are usually used in conventional procedures. These solvents are frequently used in larger amounts, which raises expenses and may hurt the environment. (IV)Low extraction yield (Hewage *et al*., 2022).

The technological and scientific limits of existing protein extraction methods conventionally thus call for the urgent development of novel and renewable methods for protein extraction.

The extraction of plant proteins with enhanced techno-functionality has shown potentiality by using novel green extraction technologies, among which are enzyme-assisted extraction (Naseri *et al*., 2020), deep eutectic solvent extraction (Yue *et al*., 2021), reverse micelles extraction (Sankaran *et al*., 2019), microwave-assisted extraction (Varghese and Pare, 2019), and ultrasonic-assisted extraction (Dabbour *et al*., 2018).

Furthermore, according to Pojić *et al*. (2018), these green technologies are thought to be priced, safe, and ecologically benign; as a result, they may be eligible for clean label designation. But the potential of these technologies to extract plant-based proteins has not yet been fully realized (Hewage *et al*., 2022).

Enzyme-assisted extraction (EAE) - EAE demonstrates the ability to recover pectin from wastes and byproducts by improving plant cell wall permeability (Steimikyte *et al*., 2022). It degrades cell walls and other cell components via hydrolytic enzymes (cellulase, amylase, and pectinase). This permits the solvent to infiltrate into the plant components, making it easier to extract the metabolites (Łubek-Nguyen *et al*.,2022). It has various advantages, including the potential to scale up the process while eliminating the need for additional extract filtration and purification. (Vergara-Barberán *et al*., 2015).

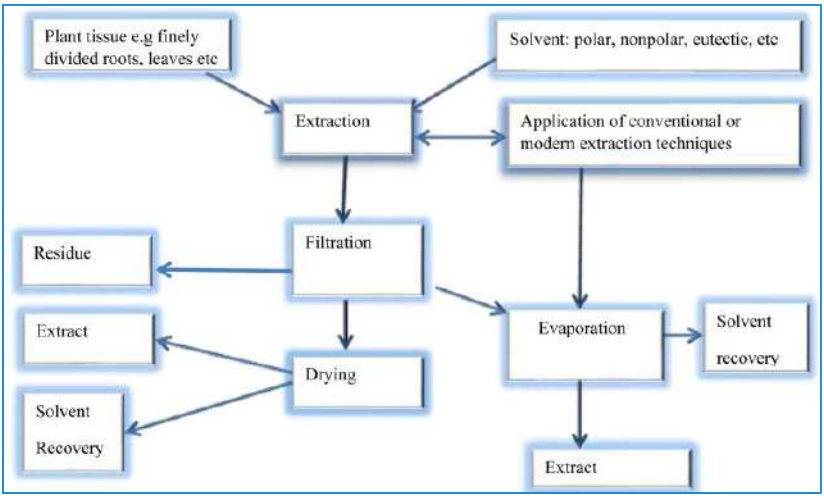
Deep Eutectic solvent extraction / Accelerated solvent extraction (ASE) - This method of pre-heating samples quickly eliminates undesired components from a sample by applying high pressures and temperatures. The advantages of this method are high yield, little time required, and low solvent requirement (Bitwell *et al*., 2023).

Microwave-assisted extraction - MAE is deemed eco-friendly because it uses no hazardous solvents. It also differs from typical approaches in that it uses electromagnetic waves (between 300 MHz and 300 GHz) to modify the cell structure. It also provides a targeted and selective heating mechanism (by ion conduction and dipole rotation) (Mandal *et al*., 2007)

Ultrasound-assisted extraction, UAE (sonication extraction) - Ultrasonic-assisted extraction (UAE) is a technique for extracting chemicals from plant materials by using ultrasonic radiation (20 kHz to 2000 kHz) and solvents. It entails transferring ultrasonic energy through a liquid solution that contains solid particles. The waves cause cavitation, which is the production of tiny vacuum bubbles in the liquid. These bubbles collapse on the solid sample, causing localized elevated temperatures. It can help to improve the quantity and quality of bioactive substances (Roselló-Soto *et al*., 2015).

Supercritical fluid extraction (SFE) - SFE is a method of separating one component from another utilizing supercritical fluids or solids as extracting solvents. It is based on the idea that the solubilities in a surface solution increase with increasing density. It is likewise founded on the idea that multiple solubilities exist in the same environment (Bitwell *et al*., 2023).

Pressurized hot water extraction (PHWE) - Using liquid water as an extractant (extractant solvent) at temperatures above atmospheric water boiling point but below water's critical point (374^{o}C), pressurized hot water extraction is a green extraction method (Turner and Plaza, 2017). The technique leverages the characteristics of subcritical water at elevated temperatures to augment the solubility of target chemicals within solid matrixes (Bitwell *et al*., 2023).



(Source: Bitwell *et al*., 2023)

Fig 2: A Schematic Diagram that shows the extraction of proteins from plant sources

3. Challenges to producing food product from the isolated proteins

1) **Taste and Flavour:** It's crucial to remember that the kind of isolated protein, where it comes from, and the processing techniques used may all affect how the protein tastes. (Shahidi & Abad, 2019) There is a natural flavour to many separated proteins derived from natural sources. Because of their inherent qualities, formulators may use them in a variety of food items (Kang *et al*., 2020) without adding overpowering or unwanted flavours. Certain formulations contain off-flavours that can be neutralized or covered up with isolated proteins. This can help a product's flavours remain stable without compromising its volatile flavour components (Yu *et al*., 2018).

2) **Allergen free:** One of the most common ways for reducing protein allergeni city is enzymatic hydrolysis, which involves the splitting of antigenic areas which are called epitopes. However, in certain situations, proteolysis did not completely remove the epitopes, leaving allergens in the formulations. So, detecting these allergies is critical for producing safe food items (Cucu *et al*., 2013). To overcome this issue, protein hydrolysates, an enzyme, are utilized to reduce the antigenic reaction. This enzyme is economically viable since it can be recycled and repurposed (Brena and Batista-Vieira, 2006; Yust *et al*., 2010). However, the activity of this enzyme with

immobilised enzyme has not yet been demonstrated (Pessato *et al*., 2016).

3) **Solubility:** According to, Ries-Kautt and Ducruix, 1989, Protein solubility is defined as "the maximum amount of protein that sediments at 30,000 g centrifugation for 30 min, or that remains in a visibly clear solution (i.e., does not show protein precipitates, crystals, gels, or hazy soluble aggregates)". Protein solubility is determined by a variety of factors, both exogenous and intrinsic. Extrinsic factors that can transform protein solubility include ionic strength, pH, temperature, the presence of different solvent additions, and the polarity of these solvents (Ries-Kautt and Ducruix, 1997). The amino acid composition of protein affects the physiochemical characteristics, processing, sensory aspects, shelf life, and nutritional makeup of foods that are made with high-protein ingredients. We must standardize the characteristics and fluidity of these proteins as new protein sources are found daily. Given the fact, that they are all unique in their qualities. Knowing their molecular properties allows us to determine their solubility qualities. This will assist us in locating different sources of protein that may be used to produce meals (Grossmann & McClements, 2023).

4) **Customer satisfaction:** In advance of proceeding to the next stage, proteins rich in essential amino acids found in plants must pass muster concerning their impact on the digestive systems of animals and humans. The use of genetic transformation to enhance plant protein quality also ran into issues with the adoption of genetically modified crops (GMC) across the world. Genetically modified organisms (GMOs) must be accepted by the public for plants to have high concentrations of critical amino acids (Ufaz & Galili, 2008).

5) **Nutritional quality improvement:** Nutritional Quality Improvement: Plant-based proteins have lately gained popularity due to their sustainable sources, lower economic expenses, and multiple health benefits over animal-based proteins. Protein modification techniques are employed in culinary and pharmaceutical applications due to their significant influences on the nutritional value as well as the functional and organoleptic qualities of the protein. For enrichment, many modification techniques are used, such as complexation, enzymatic, physical, chemical, and the most current and effective method, fibrilization.

Conclusion

It's essential to remember that plant-based proteins have various benefits, including a balanced and well-planned diet, lower levels of saturated fat and cholesterol, a fibre-rich diet, and allergen-free food options. It is also critical to ensure that all dietary requirements are satisfied. A plant-based protein-rich diet has been linked to a lower risk of several chronic diseases, including heart disease, diabetes, and several types of cancer. Plant-based proteins often require less land, water, and energy to produce, which helps to promote sustainability and reduces greenhouse gas emissions. Plant-based proteins can help to improve global food security by lowering resource demand and providing alternative, sustainable sources of nutrition. The success and effectiveness of isolating proteins from various plant wastes are evaluated using parameters such as yield, purity, and ease of extraction procedures. The isolated proteins' nutritional content, amino acid profile, and functional qualities. We should investigate how diverse sources influence the overall quality and variety of isolated proteins. It promotes sustainability by using plant waste for protein extraction, potentially lowering environmental impact and waste output. It opens a promising field for future study and improvements in protein isolation techniques or food formulation strategies on a limited budget.

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