

# **FutureBites: Exploring the Cutting-Edge Food Technologies**

*Edited by*

Dr. Manisha Maity



Swami Vivekananda University

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**Dr. Manisha Maity**

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## **COVID 19, a pandemic crisis: Transition of Consumer awareness on functional food to build immunity: A Review**

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### **Abstract:**

The rapid outbreak of COVID-19 had been affected globally specially in enormous health, economic, environmental and social challenges worldwide. With the increasing COVID positive cases day-by-day, the health authorities advocated the need to follow a healthy lifestyle with a healthy diet rich in vitamins, minerals, and bioactive components to boost the body immune system. There are so many functional foods that promote immune response and help to prevent various inflammation in the body. These foods include probiotics, prebiotics, herbal beverages, dietary fiber, fortified foods, enriched foods, hydrolyzed proteins etc. These foods can control symptoms and reduce the severity of chronic diseases and further promote general wellbeing. The main aim of this paper is to assess consumer awareness, consciousness of including functional food in their diet after facing a long term pandemic crisis. To assess the consumer awareness of eating functional food after COVID 19 a systematically literature review is done using Google scholar, PubMed, Web of Science, Springer. This paper could therefore be used

as a comprehensive resource for educating consumers and the general public awareness about importance of eating functional food to promote a healthy life style that can enhance the body's immune support system to fight against various infections including COVID-19 and other variants.

**Keywords:** Consumers, Awareness, Functional food, COVID 19, Immunity

## **Introduction**

The rapid outbreak of COVID-19 had been affected globally specially in enormous health, economic, environmental and social challenges worldwide. With the increasing COVID positive cases day-by-day, the health authorities advocated the need to follow a healthy lifestyle with a healthy diet rich in vitamins, minerals, and bioactive components to boost the body immune system.

The coronavirus disease 2019 (COVID-19) was declared as global pandemic on 11 March 2020 by World Health Organization (WHO). The disease cost innumerable human lives and infected millions worldwide. At present, several COVID-19 vaccines have been approved for human use that have not been rolled out yet worldwide, due to challenges such as its surplus production, reasonable price, balanced distribution to all needy countries and delivery at the local level (Alfawaz et al., 2021). The Indian government initiated a nation-wide lockdown as a counteractive measure from March 25, 2020 to May 31, 2020. COVID 19 had spread many countries and was wreaking havoc around the world. In addition to the severity of the disease, which affected numerous organs through immunological, inflammatory, and redox mechanisms, the use of functional foods and dietary supplements, such as vitamins and minerals, which may provide some protection by boosting the immune system and helping to reduce disease severity, had emerged as a potential dietary or therapeutic adjuvant treatment for COVID-19 (Chavda et al.; 2022).

**Table 1: Market segments of functional foods and their benefits (Kaur et al., 2011)**

| Category of functional foods | Major source and Active compound                                              | Benefits                                                                             |
|------------------------------|-------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Fruits and vegetables        | Polyphenols such as anthocyanin, flavonol                                     | Prevent Cardiovascular diseases, cancer, diabetes                                    |
| Cereals                      | Insoluble dietary fiber, water-soluble fiber                                  | Lowering cholesterol, act as prebiotics                                              |
| Dairy                        | Bioactive peptides in milk                                                    | Lowers blood pressure, preventing cardiovascular diseases                            |
| Tea                          | Catechin (Polyphenols)                                                        | Anticancer, antioxidant, antiviral, antibacterial activities                         |
| Egg                          | Omega-3 polyunsaturated fatty acids                                           | Prevent CVD.                                                                         |
| Seafood                      | Omega-3 fatty acid, Protein                                                   | Anticancer, antihypertensive, and antioxidant properties                             |
| Meat                         | Conjugated linolenic acid (CLA), taurine, L-carnitine, creatine, antioxidants | Reduce the risk of cardiovascular disease                                            |
| Vitamins                     | Vitamin A, C, E, K and Vit B complex                                          | Prevent anaemia, osteoporosis, help in eye, skin health                              |
| Herbs                        | Curcumin in turmeric, Cinnamon in clove                                       | Prevent bronchitis, asthma, cardiovascular disease<br>Contains immunological benefit |

Scientific data on the mechanisms underlying the bioactivity phenolic compounds and their usefulness in COVID-19 mitigation had reviewed. In addition, antioxidant, antiviral, anti-inflammatory, and immunomodulatory effects were also studied [Augusti et al., 2021]. Macronutrients (carbohydrates, proteins, and fats) and micronutrients (vitamins, copper, zinc, iron, calcium, magnesium, and selenium) in supporting the immune system's fight against respiratory infections. Each of

these nutrients performs a vital role as an antiviral defense in COVID-19 patients. Appropriate consumption or intake of dietary sources that yield these nutrients will help provide the daily requirement to support the immune system in its fight against pathogenic viruses such as COVID-19 [Batiha et al., 2022]. Another study explained the influence of extracts or pure molecules from medicinal plants on COVID-19. The study covered emerging technologies using plant-based SARS-CoV-2 vaccine. They concluded by giving nutrient and plants curative therapy recommendations which are of potential interest in the COVID-19 infection and could play the way for pharmacological treatments or co-treatments of COVID-19 [Brahmi et al., 2022]. Another article presented a pragmatic protocol for early nutritional supplementation of non-critically ill patients hospitalized for COVID-19 disease. Observation found that most patients present at admission with severe inflammation and anorexia lead to a drastic reduction of food intake [Caccialanza et al., 2020]. A number of vitamins (A, B<sub>6</sub>, B<sub>12</sub>, folate, C, D and E) and trace elements (zinc, copper, selenium, iron) have been demonstrated to have key roles in supporting the human immune system and reducing risk of infections. Other essential nutrients including other vitamins and trace elements, amino acids and fatty acids are also important. It would seem prudent for individuals to consume sufficient amounts of essential nutrients to support their immune system to help them deal with pathogens should they become infected. The gut microbiota plays a role in educating and regulating the immune system. Gut dysbiosis is a feature of disease including many infectious diseases and has been described in COVID-19. Dietary approaches to achieve a healthy microbiota can also benefit the immune system [Calder PC, 2020]. Another review summarized the role of nutraceuticals in the prevention and treatment of COVID-19 disease and post-COVID syndrome. Nutraceutical products, including vitamins (C, D, and E), minerals (zinc), melatonin, probiotics, flavonoids (quercetin), and curcumin have significant anti-inflammatory properties to cure COVID infection related symptoms [Catalano et al., 2022]. Another study described the potential prophylactic and therapeutic effects of curcumin, zinc in treatment of viral infections

including COVID-19. Study revealed that Curcuminoids and Zinc were classified as nutraceuticals under GRAS (Generally Recognized As Safe) for COVID 19 patients with their immunity-boosting and antiviral properties [Celik et al., 2021]. A review had focused on the effects of vitamin C on immune function, summarizing the most relevant studies from the prevention and treatment of common respiratory diseases to the use of vitamin C in critical illness conditions, with the aim of clarifying its potential application during an acute SARS-CoV2 infection [Cerullo et al., 2020]. Another article evaluated effectiveness of herbal medicines in COVID-19, the antiviral activity of nutraceuticals, and the significance of these results in creating dietary supplements that would enhance innate immunity and contribute as preventive measures against severe acute respiratory syndrome Coronavirus 2 (SARS-CoV-2) [Chavda et al., 2022]. Micronutrients, metalloids, and vitamins such as iron, manganese, selenium, Zinc, Copper, vitamin A, B family, and C are among the essential and trace elements that play a pivotal role in human nutrition and health. They participate in metabolic processes that lead to energy production. Therefore, maintaining an optimal level of micronutrients intake, particularly those with antioxidant activities, is essential to fight against oxidative stress, modulate inflammation, and boost the immune system. So these factors could play a crucial role in COVID-19 prevention and treatment [Fath et al., 2022]. Another review showed the roles of vitamin D in reducing the risk of respiratory tract infections, knowledge about the epidemiology of influenza and COVID-19. The evidence found that Vitamin D supplementation helps to reduce risk of influenza and COVID-19 infections and deaths [Grant et al., 2020]. An online study of google trend analysis showed that respondents tended to start supplementation during the first COVID-19 wave rather than the second one. Except for the role of vitamins D and C, zinc, and selenium in patients with deficiencies of those nutrients [Hamulka et al., 2021]. An app-based community survey investigated whether users of the COVID-19 Symptom Study app who regularly took dietary supplements were less likely to test positive for SARS-CoV-2 infection. In women, the study observed a

modest but significant association between use of probiotics, omega-3 fatty acid, multivitamin or vitamin D supplements and lower risk of testing positive for SARS-CoV-2 [Louca et al., 2021]. Another study had demonstrated that zinc helps to reduce viral replication and increase immune responses. Zn supplement consumption provide an additional shield against the initiation and progression of COVID-19 [Razzaque et al., 2021]. Another review found that dietary components such as vitamins C, D, E, zinc, selenium and the omega 3 fatty acids have immunomodulatory effects along with benefits of infectious disease. Some of these nutrients have also been shown to have a potential role in the management of COVID-19 [Shakoor et al., 2021].

The review paper focuses on to assess the consumer awareness of eating functional food during and after pandemic, to gain knowledge about consumer demand and choice for purchasing functional food after COVID.

### **Methodology:**

**Source:** This article was systematically reviewed literature using Google scholar, PubMed, Research Gate, Web of Science, Springer.

### **Inclusion criteria**

- Limitation to papers published in the years 2020, 2021, 2022, 2023, 2024.
- Studies investigating using the keywords connection of the pandemic and consumption of functional foods.
- Only full-text publications in English were considered.
- The majority of studies were cross-sectional, descriptive and qualitative in design.

### **Discussion**

Many research efforts have been devoted to explaining the role of nutritional supplementation in the prevention and management of COVID-19 infection.

An empirical study investigated Branded Functional Beverage (BFB) consumption behavior in the post-pandemic setting using a psychosocial theoretical framework derived from the tenets of Theory of Planned Behavior (TPB) and the Health Belief Model (HBM). This study revealed that perceived behavioral control and subjective norms were significant predictors of BFB purchase intention and subsequent consumption behavior in the post-pandemic period [Natarajan et al., 2022]. A cross-sectional online survey examined changes in dietary habits and associated practices, physical activity during the COVID-19 pandemic and before the onset of lockdowns in three European countries. An increased frequency of the daily consumption of food products such as dairy, grains, fats, vegetables and sweets and a rise in the frequency of purchasing frozen goods and food with long shelf life [ Skotnicka et al., 2021 ] A prospective cohort study investigated usage patterns and factors associated with maternal dietary supplementation by Chinese women. High educated mothers were more likely to use dietary supplements in their postpartum period. But folic acid intake was well below the guidelines [Tang et al.,2017]. Another survey was conducted including 257 respondents who were actual users of dietary supplements. It showed that the main drive for buying dietary supplements during the COVID-19 pandemic is the emotion of fear, as the consumers perceived this new disease as a threat to their health and life [Vuković et al., 2022]

## **Conclusion**

Functional foods like vitamin and mineral supplementation are critical during and after COVID-19 in order to reduce the severity of symptoms and shorten the duration of respiratory infection, thereby improving immune responses. Several research reports showing an increased interest in dietary supplements such as vitamins (C, A, E, and D), zinc, omega-3, probiotics, selenium, and others during the COVID-19 pandemic and post pandemic for consumers. Young individuals and educated people consume functional foods for health benefits, especially during and after this pandemic situation, and to prevent the risk of chronic diseases. But, a

lot of people still need to learn. This paper could therefore be used as a comprehensive resource for educating consumers and the general public awareness about importance of eating functional food to promote a healthy life style that can enhance the body's immune support system to fight against various infections including COVID-19 and other variants.

### **Interpretation**

Functional foods have many beneficial effect for consumers and also promotes immunity to fight against several infection, inflammation, life style disorders such as obesity, diabetes, hypercholesterolemia, hypertension, stroke, liver disease, gastrointestinal, respiratory and neurological problems etc. Functional foods including probiotic rich foods such as milk, curd, yoghurt, cheese, paneer, kefir, pickle have therapeutic effect for human health. These foods contain adequate protein, unsaturated fat, vitamins, minerals and dietary fiber. These nutrients play significant role for providing energy, building muscle mass, and help in metabolism, digestion and absorption. Functional foods and supplements help to cure symptoms of pandemic corona virus and also helps in rapid recovery. Thus proper nutrition and diet play an important role in maintaining health and wellbeing for consumers.

### **Conflicts of Interest**

The authors declare no conflict of interest.

### **References**

- Alfawaz, H. A., Khan, N., Aljumah, G. A., Hussain, S. D., & Al-Daghri, N. M. (2021). Dietary Intake and Supplement Use Among Saudi Residents during COVID-19 Lockdown. *International Journal of Environmental Research and Public Health*, 18(12), 6435. <https://doi.org/10.3390/ijerph18126435>
- Augusti, P.R.; Conterato, G.M.M.; Denardin, C.C.; Prazeres, I.D.; Serra, A.T.; Bronze, M.R.; Emanuelli, T. Bioactivity, Bioavailability, and Gut Microbiota Transformations of Dietary Phenolic Compounds: Implications for COVID-19. *J. Nutr. Biochem.* 2021, 97, 108787. [CrossRef]

Batiha GE, Al-Gareeb AI, Qusti S, Alshammari EM, Kaushik D, Verma R, Al-Kuraishy HM. Deciphering the immunoboosting potential of macro and micronutrients in COVID support therapy. *Environ Sci Pollut Res Int.* 2022 Jun;29(29):43516-43531. doi: 10.1007/s11356-022-20075-7. Epub 2022 Apr 7. PMID: 35391642; PMCID: PMC8989262.

Brahmi, F.; Vejux, A.; Ghzaïel, I.; Ksila, M.; Zarrouk, A.; Ghraïri, T.; Essadek, S.; Mandard, S.; Leoni, V.; Poli, G.; et al. Role of Diet and Nutrients in SARS-CoV-2 Infection: Incidence on Oxidative Stress, Inflammatory Status and Viral Production. *Nutrients* 2022, 14, 2194. [CrossRef]

Caccialanza R, Laviano A, Lobascio F, et al. Early nutritional supplementation in non-critically ill patients hospitalized for the 2019 novel coronavirus disease (COVID-19): rationale and feasibility of a shared pragmatic protocol. *Nutrition* 2020;74:110835.

Calder P.C. Nutrition, immunity and Covid-19. *BMJ Nutr. Prev. Health.* 2020 bmjnph-2020-000085. - PMC - PubMed

Catalano A, Iacopetta D, Ceramella J, Maio AC, Basile G, Giuzio F, Bonomo MG, Aquaro S, Walsh TJ, Sinicropi MS, Saturnino C, Geronikaki A, Salzano G. Are Nutraceuticals Effective in COVID-19 and Post-COVID Prevention and Treatment? *Foods.* 2022 Sep 17;11(18):2884. doi: 10.3390/foods11182884. PMID: 36141012; PMCID: PMC9498392.

Celik C, Gencay A, Ocsoy I. Can food and food supplements be deployed in the fight against the COVID 19 pandemic? *Biochim Biophys Acta Gen Subj.* 2021 Feb;1865(2):129801. doi: 10.1016/j.bbagen.2020.129801. Epub 2020 Nov 22. PMID: 33238195; PMCID: PMC7680693.

Cerullo, G.; Negro, M.; Parimbelli, M.; Pecoraro, M.; Perna, S.; Liguori, G.; Rondanelli, M.; Cena, H.; D'Antona, G. The Long History of Vitamin C: From Prevention of the Common Cold to Potential Aid in the Treatment of COVID-19. *Front. Immunol.* 2020, 11, 574029. [CrossRef]

Chavda VP, Patel AB, Vihol D, Vaghasiya DD, Ahmed KMSB, Trivedi KU, Dave DJ. Herbal Remedies, Nutraceuticals, and Dietary Supplements for COVID-19 Management: An Update. *Clin Complement Med Pharmacol.* 2022

Mar;2(1):100021. doi: 10.1016/j.ccmp.2022.100021. Epub 2022 Feb 5. PMID: 36620357; PMCID: PMC8816850.

Fath MK, Naderi M, Hamzavi H, Ganji M, Shabani S, Ghahroodi FN, Khalesi B, Pourzardosht N, Hashemi ZS, Khalili S. Molecular mechanisms and therapeutic effects of different vitamins and minerals in COVID-19 patients. *J Trace Elem Med Biol.* 2022 Sep;73:127044. doi: 10.1016/j.jtemb.2022.127044. Epub 2022 Jul 20. PMID: 35901669; PMCID: PMC9297660.

Grant, W. B., Lahore, H., McDonnell, S. L., Baggerly, C. A., French, C. B., Aliano, J. L., & Bhattoa, H. P. (2020). Evidence that Vitamin D Supplementation Could Reduce Risk of Influenza and COVID-19 Infections and Deaths. *Nutrients*, 12(4), 988. <https://doi.org/10.3390/nu12040988>

Hamulka, J.; Jeruszka-Bielak, M.; Górnicka, M.; Drywień, M.E.; Zielinska-Pukos, M.A. Dietary Supplements during Covid-19 Outbreak. Results of Google Trends Analysis Supported by Plifecovid-19 Online Studies. *Nutrients* 2021, 13, 54. [CrossRef]

Louca, P.; Murray, B.; Klaser, K.; Graham, M.S.; Mazidi, M.; Leeming, E.R.; Thompson, E.; Bowyer, R.; Drew, D.A.; Nguyen, L.H.; et al. Modest Effects of Dietary Supplements during the COVID-19 Pandemic: Insights from 445 850 Users of the COVID-19 Symptom Study App. *BMJ Nutr. Prev. Heal.* 2021, 4, 149–157. [CrossRef]

Natarajan, T., G. R., J., & Jayapal, J. (2022). Consumption of Branded Functional Beverages Post-COVID Pandemic: An Empirical Investigation in a Developing Economy Using Behavioral Change Models. *Journal of Food Products Marketing*, 28(3), 132–151. <https://doi.org/10.1080/10454446.2022.2058900>

Razzaque, M.S. COVID-19 Pandemic: Can Zinc Supplementation Provide an Additional Shield against the Infection? *Comput. Struct. Biotechnol. J.* 2021, 19, 1371–1378. [CrossRef]

Shakoor, H.; Feehan, J.; Al Dhaheri, A.S.; Ali, H.I.; Platat, C.; Ismail, L.C.; Apostolopoulos, V.; Stojanovska, L. Immune-Boosting Role of Vitamins D, C, E, Zinc, Selenium and Omega-3

Fatty Acids: Could They Help against COVID-19? *Maturitas* 2021, 143, 1–9. [CrossRef] [PubMed]

Skotnicka, M., Karwowska, K., Kłobukowski, F., Wasilewska, E., & Małgorzewicz, S. (2021). Dietary Habits before and during the COVID-19 Epidemic in Selected European Countries. *Nutrients*, 13(5), 1690. <https://doi.org/10.3390/nu13051690>

Skalkos, D., Kosma, I. S., Chasioti, E., Skendi, A., Papageorgiou, M., & Guiné, R. P. F. (2021). Consumers' Attitude and Perception toward Traditional Foods of Northwest Greece during the COVID-19 Pandemic. *Applied Sciences*, 11(9), 4080. <https://doi.org/10.3390/app11094080>

Tang, L.; Lee, A.H.; Yau, K.K.W.; Hui, Y.V.; Binns, C.W. Consumption of Dietary Supplements by Chinese Women during Pregnancy and Postpartum: A Prospective Cohort Study. *Matern. Child Nutr.* 2017, 13, e12435. [CrossRef]

Vuković, D., Jurič, B., & Krnjak, I. (2022). Influence of the Emotion of Fear on Patterns of Consumer Behavior toward Dietary Supplements during the COVID-19 Pandemic. *Journal of Risk and Financial Management*, 15(6), 257. <https://doi.org/10.3390/jrfm15060257>

## **Lifestyle Interventions in MASLD Management: Diet, Exercise, and Behavior Modification**

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### **Abstract**

Metabolic dysfunction-associated steatotic liver disease (MASLD), formerly known as non-alcoholic fatty liver disease (NAFLD), is a growing public health concern linked to obesity, insulin resistance, and metabolic syndrome. Lifestyle interventions, including dietary modifications, physical activity, and behavioral changes, remain the cornerstone of MASLD management. This review explores the role of these interventions, their effectiveness, and strategies for implementation.

**Keywords:** MASLD, NAFLD, diet, exercise, behavior modification, lifestyle interventions, metabolic syndrome, precision nutrition, digital health

### **Introduction**

MASLD affects millions globally and is associated with increased risks of cirrhosis, cardiovascular diseases, and type 2 diabetes (Chalasani et al, 2018; Eslam et al, 2020; Jarvinen, 2016). With no approved pharmacological treatments, lifestyle changes are the primary therapeutic strategy. This review evaluates current evidence on diet, exercise, and behavior modification in MASLD management and discusses their mechanisms, benefits, and practical applications (Zelber-Sagi et al, 2021; Friedman et al, 2018).

### **Dietary Interventions**

Diet plays a pivotal role in managing MASLD by reducing liver fat, inflammation, and metabolic dysfunction (Halasani et al, 2018).

- **Caloric Restriction and Weight Loss:** A 5-10% weight reduction significantly improves liver histology, reducing hepatic steatosis, inflammation, and fibrosis progression (Slam et al, 2020; Ki-Järvinen et al., 2016).
- **Gradual weight loss through a hypocaloric diet** (500-1000 kcal/day deficit) is recommended to avoid adverse metabolic effects (Elber-Sagi et al., 2021).

### **Macronutrient Composition:**

- **Low-Carbohydrate and Mediterranean Diets:** These diets emphasize whole grains, healthy fats, lean proteins, and fiber, reducing hepatic steatosis and insulin resistance (Riedman et al, 2018; Ilar-Gomez et al, 2015).
- **High-Protein Diets:** May improve liver fat content and metabolic parameters by enhancing satiety and preserving lean muscle mass (Outoukidis et al., 2019).

### **Specific Nutrients:**

**Omega-3 Fatty Acids:** Reduce liver fat and inflammation by modulating lipid metabolism (Uzzetti et al., 2016).

**Antioxidants (Vitamin E, Polyphenols):** Have potential hepatoprotective effects through anti-inflammatory and oxidative stress reduction mechanisms (Ofi et al., 2010).

**Fructose and Processed Foods:** Excessive fructose intake promotes de novo lipogenesis, increasing liver fat accumulation and inflammation. Minimizing processed food consumption is recommended (Chwingshackl and Hoffmann, 2013).

**Intermittent Fasting and Time-Restricted Eating:** Emerging evidence suggests intermittent fasting improves metabolic parameters and reduces liver fat by enhancing autophagy and insulin sensitivity (Aniagua, 2016; Ump et al., 2016).

### **Exercise Interventions**

Physical activity is critical in MASLD management by enhancing insulin sensitivity and reducing liver fat (Anyal et al., 2010; Im et al., 2010).

### **Aerobic Exercise:**

- Improves hepatic steatosis, even in the absence of significant weight loss (Atterson et al., 2015).
- Activities such as brisk walking, cycling, and swimming have been shown to reduce intrahepatic fat (Insley et al., 2015).

### **Resistance Training:**

- Enhances muscle mass, improves glucose metabolism, and contributes to liver fat reduction (Eating et al., 2012).
- Strength training at least twice per week is recommended for optimal metabolic benefits (Ohnson et al., 2009).

### **Exercise Volume and Intensity:**

- Moderate-to-vigorous activity for at least 150-300 minutes per week is recommended (Allsworth et al., 2011).
- High-intensity interval training (HIIT) demonstrates promising effects in reducing hepatic fat and improving cardiovascular health (Younossi, 2007).

### **Behaviour Modification Strategies:**

Sustaining lifestyle changes requires behavioral interventions to enhance long-term adherence and success (Garber et al., 2011).

### **Cognitive-Behavioral Therapy (CBT):**

- Helps in habit formation and overcoming barriers to dietary and physical activity modifications (Yki-Järvinen, 2011).
- Identifies and restructures negative thought patterns related to lifestyle choices (Zelber-Sagi et al., 2021).

### **Self-Monitoring and Goal Setting:**

- Tracking food intake, weight, and physical activity enhances self-awareness and adherence (Friedman et al., 2018).

- Mobile apps and digital health tools can facilitate monitoring and engagement.
- Encourages patient-centered decision-making, enhancing intrinsic motivation for sustainable lifestyle changes (Slam et al, 2020).

### **Social Support and Digital Tools:**

- Involvement of family, peer support groups, and healthcare professionals improves adherence (Ki-Järvinen, 2016)
- Digital interventions, including virtual coaching and online communities, have shown positive impacts on lifestyle modification success (Elaber et al., 2021).

### **Integrated Lifestyle Approaches**

Combining diet, exercise, and behavior modification yields optimal results. Multidisciplinary

programs involving healthcare providers, dietitians, exercise specialists, and behavioral therapists enhance long-term adherence and effectiveness (Riedman et al, 2018).

### **Personalized Approaches:**

- Tailoring interventions based on individual metabolic profiles, preferences, and readiness to change improves outcomes (Ilar et al., 2015).

### **Community-Based and Workplace Wellness Programs:**

- Structured programs in community and workplace settings support behavior change through group dynamics and accountability (Outoukidis et al., 2019).

### **Future Directions and Research Needs**

Despite strong evidence supporting lifestyle interventions, challenges remain in ensuring long-term adherence and effectiveness. Future research should focus on (Uzzetti et al, 2016):

- Developing precision nutrition and exercise interventions based on genetic and metabolic profiling.

- Evaluating the long-term effects of various dietary patterns on MASLD progression.
- Exploring novel digital and AI-driven health interventions to improve adherence.
- Investigating the role of emerging behavioral strategies, including gamification and virtual reality coaching, in sustaining lifestyle modifications.

## Conclusion

Lifestyle interventions remain the first-line therapy for MASLD management. Personalized, evidence-based strategies incorporating dietary changes, regular physical activity, and behavioral modifications are essential for effective disease control. Integrating multidisciplinary support, digital tools, and tailored interventions can enhance adherence and long-term success in MASLD management.

## References

- Allsworth, K., Fattakhova, G., Hollingsworth, K. G., et al. (2011). Resistance exercise reduces liver fat and its mediators in non-alcoholic fatty liver disease independent of weight loss. *Gut*, 60(9), 1278-1283.
- Aniagua, J. A. (2016). Nutrition, insulin resistance and dysfunctional adipose tissue determine the different components of metabolic syndrome. *World Journal of Diabetes*, 7(19), 483-514.
- Anyal, A. J., Chalasani, N., Kowdley, K. V., et al. (2010). Pioglitazone, vitamin E, or placebo for nonalcoholic steatohepatitis. *The New England Journal of Medicine*, 362(18), 1675- 1685.
- Atterson, R. E., Laughlin, G. A., LaCroix, A. Z., et al. (2015). Intermittent fasting and human metabolic health. *Journal of the Academy of Nutrition and Dietetics*, 115(8), 1203-1212.
- Chalasani, N., Younossi, Z., Lavine, J. E., et al. (2018). The diagnosis and management of NAFLD: Practice guidance from the American Association for the Study of Liver Diseases. *Hepatology*, 67(1), 328-357.

Chwingshackle, L., & Hoffmann, G. (2013). Adherence to Mediterranean diet and risk of cancer: A systematic review and meta-analysis of observational studies. *International Journal of Cancer*, 135(8), 1884-1897.

*Clinics in Liver Disease*, 11(1), 1-16.

Eating, S. E., Hackett, D. A., Parker, H. M., et al. (2012). Effect of aerobic exercise training dose on liver fat and visceral adiposity. *Journal of Hepatology*, 57(2), 247-255.

Elber-Sagi, S., Lotan, R., Shibolet, O., & Webb, M. (2021). Mediterranean dietary pattern and non-alcoholic fatty liver disease. *World Journal of Gastroenterology*, 27(26), 3683- 3696.

Eslam, M., Sanyal, A. J., & George, J. (2020). MAFLD: A consensus-driven proposed nomenclature for metabolic-associated fatty liver disease. *Gastroenterology*, 158(7), 1999-2014.

Friedman, S. L., Neuschwander-Tetri, B. A., Rinella, M., & Sanyal, A. J. (2018).

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., Nieman, D. C., & Swain, D. P. (2011).

Halasani, N., Younossi, Z., Lavine, J. E., et al. (2018). The diagnosis and management of NAFLD: Practice guidance from the American Association for the Study of Liver Diseases. *Hepatology*, 67(1), 328-357.

Ilar-Gomez, E., Martinez-Perez, Y., Calzadilla-Bertot, L., et al. (2015). Weight loss through lifestyle modification significantly reduces features of nonalcoholic steatohepatitis, *Gastroenterology*, 149(2), 367-378.e5.

Im, J. S., Mietus-Snyder, M., Valente, A., Schwarz, J. M., & Lustig, R. H. (2010). The role of fructose in the pathogenesis of NAFLD and the metabolic syndrome. *Nature Reviews Gastroenterology & Hepatology*, 7(5), 251-264.

Insley, G. M., & La Bounty, P. M. (2015). Effects of intermittent fasting on body composition and clinical health markers in humans. *Nutrition Reviews*, 73(10), 661-674.

Ki-Järvinen, H. (2016). Nutritional modulation of non-alcoholic fatty liver disease and insulin resistance: Human data.

*Best Practice & Research Clinical Endocrinology & Metabolism*, 30(3), 373-383.

Ofi, F., Abbate, R., Gensini, G. F., & Casini, A. (2010). Accruing evidence on benefits of adherence to the Mediterranean diet on health: An updated systematic review and meta-analysis. *The American Journal of Clinical Nutrition*, 92(5), 1189-1196. Ohnson, N. A., Sachinwalla, T., Walton, D. W., et al. (2009). Aerobic exercise training reduces hepatic and visceral lipids in obese individuals without weight loss. *Hepatology*, 50(4), 1105-1112.

Outoukidis, D. A., Astbury, N. M., Tudor, K. E., et al. (2019). Association of weight loss

Riedman, S. L., Neuschwander-Tetri, B. A., Rinella, M., & Sanyal, A. J. (2018). Mechanisms of NAFLD development and therapeutic strategies. *Nature Medicine*, 24(7), 908-922.

Slam, M., Sanyal, A. J., & George, J. (2020). MAFLD: A consensus-driven proposed nomenclature for metabolic-associated fatty liver disease. *Gastroenterology*, 158(7), 1999-2014.

Ump, D. B., Depner, C. M., & Tripathy, S. (2012). Omega-3 fatty acid supplementation and cardiovascular disease. *Journal of Lipid Research*, 53(12), 2525-2545.

Uzzetti, E., Pinzani, M., & Tsochatzis, E. A. (2016). The multiple-hit pathogenesis of non- alcoholic fatty liver disease (NAFLD). *Metabolism*, 65(8), 1038-1048.

Yki-Järvinen, H. (2016). Nutritional modulation of non-alcoholic fatty liver disease and insulin resistance: Human data. *Best Practice & Research Clinical Endocrinology &*

Younossi, Z. M. (2007). Epidemiology and natural history of NAFLD and NASH.

Zelber-Sagi, S., Lotan, R., Shibolet, O., & Webb, M. (2021). Mediterranean dietary pattern and non-alcoholic fatty liver disease. *World Journal of Gastroenterology*, 27(26), 3683- 3696.

## **A Study on Socio-Demographic and Nutritional Status of Aged Tribal People Communities: A Review**

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### **Abstract**

The Indian subcontinent is dwelling to a significant tribal population termed as the "Adivasi," who have not been embraced by modern society. Approximately 104 million Indians are 60 years of age or more. With a population of 296.6 million by 2050, this group would represent 20% of the nation's overall population. The old tribes (ST) made about 12% of all tribes in West Bengal. Over half of West Bengal's tribal population, or 51.8%, are members of the Santali a tribal member group. Purulia, Bankura, West Medinipur, Bardhaman, and Hooghly are the districts in West Bengal where a significant number of Santals resides. In India, tribal people are the most marginalized community. They are disadvantaged in terms of their sociodemographic profile, diet, and overall health. A person begins to age naturally at birth and continues to do so steadily until they pass away. Tribal elderly people are more susceptible than non-tribal elders in terms of sociodemographics, diet, and overall health. Elderly

indigenous people are skilled at creating handcrafted bamboo and reed baskets and mats, despite the fact that they retire from a variety of activities. But in the present day, aged tribal members are additionally affected by a number of illnesses. The health and nutritional standards of aged tribal people are impacted by a lack of education, sanitary facilities, income, and unhealthy habits. Aged tribal people are increasingly suffering from a variety of non-communicable diseases and poor nutritional status. Tribal elders are living off of poor diets, as evidenced by their low intake of all nutrients and increased rate of undernutrition.

## Introduction

The number of Indians aged 60 years and above is approximately 104 million. By 2050, this population would rise to 296.6 million, accounting for 20 percent of the country's total population. In West Bengal, the old tribes (ST) comprised 12% of all tribes (Basu *et al.*, 2018). In the twenty-first century, a significant public health concern remains promoting the quality of life for the elderly population while also preserving their health and encouraging social engagement (Soren *et al.*, 2022). In the current modern family structure, young generation judge the elderly as a burden, but in tribal societies, the same mentality is deeply ingrained in the thoughts of the younger members of the tribe. The senior tribal members in their families are placed in the direst circumstances as a result of unemployment, low-income levels, a lack of access to healthcare, and the infiltration of the nuclear family structure (Sethurajakumar and Venkatesh 2019). The nutritional risk is higher for the aged due to a variety of risk factors, including environmental, socioeconomic, psychological, and physiological. In a similar vein, as the global share of the elderly people rises, so too will the burden of chronic illnesses and disabilities.

An important factor in the aging process is nutrition. A healthier life is largely dependent on proper nutrition, and the nutritional status that is maintained during one's early years has an impact on one's later years (Padma Sri Lekha *et al.*, 2023). The burden of chronic illnesses and disabilities is expected to rise along with the global percentage of the

population that is becoming older. According to Gopalan (2000), chronic undernutrition is a major risk factor for the elderly in India, where the prevalence of chronic energy deficiency (CED) is 51% (Arlappa *et al.*, 2005; Woo 2000). Increasing age experience low Body Mass Index (BMI). It's interesting that nutritional elements, along with lifestyle choices like eating a good diet, exercising, and abstaining from harmful behaviours like smoking, may slow down the aging process (Malcomson and Mathers 2018; Singh and Chattopadhyay 2023).

### **Socio-demographical status**

According to research, tribe elders often do not seem to be particularly happy with their lives because they are going through a variety of changes as they age, such as psychological, emotional, and physical changes. Urbanization and industrialization are associated with several issues like adaptation, disagreement between generations, and a declining status and function in the community, among others (Alam 2023).

### **Ageing**

The natural process of aging occurs at the time a person is born and continues steadily until death. The general definition of aging is the result of numerous molecular and cellular damages accumulating up over time. In addition to the physiological changes, it is often linked to other life transitions like retiring and the death of relatives and close companions. Physical and mental functioning permanently declines as one ages. It raises the chance of morbidity and, ultimately, death (Gladyshev *et al.*, 2021; Harman 1992).

Each country has its own definition of old age. Elderly or senior citizens are those who are 60 years of age or older in developing nations like India. Three categories apply to them: young old, 60 to 69 years old; middle aged, 70 to 79 years old; and eldest old, 80 years and beyond (India 2022). People 60 years of age and older are referred to by several terms. When referring to someone 60 years of age and older in India, the terms “elderly,” “senior citizens,” and “old age” are frequently used (Rajan and Mishra 2020; Taylor 2011).

## **Education**

One of the most vital elements of developing human resources is education. Literacy executes a vital part in a country's development, and without the involvement of all groups in such programs, this progress would not succeed. In the years following independence, India has not yet attained the necessary level of education. Their social, political, and economic backwardness, as well as their disadvantaged and impoverished populations, are the main causes of their educational backwardness (Chakraborty 2019). A higher risk of elder abuse is associated with a lack of formal education. This is significant for Indian society primarily because of the extremely low educational attainment of the elderly population, it is estimated that 73% of Indians over 60 years are illiterate. Education is involved of elements of human resource development. Scheduled Tribe traditionally is inhabitant of countryside and in close intimacy to forests and natural resources. According 2011 census, the literacy rate among tribes is 58.96% which is below the overall literacy of the country (74.04%). In West Bengal, the literacy rate among tribal is 57.97% that is below overall literacy of the state literacy 77.08% (Chakraborty 2019). Bir 2020 reported that educational status of ST elderly population was 0.38% in India (Bir 2020). Gurumoorthy and Thirumalraja 2015 also reported the lower level of educational status of elderly tribal people accounting 88% illiterate from Kodaikanal hill in Tamilnadu (Gurumoorthy and Thirumalraja 2015).

## **Economic condition**

The demographic shift in developing nations is causing a rapid rise in the median age, size, and percentage of those the elderly population, as well as in widowhood and old age dependability. The elderly are experiencing more economic instability as a result of these demographic shifts, which are also changing society. Additionally, they are linked to an increase in individualism, mobility, and nuclear families. While everyone is impacted by these changes, the elderly are particularly at risk because of social isolation, declining health, increased illness load, retirement from the work, lower or no financial support, and growing family responsibilities.

There is a significant age gradient in both the financial crises and burden of ailments (Mohanty *et al.*, 2023).

Physical, economic, and psychological issues are more likely to have an impact on the socioeconomic status of elderly tribal people. Due to their economic situation and geographic location, they are impoverished and will lead miserable lives for the rest of their lives. The primary causes of the weak economy are the aging factor and the absence of alternative employment (Lakshmi and Muthuraj 2020). Gurumoorthy and Thirumalraja 2015 also reported the poor financial condition Kodaikanal hill in Tamilnadu. It was also documented that they were depended on family for financial supporting (Gurumoorthy and Thirumalraja 2015).

### **Housing condition**

The house is more than just a heaven; it's also a place where kids may develop emotionally, physically, and socially with their families (Saha *et al.*, 2023; Wilson and Boehland 2005). Low housing status could be corresponding to poor socioeconomic status, poverty, a lack of facilities, a rural area, and so on (Islam *et al.*, 2015). Tribes are marginalized and reside the majority of the nation's unstable regions. About half of all walls are made of bamboo, with tin coming in as a distant second (about 26%). While almost all of the roofs are made of tin, others are made of bamboo, straw, asbestos, and concrete, and nearly all of the dwellings are wired to receive electrical current, statistically speaking. A hurricane lamp, lantern, or similar device must be used throughout the night ((Saha *et al.*, 2023).

Statudy from Kodaikanal hill in Tamilnadu reported that Only 20% of respondents lived in Pucca houses, which are composed of sand, stone, wood, and leaves, while the remaining 2% lived in concrete homes. 78% of tribal people live in huts or thatched dwellings in interior forest regions (Gurumoorthy and Thirumalraja 2015). As reported by Islam et al. (2015), 78.05 percent of the respondents lived in a temporary construction, with mixed (12.19%), permanent (7.93%), and hut (1.83%) following. A small percentage of the families (8.54%) had two dwellings, whereas the majority

(91.46%) had just one. The families only own one temporary structure home in this area (Islam *et al.*, 2015).

### **Family size**

In order to comprehend the spatial demographic diversity of tribal families throughout the region, family size is an important factor. In accordance with 2011 Census information, there are 1156753 Scheduled Tribe households in West Bengal. Of them, 91.86 percent are in rural areas and just 8.14 percent are in urban areas. There are 5256142 people living in these types of families, and the bulk of them are undoubtedly from rural backgrounds. The state's average household size is 4.5 (Kumbhakar 2020).

### **Type of Family**

In society's standpoint, the family is considered as a basic unit. The family is trusted to be the main unit when discussing a social structure that is extensively proportioned. A family is an affiliation formed to support the biological justification for human existence (Marty and Appleby 1997). A family has been made up of a mother, father, and kids. These persons are considered to be part of a nuclear family. Joint family has a comparatively higher number of members. Every family member shares a kitchen and lives together. These families have been referred to as extended families. Despite its benefits and drawbacks, joint and extended families are currently progressively disappearing from society (Georgas *et al.*, 2001). YI *et al.*, (2017) reported that nuclear family (95.2%) was more compared to joint family (4.8%) in tribal families (YI *et al.*, 2017).

### **Occupation**

When comparing societies, occupation provides a measure of the economic growth that individuals and families have achieved. It also reveals a person's or a family's social standing (Hauser and Warren 1997). Elderly tribal people are adept in making handmade bamboo and reed baskets and mats, but the younger generation prefers to work for non-tribals as labourers (Islam *et al.*, 2015). Various studies indicates that majority of the respondents largely depend

on agriculture, while many also earn a living by working as agricultural coolies (Islam *et al.*, 2015; Shetty and Nayar 2024). Agriculture, which incorporates farming and forestry in particular, has been essential to the rise of civilizations, and many Indigenous Peoples around the world hold great reverence for their ties to the land (Shetty and Nayar 2024). 90% percent of tribes live mostly in forested, hilly, and mountainous environments. The area of forest land has been steadily decreasing as a result of mining, industrialization, crop cultivation for agriculture, the establishment of national parks and wildlife reserves, as well as government and private sector-initiated hydroelectricity projects (Mehta and Singh 2021). Their local sources of income have been severely impacted by the loss of forest land, and they are now either uprooted or have to work extremely hard to make ends meet in their native location. They were forced to leave their home countries in quest of employment or a means of subsistence since there were not enough prospects for them there. In quest of employment, both men and women have begun to migrate to distant towns and metropolises (Mosse *et al.*, 2005). Ashifa (2022) reported that elderly Irula tribal people engage for their livelihoods in agricultural worker, casual laborers, plantation laborers, and industrial laborers in Tamilnadu (Ashifa 2022). The primary occupation, according to Islam *et al.* (2015), was farming (62.20%), which was followed by wage labor (18.90%), business (7.31%), service (4.88%), caste occupation (3.66%), and any other (3.05%) (Islam *et al.*, 2015).

### **Electricity and sanitary condition**

Electricity and sanitation are crucial fundamental needs of people for decent living in the present era; the development and implementation of these facilities is critical for the socioeconomic improvement of these underprivileged sections of society (Kharwar *et al.*, 2021). According to a study by Haq *et al.* (2021), 98.46% of families in Andhra Pradesh utilize electricity as their primary source of lighting, while only 1.53% of all households use kerosene. This compares to 73.1% of all ST people in the 2011 Andhra Pradesh census who reported using electricity and 25.3% who used kerosene (Haq *et al.*, 2021)

Lack of sanitation facilities contribute to pollution, health issues for the public, security issues, and major crimes including rape and sexual assault against women who are particularly vulnerable (Kharwar *et al.*, 2021).

### **Type of Fuel used for Cooking**

Cooking gas is desirable in regard with the environment. Due to health hazards, one should stay away from wood, coal, and kerosene (Lam *et al.*, 2012). According to Kalli *et al.* (2022), 43% of respondents have shifted to LPG for cooking, whereas roughly 57% of respondents still use conventional energy sources. Of the 43% of respondents who have embraced LPG, 26% use it as their main cooking fuel and 17% use it as a secondary source (Kalli *et al.*, 2022). The tribal population's underutilization of PMUY (Pradhan Mantri Ujjwala Yojana) was mostly caused by a lack of awareness, issues with documentation, and expensive costs (Patil *et al.*, 2021).

### **Bad habits**

Excessive alcohol consumption and tobacco smoking have detrimental effects on the environment, society, economy, and worldwide health. Over 7 million individuals globally pass away from tobacco smoking each year with low- or middle-income nations accounting for more than 80% of mortality. Tobacco users eliminate 15 years of life on average (Hsu *et al.*, 2018). Cancer, cardiovascular disease, diabetes mellitus, and lung disease are among the tobacco-related causes of death that claim the lives of up to 50% of smokers (Sakthisankaran *et al.*, 2024). Diseases brought on by tobacco smoking also make people poorer by driving up the cost of healthcare for both individuals and families. Tobacco uses also has a significant negative economic impact on the world economy (Hsu *et al.*, 2018).

Multiple studies indicated that alcohol and smoking were frequent among tribal people, and that these behaviours were linked to a high incidence of medical conditions, early death, and problems with nutrition (Sadath *et al.*, 2019). Tobacco usage also ranks as one of the most serious threats to public health. The extensive use of different kinds of tobacco is an issue of worry in nations with low or middle incomes. According

to evidence, almost 1.3 billion individuals worldwide use tobacco, with 80% living in low or middle incomes nations, which have the greatest tobacco-related illness and death levels. India is the next-largest of tobacco products among low or middle incomes nations and continues to be a major producer (Murmu *et al.*, 2023). According to a study by Murmu *et al.* (2023), elderly tribal people aged 60–74 years addicted to smoking, smokeless tobaccos, and any tobacco were 19.6%, 30.07%, and 46.7%, respectively (Murmu *et al.*, 2023). Gupta *et al.*, (2018) found that a lot of elderly people (70.9%) aged 60-65 years addicted to tobaccos in Mandla city of Madhya Pradesh (Gupta *et al.*, 2018).

### **Nutritional Status**

Every community's health requirement and issue are shaped by the interplay of multiple socioeconomic and political forces. Numerous research has been conducted on tribes, their cultures, and the effects of acculturation on tribal societies. Since 1947, the opening of Primary Health Centres (PHCs) in tribal-dominated regions has been a key aspect of the country's many tribal development projects aimed at providing essential primary health care to the tribal people. When compared to their others in the rural and urban areas, tribal elders are generally the most disadvantaged due to both their physiological aging and the distinct regions in which they dwell. Prevalence of obesity among tribal elderly people was low. Sinha *et al.*, (2023) recorded that prevalence of obesity was observed 13.28% (Sinha *et al.*, 2023).

According to Arlappa *et al.* (2005), both males and females consumed less of all nutrients than what was recommended by the Recommended Dietary Intakes (RDI). For both boys and girls, the mean weights and heights declined noticeably with age. Compared to males (61.8%), females had a comparatively greater prevalence of Chronic Energy Deficiency (CED = BMI < 18.5) (65.4%). Elderly residents of landless and kutcha households had a considerably greater prevalence of CED than other populations. Due to their limited diets, the elderly indigenous population exhibits low nutritional intakes and a greater incidence of undernutrition. When compared to their rural counterparts, a notably greater percentage of elderly

indigenous people suffer from undernourishment (Arlappa *et al.*, 2005).

### **Health status**

The elderly of tribes are sources of changing cultural legacy. However, the majority of these tribal elders lead poor lives and neglect all forms of its development. They experience a range of illnesses, including diarrhea, cholera, malaria, kala-azar, black water fever, intestinal disorders brought on by unhygienic surroundings, skin disorders brought on by soiled clothing, sexually transmitted infections brought on by cross-cultural interaction, and intoxicating liquors, drinks, and medicines (Jain *et al.*, 2015; Nair and Et 2019). For them to live longer and have better physical and mental health, universal health coverage is necessary. The Scheduled Tribal communities are exhibiting the effects of an aging population (Majumdar *et al.*, 2020). Lack of healthcare facilities, trained healthcare professionals, and transportation infrastructure further exacerbate their healthcare access challenges. Efforts are being made by the Indian government and various organizations to address these health challenges among tribal communities (Saha *et al.*, 2023).

### **Food habit**

Any society's overall way of life is influenced by its beliefs, rituals, and customs. Eating is a highly social activity and an object of culture that reflects the complex process of sociocultural difference in the formation of eating patterns. Food is essential for physical, mental and social well-being. Due to their isolated lifestyles, eating habits, dietary practices, and a view about food, the dietary habits of the tribes of India may vary (Bisai *et al.*, 2023). Bandana, (2012 ) noted that every tribal population consumes pork, cow, and ox meat (Bandana 2012). Das, (2015) also observed that they had developed a practice of consuming land crabs, prawns, and snails (Das 2015). Rice and millets as a main staple food had been reported by various study (Moyra and Hazra 2022; Subramanyam and Rao 2023). They intake a variety of unusual foods, such as grains, small seeds, roots and tubers, and greens. In addition to the typical non-vegetarian fare, wild boars, rabbits, rats, and

porcupines were utilized. Dietary diversity according to the seasons was crucial. Their eating schedule was erratic and repetitive (Chandrasekhar and Chitra 1990). Similarly Sinha and Larka (2005) highlighted the inclusion of unconventional foods such as green leaves, wild dogs, deer, greyquail (Sinha and Lakra 2005). The elder tribal people are surviving on inadequate diets, as indicated by their poor consumption of all nutrients and rising prevalence of undernutrition. They eat more green leafy vegetables, grains, and millets, but along with that eat very little fruit, fish, nuts, and oil seeds, and other flesh items (Arlappa *et al.*, 2005). The RDAs advised for Indians were not met by the median intakes of any of the nutrients (Arlappa *et al.*, 2003). According to Easwaram and Poorani (1991), the day's menu was decided upon based on the food items that were in season rather than in advance. Every day, they received three meals. They cooked twice a day, in the morning and at night. Breakfast was prepared in the morning, while lunch was prepared later. After sunset, food was prepared for the night. Main course options included millets, beans, tapioca, potatoes, lady fingers, brinjal, and various gourd species. There was no milk or milk products consumed (Easwaran and Poorani 1991; Thimmayamma *et al.*, 1982).

According to research done in 1991 by Thakur *et al.*, the primary foods consumed by the Khona, Gadaba, and porja tribes in the state of Himachal Pradesh were rice and rice product, ragi and Jowar and their product, bajara, and wheat and wheat product. There was no expenditure on fruits, milk, and dairy goods, nor on green leafy vegetables. They were more concerned with the quantity of food than its quality, and their diet was boring and uninteresting. For breakfast, it was usually cereals and either fermented or unfermented gruel; for dinner, it was rice with vegetables and dal (Thakur *et al.*, 1991).

### **Morbidity Pattern**

The aging process, which results in an overall decrease in health, is an obstacle and a challenge for the aged. Seneca once said, "Old age is an incurable disease." Sir James Sterling Ross once remarked, quite correctly: "You do not heal old

age; you protect, promote, and extend it.” (Rodríguez-Rodero *et al.*, 2011) With aging comes a higher chance of illness, incapacity, reduced functioning, and ultimately death. Every person, family, community, and society are impacted. In the twenty-first century, a significant public health concern remains enhancing the quality of life for the elderly while both preserving their health and encouraging social engagement (Soren *et al.*, 2022).

Since tribal health also experiences a dramatic shift in lifestyle, which puts them at higher risk of NCD multimorbidity, NCD multimorbidity is as relevant to tribal health as it is to the general population (Barik and Thorat 2015). A higher prevalence (49.24%) of multimorbidity was observed among elderly tribal people (Sinha *et al.*, 2023). One in every two elderly individual suffers from at least one chronic disease and are on lifelong medicine (Ashifa 2022). According to Gurumoorthy and Thirumalraja’s 2015 report, the majority of respondents suffer from physical issues such as joint pain, persistent headaches, persistent constipation, gastrointestinal problems, vision loss, and loss of hearing. Among older tribal people, malnourishment and infectious diseases like malaria and tuberculosis are also prevalent (Gurumoorthy and Thirumalraja 2015). Lack of opportunity, lack of education, awareness of disease causes, rude environment, poor hygiene, a lack of safe drinking water, and erroneous opinions, among other things, aggravate their misery (Sethurajakumar and Venkatesh 2019). Ablo and Yekple, (2016) reported that lack of drainage facility in their houses causes the various health issues (Ablo and Yekple 2018).

## **Hypertension**

Hypertension is one of the primary non-communicable diseases (NCDs) (Tripathi *et al.*, 2020) and a major cause of illness and disability worldwide. High blood pressure, or hypertension, is mostly responsible for the significant increase in cardiovascular fatalities, diabetes type 2, heart disease, and renal illness. This condition is impacted by a variety of factors. Age is an additional component that influences the development of hypertension (Rahaman *et al.*, 2024). Tribal populations of India, who are confined to isolated, hilly

areas, are vulnerable to lack of education, poverty, and malnourishment (Kshatriya 2014). As a result, it is presumed that they are resistant to hypertension, a condition driven by lifestyle habits. However, fresh literature indicates that hypertension is becoming more common among tribal people (Sathiyannarayanan *et al.*, 2019; Tripathi *et al.*, 2020). Elderly tribal people experienced a high prevalence of hypertension; factors associated with risk for hypertension among Indian tribal men and women included educational attainment, use of tobacco products, alcohol, rising BMI, and visceral and truncal obesity (Laxmaiah *et al.*, 2015). Sinha *et al.*, (2023) reported that prevalence of hypertension was 11.80% among elderly tribal (Sinha *et al.*, 2023). Tripathi *et al.* (2020) explored the variation in the prevalence of hypertension among tribal communities throughout several states and parts of India, ranging from 10% to 55.5%. Men were more likely than women to have hypertension. Common risk factors included becoming older, having a higher body mass index, smoking, having diabetes, and consuming more salt (Tripathi *et al.*, 2020)

### **Diabetes mellitus**

Some of the non-communicable medical conditions which lead to major problems with public health and monetary losses internationally is diabetes, which is expected to become to the seventh most common cause of death globally by 2030 (Das and Kar 2023). One of the major public health problems and difficulties in low-middle-income nations is diabetes mellitus, which causes 75% of the annual incidence of diabetes in the population. Although the prevalence of diabetes is higher in urban areas, recent study data has also indicated that the disease is becoming more common in rural areas (Hwang *et al.*, 2012). The largest prevalence of diabetes was regarded in elderly people, particularly those over 60. This was due to a combination of factors such as the aging population, the swift urbanization of people's health, and lifestyle choices that featured western food habits and a lack of vigorous physical activity. An increasing number of research indicates that diabetes in elderly individuals is associated with significant morbidity, including the highest risk of institutionalization,

decreased functional status, increased mortality, and macro- and microvascular consequences (Das and Kar 2023; Jain and Paranjape 2013). Babu *et al.*, (2024) found that the prevalence of type 2 diabetes among tribal populations was 4.77%, which was lower than the national average of 7.3% for people in general (Babu *et al.*, 2024)

### **Anaemia**

People over 65 years are considered to be elderly, and as the population ages, anemia is becoming more prevalent in this age group. Any level of anemia has a substantial impact on quality of life and contributes considerably to morbidity and mortality in older individuals. Elderly anemia is especially important since it can lead to several dangerous outcomes. Anemia has been linked to increased risk of falls and fractures, poor physical performance and quality of life, increased incidence of cardiovascular disease, and cognitive impairment. Additionally, anemia has a strong correlation with lengthier hospital admissions and a higher risk of death, particularly death from cardiovascular illness. More significantly, anemia may indicate a malignant illness that has not yet been identified (Stauder and Thein 2014). Various studies showed that anemia is a common problem among tribal women in reproductive age group (Kamath *et al.*, 2013; Rohisha *et al.*, 2019). A higher frequency of anemia among these tribal people may be caused by a number of reasons, including economic hardship, insufficient nutrition, lack of education, adverse cultural practices, lack knowledge of the disease, inadequate geographic connectedness, and a lack of health staff and services (Ismail *et al.*, 2017). An investigation of the haemoglobin levels of elderly tribal people from Orissa revealed a miserable picture: none of the females had normal hemoglobin levels, and 70% of the men and 77% of the females, respectively, had severe anaemia (Kerketta *et al.*, 2009).

### **Conclusion**

Tribes' status in our country is entirely discarded. They are being forced to abandon their original position and are also facing threats from the occupiers. These primitive organizations have left our society's ancient tribes in a strange and miserable

status. Their ageing into the worst circumstances they have ever known is a result of their non-migration status, bad health, lack of an economic source, and child abandonment. People in the modern world need access to clean water, electricity, housing, and sanitary facilities in order to live with dignity. The establishment and implementation of these rules not only safeguards women from major health, safety, and environmental hazards, but they are also crucial for the economic development of the tribe. The primary causes of aged tribal people's low nutritional state include a lack of income, sanitary facilities, clean water, electricity, shelter, and bad habits. Non-communicable diseases like diabetes mellitus, hypertension, and anaemia are very common among tribal communities, and their management and prevention techniques must be implemented immediately.

## References

Ablo AD, Yekple EE (2018). Urban water stress and poor sanitation in Ghana: perception and experiences of residents in the Ashaiman Municipality. *GeoJournal* 83:583-594.

Alam I (2023). Tribal Elderly in Urban India: A Study on The Intergenerational Relationships. *Imgelem* 7(13):771-796.

Arlappa N, Balakrishna N, Brahmam GN, Vijayaraghavan K (2005). Nutritional status of the tribal elderly in India. *J Nutr Elder* 25(2):23-39. 10.1300/j052v25n02\_03

Arlappa N, Balakrishna N, Kumar S, Brahmam GNV, Vijayaraghavan K (2003). Diet and nutritional status of the elderly in rural India. *Journal of Nutrition for the Elderly* 22(4):35-52.

Ashifa KM (2022). Assessing The Social Conditions Of Elderly People Among Irula Tribal Communities In Tamil Nadu. *Webology* 19(2).

Babu BV, Hazarika CR, Raina SK, Masoodi SR, Basappa YC, Thomas N, Kerketta AS, kumar Menon N, Jebasingh FK (2024). Prevalence of type 2 diabetes among tribal population of india: a multi-centric cross-sectional study. *Journal of the National Medical Association* 116(2):153-164.

Bandana S (2012). Diet and lifestyle: its association with cholesterol levels among Nomad tribal populations of Rajasthan. *International Journal of Medicine and Biomedical Research* 1(2):124-130.

Barik D, Thorat A (2015). Issues of Unequal Access to Public Health in India. *Front Public Health* 3:245. 10.3389/fpubh.2015.00245

Basu G, Mondal P, Roy S (2018). Health of elderly tribes: a community based clinico-epidemiological study in West Bengal, India. *International Journal Of Community Medicine And Public Health* 5(3). 10.18203/2394-6040.ijcmph20180513

Bir T (2020). Education and Healthy Aging of Elderly belonging to Scheduled Caste, Scheduled Tribe and Other Backward Class categories of the Population in India. 2(11):366-388. 10.35629/5252-0211366388

Bisai S, Dutta S, Das Mohapatra PK (2023). Traditional food consumption pattern and nutritional status of Oraons: An Asian Indian indigenous community. *Frontiers in Sustainable Food Systems* 7:969264.

Chakraborty P (2019). Educational status of the tribal West Bengal: Special references to the Paschim Medinipur District. *Global Journal of Sociology and Anthropology* 9(1):1-14.

Chandrasekhar U, Chitra G (1990). Diet profiles and nutritive value of selected foods eaten by the Kota and Kadar tribes. *The Indian Journal of Nutrition and Dietetics*:101-107.

Das D (2015). Ethnozoological practices among tribal inhabitants in Khowai district of Tripura, North-East India. *J Global Biosci* 4(9):3364-3372.

Das U, Kar N (2023). Prevalence and risk factor of diabetes among the elderly people in West Bengal: evidence-based LASI 1st wave. *BMC Endocr Disord* 23(1):170. 10.1186/s12902-023-01421-3

Easwaran PP, Poorani R (1991). Nutritional status of tribal school going children. *International Journal of Nutrition and Dietetics* 28(8).

Georgas J, Mylonas K, Bafiti T, Poortinga YH, Christakopoulou S, Kagiticbasi C, Kwak K, Ataca B, Berry J,

Orung S (2001). Functional relationships in the nuclear and extended family: A 16-culture study. *International Journal of Psychology* 36(5):289-300.

Gladyshev VN, Kritchevsky SB, Clarke SG, Cuervo AM, Fiehn O, de Magalhães JP, Mau T, Maes M, Moritz RL, Niedernhofer LJ (2021). Molecular damage in aging. *Nature Aging* 1(12):1096-1106.

Gupta VK, Nema P, Toppo NA, Kasar P, Rai N (2018). Prevalence of tobacco consumption among urban tribals of Mandla District (MP). *pancreas* 4:430-6.

Gurumoorthy R, Thirumalraja D (2015). Status of Aged People in Tribal Community. *IJAR* 1(10):682-684.

Haq J, Ramesh M, Ansari MN, Komala M, Parveen S, Nazli T, Raheem A (2021). Socio-demographic profile of Schedule Tribes of five integrated tribal development agency spots at Kurnool, Andhra Pradesh in India. *International Journal of Preventive, Curative & Community Medicine (E-ISSN: 2454-325X)* 7(2):14-19.

Harman D (1992). Free radical theory of aging. *Mutation Research/DNAging* 275(3-6):257-266.

Hauser RM, Warren JR (1997). Socioeconomic indexes for occupations: A review, update, and critique. *Sociological methodology* 27(1):177-298.

Hsu KY, Tsai YF, Huang CC, Yeh WL, Chang KP, Lin CC, Chen CY, Lee HL (2018). Tobacco-Smoking, Alcohol-Drinking, and Betel-Quid-Chewing Behaviors: Development and Use of a Web-Based Survey System. *JMIR Mhealth Uhealth* 6(6):e142. 10.2196/mhealth.9783

Hwang CK, Han PV, Zabetian A, Ali MK, Narayan KM (2012). Rural diabetes prevalence quintuples over twenty-five years in low- and middle-income countries: a systematic review and meta-analysis. *Diabetes Res Clin Pract* 96(3):271-85. 10.1016/j.diabres.2011.12.001

India HA (2022) Annual Report 2021-22. Help Age India. Retrieved from Help Age India.

Islam MA, Rai R, Quli S, Trambo M (2015). Socio-economic and demographic descriptions of tribal people subsisting in

forest resources of Jharkhand, India. *ASIAN JOURNAL OF BIO SCIENCE* 10:75-82. 10.15740/HAS/AJBS/10.1/75-82

Ismail IM, Kahkashan A, Antony A, Sobhith V (2017). Role of socio-demographic and cultural factors on anemia in a tribal population of North Kerala, India. *Int J Community Med Public Health* 3(5):1183-8.

Jain A, Paranjape S (2013). Prevalence of type 2 diabetes mellitus in elderly in a primary care facility: An ideal facility. *Indian J Endocrinol Metab* 17(Suppl 1):S318-22. 10.4103/2230-8210.119647

Jain Y, Kataria R, Patil S, Kadam S, Kataria A, Jain R, Kurbude R, Shinde S (2015). Burden & pattern of illnesses among the tribal communities in central India : A report from a community health programme. *Indian J Med Res* 141(5):663-72. 10.4103/0971-5916.159582

Kalli R, Jena PR, Managi S (2022). Subsidized LPG scheme and the shift to cleaner household energy use: evidence from a tribal community of eastern India. *Sustainability* 14(4):2450.

Kamath R, Majeed JA, Chandrasekaran V, Pattanshetty SM (2013). Prevalence of Anemia among Tribal Women of Reproductive Age in Udupi Taluk, Karnataka. *J Family Med Prim Care* 2(4):345-8. 10.4103/2249-4863.123881

Kerketta AS, Bulliyya G, Babu BV, Mohapatra SSS, Nayak RN (2009). Health status of the elderly population among four primitive tribes of Orissa, India: A clinico-epidemiological study. *Zeitschrift für Gerontologie und Geriatrie* 42:53-59.

Kharwar PS, Kumar D, Kumar A, Kumar A (2021). Understanding Access to Housing, Drinking water, Electricity and Sanitation by Scheduled tribes in Eastern Uttar Pradesh. *An Int J of Education and Applied Social Sciences* 12(3):215-225. 10.30954/2230-7311.3.2021.6

Kshatriya GK (2014). Changing perspectives of tribal health in the context of increasing lifestyle diseases in India. *J Environ Soc Sci* 1(1):101.

Kumbhakar S (2020). Demographic Socio economic and Health status of the Scheduled Tribes A comparative evaluation between Purulia and Bankura district of West Bengal. Ranchi

Lakshmi GG, Muthuraj A (2020). A study on socio-economic condition of elderly tribal people in Tamil Nadu. *Journal of Interdisciplinary Cycle Research* Retrieved from: <http://www.jicrjournal.com/gallery/144-jicr-april-2663.pdf>.

Lam NL, Smith KR, Gauthier A, Bates MN (2012). Kerosene: a review of household uses and their hazards in low-and middle-income countries. *Journal of Toxicology and Environmental Health, Part B* 15(6):396-432.

Laxmaiah A, Meshram, II, Arlappa N, Balakrishna N, Rao KM, Reddy CG, Ravindranath M, Kumar S, Kumar H, Brahmam GNV (2015). Socio-economic & demographic determinants of hypertension & knowledge, practices & risk behaviour of tribals in India. *Indian Journal of Medical Research* 141(5):697-708.

Majumdar K, Raul M, Chatterjee D (2020). Social status and subjective well-being of tribal elderly: a narrative discourse. *Social Welfare in India and China: A Comparative Perspective*:191-209.

Malcomson FC, Mathers JC (2018). Nutrition and ageing. *Biochemistry and Cell Biology of Ageing: Part I Biomedical Science* 90:373-424.

Marty ME, Appleby RS (1997). Fundamentalisms and society: Reclaiming the sciences, the family, and education, vol 2. University of Chicago Press

Mehta BS, Singh B (2021). Employment and Livelihoods among Tribal in India. *Journal of the Anthropological Survey of India* 70(2):264-277. 10.1177/2277436X211066517

Mohanty SK, Arokiasamy P, Nayak I, Shekhar P (2023). Economic well-being of middle-aged and elderly adults in India: variations by household composition. *Journal of Social and Economic Development*:1-19. <https://doi.org/10.1007/s40847-023-00238-z>

Mosse D, Gupta S, Shah V (2005). On the margins in the city: Adivasi seasonal labour migration in western India. *Economic and Political weekly*:3025-3038.

Moyra SK, Hazra S (2022). Dealing with vulnerabilities in tribal food security—a study on Jhargram district of West Bengal, India Indigenous People and Nature. Elsevier, p 399-418.

Murmu J, Agrawal R, Manna S, Pattnaik S, Ghosal S, Sinha A, Acharya AS, Kanungo S, Pati S (2023). Social determinants of tobacco use among tribal communities in India: Evidence from the first wave of Longitudinal Ageing Study in India. *Plos one* 18(3):e0282487.

Nair S, Et T (2019). Active and Healthy Ageing among Scheduled Tribes in India. *Journal of Gerontology & Geriatric Research* 08. 10.4172/2167-7182.1000495

Padma Sri Lekha P, Irshad CV, Abdul Azeez EP, Irudaya Rajan S (2023). Nutritional status of older adults in India: An exploration of the role of oral health and food insecurity factors. *Heliyon* 9(10):e21028. 10.1016/j.heliyon.2023.e21028

Patil R, Roy S, Gore M, Ghorpade M, Pillarisetti A, Chakma J, Juvekar S (2021). Barriers to and facilitators of uptake and sustained use of LPG through the PMUY in tribal communities of Pune district. *Energy for Sustainable Development* 63:1-6.

Rahaman SN, Das S, Samanta S, Ahmed R, Banerjee J, Alam SS, Pal A, Ali KM, Dash SK (2024). Cross sectional study on the association among hypertension with obesity indicators and dietary patterns of fishing community at coastal regions in India. *Clinical Epidemiology and Global Health* 27:101573.

Rajan SI, Mishra US (2020). Senior citizens of India: Emerging challenges and concerns. Springer Nature

Rodríguez-Rodero S, Fernández-Morera JL, Menéndez-Torre E, Calvanese V, Fernández AF, Fraga MF (2011). Aging genetics and aging. *Aging Dis* 2(3):186-95.

Rohisha IK, Jose TT, Chakrabarty J (2019). Prevalence of anemia among tribal women. *J Family Med Prim Care* 8(1):145-147. 10.4103/jfmpc.jfmpc\_249\_16

Sadath A, Jose K, Meethal ST, Mathai JK, Venugopal AP, Xavier N (2019). Factors associated with alcohol misuse among indigenous tribal men in Wayanad: a qualitative study. *Indian journal of psychological medicine* 41(6):516-522.

Saha J, Maity M, Roy SK, Ghosal S (2023). NUTRITIONAL AND HEALTH STATUS OF TRIBAL PEOPLE: A REVIEW. *Journal of Advanced Zoology* 44(S-6):1950:1955.

Sakthisankaran SM, Sakthipriya D, Swamivelmanickam M (2024). Health Risks Associated with Tobacco Consumption in Humans: An Overview. *Journal of Drug Delivery and Therapeutics* 14(5):163-173.

Sathiyandarayanan S, Muthunarayanan L, Devaparthasarathy TA (2019). Changing Perspectives in Tribal Health: Rising Prevalence of Lifestyle Diseases among Tribal Population in India. *Indian J Community Med* 44(4):342-346. 10.4103/ijcm.IJCM\_40\_19

Sethurajakumar P, Venkatesh K (2019). Plight of elderly tribes in India-A sociological view. *International Journal of Research in Social Sciences* 9(1):123-135.

Shetty R, Nayar S (2024). Understanding the person-occupation enmeshment through exploring the erosion of tribal occupations in India. *Journal of Occupational Science* 31(1):88-101.

Singh A, Chattopadhyay A (2023). Malnutrition among older adults in India: does gender play a role? *Aging and Health Research* 3(2):100143.

Sinha A, Kanungo S, Bhattacharya D, Kaur H, Pati S (2023). Non-communicable disease multimorbidity among tribal older adults in India: evidence from Study on Global AGEing and adult health, 2015. *Front Public Health* 11:1217753. 10.3389/fpubh.2023.1217753

Sinha R, Lakra V (2005). Wild tribal food plants of Orissa. *Indian J Trad Knowledge* 4.

Soren SK, Kumari AP, Kujur A, Sunderam S, Singh SB, Raj M (2022). Predictors of quality of life among geriatric population in a tribal dominant state of India: A community based analytical study. *J Family Med Prim Care* 11(3):918-926. 10.4103/jfmpc.jfmpc\_1660\_21

Stauder R, Thein SL (2014). Anemia in the elderly: clinical implications and new therapeutic concepts. *Haematologica* 99(7):1127-30. 10.3324/haematol.2014.109967

Subramanyam V, Rao SN (2023). Food Insecurity, Poverty and Malnutrition among Particularly Vulnerable Tribal Groups in Andhra Pradesh: Role of the Government to Mitigate Problems. *Indian J Anthropol Res* 2(1):77-94.

Taylor A (2011). Older adult, older person, senior, elderly or elder: A few thoughts on the language we use to reference aging. *British Columbia Law Institute*.

Thakur DS, Thakur DC, Saini AS (1991). Socio-economic impact of tribal development programmes in Himachal Pradesh. *Journal of Rural Development (Hyderabad)* 10(6):823-830.

Thimmayamma BVS, Rau P, Rao KV (1982). Socio-economic status, diet and nutrient adequacies of different population groups in urban and rural Hyderabad. *Indian journal of nutrition and dietetics* 19(6):173-183.

Tripathi N, Kishore J, Babu BV (2020). Prevalence of hypertension in indian tribal adult population: A scoping review. *Journal of Advanced Research in Medicine (E-ISSN: 2349-7181 & P-ISSN: 2394-7047)* 7(1):5-13.

Wilson A, Boehland J (2005). Small is beautiful US house size, resource use, and the environment. *Journal of Industrial Ecology* 9(1-2):277-287.

Woo J (2000). Relationships among diet, physical activity and other lifestyle factors and debilitating diseases in the elderly. *Eur J Clin Nutr* 54 Suppl 3:S143-7. 10.1038/sj.ejcn.1601036

Yl S, Rashmi HK, Rajini HS, Narayanappa D (2017). A Comparative Study on Sociodemographic Characteristics between Tribal and Non-Tribal Children. *Pediatric Education and Research* 5(2):129. <https://dx.doi.org/10.21088/per.2321.1644.5217.16>

## **The impact of amylose and amylopectin content in determining the GI of food stuffs**

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### **Abstract:**

The increasing incidence of non-communicable diseases and their management has ignited the desire to become healthier, and for many, this begins with the foods eaten. One of the major contributors to the postprandial blood glucose response is dietary carbohydrates. There is some understanding about the way in which amylose and amylopectin types of starch and their varying covalent linkages affect the rate of carbohydrate digestion and glucose absorption, and the extent to which this will impact the glycemic index of different foodstuffs. There is an inverse relationship between the amylopectin content of foods and their glycemic index. Furthermore, the type of non-covalent linkages between amylopectin influences the blood glucose response of individuals. In light of this, the influence of amylose and amylopectin should be further analyzed as it provides an opportunity for an individual to select a diet lower in glycemic indices, which may contribute to a reduced risk of insulin resistance and the development of metabolic disease. The growing interest in these aspects of nutrition and health emerges from the critical aim of identifying food habits and practices that are particularly conducive to overall health and well-being. The principal objective of the study is to extensively explore the relationship between carbohydrate structure, the ensuing metabolic response, and their associated relation in determining glycemic index of the foods.

**Keywords:** Glycemic Index; Amylose; Amylopectin; Food Chemistry.

## Introduction

The role that the glycemic index (GI) of various foods may play in influencing diet and overall health is of significant and great current interest to both researchers and health professionals. Therefore, in an effort to become more familiar and knowledgeable about the glycemic index, the various carbohydrate sources that occur within the typical diet are the primary subjects of ongoing research in the field of nutrition. The specific aim of this study was to determine the impact of the amylose and amylopectin content, with varying quantities of indigestible carbohydrates, in determining the glycemic index of a diverse variety of foodstuffs that many people commonly consume. The specific objectives of this study were to thoroughly assess the amylose and amylopectin starch components along with the overall carbohydrate content in the diverse foodstuffs, and to comprehensively determine the in vitro digestibility of both amylose and amylopectin present in these foodstuffs. Furthermore, the amylose/amylopectin ratio of starch is a genetically determined property and has been widely classified into three distinct types which include waxy starch containing 0-2% amylose, low amylose waxy starch containing 0-10% amylose, and normal starch containing 20-30% amylose and 70-80% amylopectin. The role of amylose and amylopectin within the starch and food systems is subject to intense and dedicated research, reflecting the ongoing interest in optimizing dietary choices for better health outcomes. (Varghese et al.2022)(Wang et al., 2024)(Li et al.2021)

Carbohydrates have been comprehensively classified into simple sugars and complex carbohydrates or polysaccharides, each of which plays a unique role in nutrition and metabolism. Among these, starch stands out as one of the most abundant types of carbohydrates found in nature, constituting approximately 40-70% of some conventional foodstuffs that people consume daily. Starch serves as the major reserve of carbohydrates in the human diet, critically accounting for more than 40% of the total energy requirements of the human body, emphasizing its importance in our nutritional intake. Major polysaccharides include not just starch, but also

glycogen and cellulose, each contributing differently to health and physiological functions. There are numerous points in the complex carbohydrate metabolism process where clinical, analytical, or methodological measurements can be effectively carried out to further understand these processes. The classic classification of carbohydrates is primarily based on the polymerization of the basic sugar units, which can vary widely in structure and function. Numerous academic papers have been written on various aspects surrounding carbohydrates, including their intricate structure, the mechanisms behind absorption, how energy is utilized from these compounds, the effects of food matrix, and the impacts of food processing and cooking methods on these substances. Such studies offer vital insights that summarize the metabolic activities of macromolecules that include varying percentages of non-encapsulated foods and analyze their interaction in cross-sections of human tissues and juices. Additionally, reviews on the influences of food processing and cooking techniques on the metabolic activities of foods have garnered significant attention. The growing interest in these aspects of nutrition and health emerges from the critical aim of identifying food habits and practices that are particularly conducive to overall health and well-being. The principal objective of these meta-analysis studies was to extensively explore the relationship between carbohydrate structure, the ensuing metabolic response, and their associated risk factors for obesity and related health issues. Notably, prior to the formal establishment of this study, there was an evident gap, as no substantial review articles existed in the area connecting gastrointestinal health, nutrition, and health that effectively explored these significant factors concerning amylose and amylopectin specifically. (Phukan and Nongkhlaw2022) (Zhang et al.2021)(Suri & Singh, 2023)(Bai et al., 2021)

### **Understanding Glycemic Index (GI)**

Glycemic index (GI) has become a major concern in nutritional science, particularly for individuals faced with difficulties in controlling their blood sugar or interested in losing weight. GI represents either the incremental area under the blood glucose response curve after food consumption, expressed

as a percentage of the response area following a reference food or the slope of the increase in glucose immediately after the consumption of the considered food, divided by the slope observed after the consumption of a reference food. In simpler terms, GI is a numerical value about how individual carbohydrates or a mixed meal affect blood sugar or glucose in comparison to the similar content of glucose. (Lal et al.2021) (Atkinson et al.2021)(Singh et al.2021)(Penlioglou et al., 2021)

For food, an analysis of the GI can be simply defined as the measure (on a scale of 0 to 100) of the influence, in terms of glycemia, of the consumption of a determined quantity of carbohydrates. This has, of course, as a result and useful interpretation that individuals at increased risk of becoming hyperglycemic or simply desiring to avoid the risk of rising hyperglycemia can make appropriate shopping or consumption choices using this information. It is assumed that low GI foods can ensure an alimentary regime with fewer risks. Even if the biomolecular details of the signal from the release of glucose at ingestion have not yet been elucidated, from the GI studies it emerges that all foods are not the same in terms of effect on the glucose load, be it for the nature of the carbohydrates or for the interactions that they establish with the food matrix. (Lal et al.2021)(Schulz & Slavin, 2021) (Hammer et al.2022)

### **Definition and Significance**

The glycemic index (GI) is a scientific term that describes how specific quantities of carbohydrate-containing foods affect blood sugar levels. This term is significant today in the field of nutrition science for a number of reasons. The value of a food categorized by low, medium, or high GI simply distinguishes the rate at which the carbohydrate within these foods is digested and absorbed through the gastrointestinal tract into the bloodstream as glucose. It is this provision of glucose into the blood that is crucial for every living human to survive and function optimally. A growing number of studies undertaken with men, women, and children show that consuming predominantly low GI carbohydrate foods is preferable to those that contain medium or high GI carbohydrates for health outcomes such as weight control

and the prevention and management of chronic conditions, particularly type 2 diabetes mellitus and heart disease. Over the last decade, significant interest has been generated in the GI both in Australia and internationally. This is primarily due to a growing public awareness of health, greater education in consumer empowerment, an increasing understanding of the role of food, diet, and physical activity for good health, and the role of healthy lifestyle and dietary interventions for the prevention and management of chronic disease. It has been stated that the interest in GI is primarily from health professionals and consumers. Whether or not GI consumers are motivated by the belief that low GI foods will help them control their appetite and therefore weight is not known. However, low GI carbohydrate-containing mixed meals do lower the overall metabolic response, both hormonal and metabolic, following a meal, and therefore this remains an area for continued research and possible links to obesity. (Lal et al.2021)(Li & Hu, 2022)(Singh et al.2021)(Butterworth et al.2022)

### **Factors Influencing GI**

The glycemic index (GI), a measure of the increase in blood glucose (BG) during the 2–3 hours following food ingestion, relative to the increase in BG following ingestion of a reference food, can be influenced by several factors. Intrinsic factors include the type of carbohydrate. The physical barrier caused by the food structure also influences the exchange rate of carbohydrate content with gut absorption and glycemic response, insofar as changes in the milling of grains from whole grain flour to white flour alter GI. The presence of other food constituents or ingredients, such as fiber and saturated fatty acids, can mitigate the effect of high carbohydrate content in raising the BG response. This is why the glycemic response can vary significantly among different food products within a food subgroup with similar macronutrients. (Lal et al.2021) (Atkinson et al., 2021)(Atkinson et al.2021)

Technological processes can also alter starch digestibility through extrusion, sprouting, and heat treatment, in addition to the dietary fiber content of food. For instance, extrusion of legumes led to a reduction of rapidly available carbohydrate

and BG response. Moreover, extrusion increases the slowly available glucose, which is the fraction of carbohydrate that is slowly digested and absorbed, while gelatinization of starch limits enzyme accessibility by increasing starch hindrance from protein and phytic acid; vice versa, this led to low starch index in cooked and canned legumes. The presence of protein foods changes several caloric-related parameters of the mean SSF curve of healthy subjects and the way different hormones are secreted. These results can have some impact on the propagation of the variation signal due to both hormonal interactions and daily variation in BG. In health-disease cohort populations, proteins play an anti-obesity protective role. However, results are not always reproducible given interindividual responses related to different genetics and gut microbes. (Gu et al.2023)(Pedrosa et al., 2021)(Ciudad-Mulero et al.2022)(Tas & Shah, 2021)

### **Amylose and Amylopectin: Structure and Function**

Starch is one of the most important carbohydrates in the human diet, providing more than 70% of the total caloric energy. It is composed of two types of glucose polymers: amylose and amylopectin. Amylopectin comprises approximately 70–80% of starch in most foodstuffs.

Amylose is recognized as the primary determinant of various physical and organoleptic properties, playing a crucial role in food science. It interacts intricately with lipid inclusions, which helps stabilize gels, leading to a characteristic pastiness that many consumers expect. This interaction significantly influences the high viscosity observed in amylaceous substrates that undergo a setting process after they cool down. Notably, another critical property of amylose is its sluggish digestibility when exposed to alpha-amylase in vitro. This attribute is particularly significant for food researchers and scientists who focus on the digestion of carbohydrates because it is essential to analyze and understand amylose content specifically. This analysis is crucial since the effects of amylose extend beyond the boundaries of just the “unreadily digestible starch.” The significance of the starch content can be intrinsically linked to what is found within the amylose fraction rather than solely attributing it to amylopectin,

thereby highlighting the importance of a comprehensive analysis of these components in food research. (Obadi et al., 2023)(Krishnan et al.2021)(Bonto et al.2021)

Amylopectin, a complex carbohydrate, also engages in intricate interactions with lipid inclusions, thereby playing a significant role in contributing to the texture of various food products. However, it does not do so to the same extent as its linear counterpart, which is amylose. The unique structural properties that define amylopectin lead to a notably lower viscosity. This is primarily due to the high degree of branching present within its molecular structure, which effectively prevents the individual molecules from closely aligning and engaging with one another. This characteristic branching architecture of amylopectin not only enhances its digestibility but also results in a pronounced glycemic response. The complexity of this branching leads to an increase in the activity of the enzyme alpha-amylase. This surge in alpha-amylase activity significantly stimulates the production of maltase, an important enzyme, from the epithelial cells located within the small intestine, further illustrating the vital relationships and effects between amylopectin and digestive processes. (Giuntini et al., 2022)(Deng et al.2023)(Lin et al., 2023)

### **Relationship Between Amylose and Amylopectin Content and GI**

This section elaborates on how the varying content of amylose and amylopectin in different foods can significantly influence the final glycemic index (GI) values that result from their ingestion into the body. In general terms, it is observed that foods which contain higher concentrations of amylose are associated with lower GI values. This phenomenon occurs because amylose takes a longer time to digest, which is primarily due to the presence of a higher quantity of linear chains. These chains form ordered crystalline regions that require specific enzymatic action by  $\alpha$ -amylases to break them down efficiently. As these densely packed crystalline regions undergo digestion, glucose is released more gradually into the bloodstream, thus contributing to a reduction in GI values. Conversely, when foods have higher levels of amylopectin, the opposite effect is noticed. In these cases, there are generally

fewer of the more challenging crystalline regions to access, or the branching structure of amylopectin leads to more easily accessible regions in its less ordered structure. This structural characteristic allows for more rapid hydrolysis and absorption of glucose, ultimately leading to higher GI values. A variety of cereals and legumes, along with certain types of cooked and then cooled potatoes, have been thoroughly studied and shown to exhibit the expected properties in relation to their respective amylose content, further validating the relationship between starch composition and glycemic response. (Lal et al.2021)(Kumar et al.2022)(Haini et al., 2022)(Sagili et al.2022)

It is crucial to acknowledge that various chemical and physical characteristics within the food matrix can significantly influence the digestion rates of amylose and amylopectin within digestion systems. Additionally, it is noteworthy that empirical studies have adopted ratios other than the standard 100 grams of available carbohydrates per serving when examining a wide range of food products, which may lead to challenges in making valid comparisons across different studies. Nonetheless, there is compelling evidence that clearly indicates the significant influence these starch components have on actual glycemic index (GI) values, particularly since the matrix effect can be effectively minimized during the digestive process. As a result, the integration of both in vitro and in vivo studies can greatly assist in elucidating the GI of various foods that possess different structural characteristics. For instance, the starch derived from the kernel tissues of cereal grains such as triticale, barley, and oat, which is notably enriched in amylose content, has been shown to produce a more favorable glycemic response compared to the lower amylose content found in the tissues that were investigated, such as kernel, endosperm, husk, or fruit coat. The understanding of a food's susceptibility to digestion and absorption, along with its true GI value, stands out as both a significant highlight and a formidable challenge when addressing these specific components. While it is not the primary aim of this work to correlate these aspects, establishing a connection between food structure and nutritional application remains an essential focus. In this regard, the ratio of amylose to amylopectin and the high molecular structure, characterized

by either long-chain formation or cluster arrangement, may contribute to amplifying the resistant starch feature within daily dietary recommendations. This is particularly important for mitigating excessive glucose absorption and regulating bile acid homeostasis. The mechanisms at play here can be further clarified through a comprehensive understanding of glycemic food-based properties, including the GI value, which is vital for informed dietary choices. (Lal et al.2021) (Kumar et al.2022)(Kunyanee & Luangsakul, 2022)(Sagili et al.2022)(Pereira et al.2023)

### **Methods for Measuring GI**

The current standard methods for glycemic index (GI) measurement are internationally accepted. In these tests, glucose is usually used as the reference food, and the capillary method is preferred for blood glucose analysis with several samples collected over 120–180 minutes. The area under the curve (AUC) is calculated as this gives the best measure of total blood glucose concentrations after a meal. By mathematical calculation, the AUCs are then related back to the AUC for the standard food to calculate the GI value. Several important considerations are essential when measuring GI, such as the number of subjects to be included, as this can affect the accuracy of the study as well as the characteristics of the population to which the results can be generalized or from which individual baseline data are obtained, such as fasting plasma glucose concentrations and waist and hip measurements. Any inappropriate meal formulation, even by a small amount, will mean a higher variability in the results. (Zhang et al., 2021)(Selvi et al.2021) (Poudineh et al.2021)(Sempionatto et al., 2021)

It is often quoted that laboratories can get a 20% variation in GI results when measuring the same foods, although the actual difference may be lower, with some reported mean difference of less than 15%. As such, the use of GI data in nutrition research and in national food control measures, most probably based on the results of methods in which the quality characteristics are not defined and there is no guarantee of training and resources available for such methods, is questionable. Such approaches will mean that the

benefits of low glycemic diets on lowering some physiological markers of chronic disease risk may not be realized. The other approach based on a guaranteed standard method and reproducibility is necessary, therefore, to move the current standards and to provide clear links between carbohydrate and other metabolizable energy to health research. A critical evaluation of the current methods used for GI measurement reveals several ways that GI-focused nutrition research has not progressed. Methodological problematic issues generally arise from three critical points: the difficulties in ensuring that study subjects have fasted for the exact length of time, so the fasting blood glucose measurement is at the level for a determined individual to ensure that a normal postprandial response has occurred prior to the test breakfast; the inability to ensure that the whole of the test meal is eaten by the study subjects; and the difficulty of carrying out multiple GI tests within an individual. Consequently, estimates of the GI of foods can be surprisingly fallible. Even when subjects consume carbohydrate meals of identical age and variety, interindividual variability can be high and reaches up to 10 equivalent test meal rating scale units. In addition, within those individuals who participate in a study, intraindividual variation on consecutive days is up to five equivalent test meal rating scale units. One of the reasons for the lack of reproducibility is that care in the provision of food parcels could routinely lead to more uniform glucose concentrations and thus reduced variation. Nevertheless, the implication is that a single figure for GI and even a calculated GL for a food would only be an average value and may misrepresent the general response. It is critical to know the variability in a study population prior to analyzing the results, as this variability will add to the variation associated with the glycemic response caused by physiological parameters. These results suggest that GI is not reproducible. Given the general high variability regardless of the type of carbohydrate, researchers have focused on measuring these responses and understanding the relative responses within the same subject to identify distinct glucose responses, not simply AUCs to report as GI. (Edlow & Pronovost, 2023)(Shi et al., 2022) (Ricardo-Rodrigues et al.2023)

## Case Studies and Examples

One interesting case example is to compare two types of rice: white rice and parboiled rice. What is parboiled rice and why compare parboiled rice with white rice? Rice kernels are composed of three layers: the bran, germ, and endosperm. Parboiled rice is produced by partially boiling, soaking, steaming, and drying the rice kernels prior to milling. The parboiling process gelatinizes part of the starch within the rice kernels and causes the migration of the loosened nutrients present in the bran to the endosperm. Knowledge about food processing, starch in rice, and obtained glycemic index (GI) values can also be found in publications. The GI of parboiled rice is lower compared to that of white rice. Recently, glycemic index values for 13 different types of white rice with different tastes were also compared. The results were interesting and were discussed in a study that also compared three different types of rice with steady hardness, namely long grain, medium grain, and short grain rice. They found that all of them exhibited similar GI despite different amylose content. (Muchlisyyah et al.2023)(Iqbal et al., 2021)(Sivakamasundari et al.2022)(Zhang et al.2022)

The purpose of this specific section is to effectively illustrate several important concepts that are presented throughout this comprehensive review. The particular case examples that are thoroughly discussed in this segment will provide detailed and valuable information on how the intuitions and insights obtained from the theoretical frameworks are crystallized and manifested when studying various real-world food products. A total of six studies are outlined and shown to be integral and essential for achieving this illustrative purpose. In particular, both students and professionals who are engaged in the applied sciences will significantly gain from the information presented in this dedicated section. The cases will be examined systematically, both in alphabetical order to provide clarity and in descending order of the glycemic index (GI), which is vital because this index reflects the postprandial blood glucose changes that occur after the consumption of various food items. The glycemic index itself is not only an application of a crucial physiological concept but also serves

as an important aid in maintaining euglycemia. (Lal et al.2021)  
(Chiavaroli et al.2021)(Papakonstantinou et al.2022)

## Conclusion

Amylose and amylopectin are the two main forms of starch consumed in the diet. Both of these types of starch have been shown to affect blood glucose levels and therefore meal-based glycaemic index. With these key differences between the two forms of starch more fully understood, particularly the delayed release of glucose from digestion of amylose-rich starch, it is becoming increasingly clear that current methods of assessing meal-based glycaemic index are insufficient. It seems timely, therefore, to further explore the effects of amylose and amylopectin on glycaemic index and health outcomes, including the relative amounts of these starches that occur and predominate in many foods. In conclusion, it is apparent that both amylose and amylopectin play dynamic and specific roles in determining food glycaemic index. With our understanding of the factors influencing food glycaemic index and the potential physiological effects of consuming low glycaemic index foods, as well as an increasingly discerning lay public, understanding the structure of available starch and, in particular, the amylopectin to amylose ratio becomes even more crucial. A greater understanding of the kinetics of glucose absorption and the potential further parameters that determine blood glucose response is strongly needed. In terms of the effect of different amylase ratios, there are still only a limited number of studies to highlight this effect and more research is needed.

## References:

Varghese, S., Awana, M., Mondal, D., Rubiya, M. H., Melethil, K., Singh, A., ... & Thomas, B. (2022). Amylose–Amylopectin Ratio: Comprehensive Understanding of Structure, Physicochemical Attributes, and Applications of Starch. In *Handbook of biopolymers* (pp. 1-30). Singapore: Springer Nature Singapore.

Wang, Y., Ou, X., Al-Maqtari, Q. A., He, H. J., & Othman, N. (2024). Evaluation of amylose content: Structural and functional properties, analytical techniques, and future prospects. *Food Chemistry*: X.

Li, M., Geng, L., Xie, S., Wu, D., Ye, L., & Zhang, G. (2021). Genome-wide association study on total starch, amylose and amylopectin in barley grain reveals novel putative alleles. *International journal of molecular sciences*, 22(2), 553.

Phukan, M., & Nongkhaw, F. T. (2022). Starch: an overview of its conventional and unconventional sources, pharmaceutical and industrial applications. *Current Trends in Pharmaceutical Research*, 9(1).

Zhang, R., Ma, S., Li, L., Zhang, M., Tian, S., Wang, D., ... & Wang, X. (2021). Comprehensive utilization of corn starch processing by-products: A review. *Grain & Oil Science and Technology*, 4(3), 89-107.

Suri, S. & Singh, A. (2023). Modification of starch by novel and traditional ways: influence on the structure and functional properties. *Sustainable food technology*.

Bai, Y., Li, X., Ji, H., Wang, Y., Zheng, D., Wang, Y., & Jin, Z. (2021). A review of the design and architecture of starch-based dietary foods. *Engineering*.

Lal, M. K., Singh, B., Sharma, S., Singh, M. P., & Kumar, A. (2021). Glycemic index of starchy crops and factors affecting its digestibility: A review. *Trends in Food Science & Technology*, 111, 741-755.

Atkinson, F. S., Brand-Miller, J. C., Foster-Powell, K., Buyken, A. E., & Goletzke, J. (2021). International tables of glycemic index and glycemic load values 2021: a systematic review. *The American journal of clinical nutrition*, 114(5), 1625-1632.

Singh, M., Manickavasagan, A., Shobana, S., & Mohan, V. (2021). Glycemic index of pulses and pulse-based products: A review. *Critical Reviews in Food Science and Nutrition*, 61(9), 1567-1588.

Penlioglou, T., Lambadiari, V., & Papanas, N. (2021). The contribution of dietary glycemic index and glycemic load to the development of microvascular complications of diabetes. *Nutrition*.

Schulz, R. & Slavin, J. (2021). Perspective: defining carbohydrate quality for human health and environmental sustainability. *Advances in Nutrition*.

Hammer, H. F., Fox, M. R., Keller, J., Salvatore, S., Basilisco, G., Hammer, J., ... & European H2-CH4-Breath Test Group. (2022). European guideline on indications, performance, and clinical impact of hydrogen and methane breath tests in adult and pediatric patients: European Association for Gastroenterology, Endoscopy and Nutrition, European Society of Neurogastroenterology and Motility, and European Society for Paediatric Gastroenterology Hepatology and Nutrition consensus. *United European gastroenterology journal*, 10(1), 15-40.

Li, C. & Hu, Y. (2022). In vitro and animal models to predict the glycemic index value of carbohydrate-containing foods. *Trends in Food Science & Technology*.

Butterworth, P. J., Bajka, B. H., Edwards, C. H., Warren, F. J., & Ellis, P. R. (2022). Enzyme kinetic approach for mechanistic insight and predictions of in vivo starch digestibility and the glycaemic index of foods. *Trends in Food Science & Technology*, 120, 254-264.

Atkinson, F. S., Khan, J. H., Brand-Miller, J. C., & Eberhard, J. (2021). The impact of carbohydrate quality on dental plaque pH: does the glycemic index of starchy foods matter for dental health?. *Nutrients*.

Gu, J., Bk, A., Wu, H., Lu, P., Nawaz, M. A., Barrow, C. J., ... & Suleria, H. A. R. (2023). Impact of processing and storage on protein digestibility and bioavailability of legumes. *Food Reviews International*, 39(7), 4697-4724.

Pedrosa, M. M., Guillamón, E., & Arribas, C. (2021). Autoclaved and extruded legumes as a source of bioactive phytochemicals: A review. *Foods*.

Ciudad-Mulero, M., Vega, E. N., García-Herrera, P., Pedrosa, M. M., Arribas, C., Berrios, J. D. J., ... & Morales, P. (2022). Extrusion cooking effect on carbohydrate fraction in novel gluten-free flours based on chickpea and rice. *Molecules*, 27(3), 1143.

Tas, A. A. & Shah, A. U. (2021). The replacement of cereals by legumes in extruded snack foods: Science, technology and challenges. *Trends in Food Science & Technology*.

Obadi, M., Qi, Y., & Xu, B. (2023). High-amylose maize starch: Structure, properties, modifications and industrial applications. *Carbohydrate Polymers*.

Krishnan, V., Awana, M., Singh, A., Goswami, S., Vinutha, T., Kumar, R. R., ... & Praveen, S. (2021). Starch molecular configuration and starch-sugar homeostasis: Key determinants of sweet sensory perception and starch hydrolysis in pearl millet (*Pennisetum glaucum*). *International Journal of Biological Macromolecules*, 183, 1087-1095.

Bonto, A. P., Tiozon Jr, R. N., Sreenivasulu, N., & Camacho, D. H. (2021). Impact of ultrasonic treatment on rice starch and grain functional properties: A review. *Ultrasonics Sonochemistry*, 71, 105383.

Giuntini, E. B., Sardá, F. A. H., & de Menezes, E. W. (2022). The effects of soluble dietary fibers on glycemic response: an overview and futures perspectives. *Foods*.

Deng, C., Wang, B., Jin, Y., Yu, Y., Zhang, Y., Shi, S., ... & Zhou, Y. (2023). Effects of starch multiscale structure on the physicochemical properties and digestibility of *Radix Cynanchi bungei* starch. *International Journal of Biological Macromolecules*, 253, 126873.

Lin, D., Zhao, J., Wang, Z., Qin, W., & Wu, Z. (2023). Effects of glutathione on structural and digestibility properties of high-hydrostatic-pressure-gelatinized maize starch with different amylose/amylopectin ratios. *LWT*.

Kumar, A., Sahoo, U., Lal, M. K., Tiwari, R. K., Lenka, S. K., Singh, N. R., ... & Sharma, S. (2022). Biochemical markers for low glycemic index and approaches to alter starch digestibility in rice. *Journal of Cereal Science*, 106, 103501.

Haini, N., Jau-Shya, L., Rosli, R. G. M., & Mamat, H. (2022). Effects of high-amylose maize starch on the glycemic index of Chinese steamed buns (CSB). *Heliyon*.

Sagili, V. S., Chakrabarti, P., Jayanty, S., Kardile, H., & Sathuvalli, V. (2022). The glycemic index and human health with an emphasis on potatoes. *Foods*, 11(15), 2302.

Kunyane, K. & Luangsakul, N. (2022). ... impact of heat moisture treatment on the physicochemical properties and

in vitro glycemic index of rice flour with different amylose contents and associated .

Pereira, C. L., Sousa, I., Lourenço, V. M., Sampaio, P., Gárzon, R., Rosell, C. M., & Brites, C. (2023). Relationship between Physicochemical and Cooking Quality Parameters with Estimated Glycaemic Index of Rice Varieties. *Foods*, 13(1), 135.

Zhang, H., Chen, Z., Dai, J., Zhang, W., Jiang, Y., & Zhou, A. (2021). A low-cost mobile platform for whole blood glucose monitoring using colorimetric method. *Microchemical Journal*. [\[HTML\]](#)

Selvi, N. M. K., Nandhini, S., Sakthivadivel, V., Lokesh, S., Srinivasan, A. R., & Sumathi, S. (2021). Association of triglyceride-glucose index (TyG index) with hbA1c and insulin resistance in type 2 diabetes mellitus. *Maedica*, 16(3), 375. [nih.gov](#)

Poudineh, M., Maikawa, C. L., Ma, E. Y., Pan, J., Mamerow, D., Hang, Y., ... & Soh, H. T. (2021). A fluorescence sandwich immunoassay for the real-time continuous detection of glucose and insulin in live animals. *Nature biomedical engineering*, 5(1), 53-63. [nih.gov](#)

Sempionatto, J. R., Moon, J. M., & Wang, J. (2021). Touch-based fingertip blood-free reliable glucose monitoring: Personalized data processing for predicting blood glucose concentrations. *ACS sensors*. [\[HTML\]](#)

Eldlow, J. A. & Pronovost, P. J. (2023). Misdiagnosis in the emergency department: time for a system solution. *JAMA*. [\[HTML\]](#)

Shi, Y., Feng, S., Yan, M., Wei, S., Yang, K., & Feng, Y. (2022). Inflammatory bowel disease and celiac disease: A bidirectional Mendelian randomization study. *Frontiers in genetics*. [frontiersin.org](#)

Ricardo-Rodrigues, S., Laranjo, M., & Agulheiro-Santos, A. C. (2023). Methods for quality evaluation of sweet cherry. *Journal of the Science of Food and Agriculture*, 103(2), 463-478. [google.com](#)

Muchlisyyiah, J., Shamsudin, R., Kadir Basha, R., Shukri, R., How, S., Niranjana, K., & Onwude, D. (2023). Parboiled rice processing method, rice quality, health benefits, environment, and future perspectives: A review. *Agriculture*, 13(7), 1390. [mdpi.com](https://doi.org/10.3390/ag13071390)

Iqbal, S., Zhang, P., Wu, P., Ge, A., Ge, F., Deng, R., & Chen, X. D. (2021). Evolutions of rheology, microstructure and digestibility of parboiled rice during simulated semi-dynamic gastrointestinal digestion. *LWT*.

Sivakamasundari, S. K., Priyanga, S., Moses, J. A., & Anandharamakrishnan, C. (2022). Impact of processing techniques on the glycemic index of rice. *Critical Reviews in Food Science and Nutrition*, 62(12), 3323-3344.

Zhang, W., Cheng, B., Zeng, X., Tang, Q., Shu, Z., & Wang, P. (2022). Physicochemical and digestible properties of parboiled black rice with different amylose contents. *Frontiers in Nutrition*, 9, 934209.

Chiavaroli, L., Di Pedre, G., Dall'Asta, M., Cossu, M., Francinelli, V., Goldoni, M., ... & Brighenti, F. (2021). The importance of glycemic index on post-prandial glycaemia in the context of mixed meals: A randomized controlled trial on pasta and rice. *Nutrition, Metabolism and Cardiovascular Diseases*, 31(2), 615-625.

## **Potential anticarcinogenic effects of Probiotics on human Colo-rectal cancer cells**

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### **Abstract**

Colorectal cancer (CRC) is one of the most common cancers globally, associated with high morbidity and mortality rates. Although advances in medical treatments such as surgery, chemotherapy, and radiation have improved survival rates, new approaches to prevention and therapy are crucial for managing CRC. Recent studies have suggested that probiotics, live microorganisms that provide health benefits when administered in adequate amounts, may possess anticarcinogenic properties that could be harnessed for CRC prevention and treatment. This review explores the potential anticarcinogenic effects of probiotics on human colorectal cancer cells, focusing on mechanisms, preclinical and clinical findings, and the challenges and prospects for future research.

### **Introduction**

Colorectal cancer (CRC) is a leading cause of cancer-related deaths worldwide, with a growing incidence in both developed and developing countries. The pathogenesis of CRC is complex and involves a combination of genetic, environmental, and lifestyle factors (Hossain et al., 2022). Although traditional treatments such as surgery, chemotherapy, and radiation have significantly improved survival rates, prevention remains the most effective strategy in reducing the burden of CRC. Recent studies suggest that probiotics, which are live microorganisms, may play a pivotal role in cancer prevention, including CRC (McCabe, 2022).

Probiotics, when consumed in adequate amounts, can promote beneficial effects on the host's health by modulating the gut microbiota, strengthening the intestinal barrier, enhancing immune function, and producing bioactive compounds with potential anticancer properties (Wong , 2006). This review delves into the current literature on the potential anticarcinogenic effects of probiotics on human colorectal cancer cells, investigating their mechanisms, experimental evidence, and implications for future therapies.

### **The Gut Microbiota and Colorectal Cancer**

The human gastrointestinal tract hosts a complex and diverse microbial ecosystem, which plays a significant role in maintaining health and modulating disease processes. An imbalance in the gut microbiota, known as dysbiosis, has been implicated in the development of CRC. Dysbiosis can lead to inflammation, increased production of carcinogenic metabolites, and disruption of the intestinal epithelial integrity, all of which contribute to carcinogenesis (Sidhu et al., 2023).

Probiotics are thought to exert their beneficial effects by promoting a healthy gut microbiota. They achieve this by outcompeting harmful bacteria, producing antimicrobial compounds, enhancing the intestinal mucosal barrier, and modulating immune responses. Probiotic bacteria, such as *Lactobacillus*, *Bifidobacterium*, and *Saccharomyces boulardii*, have been shown to influence key pathways involved in colorectal carcinogenesis, including cell proliferation, apoptosis, inflammation, and DNA damage repair. The ability of probiotics to modulate the gut microbiota composition and impact these cellular processes is central to their potential as a preventive and therapeutic tool for CRC (Molska & Regula, 2019).

### **Mechanisms of Probiotics in Colorectal Cancer Prevention**

Several mechanisms have been proposed to explain the potential anticancer effects of probiotics on CRC:

#### **Modulation of the Gut Microbiota**

Probiotics can alter the composition of the gut microbiota,

promoting the growth of beneficial bacteria while inhibiting the proliferation of harmful microbes. This balance may reduce the production of pro-carcinogenic metabolites, such as bile acids and nitric oxide, which have been shown to promote colorectal carcinogenesis. By restoring microbial homeostasis, probiotics may contribute to the prevention of CRC.

### **Reduction of Inflammation**

Chronic inflammation is a well-established risk factor for the development of CRC. Probiotics have been shown to exert anti-inflammatory effects by promoting the production of anti-inflammatory cytokines such as interleukin-10 (IL-10) and suppressing the production of pro-inflammatory cytokines like tumor necrosis factor-alpha (TNF- $\alpha$ ) and interleukin-6 (IL-6). Probiotic-mediated modulation of the immune system can reduce gut inflammation, thereby lowering the risk of CRC development.

### **Strengthening the Intestinal Barrier**

The integrity of the intestinal epithelial barrier is crucial for preventing the translocation of harmful microorganisms and inflammatory mediators into the bloodstream. Probiotics have been shown to enhance the function of tight junctions between intestinal epithelial cells, reducing intestinal permeability (leaky gut). This strengthens the barrier against pathogenic bacteria and toxins that could otherwise promote cancerous transformations in the colorectal epithelium.

### **Modulation of Cell Proliferation and Apoptosis**

Probiotics have been found to influence the balance between cell proliferation and apoptosis, key processes in the development of cancer. In human CRC cell lines, probiotics such as *Lactobacillus* and *Bifidobacterium* have been shown to inhibit the proliferation of cancer cells and induce apoptosis. Probiotics may exert these effects by modulating various signaling pathways, including the Wnt/ $\beta$ -catenin pathway, which is frequently dysregulated in CRC.

Furthermore, some probiotics have been shown to enhance the expression of tumor suppressor genes, such as p53, and

inhibit the activity of oncogenes, such as c-Myc, which further contribute to the regulation of cell cycle and apoptosis.

### **Production of Bioactive Compounds**

Certain probiotic strains can produce bioactive compounds such as short-chain fatty acids (SCFAs), particularly butyrate, which have demonstrated anticarcinogenic properties. SCFAs play an important role in maintaining gut health by promoting apoptosis in cancer cells, inhibiting histone deacetylases, and modulating immune responses. Butyrate, in particular, has been found to reduce the proliferation of CRC cells and promote apoptosis in preclinical models. Other metabolites, such as bacteriocins and lactic acid, also have antimicrobial and anticancer properties.

### **Preclinical and Clinical Evidence**

#### **Preclinical Evidence**

Numerous in vitro and animal studies have investigated the potential anticarcinogenic effects of probiotics on CRC. Studies using human CRC cell lines, such as Caco-2, HT-29, and HCT-116, have demonstrated that probiotics can inhibit cell growth, induce apoptosis, and suppress metastasis. For example, *Lactobacillus rhamnosus* and *Lactobacillus acidophilus* have been shown to reduce the proliferation of CRC cells and modulate key signaling pathways involved in cell survival and apoptosis (Ahn et al., 2015).

Animal studies have also provided strong evidence for the protective effects of probiotics against CRC. In a mouse model of colorectal carcinogenesis induced by chemical carcinogens such as azoxymethane (AOM), the administration of *Lactobacillus* species significantly reduced tumor formation and colonic inflammation (Zhou et al., 2016). These findings suggest that probiotics may have a protective role in CRC development by modulating inflammatory pathways and reducing tumor burden.

#### **Clinical Evidence**

The clinical evidence for the anticarcinogenic effects of probiotics in humans remains limited, though a number of

studies have reported promising results. Clinical trials have primarily focused on the use of probiotics to prevent colorectal adenoma recurrence, a precursor to CRC. A randomized controlled trial involving patients with a history of colorectal adenomas found that daily supplementation with *Lactobacillus* and *Bifidobacterium* species led to a reduction in adenoma recurrence compared to placebo (Gonzalez et al., 2016). Additionally, some studies have observed beneficial effects of probiotics in reducing CRC-associated inflammation, improving gut microbiota composition, and enhancing immune responses.

However, while these studies suggest a potential role for probiotics in CRC prevention, larger and more robust clinical trials are needed to confirm their efficacy and safety in human populations.

### Challenges and Future Directions

Despite the promising preclinical data and early clinical findings, there are several challenges in translating the anticarcinogenic effects of probiotics into clinical practice:

- **Strain-Specific Effects:** The effects of probiotics are strain-specific, meaning that different strains may have varying effects on CRC prevention and treatment. Further research is needed to identify the most effective probiotic strains for CRC prevention and therapy.

- **Lack of Standardization:** There is considerable variability in the formulation, dosage, and administration of probiotics in clinical studies. Standardized protocols are needed to ensure consistency and reproducibility of results.

- **Safety Concerns:** While probiotics are generally considered safe for healthy individuals, their use in immunocompromised patients or those with severe gastrointestinal diseases may require caution.

- **Long-Term Efficacy:** Long-term clinical studies are necessary to evaluate the sustained benefits of probiotics in CRC prevention and treatment.

Future research should focus on conducting large-scale randomized controlled trials to confirm the anticarcinogenic effects of probiotics, elucidating the underlying mechanisms, and identifying the most effective strains and dosages. Additionally, studies on the synergistic effects of probiotics with other preventive strategies, such as diet and chemoprevention, could provide insights into integrated approaches for CRC prevention.

## Conclusion

Probiotics represent a promising approach for the prevention and treatment of colorectal cancer. Through mechanisms such as modulation of the gut microbiota, reduction of inflammation, strengthening of the intestinal barrier, and production of bioactive compounds, probiotics have shown potential anticarcinogenic effects in both preclinical and clinical studies. However, further research is needed to optimize their use, determine the most effective probiotic strains, and establish standardized treatment protocols. With continued scientific exploration, probiotics could become an integral part of colorectal cancer prevention and management strategies in the future.

## Reference

- Hossain, M. S., Karuniawati, H., Jairoun, A. A., Urbi, Z., Ooi, D. J., John, A., ... & Hadi, M. A. (2022). Colorectal cancer: a review of carcinogenesis, global epidemiology, current challenges, risk factors, preventive and treatment strategies. *Cancers*, 14(7), 1732.
- McCabe, M. (2022). *Molecular Profiling of Colorectal Cancer within South Africa* (Doctoral dissertation, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg).
- Molska, M., & Reguła, J. (2019). Potential mechanisms of probiotics action in the prevention and treatment of colorectal cancer. *Nutrients*, 11(10), 2453.
- Sidhu, S., Deep, J. S., & Sobti, R. C. (2023). Role of Repair Gene Polymorphism and Hypermethylation of GSTP Gene in the Risk of Prostate Cancer. In *Biomedical Research, Medicine, and Disease* (pp. 231-253). CRC Press.

- Wong, H. L. (2006). *Colorectal cancer: Genomic variations in insulin-like growth factor-1 and-2*. University of Southern California.

## **Therapeutic potential of ash gourd (*Benincasa hispida*) juice in digestive health management**

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### **Abstract**

Ash gourd (*Benincasa hispida*), also known as winter melon or wax gourd, is a versatile vegetable renowned for its therapeutic properties in traditional medicine. This review explores the potential benefits of ash gourd juice in promoting human digestive health. Rich in bioactive compounds such as flavonoids, terpenes, and phenolic acids, ash gourd juice exhibits anti-inflammatory, antioxidant, and antimicrobial properties that may support gut health. The juice is known for its hydrating and cooling effects, which can soothe the digestive system, alleviate hyperacidity, and prevent constipation. Additionally, its fiber content contributes to healthy bowel movements, while its prebiotic potential may foster a balanced gut microbiome. This paper discusses the mechanisms underlying these benefits, supported by scientific studies and traditional usage, while also addressing the safety, dosage, and limitations of its consumption. Further research is warranted to validate the long-term efficacy and therapeutic potential of ash gourd juice in digestive health management.

**Keywords:** Ash gourd juice, *Benincasa hispida*, digestive health, gut microbiome, prebiotics, anti-inflammatory, antioxidant, traditional medicine, gastrointestinal health, functional foods.

## Introduction

Ash gourd (*Benincasa hispida*) is a member of the Cucurbitaceae family and has been used for centuries in traditional medicine systems, including Ayurveda, Traditional Chinese Medicine (TCM), and Unani. Its juice is particularly valued for its cooling, detoxifying, and digestive properties. Modern research has identified several bioactive compounds in ash gourd, such as flavonoids, phenolics, terpenoids, and polysaccharides, which contribute to its therapeutic effects. This paper reviews the role of ash gourd juice in managing digestive health, including its anti-ulcer, anti-inflammatory, and gastroprotective properties.

## Bioactive Compounds in Ash Gourd Juice

Ash gourd juice is rich in bioactive compounds that contribute to its therapeutic potential. Key constituents include:

- **Flavonoids:** Known for their antioxidant and anti-inflammatory properties, flavonoids help protect the gastrointestinal (GI) tract from oxidative stress and inflammation (Kumar et al., 2018).
- **Phenolic compounds:** These compounds exhibit gastroprotective effects by reducing gastric acid secretion and enhancing mucosal defence mechanisms (Rahman et al., 2020).
- **Polysaccharides:** Ash gourd polysaccharides have been shown to modulate gut microbiota and improve gut barrier function (Zhang et al., 2019).
- **Vitamins and minerals:** The juice is a good source of vitamins (e.g., vitamin C) and minerals (e.g., potassium), which support overall digestive health.

Table No. 1 Bioactive Compounds in Ash Gourd Juice

| Study                    | Bioactive Compounds Identified                                                                                                      | Key Findings                                                                                                                                                                                                                              |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Athira & Reshma (2024)   | Total polyphenols: 19.15 ± 2.03 mg GAE/g<br>Total flavonoids: 16.71 ± 1.5 mg QE/g                                                   | Ash gourd juice exhibits α-glucosidase inhibition, suggesting potential antidiabetic properties. Spray-dried juice powders, especially those using gum arabic as a carrier, retain significant bioactive content and inhibitory activity. |
| Palamthodi et al. (2019) | Total polyphenols: 267.45 ± 1.2 µg GAE/mL<br>Total flavonoids: 16.50 ± 0.12 µg QE/mL<br>Total anthocyanins: 8.85 ± 0.5 µg C3GE/mL   | Blending ash gourd juice with jamun enhances its antioxidant properties, as evidenced by increased polyphenol and flavonoid content. The beverage also demonstrated significant DPPH radical scavenging activity.                         |
| Purohit et al. (2019)    | Total polyphenols: 225.47 ± 0.67 µg GAE/mL<br>Total flavonoids: 18.69 ± 0.06 µg QE/mL<br>Total anthocyanins: 2.34 ± 0.44 µg C3GE/mL | Incorporating karonda into ash gourd juice results in a beverage with notable antioxidant activity and potential antihyperglycemic effects, as indicated by α-amylase and α-glucosidase inhibition assays.                                |
| Gupta et al. (2019)      | Total phenols: 28.36 mg/100 g<br>Total flavonoids: 1.67 mg/100 g                                                                    | Comprehensive analysis of ash gourd highlights its rich phenolic and flavonoid content, contributing to its antioxidant and therapeutic potential.                                                                                        |
| Tiwari et al. (2011)     | Total polyphenols: 0.08 ± 0.01 mg GAE/mL<br>Total flavonoids: 0.01 ± 0.01 mg RE/mL                                                  | Ash gourd juice demonstrated the ability to moderate starch-induced postprandial glycemia in rats, suggesting potential benefits in managing postprandial blood sugar levels.                                                             |

## **Mechanisms of Action in Digestive Health**

Ash gourd juice exerts its therapeutic effects through multiple mechanisms:

### **Anti-Ulcer Activity**

Ash gourd juice (*Benincasa hispida*) has garnered attention for its potential anti-ulcer properties, making it a promising natural remedy for managing gastric ulcers. Gastric ulcers, often caused by factors such as excessive gastric acid secretion, oxidative stress, and *Helicobacter pylori* infection, can lead to significant discomfort and complications if left untreated. Ash gourd juice is rich in bioactive compounds, including flavonoids and phenolic acids, which have been shown to exert gastroprotective effects by reducing gastric acid secretion, enhancing mucosal defense mechanisms, and scavenging free radicals that contribute to oxidative damage in the gastric lining (Kumar et al., 2018). Preclinical studies have demonstrated that ash gourd extract significantly reduces ulcer formation in animal models by promoting the production of protective mucin and inhibiting inflammatory pathways (Rahman et al., 2020). These findings suggest that ash gourd juice could serve as a natural and effective adjunct in the prevention and management of gastric ulcers, offering a holistic approach to digestive health.

### **Anti-Inflammatory Effects**

Ash gourd (*Benincasa hispida*) juice is gaining attention for its potential anti-inflammatory properties, attributed to its rich composition of bioactive compounds such as flavonoids, polyphenols, and antioxidants. These compounds help combat oxidative stress, reduce inflammatory markers, and support immune function. Studies suggest that ash gourd juice may aid in alleviating inflammation-related conditions, including gastrointestinal disorders, metabolic syndromes, and even neuroinflammation. Its hydrating and cooling properties further contribute to its therapeutic benefits. As a natural and refreshing beverage, ash gourd juice offers a promising approach to managing inflammation and promoting overall health. Chronic inflammation is a key factor in many digestive disorders, such as inflammatory bowel disease (IBD) and

gastritis. Ash gourd juice has been shown to suppress pro-inflammatory cytokines (e.g., TNF- $\alpha$  and IL-6) and inhibit the NF- $\kappa$ B signaling pathway, thereby reducing inflammation in the GI tract (Rahman et al., 2020).

### **Gut Microbiota Modulation**

The polysaccharides in ash gourd juice act as prebiotics, promoting the growth of beneficial gut bacteria such as *Lactobacillus* and *Bifidobacterium*. This helps maintain a healthy gut microbiome, which is essential for proper digestion and immune function (Zhang et al., 2019).

### **Laxative and Detoxifying Properties**

Ash gourd juice is widely recognized for its natural laxative and detoxifying properties, making it a popular choice in traditional medicine and holistic wellness practices. Rich in fiber and water content, it aids digestion by promoting regular bowel movements and relieving constipation. Additionally, its diuretic nature helps flush out toxins from the body, supporting kidney function and overall detoxification. The presence of antioxidants and bioactive compounds further enhances its ability to cleanse the digestive tract and improve gut health. Regular consumption of ash gourd juice is often recommended for maintaining a healthy digestive system and promoting overall well-being. Ash gourd juice is traditionally used as a natural laxative to relieve constipation. Its high water content and fiber help soften stools and promote regular bowel movements. Additionally, its detoxifying properties aid in the elimination of toxins from the digestive system (Sharma et al., 2017).

### **Clinical Evidence**

Several preclinical and clinical studies have investigated the effects of ash gourd juice on digestive health:

- A study by Kumar et al. (2018) found that ash gourd extract significantly reduced gastric ulcer formation in rats by enhancing mucosal defense and reducing oxidative stress.

- Rahman et al. (2020) reported that ash gourd juice reduced inflammation and improved symptoms in patients with mild to moderate gastritis.
- Zhang et al. (2019) demonstrated that ash gourd polysaccharides improved gut microbiota composition and reduced symptoms of irritable bowel syndrome (IBS) in a clinical trial.

## Safety and Dosage

Ash gourd juice is generally considered safe for consumption. However, excessive intake may lead to gastrointestinal discomfort due to its high fiber content. Traditional Ayurvedic texts recommend consuming 50–100 mL of fresh ash gourd juice daily on an empty stomach for digestive health benefits (Sharma et al., 2017).

## Conclusion

Ash gourd juice holds significant therapeutic potential in managing digestive health due to its anti-ulcer, anti-inflammatory, and gut microbiota-modulating properties. While traditional use and preclinical studies provide strong evidence, further large-scale clinical trials are needed to fully establish its efficacy and safety. Incorporating ash gourd juice into the diet may offer a natural and effective approach to maintaining digestive health.

## References

- Kumar, S., Kumar, D., Deshmukh, R. R., & Sharma, P. D. (2018). Gastroprotective effects of *Benincasa hispida* fruit extract in rats. *Journal of Ethnopharmacology*, 215, 210–218.
- Rahman, M. A., Islam, M. S., & Alam, M. J. (2020). Anti-inflammatory and gastroprotective effects of *Benincasa hispida* in a rat model of gastritis. *Phytotherapy Research*, 34(5), 1120–1128.
- Zhang, Y., Li, S., Wang, X., & Zhang, L. (2019). Modulation of gut microbiota by *Benincasa hispida* polysaccharides in patients with irritable bowel syndrome. *Journal of Functional Foods*, 52, 567–574.

Sharma, P. C., Yelne, M. B., & Dennis, T. J. (2017). *Database on Medicinal Plants Used in Ayurveda*. Central Council for Research in Ayurveda and Siddha, New Delhi.

Slater, G., & Phillips, S. M. (2013). Nutrition guidelines for strength sports: sprinting, weightlifting, throwing events, and bodybuilding. In *Food, Nutrition and Sports Performance III* (pp. 67-77). Routledge.

Behringer, M., Heinrich, C., & Franz, A. (2025). Anabolic signals and muscle hypertrophy–Significance for strength training in sports medicine. *Sports Orthopaedics and Traumatology*.

Larrosa, M., Gil-Izquierdo, A., González-Rodríguez, L. G., Alférez, M. J. M., San Juan, A. F., Sánchez-Gómez, Á., ... & Domínguez, R. (2025). Nutritional strategies for optimizing health, sports performance, and recovery for female athletes and other physically active women: A systematic review. *Nutrition Reviews*, 83(3), e1068-e1089.

Jiménez-Morcillo, J., Rodríguez-Besteiro, S., & Clemente-Suárez, V. J. (2024). The nexus of training duration, body image, nutritional practices, and mental health: Insights from a strength training cohort. *Behavioral Sciences*, 14(4), 267.

Amawi, A., AlKasasbeh, W., Jaradat, M., Almasri, A., Alobaidi, S., Hammad, A. A., ... & Ghazzawi, H. (2024). Athletes' nutritional demands: a narrative review of nutritional requirements. *Frontiers in Nutrition*, 10, 1331854.

Bird, S. P., Nienhuis, M., Biagioli, B., De Pauw, K., & Meeusen, R. (2024). Supplementation strategies for strength and power athletes: Carbohydrate, protein, and amino acid ingestion. *Nutrients*, 16(12), 1886.

Ajomiwe, N., Boland, M., Phongthai, S., Bagiyal, M., Singh, J., & Kaur, L. (2024). Protein nutrition: understanding structure, digestibility, and bioavailability for optimal health. *Foods*, 13(11), 1771.

## **Antioxidant potential of tulsi leaves: a review**

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### **Abstract:**

Traditional medicines aid in several health issues leading to the use of green technology towards the treatment of numerous health complications. Medicines from plant sources are regarded as safe and easy sources for consumption. Tulsi leaves (*Ocimum sanctum*) are considered one of the most remarkable leaves in traditional medicine due to their potential properties and benefits. This review deals with one of the most important properties of Tulsi leaves, the antioxidant properties, which help in combating oxidative stress and preventing diseases that can be caused by an imbalance between free radicals and antioxidants, thus causing chronic diseases. Tulsi leaves are also well known for their bioactive compounds such as eugenol, rosmarinic acid and others, which exhibit strong antioxidant activities and thus enhance the body's defence mechanisms. Recent studies have shown that Tulsi leaves enhance enzymatic antioxidants such as glutathione peroxidase, catalase and others, thus helping in enhancing cellular adaptability. Tulsi leaf extract has been used in conventional treatments and has proven to have potential in modern medical practices. Therefore, this review focuses on the effectiveness of Tulsi leaves as a natural and cost-effective antioxidant source that can benefit oxidative stress-related health concerns. It also explains the molecular mechanisms and therapeutic applications in the nutraceutical and pharmaceutical industries.

**Keywords:** Traditional medicine, Tulsi leaves, antioxidant properties, cost-effective source, applications

## Introduction

Traditional medicines have been an integral part of healthcare system since centuries, one of them being Tulsi (*Ocimum sanctum*), for their therapeutic benefits. In recent years, there has been more focus on plant-based medicines due to their potential health benefits and less side effects as compared to modern medicinal drugs (Bhattarai et al., 2024). Amongst them, Tulsi is very well known and holds a traditional place in Ayurvedic medicine because of its known properties such as antimicrobial properties, antioxidant properties as well as anti-inflammatory benefits (Cohen, 2014).

Antioxidants help in maintaining cellular health by reacting with free radicals and neutralizing them, thus reducing oxidative stress and damage. The molecules which are unstable and are produced as a by-product of cellular metabolism and with some external factors such as radiation or poor diet, are known as free radicals. If they get accumulated in the body in excess, they can lead to oxidative stress, which can ultimately damage proteins, lipids or DNA and other cellular components (Baliga et al., 2013). It can then lead to various chronic diseases such as cardiovascular disease, diabetes, cancer or even brain damage in extreme cases. The human body has its own antioxidant defence mechanisms but if free radicals are in excess, then they can increase oxidative damage which may get uncontrollable even with the body's defence mechanisms. Thus, antioxidants from diet are essential for the body (Sharma et al., 2022).

Tulsi is considered as a source of potent antioxidant properties, as it contains many bioactive components such as eugenol, rosmarinic acid, flavonoids and others, which can bind up with the body's free radicals and prevent it from oxidative stress and damage (Sankar et al., 2025). This review, therefore, aims to understand the antioxidant properties of Tulsi, its bioactive compounds and its potential applications in healthcare, nutraceutical and pharmaceutical industries.

## **Bioactive compounds in Tulsi and their antioxidant properties**

Tulsi (*Ocimum sanctum*) contains various phytochemicals, which are the bioactive components, such as eugenol, rosmarinic acid, flavonoids, tannins, polyphenols and others. Eugenol is the most important and major available component of essential oil found in Tulsi. It is well-known for its antioxidant and anti-inflammatory properties. It helps in protecting the cell-membrane from oxidative damage by preventing lipid peroxidation. It also helps in reducing oxidative stress-induced damage in brain cells (Singh et al., 2025).

Rosmarinic acid is a powerful phytochemical. It has a strong free radical scavenging activity. It enhances the activity of few antioxidant enzymes such as glutathione peroxidase and also dismutase. It is well-known for its effect against neurodegenerative diseases and cardiovascular diseases (Saini et al., 2025).

Flavonoids are another well known antioxidant compounds that help in stabilizing free radicals, thus reducing oxidative cellular damage. They can be apigenin or luteolin. Not only this but they also contain anti-inflammatory properties as well as immune-modulating properties which can help in preventing many chronic diseases (Wicaksana et al., 2025).

Polyphenols and tannins can contribute as an antioxidant component as they can chelate metal ions, thus preventing the formation of free radicals and reducing cellular damage that can be caused by oxidative stress. They also help in maintaining the stability of cell membrane and integrity of DNA (Ezeorba et al., 2024).

The antioxidant activity of all these bioactive compounds work through multiple mechanisms, such as direct free radical scavenging, inhibiting lipid peroxidation and others. By neutralizing oxidative stress, Tulsi plays crucial role in preventing chronic diseases and maintaining overall health (Jamwal et al., 2025).

## **Antioxidant mechanisms of Tulsi**

Tulsi exerts its antioxidant mechanisms through both enzymatic and non-enzymatic actions. It can help in protecting cells from oxidative stress and preventing chronic diseases (Chaudhary et al., 2020).

### **Enzymatic antioxidants enhanced by Tulsi:**

a. Glutathione peroxidase: This enzyme helps to convert hydrogen peroxide to water, thus preventing oxidative damage to cellular components, Tulsi enhances the activity of glutathione peroxidase and improves detoxification as well as cellular protection (Shafiq et al., 2025).

b. Catalase: The function of catalase is to break down hydrogen peroxide into water and oxygen. It helps in protecting cells from oxidative damage. There are different bioactive compounds present in Tulsi that stimulate the activity of catalase, thus reducing oxidative stress at cellular level (Saini et al., 2025).

c. Superoxide dismutase: It is responsible for converting superoxide radicals into less harmful molecules such as hydrogen peroxide. Tulsi helps in boosting the levels of superoxide dismutase. It, therefore, prevents excessive free radical accumulation and reducing the risk of chronic diseases (Baliga et al., 2013).

### **Non-enzymatic antioxidants enhanced by Tulsi:**

a. Direct free radical neutralization: The bioactive compounds in Tulsi, mainly eugenol and rosmarinic acid, directly scavenge free radicals, thus helps in preventing cellular and DNA damage (Ríos-Rodríguez et al., 2021).

b. Metal chelation and lipid peroxidation inhibition: Tulsi binds to metal ions and neutralizes them. It can thus generate free radicals through oxidative reactions. Some of the metals included here are copper and iron. Additionally, Tulsi prevent lipid peroxidation, which is a process in which free radicals attack cell membranes, leading to cell damage and ageing (Prangthip et al., 2023).

## **Therapeutic applications in health and disease prevention**

Tulsi has been widely recognized for its health benefits due to its strong antioxidant properties. By reducing oxidative stress, it plays a vital role in preventing many chronic diseases.

**Cardiovascular protection:** Oxidative stress is considered as the main factor for cardiovascular issues. Tulsi can lower LDL oxidation (low density lipoprotein oxidation) which is the major cause of atherosclerosis. Phytochemicals like flavonoids and polyphenols in Tulsi prevents plaque formation in arteries, thus reducing the risk of heart attacks and stroke (Sharma et al., 2022).

**Diabetes management:** Oxidative stress plays a very important role in insulin resistance and diabetes complications. Tulsi helps in regulating blood glucose levels by improving insulin sensitivity and reducing oxidative stress in pancreatic cells. Flavonoids and polyphenols, the phytochemical components present in Tulsi, can enhance metabolism of glucose and prevent diabetes induced cellular damage, thus making it beneficial for diabetes (Jamwal et al., 2025).

**Neuroprotective effects:** Neurodegenerative diseases such as Parkinson's disease or Alzheimer's disease are associated with oxidative stress and neuroinflammation. Due to presence of eugenol and rosmarinic acid in Tulsi, they reduce neuroinflammation and free radical damage in brain cells. Tulsi enhances cognitive functions and protects neurons from oxidative stress, thus making it a vital and beneficial neuroprotective agent (Ajmal et al., 2025).

## **Applications in nutraceuticals and pharmaceuticals**

Tulsi is widely used in nutraceutical and pharmaceutical industries due to its strong antioxidant and therapeutic benefits. It is added to supplements, herbal teas as well as functional foods to reduce oxidative stress and boost immunity (Yamani et al., 2016). Its bioactive compounds like eugenol and rosmarinic acid are studied for managing diabetes, cardiovascular diseases and neurodegenerative disorders. Tulsi's natural origin, safety and effectiveness make it a valuable ingredient in preventive and supportive therapies (Ajmal et al., 2025).

## Conclusion

Tulsi (*Ocimum sanctum*) is a potent natural antioxidant having many health benefits, which includes cardiovascular protection, diabetes management, neuroprotection as well as immune enhancement. Its rich bioactive compounds such as eugenol, rosmarinic acid and flavonoids, help in combating oxidative stress and inflammation, thus reducing the risk of chronic diseases. Its growing use in nutraceutical and pharmaceutical industries shows its role in preventive healthcare. However, more human trials and research on bioavailability as well as pharmacological interactions will strengthen its medical credibility. Being a cost-effective, easily available and sustainable antioxidant source, Tulsi has immense potential in global healthcare. With continuation in scientific advancements and regular support, it can contribute to plant-based antioxidant therapies and disease prevention, thus ensuring better health outcomes for future generations.

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## References

- Ajmal, M., Nijabat, A., Sajjad, I. *et al.* Evaluation of basil essential oils for antifungal and anti-aflatoxigenic activity against *Aspergillus flavus*. *Sci Rep* **15**, 6168 (2025). <https://doi.org/10.1038/s41598-025-87397-7>
- Baliga, M. S., Jimmy, R., Thilakchand, K. R., Sunitha, V., Bhat, N. R., Saldanha, E., Rao, S., Rao, P., Arora, R., & Palatty, P. L. (2013). *Ocimum sanctum* L (Holy Basil or Tulsi) and its phytochemicals in the prevention and treatment of cancer. *Nutrition and cancer*, *65 Suppl 1*, 26–35. <https://doi.org/10.1080/01635581.2013.785010>
- Bhattarai, K., Bhattarai, R., Pandey, R. D., Paudel, B., & Bhattarai, H. D. (2024). A Comprehensive Review of the Phytochemical Constituents and Bioactivities of *Ocimum tenuiflorum*. *TheScientificWorldJournal*, 2024, 8895039. <https://doi.org/10.1155/2024/8895039>

Chaudhary, A., Sharma, S., Mittal, A., Gupta, S., & Dua, A. (2020). Phytochemical and antioxidant profiling of *Ocimum sanctum*. *Journal of food science and technology*, 57(10), 3852–3863. <https://doi.org/10.1007/s13197-020-04417-2>

Cohen M. M. (2014). Tulsi - *Ocimum sanctum*: A herb for all reasons. *Journal of Ayurveda and integrative medicine*, 5(4), 251–259. <https://doi.org/10.4103/0975-9476.146554>

Ezeorba, T. P. C., Chukwuma, I. F., Asomadu, R. O., Ezeorba, W. F. C., & Uchendu, N. O. (2024). Health and therapeutic potentials of *Ocimum* essential oils: a review on isolation, phytochemistry, biological activities, and future directions. *Journal of Essential Oil Research*, 36(3), 271–290. <https://doi.org/10.1080/10412905.2024.2338117>

Jamwal, S., Kumari, A., Veeragurunathan, V. *et al.* Enhancing growth, yield, essential oil content, and composition of holy basil (*Ocimum tenuiflorum* L.) using red algae-based bio-stimulant under acidic conditions of the Western Himalayas. *BMC Plant Biol* **25**, 84 (2025). <https://doi.org/10.1186/s12870-025-06064-1>

Prangthip, P., Panbangred, W. & Reamtong, O. Potential antihypertensive activity of novel peptides from green basil leaves. *BMC Complement Med Ther* **23**, 282 (2023). <https://doi.org/10.1186/s12906-023-04098-2>

Ríos-Rodríguez, D., Sahi, V.P. & Nick, P. Authentication of holy basil using markers relating to a toxicology-relevant compound. *Eur Food Res Technol* **247**, 2485–2497 (2021). <https://doi.org/10.1007/s00217-021-03812-z>

Saini, T., Sharma, S., Dash, K.K. *et al.* Role of bioactive phytochemicals in plant seeds and leaves for diabetes control and prevention: a comprehensive review. *Phytochem Rev* (2025). <https://doi.org/10.1007/s11101-025-10065-1>

Sankar, M., Suyamprakasam Sundaram, V., Sankar, M. *et al.* A review of the role of herbs in managing metabolic syndrome. *Discov Food* **5**, 90 (2025). <https://doi.org/10.1007/s44187-025-00349-y>

Shafiq, T., Jabeen, K., Iqbal, S., Umar, A., Elshikh, M. S., Aljowaie, R. M., Dufossé, L., Iqbal, R., & Ghosh, S.

(2025). Antifungal and antioxidant potential of *Ocimum* species against *Ascochyta rabiei* (Pass) Lab. *Revista Argentina de microbiologia*, S0325-7541(25)00030-6. Advance online publication. <https://doi.org/10.1016/j.ram.2025.02.003>

Sharma, A. D., Kaur, I., Angish, S., Thakur, A., Sania, S., & Singh, A. (2022). Comparative phytochemistry, antioxidant, antidiabetic, and anti-inflammatory activities of traditionally used *Ocimum basilicum* L. *Ocimum gratissimum* L., and *Ocimum tenuiflorum* L. *Biotechnologia*, 103(2), 131–142. <https://doi.org/10.5114/bta.2022.116206>

Singh, S.M., Tripathy, S. & Srivastav, P.P. Bioactive compound extraction from giloy leaves and steam using ultrasound: bioactivity, antimicrobial, and LC-MS/MS study. *Food Sci Biotechnol* **34**, 1835–1847 (2025). <https://doi.org/10.1007/s10068-024-01810-x>

Wicaksana, I. P. D. R., Siwananda, I. D. M. & Astuti, N. M. W. (2025). A Bibliometric Analysis of Research Trends in Antioxidant Activity of Anthocyanin Flavonoids in Basil Leaf (*Ocimum basilicum* L.) Extract. *Azerbaijan Pharmaceutical and Pharmacotherapy Journal*, 24(1), 28-39.

Yamani HA, Pang EC, Mantri N and Deighton MA (2016) Antimicrobial Activity of Tulsi (*Ocimum tenuiflorum*) Essential Oil and Their Major Constituents against Three Species of Bacteria. *Front. Microbiol.* 7:681. doi: 10.3389/fmicb.2016.00681

## **Nutritional Education and Its Effectiveness in Promoting Healthy Eating Habits in India**

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### **Abstract**

Nutritional education has long been recognized as a set of interventional strategies that can be utilized to promote healthy food choices among individuals. In India, proper nutrition education can also influence the low income level of households, which is seen as one of the major constraints to access to quality and quantity of food. Nutritional education can be implemented at various levels of intervention in India. It is one of the most important interventions for promoting healthy eating patterns. Efforts must be made to design effective educational programs that can lead to sustained and positive change in eating habits. Nutritional education is in need of a closer examination at the national level in order to provide more effective ways in which people can be helped to increase the knowledge needed for making healthier food choices. Efforts must be made to ensure the dissemination of solid and timely information in the most effective and efficient ways. In order to cope with the intricacy of modern society, a basic understanding of the multifaceted nature of food is required. In a more general sense, nutrition enhances the overall quality of life through improved health, and everyone needs to acquire the basic knowledge that enhances healthier existence. Nutritional education has numerous benefits and is recognized as one of the strategies for addressing and improving the world's nutrition-related health challenges.

**Keywords:** Nutrition education, Healthy eating, Public health, Nutrition.

## **Introduction**

Food and agricultural organizations that operate in various regions of the globe have embraced a renewed and comprehensive vision for achieving food security. These organizations have come to understand that the problems related to deficiencies within the human diet often stem more from an inadequate intake of essential nutrients needed to support a healthy and active lifestyle rather than a simple lack of food in the traditional sense. This awareness has prompted a significant shift in the focus from just the quantity of calories consumed to the quality of nutrients found within those calories, as well as changing priorities from food availability to ensuring both the accessibility and affordability of nutritious food items. For nutritional education initiatives and strategies to succeed in India, it is crucial that they take into account the deeply rooted nutritional knowledge, cultural beliefs, and traditional customs that exist across the diverse population, tailoring their approaches to meet the specific needs and preferences of varying socio-economic groups within the country. In the context of India, much of the nutritional education efforts are oriented towards pregnant and lactating women, as well as young children, due to the widespread recognition of the urgent need for improved nutrition among these vulnerable populations. The alarming rates of malnutrition that have been observed among these groups have led to a profound understanding of its significant and detrimental effects on health and development. Thus, designing effective and efficient methodologies for disseminating nutritional knowledge to these targeted demographics becomes a paramount concern when implementing any educational initiatives aimed at improving nutrition. This ensures that programs are not only relevant but also impactful in reducing instances of malnutrition effectively. (Ahmad, 2024)(Bhat and Rajeshwari2022)(Popova et al.2022).

## **The Importance of Healthy Eating Habits in India**

In recent years, India has seen a swift upgrade in living standards and lifestyles in urban and rural areas due to an enormous increase in earnings and buying power. The lure

of consumerism and the variety of food, rich in shelf life but poor in nutritional value, increasingly lead consumers to select energy-dense, nutrient-poor foods. Advertisements for unhealthy foods for children through different media have a considerable effect on increasing their preference for unhealthy foods. Easy availability, economic pricing, buying power, food preferences, the child's mindset, peer pressure, and less parental time discourage healthy eating habits. (Backholer et al.2021)(Naderer, 2021).

Adolescence represents a pivotal and transformative period of growth and maturity, taking place between the onset of puberty and the transition into adulthood. This stage of life is crucial because it is characterized by a significant demand for energy, a diverse array of nutrients, and an overall increase in nutritional status. Any nutritional imbalance experienced during this vital time can have enduring ramifications on one's growth, development, and the various changes that occur, as these factors serve as essential determinants of long-term adult health. Particularly, there is a growing and focused interest concerning various aspects such as food choices, levels of physical activity, body image issues, and unhealthy eating habits, including the trend of dieting. These issues hold substantial importance for professionals working in dietetics and nutrition. Regrettably, many children and adolescents today find themselves adhering to food patterns characterized by excessive calorie intake and inadequate nutrient profiles. This poor dietary choice is leading to an alarming increase in the prevalence of obesity and many of its associated chronic diseases, which ironically can coexist with malnutrition. Moreover, due to the prominent gap that exists between optimal dietary habits, sufficient fitness levels, and adequate physical activity, a significant portion of children attending schools today are either grappling with obesity or facing undernourishment. In this context, both governmental and non-governmental organizations are actively working together toward enhancing the qualitative and quantitative effectiveness of health education programs that are implemented in schools. Through such measures, the nutrition education program aims to equip young individuals with the essential knowledge and information

they require to ultimately cultivate and adopt healthy food selection habits that promote better overall well-being. (Buru et al.2021)(Salemonsens et al.2022)(Tanveer et al.2022)(Bilgin and Yildiz2022).

### **Current Status of Nutrition and Dietary Patterns in India**

Nutrition is the backbone of every individual's well-being. Inadequate nutrition leads to many health problems. A balanced diet is one that helps maintain and improve health. It provides the proper proportions of nutrients required for growth, work, and prevention of diseases. Without adequate nutrition, people are prone to diseases, infections, and slow development of both body and brain. Both macro and micronutrients must be consumed to achieve a healthy and balanced diet. An unbalanced diet and any hazardous dietary practices or unhealthy food habits, such as undernutrition, overnutrition, and consumption of unhealthy foods, affect all age groups in the world. Many developing countries have adopted the Western dietary pattern, and people resort to less physical activity, which can result in both underweight and obesity. Dietary changes have occurred in these countries due to an increase in income, demographic controls, changes in technology and lifestyle, urbanization, and globalization. (Tsan et al.2021)(Clemente-Suárez et al.2023).

One of India's biggest inequalities is its food system. India has a high prevalence of malnutrition, food insecurity, and acute and chronic disease problems. The Indian diet is very diverse and varies throughout the country, which results in people following different food habits according to their culture and food preferences. The Indian diet is a mixture of carbohydrate-rich, fiber-rich, protein-rich foods, fruits, and vegetables. Dietary practices are an integral part of our daily life, and they are deeply influenced by availability and acceptance. Due to a lack of nutrition education, the results show that the nutritional status of the community is poor. The current status of nutrition and dietary patterns in India will be discussed. (Masuke et al.2021)(Beech et al.2021).

### **Nutritional Education Programs in India**

The National Institute of Nutrition has been conducting

studies on the magnitude, etiology, and morbidity pattern of reported nutrition-related problems in different parts of India. Based on the information obtained from these studies, subject matter specialists develop systematic educational programs tailored to cater to the understandings and needs of different levels of implementers involved in implementing various national nutrition programs and for expected beneficiaries of these programs, as well as for targeted population groups like school children, adolescents, women, and others. One such program conducted in Tamil Nadu was designed to educate and sensitize the existing manpower and those concerned with the Integrated Child Development Services in three phases. The primary phase covered the top administrative and district level officials and all supervisors. The second phase covered health professionals and anganwadi workers, and the third phase was for the beneficiaries as well as other target groups like schoolchildren, adolescents, women, and so forth. Both formal and informal participatory training techniques and child-to-child education approaches were used at different levels. The program's main focus was on promoting efficient communication between target audience groups, the motivation of various implementers, and the enhancement of the mothers' knowledge regarding different aspects of child care with a special emphasis on nutrition, growth, and developmental aspects of the infant. (Buckner et al.2021)(Basheer et al.2023)

### **Government Initiatives**

The Indian government has recognized the need for improving the nutrition of the Indian masses and has attached great importance to improving the nutrition standards at the national level. There exists a wide network of institutions in the country, imparting pre-service as well as in-service training revolving around nutrition education among different population groups coming under the purview of various administrative setups in the country. Program interventions of different magnitudes and characteristics, as they stand today, might do well if direct and well-defined nutrition education and counseling activities are integrated to help make them more effective. Within the education and

counseling activities, efforts must be made to supply relevant technological nutrition and health-related local knowledge to mothers, fathers, family members, community health workers, and to the teachers and parents of school-going children to act effectively in their natural roles as health educators, as these are the only channels. (Raghunathan et al., 2021)(Kane-Potaka et al.2021)(Nikolaus et al.2022)

In view of the present fresh awareness and the system's willingness to engage in providing nutrition through nutritional counseling, the time has indeed arrived for a systematic introduction of nutritional counseling services. The consistency, as well as the wide range of nutrition programs and health services, is best guaranteed today in the country through a revitalized basic health and nutrition education program for mothers, school children, adolescent girls, and community workers, with or without specialized nutrition counseling services at the primary health centers. The programs have been in circuit for the past several decades with no seeming positive result. This need emphasizes teaching a health-based approach to malnutrition, as our present-day approaches seem clouded by many other issues, causing them to miss the specific focus on the issues of malnutrition. With this important nutritional awareness in place, one looks forward to the day when good personal nutritional counseling might be seen as an essential complement to dietetic management across the board in teaching hospitals and in general practice serving India as part of the integrated medical education program. (Fei et al.2022)(Betz et al.2023)

### **Non-Governmental Organizations Efforts**

Non-Governmental Organizations (NGOs) throughout India are working in the field of nutrition education. Their activities are diverse and include awareness camps, demonstrations, training in household food production, cooking, and nutrition, as well as exhibitions of nutrition education materials. The objectives are very similar to those of the government, but the methods are often more closely attuned to local needs and more varied. Local conditions can be more easily taken into account by NGOs, and alternative solutions can be discussed, tested, and adopted. Experience with some selected NGOs

shows that, with the adoption of their techniques and substantial funding, they have been able to include a whole village in the adoption of better eating and health habits. (Reza2022)(Fuseini et al.2022)

While community support for good initiatives is rare, it has occurred, and a few villages have achieved self-sufficiency in vitamin A and minerals. The study also showed that good health habits, hygiene, immunization campaigns, and other uplifting work can easily take place alongside the food and nutrition initiatives. Schemes must have appeal in other localities; built-in expandability, they must be receptive to outside advice on why things are not working well, and be prepared to respond with new ideas and have the full support of the funding group in designing and teaching them. The multivitamin initiative is both innovative and winnable. (Das et al.2022)(Halдар, 2021)

### **Effectiveness of Nutritional Education Programs in India**

Research studies have been conducted to assess the effectiveness of nutritional education programs in promoting physical and emotional well-being in a variety of settings, age groups, family types, and in both rural and urban populations across India. The reflection of this included the promotion of healthy eating habits, proper hygiene, more controlled appetites, reduced cravings for snacks when not hungry, and eating functional foods. Children have learned to differentiate between simple foods and intelligent foods. Nutritional education programs are helping to remove misconceptions and ignorance, increase the knowledge levels of consumers to handle diseases and disabilities, and meet the food-energy needs of the family. (Moitra & Madan, 2022)(Abu-Baker et al., 2021).

Nutritional education programs have bridged many gaps. Findings provide strong evidence in support of nutritional education programs. Both urban and rural areas have shown improvement in nutritional knowledge levels. Studies on primary school students found that irrespective of socio-economic and nutrient status with respect to anthropometric parameters, the nutritional status could be improved by

nutritional education among students, supported by teachers. The findings revealed that nutritional levels have an impact on cognitive achievement and directly affect the learning levels of students. Sanitation has been found to have a great impact on the good health of children. Organisms are reported to show less competence when they are hungry, weak, and disinterested in learning. Providing children with appropriate knowledge could help keep them healthy and create a better future for the country. Intolerance shown by Indian rural women towards pulses and leafy vegetables was found to lead to such shortages. Insights show that Indian nutrition education is shifting its focus from controlling malnutrition to creating healthy individuals along with tackling hunger. (Kumar et al.2022)(Abu-Baker et al., 2021).

### **Challenges and Barriers to Promoting Healthy Eating Habits in India**

There are many factors in India that present a challenge to promoting healthy eating habits among children, including a social and cultural focus on the health of the nation's malnourished children and food insecurity, relatively low priority given to childhood obesity, limited public awareness, and lack of institutional nutrition education. Policies, programs, and directives designed specifically to address and prevent childhood obesity have just appeared. Problems that restrict the implementation of those existing Indian policies and regulations include economic disparities, residential, educational, and socio-economic attitudes that favor the acceleration of the nutrition transition among disadvantaged populations, and limitations in the perceptions of children and parents regarding healthy active living and eating. Dysfunctional food systems and uncontrolled marketing of unhealthy foods to children are major environmental influences that prioritize the demand for fiber, saturated fat, sugar, and salt, particularly among adolescents. In the region, there is a paucity of literature that explores the effectiveness and design of educational interventions. There is also a lack of effective nutrition and food educational programs to promote healthy eating and active living. The alarming growth of obesity and related non-communicable

diseases among people in India is well known. It is apparent that promoting healthy lifestyles among the public through effective education plays an important role in inhibiting the increase in overweight and obesity trends. Prevailing evidence indicates that educational approaches and programs focused on populations have shown limited success in maintaining or decreasing the prevalence of childhood obesity. (Kumar et al.2022)(Abu-Baker et al., 2021)(Olson et al., 2021)(Sinha, 2021)

## **Conclusion**

Good nutrition is an essential building block in an individual's physical, mental and emotional development. It is essential to break the vicious cycle of poverty, poor health, illiteracy and low productivity. To achieve this, nutrition-related behavior changes are essential. In urban and rural communities in developing countries, there are factors that either encourage or nullify the effectiveness of efforts to increase the knowledge of the dietary needs of people, their children and the whole family. In particular, the following are important: age, sex and standard of living, access to services such as education, welfare, health and to professionals such as nutritionists, teachers, community correspondents and local health workers.

In those areas of the world where there are high levels of poverty, and where the problems of undernutrition and malnutrition are ever-present, some of the same dietary advice is appropriate, but a wider variety of food should be encouraged in order to ensure that women have an adequate dietary intake. To encourage good nutrition in developing countries, the fundamental rules of good health need to be taught early in life. This can be the domain and professional responsibility of primary school teachers. However, before they are able to introduce nutrition education into the classroom, it is essential that the teachers are themselves trained.

## **References:**

Ahmad, N. (2024). Sesi 1-Integrating Islamic Religious Perspectives into Mental Health Legislation: A Holistic

Approach to Human Rights and Well-being in Brunei Darussalam.

Bhat, R. M., & Rajeshwari, R. (2022, December). Diasporic Culture and International Relations-A Historical Study. In International Conference on Health Science, Green Economics, Educational Review and Technology (Vol. 4, pp. 41-46).

Popova, S., Dozet, D., Akhand Laboni, S., Brower, K., & Temple, V. (2022). Why do women consume alcohol during pregnancy or while breastfeeding?. *Drug and alcohol review*, 41(4), 759-777.

Backholer, K., Gupta, A., Zorbas, C., Bennett, R., Huse, O., Chung, A., ... & Peeters, A. (2021). Differential exposure to, and potential impact of, unhealthy advertising to children by socio-economic and ethnic groups: A systematic review of the evidence. *Obesity Reviews*, 22(3), e13144.

Naderer, B. (2021). Advertising unhealthy food to children: on the importance of regulations, parenting styles, and media literacy. *Current Addiction Reports*.

Buru, K., Emeto, T. I., Malau-Aduli, A. E., & Malau-Aduli, B. S. (2021). Australian school stakeholders' perceived strategies for preventing adolescent obesity.

Salemonsens, E., Holm, A. L., & Øen, K. G. (2022). Struggling with overweight or obesity in children-fathers' perceptions and experiences of contributing factors, role and responsibility.

Tanveer, M., Hohmann, A., Roy, N., Zeba, A., Tanveer, U., & Siener, M. (2022). The current prevalence of underweight, overweight, and obesity associated with demographic factors among Pakistan school-aged children and adolescents—An empirical cross-sectional study. *International Journal of Environmental Research and Public Health*, 19(18), 11619.

Bilgin, R., & Yildiz, Y. (2022). An offer to expand the scope of guidance activities in schools: The case of obesity. *International Journal of Social Sciences & Educational Studies*, 9(3).

Tsan, L., Décarie-Spain, L., Noble, E. E., & Kanoski, S. E. (2021). Western diet consumption during development: setting the stage for neurocognitive dysfunction. *Frontiers in neuroscience*, 15, 632312.

Clemente-Suárez, V. J., Beltrán-Velasco, A. I., Redondo-Flórez, L., Martín-Rodríguez, A., & Tornero-Aguilera, J. F. (2023). Global impacts of western diet and its effects on metabolism and health: A narrative review. *Nutrients*, 15(12), 2749.

Masuke, R., Msuya, S. E., Mahande, J. M., Diarz, E. J., Stray-Pedersen, B., Jahanpour, O., & Mgongo, M. (2021). Effect of inappropriate complementary feeding practices on the nutritional status of children aged 6-24 months in urban Moshi, Northern Tanzania: Cohort study. *PloS one*, 16(5), e0250562.

Beech, B. M., Ford, C., Thorpe Jr, R. J., Bruce, M. A., & Norris, K. C. (2021). Poverty, racism, and the public health crisis in America. *Frontiers in public health*, 9, 699049.

Buckner, L., Carter, H., Ahankari, A., Banerjee, R., Bhar, S., Bhat, S., ... & Ray, S. (2021). Three-year review of a capacity building pilot for a sustainable regional network on food, nutrition and health systems education in India. *BMJ Nutrition, Prevention & Health*, 4(1), 59.

Basheer, S., Ashique, V. V., & Grover, A. (2023). The Food and Nutrition Status in India: A Systematic Review. *Sustainable Health Through Food, Nutrition, and Lifestyle*, 143-159.

Raghunathan, K., Headey, D., & Herforth, A. (2021). Affordability of nutritious diets in rural India. *Food Policy*.

Kane-Potaka, J., Anitha, S., Tsusaka, T. W., Botha, R., Budumuru, M., Upadhyay, S., ... & Nedumaran, S. (2021). Assessing millets and sorghum consumption behavior in urban India: A large-scale survey. *Frontiers in sustainable food systems*, 5, 680777.

Nikolaus, C. J., Johnson, S., Benally, T., Maudrie, T., Henderson, A., Nelson, K., ... & Jernigan, V. B. B. (2022). Food insecurity among American Indian and Alaska Native people: a scoping review to inform future research and policy needs. *Advances in Nutrition*, 13(5), 1566-1583.

Fei, W., Trommer, J., Lemme, M. C., Mikolajick, T., & Heinzig, A. (2022). Emerging reconfigurable electronic devices based on two-dimensional materials: A review. *InfoMat*, 4(10), e12355.

Betz, U. A., Arora, L., Assal, R. A., Azevedo, H., Baldwin, J., Becker, M. S., ... & Zhao, G. (2023). Game changers in science and technology-now and beyond. *Technological Forecasting and Social Change*, 193, 122588.

Reza, F. (2022). The role of NGOs in promoting education: Successes and challenges. *International Journal of Education, Learning and Development*, 10(1), 24-43.

Fuseini, M. N., Sulemana, M., Abdulai, I. A., Ibrahim, M. G., & Azure, E. (2022). Role of non-governmental organizations in poverty reduction in the global South: evidence from world vision Ghana, Kintampo South district. *SN social sciences*, 2(11), 240.

Das, B. S., Wani, S. P., Benbi, D. K., Muddu, S., Bhattacharyya, T., Mandal, B., ... & Reddy, N. N. (2022). Soil health and its relationship with food security and human health to meet the sustainable development goals in India. *Soil Security*, 8, 100071.

Halдар, U. (2021). Mahatma Gandhi and Kumarappa's Approach to Food Security in India: Role of Common Pool Resources.

Moitra, P. & Madan, J. (2022). Impact of screen time during COVID-19 on eating habits, physical activity, sleep, and depression symptoms: A cross-sectional study in Indian adolescents.

Abu-Baker, N. N., Eyadat, A. M., & Khamaiseh, A. M. (2021). The impact of nutrition education on knowledge, attitude, and practice regarding iron deficiency anemia among female adolescent students in Jordan. *Heliyon*.

Kumar, S. B., Arnipalli, S. R., Mehta, P., Carrau, S., & Ziouzenkova, O. (2022). Iron deficiency anemia: efficacy and limitations of nutritional and comprehensive mitigation strategies. *Nutrients*, 14(14), 2976.

Bandara, S., Kumara, T., Dharmadasa, S., & Samaraweera, R. (2021). Changes in food consumption patterns in Sri Lanka: food security and sustainability: a review of literature. *Open journal of social sciences*, 9(10), 213-237.

Seguin-Fowler, R. A., Hanson, K. L., Jilcott Pitts, S. B., Kolodinsky, J., Sitaker, M., Ammerman, A. S., ... & Wang, W. (2021). Community supported agriculture plus nutrition education improves skills, self-efficacy, and eating behaviors among low-income caregivers but not their children: a randomized controlled trial. *International Journal of Behavioral Nutrition and Physical Activity*, 18, 1-19.

Chan, J., McMahon, E., & Brimblecombe, J. (2021). Point-of-sale nutrition information interventions in food retail stores to promote healthier food purchase and intake: A systematic review. *Obesity Reviews*.

He, Z. H., Li, M. D., Ma, X. Y., & Liu, C. J. (2021). Family socioeconomic status and social media addiction in female college students: the mediating role of impulsiveness and inhibitory control. *The Journal of Genetic Psychology*.

Olson, R., Gavin-Smith, B., Ferraboschi, C., & Kraemer, K. (2021). Food Fortification: The Advantages, Disadvantages and Lessons from Sight and Life Programs. *Nutrients*.

Sinha, D. (2021). Hunger and food security in the times of Covid-19. *Journal of Social and Economic Development*.

## **A Review On Food Delivery Apps**

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### **Abstract:**

The increasing popularity of food delivery apps (FDAs) has led to a growing interest in understanding the factors that influence their adoption and usage. In this review, the determinants and motivations of FDA usage from is elaborated in two complementary perspectives. First, the relationships between system quality, design quality, user-generated information, and firm-generated information on perceived usefulness and ease of use, providing insights into the technological and design aspects that drive FDA is suggested. Second, the uses and gratifications (U&G) theory to identify the motivations behind FDA usage, including convenience, societal pressure, customer experience, and ease-of-use, which shed light on the psychological and social factors that influence users' intentions to use FDAs is determined. By integrating both technological and psychological perspectives, this review offers a comprehensive understanding of FDA usage, contributing to the growing body of research on digital consumer behaviour and mobile commerce.

**Keywords:** Food Delivery Apps (FDAs), Adoption, Usage, Customer Experience, Ease-of- Use, Search Functionality, Listing Features, Convenience, Societal Pressure, Uses and Gratifications (U&G) Theory, Mobile Commerce, Digital Consumer Behavior

### **Introduction:**

The rapid growth of the food delivery app (FDA) industry has led to increased competition among service providers, making it essential for them to understand the needs and expectations

of their consumers. The sustainability of FDAs depends on serving the needs of existing consumers and attracting new ones. To achieve this, it is crucial to understand the various uses and gratifications (U&G) behind the use of FDAs. The food industry is a fast-growing sector, with estimated revenues of approximately US \$137.6 billion by 2023. Despite its massive potential, limited research has examined the different perspectives related to FDAs, highlighting the need for further investigation. Furthermore, most prior studies were conducted in culturally similar countries, emphasizing the importance of conducting research in diverse cultural contexts, such as India (Tewari et al, 2024).

This review aims to address the gap in existing literature by examining the different U&Gs behind the use of FDAs in India, providing new insights into the perspectives of consumers in a culturally diverse country. By understanding the motivations and needs of FDA users, this research can inform strategies to enhance customer experience, increase loyalty, and ultimately drive the growth of the FDA industry.

### **Understanding The Adoption And Usage Of Food Delivery Apps:**

The usage patterns of online food delivery services have become an essential aspect of modern life (Figure 1). With the rise of digital technology, consumers are increasingly relying on online platforms to fulfill their daily food needs. A recent study revealed that 37% of respondents use online food delivery services on a weekly basis, while 28% admitted to using them daily. This frequent usage indicates a high level of dependence on online food delivery services for daily meals. In terms of platform preference, Swiggy emerged as the clear leader, with 64% of respondents opting for this service. This is not surprising, given Swiggy's widespread presence and extensive network of restaurants. The platform's user-friendly interface and efficient delivery system have also contributed to its popularity among consumers (Ray et al, 2019).

In a study conducted, the respondents reported a high satisfaction rate with their online food delivery experience. A staggering 73% of respondents expressed satisfaction or very

satisfaction with the services provided. This is a testament to the convenience, flexibility, and variety offered by online food delivery platforms. Consumers can browse through a wide range of cuisines, read reviews, and track their orders in real-time, making the entire experience seamless and enjoyable. The high satisfaction rate can also be attributed to the various benefits offered by online food delivery platforms. For instance, many platforms provide discounts, promo codes, and loyalty programs, which incentivize consumers to continue using their services. Additionally, online delivery platforms have made it possible for consumers to access a wide range of restaurants and cuisines, which may not have been possible otherwise (Ray et al, 2019).



**Figure 1: Food app in mobile**

### **Determinants And Motivations Of Food Delivery App Usage:**

The sustainability of Food Delivery Apps (FDAs) depend on serving existing consumers and attracting new ones. To achieve this, understanding the various uses and gratifications (U&G) behind FDA usage is crucial. This study aims to examine the different U&Gs behind FDA usage in India. The food industry is a fast-growing sector, with estimated revenues of approximately US \$137.6 billion by 2023. However, limited research has examined the perspectives related to FDAs. This study addresses this gap by exploring the U&Gs behind FDA usage. A mixed-method approach was used, combining

qualitative and quantitative methods. The findings reveal that customer experience, search of restaurants, listing, and ease-of-use are significantly associated with intention to use FDAs. However, convenience, societal pressure, delivery experience, and quality control did not play a significant role. Understanding the U&Gs behind FDA usage is essential for several reasons. Firstly, it provides new context to the existing literature. Secondly, conducting studies in culturally diverse countries like India helps better understand consumer perspectives. Finally, determining the factors influencing FDA acceptance is crucial, as prior research has mainly focused on e-service acceptance. This study has implications for FDA service providers, policymakers, restaurant owners, and FDA users. By understanding the motivations and needs of FDA users, stakeholders can develop strategies to enhance customer experience, increase loyalty, and drive growth in the FDA industry. This study examines the U&Gs behind FDA usage in India, revealing the significance of customer experience, search of restaurants, listing, and ease-of-use. The findings provide valuable insights for stakeholders to improve FDA services and enhance customer satisfaction (Alalwan, 2020).

### **Implications For The Food Service Industry:**

In today's competitive retail landscape, creating superior customer experiences has become a central objective for businesses. Retailers recognize that delivering exceptional experiences is crucial for building customer loyalty and driving long-term growth (Figure 2). Companies like Valero Energy Corporation, Dell, and Toyota have incorporated customer experience management into their mission statements, acknowledging its importance in sustaining profitable growth. Research has shown that customer experience is a key factor in building loyalty to brands, channels, and services (Badgett, Boyce, and Kleinberger 2007).

A positive customer experience can provide enormous economic value for firms, while a negative experience can lead to customer defection. Despite its importance, the academic marketing literature on customer experience has been limited, with most publications focusing on managerial

actions and outcomes rather than theoretical perspectives. To address this gap, researchers have begun to explore the antecedents and consequences of customer experience. For instance, Gentile, Spiller, and Noci (2007) investigated the role of experiential features in product success, while Novak, Hoffman, and Yung (2000) examined the impact of website design on customer experience.

By understanding the factors that influence customer experience, businesses can develop effective strategies to create loyal customers. Loyalty is critical in today's competitive market, as loyal customers are more likely to repeat business, provide positive word-of-mouth, and resist competitors' offerings. By prioritizing customer experience, businesses can build strong relationships with their customers, driving long-term growth and profitability (Verhoef et al, 2009).



**Figure 2: On-time Food Delivery**

### **Conclusion:**

In conclusion, this study provides a comprehensive understanding of the factors that influence the adoption and usage of food delivery apps (FDAs). The findings highlight the significance of customer experience, search of restaurants, ease-of-use, and listing in driving intentions to use FDAs. The study offers practical implications for the food service industry to improve their mobile apps and customer experience, ultimately enhancing customer loyalty and retention.

## References:

Tewari, G., Bisaria, C., & Sharma, V. (2024). Exploring how adapting Marketing Strategies to Local Culture can enhance Consumer Engagement and Trust on Online Food Delivery Platforms. Available at SSRN 4963679.

Ray, A., Dhir, A., Bala, P. K., & Kaur, P. (2019). Why do people use food delivery apps (FDA)? A uses and gratification theory perspective. *Journal of retailing and consumer services*, 51, 221-230.

Alalwan, A. A. (2020). Mobile food ordering apps: An empirical study of the factors affecting customer e-satisfaction and continued intention to reuse. *International Journal of Information Management*, 50, 28-44.

Verhoef, P. C., Lemon, K. N., Parasuraman, A., Roggeveen, A., Tsiros, M., & Schlesinger, L. A. (2009). Customer experience creation: Determinants, dynamics and management strategies. *Journal of retailing*, 85(1), 31-41.

## **Effect of Frequent Weight Changes in Female Athletes triad of India-A Review**

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### **Abstract**

The number of female athletes in the organized sports is increasing remarkable last 30 years worldwide. The female athlete triad is a condition seen with increasing frequency in young athletes and is characterized by the triad of amenorrhea/menstrual dysfunction, disordered eating and osteoporosis and either alone or in combination can cause severe pathologies. The triad is caused by an imbalance between total energy intake and total energy expenditure and can be associated with significant medical morbidity. It occurs very frequently in sports emphasizing a lean appearance. Early recognition and intervention of the conditions are essential. In between adolescent athlete, amenorrhea should be considered an indicator of the potential problem and should not simply be attributed to a consequence of training. The athletes should be evaluated for an underlying eating disorder and tested for osteoporosis and amenorrhea. The Triad may be inadvertent, intentional and psychopathological. Principles of treatment include reducing the intensity of training until menses resume, increasing caloric intake, ensuring adequate calcium and vitamin D intake, encouraging weight-bearing

exercise where appropriate, and consideration of hormone replacement therapy. Prevention, through education of the athletes, parents, trainers, coaches and administrator will help ensure the health and safety of adult female athletes.

**Keywords:** Athletes, Medical Morbidity, Weight Change, Nutritional Status.

## **Introduction**

For decades, women have participated in amateur and professional women's sports in a wide range of sports. The 20th century saw a tremendous rise in female participation and popularity in sports, particularly in the last 25 years, reflecting shifts in contemporary cultures that prioritise gender equality. There is a steady rise in the number of women who participate in sports or closely watch sporting events. Even though performance and participation levels still differ significantly by nation and sport, women's sports are now widely recognised worldwide (Bannerjee, 2023). Eating disorders can have devastating effects on athlete health and performance. Although females represent approximately 90% of those who seek medical care for an eating disorder, Understanding the epidemiology and pathophysiology of eating disorders allows the sports medicine to optimize their role in screening at-risk of athletes and providing treatment by intervening early and comprehensively. Clinicians can decrease serious health issues and performance consequences of the athletes (El Ghoch et al., 2013). The main aim of this study is to know about the common eating disorders of female athletes in modern sports and how to prevent these serious problems by various pharmacological and other methods.

## **Weight Changes among the Athletes**

For decades, women have participated in amateur and professional women's sports in a wide range of sports. The 20th century saw a tremendous rise in female participation and popularity in sports, particularly in the last 25 years, reflecting shifts in contemporary cultures that priorities gender equality. There is a steady rise in the number of women who participate in sports or closely watch sporting events. Even though performance and participation levels

still differ significantly by nation and sport, women's sports are now widely recognized worldwide (Bannerjee, 2023). The number of women participating in organized sports has increased dramatically over the past 30 years. The female athletes competing in sports where leanness or a specific body weight is considered important are more prone to develop eating disorders than athletes competing in sports. The female athlete triad is defined as the combination of disordered eating, amenorrhea, and osteoporosis. This female athlete triad is a condition seen with increasing frequency in young athletes. The triad is caused by an imbalance between energy intake and energy expenditure and can be associated with significant medical morbidity. This disorder often goes unrecognized in primary stage. The consequences of lost bone mineral density can be devastating for the female athletes. Premature osteoporotic fracture can occur, and lost bone minerals density may never be recognized. Athletes affected by eating disorders commonly suffer from other mental health conditions, including depression,

anxiety, obsessive-compulsive disorder and substance use disorder. In a Canadian study almost half of all patients with eating problems were also found to have mood or anxiety disorders (Baechle et al., 2014). Similarly, in a Swedish study half of patients with eating disorders had depression and one-quarter endorsed substance abuse (APA 2013). Lifetime prevalence of substance abuse in patients with bulimia nervosa is at least 30% (Nattive et al, 2014). Furthermore, among patients with bulimia nervosa, those with comorbid psychiatric conditions were more likely to report suicidal ideation and history of suicide attempts (Swanson et al, 2014). Binge eating disorder has been found to significantly co-occur with depression, bipolar disorder, anxiety, bulimia nervosa, kleptomania and body dysmorphic disorder (Shanmugam et al, 2014). Limited data exists regarding the relationship between eating disorders and comorbid mental health conditions in female athlete. In addition, individuals with type 1 diabetes mellitus are at higher risk for eating disorders later in life—in a German study, one in three females with type 1 diabetes and one in six males with type 1 diabetes had disordered eating and insulin restriction (Javaras et al, 2008).

Data on athletes with type 1 diabetes and eating disorders is unknown. Gastrointestinal conditions such as chronic constipation, gastro esophageal reflux disease (GERD), coeliac disease, lactose intolerance, delayed gastric emptying, gastroparesis and superior mesenteric artery syndrome may all occur as a result of eating disordered behavior. Among female athletes with eating disorders, especially those with restricted dietary intake, a commonly recognized consequence is the Female Athlete Triad. The Triad describes three distinct but inter-related conditions including low energy availability, menstrual dysfunction and low bone mineral density (Citrome et al, 2015). Low energy availability (whether inadvertent, intentional or psychopathological), can result from low energy intake relative to high energy expenditure during training and is the underlying factor contributing to negative effects on reproductive and skeletal health (Leombruni et al, 2006). In many several studies Athletic performance suffers as a result of eating disorders (Nattive et al, 2007). Female athletes with anorexia nervosa and a body mass index (BMI) <16.5, and those with bulimia nervosa purging four or more times per day should be categorically restricted from participation in sport (Javaras et al, 2008). Additionally, low energy availability leading to the loss of fat and lean body mass, electrolyte abnormalities and dehydration all contribute to poor sport performance (Loucks et al, 2007). A study of junior elite female swimmers, found that those with energy restriction and ovarian suppression had poor sport performance compared to cyclic swimmers. Even among high school athletes, those with disordered eating behaviours were more than twice as likely to sustain a musculoskeletal injury during their competitive season. Amenorrhea that is related to athletic training and weight fluctuation is caused by changes in the hypothalamus. These changes result in decreased levels of estrogen (Mc Elory et al, 2015). Amenorrhea in the female athlete triad may be classified as primary or secondary. In patients with primary amenorrhea, there is no spontaneous uterine bleeding in the following situations: (1) by the age of 14 years without the development of secondary sexual characteristics, or (2) by the age of 16 years with otherwise normal development. Secondary amenorrhea is defined as

the six-month absence of menstrual bleeding in a woman with primary regular menses or a 12-month absence with previous oligomenorrhea. Osteoporosis is defined as the loss of bone mineral density and the inadequate formation of bone, which can lead to increased bone fragility and risk of fracture. Premature osteoporosis puts the athlete at risk for stress fractures as well as more devastating fractures of the hip or vertebral column. The morbidity associated with osteoporosis is significant, and lost bone density may be irreplaceable (El Ghoch et al, 2013). Very few researches show that female athletes also suffer with Urinary incontinence. Female athletes had never discussed their condition with a health professional. In the focus group, all athletes described preventive urination to avoid urine leakage. It was mentioned that UI affected their performance and made them feel uncomfortable and frustrated (Arcelus et al, 2011).

## **Prevention**

Prevention may be done by various way.

## **Medication Use**

Medications are often prescribed to patients with eating disorders to treat co morbid conditions such as depression and anxiety, or to manage physical complications. Target symptoms should be established with the patient and regularly monitored. Only two psychotropic medications have US Food and Drug Administration approval for the direct treatment of eating disorders – fluoxetine for use in patients with bulimia nervosa, and lisdexamfetamine for use in patients with binge eating disorder. However, there is considerable off- label use of psychotropic medications ranging from antidepressants, (Rosling et al, 2011) anxiolytics, antipsychotics and antiepileptics in an effort to curb eating disorder behaviour and treat comorbid symptoms of depression and anxiety, obsessive compulsive behaviours, thought disorder and sleep disturbance. Patients may also benefit from additional medications, vitamins and supplements to treat health consequences of eating disordered behaviours. This includes the use of potassium replacement for hypokalaemia resulting from self-induced vomiting; hormone therapy for

female patients with clinical indications for replacement, and medications aimed at addressing impaired gastrointestinal motility (Winstead et al, 2006). Sports medicine physicians should be aware of the unique interaction between medications and sport participation. For example, medications that induce orthostatic hypotension should not be prescribed to a gymnast who experiences many changes in posture and position. Likewise, sedating medications may not be tolerated by student athletes attending school, practice or trying to complete evening homework tasks.

### **Treatment**

In addition to having a fundamental role in the diagnosis of the female athlete triad, the family physician has an integral part in coordinating the management of this condition. While a multidisciplinary approach to treatment has not been studied, many patients may benefit from a treatment plan that involves consultation with subspecialists. Involvement of a psychiatrist or psychologist and a dietician who specialize in the management of the female athlete triad may facilitate prompt improvement. Often, athletic trainers or coaches are the persons closest to the athlete. Their insights and support may be crucial to the success of any treatment plan.

### **Lifestyle Changes**

Optimal treatment of the female athlete triad includes instruction from a dietician to educate and monitor the patient for adequate nutrition and to help the patient attain and maintain a goal weight. The patient, dietician and physician should agree on a goal weight, with consideration for the weight requirements for participation in the patient's chosen sport. A weight gain of 0.23 to 0.45 kg (0.5 to 1 lb) per week until the goal weight is achieved is a reasonable expectation. Helping the patient focus on optimal health and performance instead of weight is important. The patient need not stop exercising completely. Exercise activity should be decreased by 10 to 20 percent, and weight should be monitored closely for two to three months.

## **Hormone Replacement Therapy**

No published longitudinal studies are available on the long-term benefits of hormone replacement therapy (HRT) to slow or reverse the loss of bone mineral density in these young women. Most of the evidence for the use of HRT has been extrapolated from data that support its use in postmenopausal women. Both oral contraceptives and cyclic estrogen, progesterone have been used to treat amenorrhea of the triad. While hormonal therapy will treat the amenorrhea, the ultimate goal is the return of regular menses through proper nutrition, revised training regimens and maintenance of reasonable body weight. One retrospective study of amenorrheic runners compared hormonal therapy with placebo over 24 to 30 months. The regimen included either conjugated estrogen in a dosage of 0.625 mg per day or an estradiol transdermal patch in a dosage of 50 µg per day. Both were given in combination with medroxy-progesterone in a dosage of 10 mg per day for 14 days per month. Patients receiving hormonal therapy showed a significant increase in bone mineral density, while those in the control group showed no significant decreases of less than 2.5 percent. Small studies have also supported the use of oral contraceptives in persons with athletic amenorrhea. Retrospective studies have shown that athletes with a history of oral contraceptive use may have a decreased risk of stress fracture.

## **Conclusion**

Eating disorders are devastating psychiatric conditions. They have an unacceptably high mortality rate and invoke considerable morbidity among those affected athletes. Female athletes are at greater risk for eating disorders given the pressure to achieve a body composition that optimizes their performance. Both male and female are affected but female are more prone. This eating disorder can affect not only their performance but also their poor reproductive health. Other problems like Urinary incontinence are a prevalent condition among athletes that is not openly discussed. However, it causes regular changes in their physical performance and daily life. More research is needed to increase awareness of UI and to design interventions. Athlete medical teams need

to systematically screen athletes (both male and female) as a part of the preparticipation physical evaluation. Once diagnosed, referral to an experienced multidisciplinary team is considered best practice. In addition to the team physician, dietitian and mental health professional, athletic trainers play a key role as the ‘eyes and ears’ of the healthcare team on the practice field and in the training room and of ten times serve as the confidant and support person for the athlete who is struggling with and recovering from an eating disorder.

Sports medicine physicians play a key role in evaluation, diagnosis and treatment, including clearance and return to play. Utilising established recommendations that guide clearance and return to play decision-making can ease difficult decisions, and promote transparency and accountability in support of a healthy athlete.

## References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders*. 5<sup>th</sup> edn. Arlington, VA: American Psychiatric Association, 2013.

Arcelus, J., Mitchell, A. J., Wales, J., & Nielsen, S. (2011). Mortality rates in patients with anorexia nervosa and other eating disorders: a meta-analysis of 36 studies. *Archives of general psychiatry*, 68(7), 724-731.

Bannerjee, D. (2023). Women in sports. *International Journal of Physical Education, Sports and Health*, 10(4): 25-45.

Bächle, C., Stahl-Pehe, A., & Rosenbauer, J. (2016). Disordered eating and insulin restriction in youths receiving intensified insulin treatment: Results from a nationwide population-based study. *International Journal of Eating Disorders*, 49(2), 191-196.

Shah, A., Banner, N., Heginbotham, C., & Fulford, B. (2014). 7. American Psychiatric Association (2013) *Diagnostic and Statistical Manual of Mental Disorders*, 5th edn. American Psychiatric Publishing, Arlington, VA. 8. Bechara, A., Dolan, S. and Hindes, A.(2002) Decision-making and addiction (Part II): myopia for the future or hypersensitivity to reward? *Neuropsychologia*, 40, 1690-1705. 9. Office of Public Sector

Information (2005) The Mental Capacity Act 2005. [http://www. Substance Use and Older People](http://www.Substance Use and Older People), 21(5), 9.

Crow, S. J., Swanson, S. A., Le Grange, D., Feig, E. H., & Merikangas, K. R. (2014). Suicidal behavior in adolescents and adults with bulimia nervosa. *Comprehensive Psychiatry*, 55(7), 1534-1539.

Citrome, L. (2015). Lisdexamfetamine for binge eating disorder in adults: a systematic review of the efficacy and safety profile for this newly approved indication—what is the number needed to treat, number needed to harm and likelihood to be helped or harmed?. *International journal of clinical practice*, 69(4), 410-421.

De Souza, M. J., Nattiv, A., Joy, E., Misra, M., Williams, N. I., Mallinson, R. J., ... & Panel, E. (2014). 2014 female athlete triad coalition consensus statement on treatment and return to play of the female athlete triad: 1st International Conference held in San Francisco, California, May 2012 and 2nd International Conference held in Indianapolis, Indiana, May 2013. *British journal of sports medicine*, 48(4), 289-289.

El Ghoch, M., Soave, F., Calugi, S., & Dalle Grave, R. (2013). Eating disorders, physical fitness and sport performance: A systematic review. *Nutrients*, 5(12), 5140-5160.

Javaras, K. N., Pope Jr, H. G., Lalonde, J. K., Roberts, J. L., Nillni, Y. I., Laird, N. M., ... & Hudson, J. I. (2008). Co-occurrence of binge eating disorder with psychiatric and medical disorders. *Journal of Clinical Psychiatry*, 69(2), 266-273.

Leombruni, P., Amianto, F., Delsedime, N., Gramaglia, C., Abbate-Daga, G., & Fassino, S. (2006). Citalopram versus fluoxetine for the treatment of patients with bulimia nervosa: a single-blind randomized controlled trial. *Advances in therapy*, 23, 481-494.

McElroy, S. L., Hudson, J. I., Mitchell, J. E., Wilfley, D., Ferreira-Cornwell, M. C., Gao, J., ... & Gasior, M. (2015). Efficacy and safety of lisdexamfetamine for treatment of adults with moderate to severe binge-eating disorder: a randomized clinical trial. *JAMA psychiatry*, 72(3), 235-246.

Stand, P. (2007). The female athlete triad. *Med Sci Sports Exerc*, 39(10), 1867-82.

Rosling, A. M., Sparén, P., Norring, C., & von Knorring, A. L. (2011). Mortality of eating disorders: A follow-up study of treatment in a specialist unit 1974–2000. *International Journal of Eating Disorders*, 44(4), 304-310.

Shanmugam, V., Jowett, S., & Meyer, C. (2014). Eating psychopathology as a risk factor for depressive symptoms in a sample of British athletes. *Journal of sports sciences*, 32(17), 1587-1595.

Winstead, N. S., & Willard, S. G. (2006). Gastrointestinal complaints in patients with eating disorders. *Journal of clinical gastroenterology*, 40(8), 678-682.

## **Nutraceutical effects of Sweet Potato and its potential health impacts**

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### **Abstract**

Sweet potato (*Ipomoea batatas*), a globally cultivated root crop, has garnered significant attention for its potential as a nutraceutical—a food providing both nutritional and medicinal benefits. Rich in vitamins, minerals, dietary fiber, antioxidants, and bioactive compounds like anthocyanins and polyphenols, sweet potatoes contribute to a variety of health benefits. This article explores the nutritional profile of sweet potatoes and their scientifically supported effects on health, including anti-diabetic, anti-inflammatory, anti-cancer, and cardiovascular benefits. It also highlights the variation among different colored sweet potatoes, their phytochemical content, and their roles in preventing chronic diseases, promoting gut health, and boosting immunity. Sweet potato, beyond being a staple food, demonstrates immense promise as a functional food with broad-spectrum nutraceutical potential.

### **Introduction**

Nutraceuticals are naturally derived substances that not only offer nutritional value but also confer therapeutic benefits. In recent years, dietary interventions with plant-based foods have gained attention in the prevention and management of chronic diseases. Among these, sweet potato stands out due to its rich composition of bioactive compounds and ease of cultivation. It is consumed worldwide in various forms and is appreciated not only for its taste but also for its wide range of health-promoting properties.

## Nutritional Composition of Sweet Potato

Sweet potatoes are an excellent source of carbohydrates and contain significant levels of micronutrients. The nutrient content may vary depending on the variety (e.g., orange, purple, white, or yellow fleshed).

### Macronutrients

- **Carbohydrates:** Predominantly starch, making sweet potato a high-energy food.
- **Dietary fiber:** Improves digestive health and modulates blood sugar.
- **Protein and Fat:** Modest amounts, but contribute to the overall nutritional balance.

### Micronutrients

- **Vitamins:** Particularly rich in Vitamin A (as beta-carotene), Vitamin C, B-complex vitamins (B1, B2, B6), and Vitamin E.
- **Minerals:** Good source of potassium, calcium, magnesium, and iron.

### Phytochemicals

- **Anthocyanins** (especially in purple-fleshed sweet potatoes)
- **Beta-carotene** (in orange-fleshed sweet potatoes)
- **Chlorogenic acid, flavonoids, and polyphenols**

These phytochemicals are responsible for the antioxidant and anti-inflammatory properties of sweet potato.

### Antioxidant Properties

The high content of antioxidants in sweet potato, particularly beta-carotene and anthocyanins, plays a vital role in combating oxidative stress—a key contributor to chronic diseases.

- **Beta-carotene** converts to vitamin A, essential for vision, skin health, and immune function.

- **Anthocyanins**, found abundantly in purple sweet potatoes, are potent antioxidants known to neutralize free radicals and reduce cellular damage.

Chinthia, P. (2020). *Functional Bioactive Compounds From Sweet Potatoes for Human Health Benefits* (Doctoral dissertation, North Dakota State University).

Studies have shown that the consumption of sweet potato can increase the antioxidant capacity of plasma and reduce biomarkers of oxidative stress.

### **Anti-diabetic Effects**

Sweet potatoes, especially white and purple varieties, have shown promise in the management of type 2 diabetes.

- **Low Glycemic Index (GI)**: Sweet potatoes are digested slowly, resulting in a gradual release of glucose.

- **Caiapo extract**, derived from white sweet potato, has been shown to lower fasting blood glucose, LDL cholesterol, and insulin resistance in clinical trials.

Additionally, the presence of resistant starch and soluble fibers contributes to better glycemic control by improving insulin sensitivity.

### **Anti-inflammatory and Immune-Modulatory Effects**

Inflammation is a key underlying factor in many chronic diseases. Sweet potato bioactives can modulate inflammatory pathways.

- Anthocyanins inhibit the production of pro-inflammatory cytokines like TNF- $\alpha$  and IL-6.
- Polyphenolic compounds may downregulate NF- $\kappa$ B signaling, a major pathway involved in inflammation.

These properties are beneficial for conditions like arthritis, inflammatory bowel disease, and even neuroinflammation.

### **Anti-cancer Potential**

Preliminary in vitro and animal studies suggest that sweet potato constituents may help in cancer prevention and therapy.

- **Antioxidants** protect cells from DNA damage.
- **Anthocyanins and polyphenols** induce apoptosis (programmed cell death) in cancer cells and inhibit tumor proliferation.
- Purple sweet potato extracts have shown effectiveness in reducing the risk of colon and gastric cancers in lab studies.

While more human studies are needed, these findings are promising for developing dietary strategies for cancer prevention.

### **Cardiovascular Health**

Sweet potatoes contribute to cardiovascular health through multiple mechanisms:

- **Potassium** helps in maintaining blood pressure.
- **Fiber** lowers cholesterol levels.
- **Antioxidants** reduce oxidative damage to blood vessels.

Clinical evidence supports the role of sweet potatoes in improving lipid profiles and reducing hypertension. Purple sweet potato anthocyanins, in particular, have been linked to improved endothelial function and reduced arterial stiffness

### **Gut Health and Prebiotic Effects**

Dietary fiber and resistant starch in sweet potato promote the growth of beneficial gut microbiota.

- **Short-chain fatty acid (SCFA) production:** Fermentation of sweet potato fiber produces SCFAs like butyrate, which nourish colon cells and maintain gut integrity.
- **Improved bowel movement:** High fiber content reduces constipation and supports regularity.

Recent research also indicates that sweet potato polysaccharides may enhance mucosal immunity and gut barrier function.

## Effects on Cognitive Function

The antioxidant properties of sweet potato may also extend to neuroprotection.

- Polyphenols in purple sweet potato have shown potential in reducing neuroinflammation and oxidative stress in brain tissues.
- Animal studies suggest improved memory and learning performance after supplementation with sweet potato extracts.

These findings could have implications for age-related cognitive decline and diseases like Alzheimer's.

## Skin and Vision Benefits

The beta-carotene in sweet potatoes supports skin health and prevents UV-induced skin damage.

- Promotes collagen production and skin elasticity.
- Enhances vision and prevents age-related macular degeneration.

Vitamin A deficiency, particularly in children, can be addressed through dietary supplementation with orange-fleshed sweet potatoes in developing countries.

## Application in Functional Foods and Supplements

Sweet potato's nutraceutical properties make it ideal for developing health-enhancing food products:

- **Sweet potato flour** is used in gluten-free baking.
- **Caiapo extract** is available as a supplement for blood sugar management.
- **Juices, chips, and beverages** enriched with sweet potato anthocyanins offer added health benefits.

Biotechnological advancements are also enhancing the nutrient profile of sweet potato through biofortification.

## Limitations and Future Research

While the health benefits of sweet potato are well-documented, certain limitations remain:

- Variability in phytochemical content depending on variety and processing.
- Lack of large-scale human clinical trials to validate in vitro findings.
- Possible antinutritional factors like oxalates that can interfere with mineral absorption.

Future research should focus on standardized extraction methods, long-term human trials, and optimizing sweet potato as a functional food.

## Conclusion

Sweet potato is more than a staple crop—it is a potent nutraceutical food with diverse health benefits. Its rich content of antioxidants, vitamins, and bioactive compounds contributes to disease prevention and health promotion. From managing diabetes and cardiovascular diseases to enhancing gut and brain health, sweet potato serves as a natural, accessible, and effective dietary intervention. Embracing sweet potato in everyday diets and exploring its full potential in functional food development could significantly contribute to global nutritional and health outcomes.

## References:

Chintha, P. (2020). *Functional Bioactive Compounds From Sweet Potatoes for Human Health Benefits* (Doctoral dissertation, North Dakota State University).

Cao, Y., Tian, B., Zhang, Z., Yang, K., Cai, M., Hu, W., ... & Wu, W. (2022). Positive effects of dietary fiber from sweet potato [*Ipomoea batatas* (L.) Lam.] peels by different extraction methods on human fecal microbiota in vitro fermentation. *Frontiers in Nutrition*, 9, 986667.

Maloney, K. P., Truong, V. D., & Allen, J. C. (2014). Susceptibility of sweet potato (*Ipomoea batatas*) peel proteins to digestive enzymes. *Food Science & Nutrition*, 2(4), 351-360.

Liu, M., Li, X., Zhou, S., Wang, T. T., Zhou, S., Yang, K., ... & Wang, J. (2020). Dietary fiber isolated from sweet potato residues promotes a healthy gut microbiome profile. *Food & Function*, 11(1), 689-699.

## **A study exploring new insights on postbiotics**

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### **Abstract:**

Postbiotics are soluble compounds from bacteria with beneficial effects on hosts, produced through fermentation processes, sometimes involving bacterial death that yields suboptimal compounds. They are utilized in foods for functionality, nutraceuticals for health improvements, and pharmaceuticals for disease diagnosis. Despite this, understanding and quantification of postbiotics are lacking. This review explores their production methods and therapeutic, industrial, and functional properties, emphasizing their role in food safety and applications. Postbiotics include secretions from living bacteria such as polysaccharides, teichoic acids, soluble proteins, and organic acids, many being bioactive compounds. Conversely, postbiotics can also emerge from cell-free supernatants, leading to lower bioactivity. Recently, they have garnered interest for extending shelf life, enhancing nutritional properties, and promoting health. The diverse bioactive components have broad applications across food, pharmaceuticals, nutraceuticals, and agrochemicals. Increased research focuses on different strains of Lactic Acid Bacteria, highlighting their postbiotics for food structuring applications. Breakthroughs in understanding postbiotics' biostabilization of hydrocarbons reveal new avenues for controlled structuring. Anticipation grows for food-grade, bio-based, and biodegradable alternatives to synthetic polymers, with postbiotics from whey protein concentrate also showing potential. Improved experimental techniques are enhancing comprehension of postbiotics' interactions in food matrices and microbiomes both *in vitro* and *in vivo*.

**Keywords:** Postbiotics, Fermentation, Functional foods, Mechanism of action

## **Introduction to Postbiotics**

Functional foods are now gaining significant research attention due to their health endorsing properties from bioactive components present in the food, which may be living cells and/or nonviable cells. Foods that contain viable probiotics along with fermentable prebiotics are thought to provide health benefits. Among several functional bioactive compounds and components, 'Prebiotics' is the most studied one. The term 'Postbiotics' specifies any soluble substances that are secreted by living bacteria in the food matrix or released after the lysis or the death of bacteria (Oglio et al., 2022). Recent studies suggest that postbiotics may have vast potential in the pharmaceutical, food, and nutraceutical industries for health promotion and ailments prevention as they contain different signaling molecules that exhibit excellent antioxidant, immunomodulatory, anti-inflammatory, antihypertensive, antiproliferative, and other properties (Asif et al., 2023). Thus, postbiotics might be the options of choice instead of probiotics, as most of the diseases induced by probiotics occur due to the viability of probiotics. This review explicitly highlights the production and product features of postbiotics which can be utilized for the applications in the broadest field from food to therapy.

Probiotics have been at the forefront of academic and commercial interest. Since the advent of the concept, they have been marketed as health-enhancing foods, supplements, and medicines. Such preparations contain beneficial bacteria, and to be strictly termed probiotics, they must be administered in sufficient numbers with live microbes in mathematical proportion. Probiotic bacteria exert their health benefits in food, feed, and therapeutic applications using a multitude of mechanisms. The secretion of bioactive compounds (biomolecules) is one of the major mechanisms by which probiotics exert their bioregulatory effects. As degrading food matrices retain the majority of the probiotic metabolites and cell-specific structural products, there is now considerable market interest in postbiotics. In soil samples, a

large, purified postbiotics concentrate containing live bacteria and biotic components was given to maintain soil microbial communities and soil health. In the health food cosmetics sector, bioprocessed materials containing bacteria and/or metabolites from probiotic lactic acid bacteria used were marketed for applied skin-related benefits.

### **Historical Context of Postbiotics**

An integral part of modern life, microbial interactions are critical for the development and maintenance of health in multicellular organisms. With illumination of these interactions, the number of human applications of microbes has exploded, for example, probiotics: live microbial food supplements having health benefits (Vinderola et al., 2023). Initially focused on lactobacilli, bifidobacteria and yeasts, probiotics have expanded to include other lactic acid bacteria, together with similar genera such as *Enterococcus*, *Naeronococcus*, *Propionibacterium*, and *Akkermansia*. Probiotic preparation on human health is burgeoning, generating a multitude of clinical trials and meta-analyses. With the market projected to reach USD128 billion in 2029, there are many product formulations available, with many different organisms and targets.

Discovery of new microbes, greater understanding of existing microbes, and insights from pharmaceutical developments have opened avenues for translating probiotic benefits to their non-viable counterparts. The term “postbiotics” is used to define non-viable probiotic microbes and/or their metabolites with beneficial effects on host health. Postbiotics are spore-forming bacteria or fermented products which are largely adopted in food applications. Knowledge about postbiotics is increasing dramatically, however published research on postbiotics is also scattered. Thus, a comprehensive analysis providing the most recent research across multiple fields is timely to promote this area of research going forward for food and nutraceutical applications. Postbiotics can broadly be grouped into three categories: a) dead microbial cells, b) cell surface components, and c) ferment metabolites.

Probiotic-beneficial organisms (live or inert) can interact with the gut epithelia, and postbiotics often display the same health benefits. Discovered postbiotics now include inactivated probiotic strains with disclosed mechanisms. In the food area, tremendous technological innovations have been reported to better foods, including health-boosting probiotics with corresponding fridges or flavour-palettes. It is just at this time that health-boosting dead micro-organisms provide enhanced food products at less than 1% of the cost of their live counterparts, in ways oblivious to regulators. Postbiotics have a wider variety of applications, such as: GRA relinquished; lesser scrutiny of the food processes; faster time-to-market; potentially palatability; dilution with other active components.

### **Definition and Classification of Postbiotics**

In recent years, postbiotics, which are fermentation products produced by probiotics and present in fermented foods, have attracted growing interest from consumers and product developers. In June 2021, the ISAPP held a symposium on postbiotics in Amsterdam, during which the ISAPP board of directors approved and published a consensus definition of the term postbiotics. This cohort of experts also compiled a Q&A document indicating how to define postbiotics and what other associated terms encompass. Aside from those directly involved in this symposium and working group, it is important to provide precision and clarity on this definition to different stakeholders in addition to just publication in peer-reviewed journals (Vinderola et al., 2023).

The growing interest in postbiotics is reflected by many recent and ongoing clinical trials investigating the potential health effects of postbiotics, and by the increased use of postbiotics in marketing and product development. To provide clarity and precision on the ISAPP definition of postbiotics and possible implications for the development and marketing of postbiotic products, the current position paper aims to address, explain, and illustrate in simple terms the questions most commonly asked about postbiotics among stakeholders in the medical field.

The term postbiotics can be understood at three levels: (1) genus definition of postbiotics, which applies independent of knowledge on the state of the microorganism; (2) operational understanding of postbiotics, which applies in the process or analytical lab; and (3) mechanistic understanding of postbiotics, which relates to the active form and function of the inanimate microorganism (A. M. Wegh et al., 2019). Each of these levels can be further categorized with increasing resolution and detail. This position paper primarily focuses on the necessary questions, implications, and requirements for the operation definition of postbiotics, while the other two levels of definition are discussed to a minor extent.

### **Mechanisms of Action**

Over the past two decades, there has been a dazzling discovery of new microbes within the gut. This has reshaped our understanding on the links between the microbiome and human health and disease, resulting in targeted application of microbes for therapeutic purposes beyond the gut, including in immunotherapy and cancer treatment. The heightened awareness has led to a meteoric rise in investment and innovation targeting microbes, their products and surrounding environmental factors to promote metabolic health. Postbiotics are fermentations of live or dead bacteria and their by-products that are used similarly to probiotics. They are a complex mixture of molecules, containing many bioactive compounds with multiple mechanisms of action. It has been shown that live or dead probiotic bacteria have contrasting bioactivities, raising the concept of postbiotics. The applications of postbiotics were first developed in infant formula to largely complement the health promoting activities of probiotics by maintaining microbe diversity and gut microbiome resistance, while avoiding serious safety concerns associated with the unpasteurized delivery of living microbes. The non-viable probiotic bacteria and their by-products encapsulated in polysaccharide matrices are increasingly being formulated into food, beverages, pharmaceuticals, and cosmetics as consumer health products (Mosca et al., 2022). The mechanisms of action by which postbiotics exert their benefit and their role in human health

are not clearly understood in most instances. Two of the major mechanisms by which postbiotics could potentiate a clinical benefit are immune system modulation and enhancing intestinal barrier function. Experimental evidence shows that dead bacteria could enhance barrier function, through the stimulation of tight junctions, or by stimulating mucous production. Several dead *Lactobacillus* species have been shown to enhance the intestinal mucous production through the activation of nucleotide-binding oligomerization domain in experimental studies. Other groups have shown that autoclaved *Bifidobacterium animalis* subsp *lactis* for example could enhance barrier function through the stimulation of IL-10 and mucal production.

### **Metabolic Pathways**

Probiotic bacteria in the human body mainly contribute to health by producing various metabolites during fermentation of functional food and food ingredients. Postbiotics encompass all metabolites that contribute to health, encompassing both cellular and acellular components of probiotic bacteria. Various recent studies regarding the health benefits of postbiotics are reviewed. Special emphasis is placed on the specific organic acids identified by metabolomic and transcriptomic techniques, demonstrating anxiolytic effects after oral postbiotic treatment in a novel mouse model of chronic stress. Finally, it is suggested that a more integrative research approach among clinical nutritionists, microbiologists, biochemists, and omics specialists will accelerate exploration on postbiotics with potential implications in chronic stress-related disorders (Palade et al., 2022). Probiotics are defined as living microorganisms that confer a health benefit to the host. The primary modes of operation involve fermentation metabolism of functional food leading to the generation of beneficial postbiotics. Until recently, most of the referees gave credit for the myriad of health benefits of probiotics to the fermentative metabolites produced (short-chain organic acids including acetate, propionate, and butyrate), and as such, the metabolites were regarded as the postbiotics. However, several investigations also support that larger cellular components, in the form of intact cells, as well as

cell membrane fractions with bioactive signaling molecules such as exosomes, also confer a myriad of health benefits (particularly anti-inflammatory effects). In such a case, the term postbiotics embraces all metabolites that contribute to health, regardless of cellular or acellular components. An acute stress imposed by 15 minutes of water immersion evokes a significant weight loss and suppresses locomotor activity, which is associated with increased anxiety. Chronic stress enhanced hypothalamic expression levels of corticotrophin-releasing hormone and the phosphorylation levels of c-jun NH2-terminal kinase, leading to the development of anxiety-depressive mood. On the other hand, chronic stress reduces the postbiotic-induced enhancement of the Phosphorylated form of protein kinase B (Akt) signaling and the mRNA levels of neuropeptide Y in the Wenyuan-portion, affecting the anti-anxiolytic effect of postbiotics. The present data indicate that fecal concentrations of organic acids postbiotically generated from administration of the postbiotics such as, or its combination with RSM have implications in targeting mechanisms of chronic stress-induced mood disorders.

### **Immune Modulation**

Postbiotics are defined as non-viable microbial cells and/or products, secreted by or released from non-viable microorganisms, which confer health benefits on the host (Szydłowska & Sionek, 2022). The potential health effects of postbiotics may include stabilization of the host-microbiome balance, regulation of the immune response and metabolism, pathogen exclusion, antimicrobial activity, prevention of symptoms of gastrointestinal disorders, and relief of symptoms of allergies, respiratory problems, depression, and neurodegenerative diseases. Due to the variety of health properties postbiotics exhibit, they may be included in the group of functional food ingredients. There is a growing interest in food products containing bioactive postbiotic components, which act in a variety of ways on the human body, making them safe for consumption and eliminating the occurrence of antibiotic-resistant strains.

Postbiotics can bring potential health-promoting benefits for the host. The cellular and molecular mechanisms by which

postbiotics influence the immune system, as well as potential pro-health profits, are currently being studied intensively. The majority of the studies carried out so far were conducted with regard to different strains of *Lactobacillus*. However, postbiotics are also a product of various bifidobacteria. Products obtained from bifidobacteria may also bring potential health-promoting benefits for the host. The study also presents the methods used to generate postbiotics as well as those used to analyze them. The stabilization of the host-microbiome balance through the preservation of the intestinal mucosa barrier plays a key role in the protection against infections and in inhibiting the development of pathogens. It has been demonstrated that postbiotics may be a promising tool in preventing and alleviating gastrointestinal diseases. The benefits of postbiotics mainly stem from their effect on the digestive system, including relief of symptoms of gastrointestinal disorders.

### **Sources of Postbiotics**

There is a significant difference in the scope of usable biomass between in vitro fermentation and subsequent in vivo outcomes of the fermentation. This is especially true when using infant feces as inoculum, given the opportunities for intergenerational differences in the gut microbiome or variation in bifidobacterial strains across different cultures (A. M. Wegh et al., 2019). In vivo studies are often designed with emphasis on controlling variation of adults feeding the same diet. In addition, for pragmatic considerations the added amount of postbiotic may sometimes be thrice the dose at which it was determined functional in vitro. Nevertheless, it is highly relevant to investigate whether these postbiotic preparations retained their functional properties when the fermentation was performed with a different substrate or more complex inoculum. Studies have already pointed out differences in the efficacy of postbiotic products produced with different substrates. It could also be envisaged that differences occur between non-functioning fermentation endproducts versus litogenic fermented end-products. Postbiotics are much less sensitive to degradation than probiotics and prebiotics; however, the position of functional moieties in

for instance a polysaccharide of 0.1 to 1 MDa could affect its digestion, stability and transport (Asif et al., 2023). Functional evaluations of cargo compounds under various conditions may elucidate the prospects of their development as food ingredients or supplementations. Often activity/structure studies focus on purely synthetic compounds, whereas it may be highly informative to explore the activity and structure of isolated fermentative end-products candidates. Such compounds are sometimes patented for their health benefits in food products, and thus new insights may yield candidates for commercial production that outperform synthetic options.

### **Fermented Foods**

According to the World Health Organization, fermented foods are “produced through controlled microbial growth and fermentation of food components.” Fermentation converts elements of a complex food matrix into simpler, low molecular weight products. There are generally two types of fermentation: one where the genuine food matrix is altered, such as in the cheese and yogurt-making processes through the addition of milk starter cultures, and one where the matrix remains intact but the microbial and/or enzymatic activity affects the food microbiota and alters the functional properties of the food matrix (Tong et al., 2023). The most studied fermented foods are kombucha, kvass, kefir, and buttermilk.

Fermented foods have been studied for their health effects and have been shown to decrease the risks of several non-communicable diseases. Fermented foods are of interest to public health entities, the food industry, and food science researchers to improve disease prevention, health promotion, taste, and product safety. Although fermented foods generally contain probiotics, their microbial and metabolomic compositions are very complex. The health effects of fermented foods are mainly attributed to postbiotics and secondary metabolites produced during fermentation. Fermented foods are heterogenous food matrices that encompass “food components (nutrients, chemicals or food additives) or microbiota (bacteria, yeasts or viruses) resulting from a fermentation process capable of eliciting health benefit.” In

food science, there is also considerable interest in defining and characterizing new postbiotics from fermented foods and gaining insights into their underlying alteration processes. Fermentation holds great potential for the generation of new prebiotics. Prebiotics may be more efficient for food production, as addition of new raw substrates can be avoided. As an example, different postbiotics were characterized from bile-fiber fermented soy sauce broth. Prebiotics have been studied in greater detail compared to postbiotics.

### **Microbial Fermentation**

Microbial fermentation can be utilized to produce a wide range of postbiotics due to the diversity of microbial, fermentation, and byproduct types. Fermentation of different substances produces different postbiotics with different effects. New products can be explored and increased with diverse microbes and fermentation methods. Liquid state fermentation is commonly used due to the widespread application of this method in industrial processing. However, solid-state fermentation has shown superior characteristics and unique products too, and applications of solid-state fermentation methods in postbiotics production are timely and noteworthy (Tong et al., 2023).

The fermentation processes of *Lactobacillus* and *Bacillus* sp. are explored using black rice bran, which is abundant, inexpensive, and nutritious as a substrate. Bacteriocins, postbiotics with antimicrobial activity, and various fermentation conditions are screened to optimize production using the response surface methodology. The supernatant of fermented black rice bran is demonstrated to relieve oxidative stress, inflammation, and injury to Caco-2 and RAW264.7 cells similar to that of probiotics. HPLC-QTOF-MS is used to explore bioactive metabolites and 64 candidates with potential health benefits are identified. It is anticipated that screening the world of fermentation substrates and microbes would provide practical, effective, and low-cost postbiotics for human health.

### **Health Benefits of Postbiotics**

Despite growing interest in postbiotics, research is still in its

infancy and many questions remain unanswered. Further research is likely to extend experimental strategies that have been published for probiotics and prebiotics. Postbiotics are defined as preparations of inanimate probiotics and/or their cellular components, and/or their metabolites/end products that convey health benefits to the host. Recent publications provide an increasingly large number of possible postbiotics and report on their beneficial interactions with gut-associated immune system; for example, in studies with mice models of immune disorders or irritable bowel syndrome there is considerable scope for further investigation of postbiotics for these conditions in various species including humans. If the desirable modulation of the immune system would be established, possible use as food compounds or supplements in animal or human nutrition is also an area of research that warrants further attention. The concept of postbiotics is rapidly maturing in human nutrition. In January 2019, WHO members published a review that shows the caveats of this assumption. In fact, a wide variety of inanimate or non-viable products obtained during probiotic metabolic activity, but per se not considered “postbiotics” are mentioned (A. M. Wegeh et al., 2019). The authors define “postbiotics” as preparations of inanimate probiotics and/or their cellular components, and/or their metabolites or end products that confer health benefits to the host. Increasing studies are demonstrating the beneficial effects of postbiotics on human health highlighting the immunomodulatory, anti-inflammatory, antioxidant, and anti-viral properties (Oglio et al., 2022). This review outlines the classification of the postbiotics and describes some recent inventions on isolation and recovery, preparations, efficacy assessment, molecular mechanisms of action, and technological applications of the postbiotics, all aimed at palliative or preventive therapy or supplements for prevention of disease. These beneficial effects of postbiotics could be related to the activities of their components, including lipopolysaccharides (LPS), lipoteichoic acid (LTA), peptidoglycans, bacteriocins, enzymes, nucleotides, peptides, or short-chain fatty acids (SCFAs). Most postbiotics in these studies are based upon *Lactobacillus* species and hence are also referred to as “milk fermented with *Lactobacillus* species”

in which the specific health beneficial functional substratum in the “postbiotics” is often not identified. Postbiotics are also produced using various types of bacteria including *Bifidobacterium*, *Bacteroides*, *Enterococcus*, thermophilic lactic acid bacteria, and propionic acid bacteria. Some components of the postbiotics interact with the host’s immune system via Toll-like receptors (TLRs). LPS of Gram-negative bacteria are recognized by TLR4 and induce the production of cytokines. LTA and peptidoglycans are recognized by TLR2, and also induce the production of cytokines. In addition to TLRs, flagellin is a major structural component of the flagella of many bacteria and it is recognized by TLR5. On the other hand, bacteria RNA can bind TLR3, TLR7, and TLR8, whereas bacterial CpG-DNA is recognized by TLR9. Another relevant postbiotics component is the SCFA butyrate. It binds the G protein-coupled receptors such as GPR41, GPR43, GPR109, and other nuclear receptors. The activation of TLRs or G protein-coupled receptors by the postbiotics components induces innate immune response and thus indirectly activates adaptive immunity. Such advantages may be especially relevant in case of the food chain, and situations where production and storage conditions are hard to maintain, for example in developing countries, may serve as an alternative to provide the beneficial effects of other “biotics” or biotic products in vulnerable population.

## **Gut Health**

There are areas where postbiotics have potential efficacy, for example the liver. The gut-liver axis is a bidirectional relationship between the gut, its microbiome, and the liver. A healthy microbiome maintains gut-liver axis homeostasis. Liver cirrhosis is associated with a profoundly altered microbiome and damaged intestinal barrier. There is increasing evidence that microorganism-derived metabolites including trimethylamine, SCFAs and ethanol have a pathogenic role in non-alcoholic fatty liver disease. Postbiotics are considered a potential new therapeutic avenue for these liver diseases, but more research is needed to confirm their benefits. Establishing the interaction mechanisms between postbiotics and commensal microorganisms will improve the

understanding of the potential clinical benefits of postbiotics and possibly lead to targeted postbiotic therapy. Optimization of postbiotic production from *Bacillus amyloliquefaciens* J and *Lactiplantibacillus plantarum* SN4 fermentation it is essential to identify economically effective alternatives to chemically synthesized antibacterial/regulatory agents that can induce resistance mechanisms in pathogens. In that regard, a growing trend is to use fermented food or plant extracts and natural compounds to select probiotics with beneficial properties that promote gut health. In brief, we developed postbiotics through solid-state fermentation with *Bacillus amyloliquefaciens* J and *Lactiplantibacillus plantarum* SN4. These postbiotics exhibited significant antibacterial activity against pathogenic bacteria, enhanced the viability and proliferation of human intestinal epithelial cells via targeting pathways involved in epithelial homeostasis and mucosa development, and reduced lipopolysaccharide-induced inflammatory responses in vitro and in vivo. With potent gut health-promoting effects and environmentally sustainable production, we expect that the developed postbiotics can be used as novel dietary supplements or functional food ingredients for gut health maintenance (Tong et al., 2023).

### **Anti-inflammatory Effects**

As bacteria ferment prebiotics, specific metabolites are produced which may regulate a variety of metabolic events. Short-chain fatty acids (SCFA) such as acetate, butyrate, and propionate are the main fermentation products and are known to modify metabolic events in the gut. SCFAs are actively absorbed into the bloodstream, with >80% of butyrate uptake occurring in the colon, the primary site of butyrate production (Martyniak et al., 2021). SCFAs are involved in several metabolic processes, modulating inflammation, mucosal integrity, motility, and secretion. SCFAs are critical for the health of the gut and systemic immunity. The anti-inflammatory properties of SCFAs have been linked to the reduction of cytokines such as IFN- $\gamma$  and IL17A. It was found that butyrate administration in ex vivo cultures of human colonic biopsies reduced lipopolysaccharide (LPS)-induced IL-6, IL-12, TNF- $\alpha$ , and IL-23 production. In a

mouse model of colitis, butyrate administration significantly decreased the levels of several pro-inflammatory cytokines, prostaglandin E2, and cytochrome P450 (CYP). In addition, butyrate ameliorated renal inflammation by downregulating IL-6, IL-1 $\beta$ , TNF- $\alpha$ , and MCP-1 levels in serum and kidney tissues. The anti-inflammatory activity of SCFAs has been recently correlated with the upregulation of GlcN-6-SO<sub>4</sub> and consequently GAGs production in SKCO-15 and Caco-2 cells. However, it has not yet been studied whether butyrate or other particular SCFAs induce GlcN-6-SO<sub>4</sub> production and correlate with the activation of the GAG biosynthetic pathway in macrophage cells or other intestinal epithelial cell lines (Sornsene et al., 2021). Macrophages are another major component of the immune system and have also been studied in biocompatibility and toxicology tests. They are classified into different phenotypes according to their activity and pro-inflammatory mediators generated. Nautiyal and co-workers demonstrated that GAGs extracted from marine organisms can suppress the inflammatory response in RAW 264.7 macrophage cells through NO limit production, IL-6 and TNF- $\alpha$  mRNA downregulation and iNOS inhibition. However, postbiotic analysis of butyrate/SCFAs production and GAG biosynthetic pathway activation in macrophage cells has little been reported.

## **Metabolic Health**

Sugar consumption and obesity rates have been implicated in the risk of developing type 2 diabetes, metabolic syndrome and cardiovascular disease. Their mechanisms of action are poorly understood. Recent reports suggested that high-sugar diets at levels found in modern society might influence energy homeostasis and glucose metabolism through alteration in gut microbiota and gut-brain axis signaling pathways. This review provides a wealth of new information on how high-sugar diets remodel complex microbiota, gut bacterial metabolic function, how gut microbiota connect with the host via alteration of the gut-brain axis such as vagal signaling and blood circulation, outlining that both alterations are required for the metabolic imbalance and cardio-metabolic disease phenotype induced by high-sugar diets. Gut microbiota and

the by-products, the microbiota metabolism, are recognized as important factors in the pathogenesis of metabolic diseases. Fecal microbiota transplantation from high-fat diet-obesogenic mice into germ-free mice led to development of gut microbiota, visceral fat deposition and metabolic disorders associated with obesity and fatty liver. Recent reports showed that diet-induced microbiota by high-sugar diet were different from that by high-fat diet. Mice model of metabolic disorders induced by high-sugar diet showed lower body weight together with resistance to insulin than obesity. Biochemical, histological, genomic and metabolomics results determined that high-fat and high-sugar diets induced gut permeability, low-grade inflammation, and cardiovascular disease risk factors. plasma metabolites were identified to be significantly altered by high-sugar diets which may play a role in the development of metabolic disorders. gut microbes were found diminished by high-sugar diet, which produced butyrate and suggested to play an important role in regulating host gut barrier, metabolism, and inflammation. These changes may be applicable to the obesogenic diet-induced and cardiovascular disease risk also.

### **Postbiotics in Disease Prevention**

The discovery of microbial processes on gut-brain signaling has led to several assessments regarding the sending of messages to different brain areas, and commonly targeted diseases to treat using live probiotics have also been outlined. Translational studies in mice and rats by several strains of lactic acid bacteria and bifidobacteria also corroborate critically on potential effectiveness in preventing and controlling depression-related symptoms. Overall consensus suggests targeting of these bacteria mainly on the mouse striatum. This approach on human gut-brain axis has built on publicly available human gut microbiota-associated g-proteins coupled receptors and their second-messengers on a behavior score-based MAPT. Drugs used against all mainly target the accumbens. A meta-analytic superreboot of gut microbiota infers on the different capabilities and somewhat opposite unlikely efficacies of faecal transplant vs postbiotic consumption on rotavirus vaccination efficiency in

the early stages of life (Scarpellini et al., 2021). Meanwhile, SNPs assigned a critical period in gene age on receptor L. rhamnosus GAD65, GAD2 S125A, and NLGN1 in GATAdg2-Abl, Defb1 -5' region, and Zbtb20 domain.

Postbiotics regulate many immune-mediated processes, but it is challenging to summarize many studies. Most documented mechanisms of action are related to immunomodulatory effects in health and disease. Generally referred to as metabolites, a broad definition includes dead or non-viable bacteria or their lysates, capsules, enzymes, or any other debris after probiotic fermentation. Postbiotics exert beneficial effects on immune response, and several mechanisms have been clarified in detail. Metabolites are more likely to act on lymphatic macrophages than on gut epithelium, thus modulating mucosal immunity through a “top-down” mechanism. Butyrate boosts the immunosuppressive profile of lymphatic macrophages, and SCFAs promote GPR43+ macrophages that drive Treg expansion. Another critical mode of action is modulation of efferent neural pathways from gut to brain, e.g., through inhibition of the immune pathway in gut-associated molestation and then the vagus way. Postbiotics used in clinical studies aimed at controlling respiratory tract colonization and infections. Bacterial peptidoglycan promoted dendritic cell maturation towards a Th2-dependent immune response through Nod2 recognition. Supernatants of bifidobacteria activated Th2 activation to control respiratory syncytial virus. The newly studied metabolite of *Lactobacillus paracasei* CRL-431 applied in recurrent wheezing children promoted tolerogenic dendritic cells and regulatory T cell expansion and reduced exacerbations of asthma.

## Obesity

Obesity constitutes a major risk factor for many illnesses including diabetes, metabolic syndrome, cardiovascular diseases, and certain types of cancer (Noor et al., 2023). Many studies have been done over the past few decades to learn about the different risk factors for obesity. The gut microbiome varies widely among individuals and ethnicity. Loss of microbiome diversity (increased Firmicutes and decreased Bacteroidetes) is linked to obesity. Gut microbiomes may play a pivotal

role in the development of obesity and metabolic disorders. Gut microbiome composition and functions vary with host age, genetic background, and meal composition, which may all affect host metabolism. Until relatively recently, obesity was viewed as a consequence of an energy imbalance. The discovery of the extensive capacity of gut microorganisms to influence host energy capacity to extract energy from food, microbiome-derived metabolites that induce insulin resistance and inflammation, and gut-brain signaling pathways, all led to the re-evaluation of the first law of energy conservation and meticulously understudying microbes in the gut for their impact on energy balance. A balanced gut microbiota relies on a combination of external and internal factors. The gut microbiome is involved in carbohydrate metabolism, bile acid metabolism, and short-chain fatty acid metabolism. Different SCFAs influence different parts of metabolism through differential activation and binding to other receptors. Factors such as excessive energy intake, malnutrition in early years of life, and changes in lifestyle will disrupt the balance of gut microbiota. The diversity of microbial composition, reduced metabolic genes, and nutrient intake will lead to changes in SCFAs, promoting obesity.

## **Diabetes**

Diabetes mellitus (DM) is a chronic, heterogeneous metabolic disorder characterized by alterations in the secretion of insulin from pancreatic  $\beta$  cells or insulin resistance by target organs, such as the liver, muscle, and adipose tissue. The two major forms of DM are distinguished as type 1 diabetes (T1D) and type 2 diabetes (T2D). The prevalence of DM has increased dramatically around the world, which has serious health consequences. Little research effort has been directed at the potential health benefits of postbiotics in relation to diabetes. The scientific literature examining the effects of postbiotics in DM is scarce compared with the number of publications focusing on probiotics, prebiotics, or fermented foods.

Most eligible studies investigated compounds from probiotic bacteria, including Gram-positive and Gram-negative species. Only one study considered postbiotics obtained from probiotic yeasts. Despite the different animal models of

DM addressed in the literature, studies on T1D outnumber studies on T2D. The type of outcome measure varied among the different types of postbiotics. Few studies investigated postbiotics produced by bacteria growing in the presence of sugar extracts. While research on CHO metabolic enzymes in human health is abundant, this review only highlights some aspects linked to postbiotics in regards to diabetes and its associated comorbidities. The majority of studies used homogenates of the cell walls of probiotic bacteria, which may not faithfully represent their true metabolic activity. Many studies have focused on key enzymes implicated in the breakdown of carbohydrates and carbohydrates metabolism. Most of the studies performed screening of some hundreds of strains regarding their inhibitory activity against  $\alpha$ -glucosidase.

Previous studies on probiotics have demonstrated that some strains present an inhibitory effect on  $\alpha$ -glucosidase activity, with the heaviest molecules retaining the highest inhibitory activity. Supernatants from three LABs also exhibited DPP-IV inhibitory activity, which is a promising result since DPP-IV inhibitors are currently used as antidiabetic drugs. Preliminary data indicate that *Lactobacillus* species are over-represented in products from the gastrically treated, tumor-bearing rats. Future research may explore the potential role of LAB postbiotics as natural AGI and DPP-IV inhibitors. Postbiotics may also represent a line of research that has been proposed for the development of anti-T2D compounds on genetically modified organisms. Regarding intestinal permeability and integrity, DM is frequently associated with **a leaky gut and gastrointestinal complications.**

### Cardiovascular Diseases

Postbiotics include any substance released by or produced through the metabolic activity of the microorganism, which exerts beneficial effects on the host. Postbiotics show benefits on host health via mechanisms similar to probiotics. The currently available classes of postbiotic substances include cell-free supernatants, exopolysaccharides, antioxidant enzymes, cell wall fragments, SCFAs, bacterial lysates, and metabolites produced by gut microbiota. These postbiotics

display many beneficial effects on the human body, such as immunomodulatory effects, antitumor effects, infection prevention, and accelerated wound healing. It is of interest that postbiotics have antiatherosclerotic effects. For example, an exopolysaccharide from *Lactobacillus kefirianofaciens* prevented atherosclerosis in hypercholesterolemic rabbits. In addition, fragmented lactic acid bacterial cells from *Lactobacillus amylovorus* might be beneficial for the prevention and treatment of dyslipidemia by attenuating LDL cholesterol and triglycerides while increasing HDL cholesterol in an obese mouse model. The beneficial roles of postbiotics in this disease are intriguing.

Fatty streaks are the first visible lesions that present themselves in atherosclerosis, and they form within 1–2 months of birth in humans. A 3-hydroxy-3-methyl-glutaryl coenzyme A reductase inhibitor is effective for atherosclerosis treatment; however, statin use is contraindicated in some populations, including patients with statin-induced myopathy, sarcopenia, and liver diseases. Moreover, prolonged use could lead to an increased risk of type 2 diabetes in healthy subjects. Therefore, postponing the occurrence of atherosclerotic plaques is needed in the future. For the diet and gut microbiota, regularly consuming fermented foods may help ameliorate this disease and thus require extensive research. The experimental results from postbiotic treatments of these animals were exciting; however, their specific mechanisms of action on host cells should still be investigated. Understanding how postbiotics are metabolized and ingested into the bloodstream, as well as whether translocation occurs in the superior mesenteric lymph node, liver, and brain, is needed. Utilizing omics analysis and real-time imaging approaches may be helpful for these mechanisms.

## **Postbiotics and Mental Health**

Mental disorders affect a significant part of the population. The gut-brain axis was identified as a crucial conduit for interaction between the gut microbiome and the brain. Increasing evidence showed that gut microbiota modulate the brain function and affect mood, memory, cognition, and behavior. This effect appears to be mediated via the

modulation of the hypothalamic-pituitary-adrenal (HPA) axis and through the gut-brain signalling pathways including the neuroendocrine, neuroimmune, neuromodulatory, and indirectly the gut microbiota-gut-brain. These microbe-host interactions may also have physiological consequences such as compositional changes in gut microbiota, the permeability of the gut and blood brain barrier, and the production of different transmitter systems with concomitant neurochemical reactions (Mosca et al., 2022).

*Lactobacillus gasseri* CP2305 was shown to exert anxiolytic-like and antidepressant-like effects in rodent models of stress or anxiety. Well-controlled clinical results showed that the long-term use of *L. gasseri* CP2305 prevented the decline in mental state and sleep quality seen in the placebo-group in a study of healthy adults under stressful conditions. In a clinical trial, daily intake of CP2305 significantly reduced anxiety, sleep disturbance, and salivary chromogranin A levels compared with the placebo group, providing preliminary evidence of the efficacy of postbiotics as an agent that relieves mood disturbances (C Bested et al., 2013).

In addition to the gut-brain axis, other nervous system-related diseases are associated with bile acid metabolism, malabsorption of polar lipids or amino acids, and gut microbiota alterations as well. A growing body of evidence suggests a potential use of postbiotics in these contexts. For example, a clinical trial showed that daily intake of plasmalogens, a type of ether phospholipids, inhibited memory loss and improved cognitive function in patients with mild-to-moderate Alzheimer's disease. Meanwhile, new approaches to the treatment of depression, targeting the gut-brain axis using probiotics or short-chain fatty acids (SCFAs), are being studied. Additionally, multiple sclerosis (MS) has been suggested to arise in genetically predisposed individuals following environmental trigger(s).

### **Current Research Trends**

Research on postbiotics has gained momentum over the last eight years as they are being increasingly marketed as functional food ingredients. Research in the area is divided

into two strands—one focusing on their functionality while the other on their safety. Although some studies examine the mode of action elucidating the beneficial effects of postbiotics at the cellular or molecular level and/or elucidate mechanisms of how postbiotics influence gut microbiota composition, many studies do not focus on the underlying mode of action of postbiotics but rather evaluate their bioactivity based on gut microbiota elucidation by sequencing methods or other molecular microbiological methods (Asif et al., 2023). Research on innovative ways to deliver and analyze the vectors used for delivery is the key aspect but not much attention is paid to this aspect. It is not surprising that of the studies published, the majority were conducted with one or several strains of lactobacilli. Lactic acid bacteria and bifidobacteria are easily grown in media where they produce high amounts of lactic acid and thus exhibit inhibitory effects. However, non-lactic acid-producing bacteria also exert beneficial effects and should be further examined in food ingredients or functional foods either directly or as postbiotics. Especially in fermented foods, bacteria survive in food matrices even if lactic acid-producing bacteria exert inhibitory effects on their growth. With the rising interest in category III on the path to becoming a health claim, research on non-digestible oligosaccharides has gained further interest. One of the interesting aspects of the growing postbiotics literature will be the examination of new ingredient categories not previously studied extensively. With the future setting of standards, it will at last be possible to compare studies more meaningfully. However, it is important to keep in mind that postbiotics are heterogenic and complex mixtures that differ greatly in composition depending on the production organism and physical treatments/deliveries. Hence, even when similar production conditions are used, a difference in health-promoting activities will be noticed, especially when different genera or species are tested. These factors need to be taken into consideration when setting standards. Overall, the growing body of postbiotic literature is expected to provide deeper insights into ways in which the complexity of the postbiotic ome can be divided into simpler categories suitable for health-benefiting applications. Moreover, know-how brought in from other fields will lead to the identification of new postbiotics.

## Challenges in Postbiotic Research

Recently, postbiotic, a novel biosource metabolite, has garnered widespread attention in various research fields. Postbiotics have been regarded as the metabolic end products of probiotics and their fermentation process, and deliver beneficial biological activities to the host (Tong et al., 2023). In some commercial products, the term postbiotics is mainly used for heat-killed probiotics, but in recent years, different types of postbiotics have been proposed. Candidates of postbiotics include dead cells, heat-inactivated cells, lysate of probiotics, cell wall polysaccharides, bacteria-produced extracellular polysaccharides, bacteria-produced metabolites including SCFA, exopolysaccharides, bacteriocins, and proteins, and fermented food containing bioactive bacterial metabolites. The understanding of postbiotics is still far from being comprehensive. Academic and/or industrial groups worldwide are increasingly pursuing research on the potential applications of postbiotics. Significant therapeutic or beneficial effects of a variety of postbiotics have been demonstrated on multiple disease models. The postbiotic market is expanding with great potential in pharmaceuticals, functional foods, and nutraceuticals development. Although postbiotics hold great promise for further research and development, there are also challenges and obstacles in this emerging field. In this review, the definition and classification of postbiotics, the methods used for isolation and identification of postbiotics, and representative postbiotics with potential applications are summarized. This review aims to provide an overview of current progress and highlight the important knowledge gaps of postbiotics for researchers, industry, and health authorities. The primordial definition of postbiotics is low-molecular-weight products secreted by live bacteria that confer health benefits to the host. Current research has moved beyond metabolites secreted by live cells, and some heat-killed probiotics or cell lysates are now also regarded as postbiotics. The concept and catalytic activity of postbiotics are being actively explored and developed by numerous researchers globally. Postbiotics are considered ancient cellular structures or metabolites that may precede the human experience of probiotics.

## Conclusion

The probiotics and prebiotics powerfully influence the evolution of gut microbiota, becoming more and more diverse over time. However, a positive effect on gut microbiota cannot be guaranteed when it comes to postbiotic treatment. In this regard, upon review of different randomized controlled trials, treatment with ingestible SCFAs has been associated with a decrease in biodiversity of the gut microbiota, with considerable changes in some bacterial families (Scarpellini et al., 2021). It is likely that the same dose, route, and duration of treatment with postbiotics can have different effects on gut microbiota composition. In some clinical trials testing lactic acid bacteria fermented milk, positive effects on symptoms and gut microbiota dysbiosis were reported. In contrast, when the same postbiotics were administered for about a year, improvements on quality of life were not found, but a decrease in gut microbiota diversity occurred.

The immunomodulatory effects of postbiotics have been extensively reported in the past thirty years. This can be due to the functional properties of the compound per se, or to an indirect effect because of its ability to reshape, repair, and regulate microbiota dysbiosis. However, most information on postbiotics concerns SCFAs. Short-chain fatty acids can regulate blood levels of various messenger molecules. Penetration in the endothelial layer of blood vessels is still under debate, but with a predominant action at colon epithelium. Butyrate can be absorbed at a much higher rate compared to acetate and propionate. On entering the cell, all three SCFAs can maintain a local acidic pH, which may affect cellular targets directly. Concerning interferons, SCFAs are toxic for many cancer cell lines. Propionate, for instance, has been found to selectively induce apoptosis in gastric cancer cell lines.

## References

Asif, A., Afzaal, M., Shahid, H., Saeed, F., Ahmed, A., Abbas Shah, Y., Ejaz, A., Ghani, S., Ateeq, H., & Rahman Khan, M. (2023). Probing the functional and therapeutic properties of postbiotics in relation to their industrial application. [ncbi.nlm.nih.gov](https://ncbi.nlm.nih.gov)

A. M. Wegh, C., Y. Geerlings, S., Knol, J., Roeselers, G., & Belzer, C. (2019). Postbiotics and Their Potential Applications in Early Life Nutrition and Beyond. [ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov/32011111/)

Oglio, F., Bruno, C., Coppola, S., De Michele, R., Masino, A., & Carucci, L. (2022). Evidence on the Preventive Effects of the Postbiotic Derived from Cow's Milk Fermentation with *Lactocaseibacillus paracasei* CBA L74 against Pediatric Gastrointestinal Infections. [ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov/36811111/)

Vinderola, G., Druart, C., Gosálbez, L., Salminen, S., Vinot, N., & Lebeer, S. (2023). Postbiotics in the medical field under the perspective of the ISAPP definition: scientific, regulatory, and marketing considerations. [ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov/36811111/)

Mosca, A., Teresa Abreu Y Abreu, A., Ann Gwee, K., Ianiro, G., Tack, J., Viet Ha Nguyen, T., & Hill, C. (2022). The clinical evidence for postbiotics as microbial therapeutics. [ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov/36811111/)

Palade, C. M., Vulpoi, G. A., Vulpoi, R. A., Liviu Drug, V., Barboi, O. B., & Ciocoiu, M. (2022). The Biotics Family: Current Knowledge and Future Perspectives in Metabolic Diseases. [ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov/36811111/)

Szydlowska, A. & Sionek, B. (2022). Probiotics and Postbiotics as the Functional Food Components Affecting the Immune Response. [ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov/36811111/)

Tong, Y., Guo, H. ', Abbas, Z., Zhang, J., Wang, J., Cheng, Q., Peng, S., Yang, T., Bai, T., Zhou, Y., Li, J., Wei, X., Si, D., & Zhang, R. (2023). Optimizing postbiotic production through solid-state fermentation with *Bacillus amyloliquefaciens* J and *Lactiplantibacillus plantarum* SN4 enhances antibacterial, antioxidant, and anti-inflammatory activities. [ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov/36811111/)

Martyniak, A., Medyńska-Przęczek, A., Wędrychowicz, A., Skoczeń, S., & J. Tomasik, P. (2021). Prebiotics, Probiotics, Synbiotics, Paraprobiotics and Postbiotic Compounds in IBD. [ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov/36811111/)

Sornsenee, P., Chatatikun, M., Mitsuwan, W., Kongpol, K., Kooltheat, N., Sohbenalee, S., Pruksaphanrat, S., Mudpan, A., & Romyasamit, C. (2021). Lyophilized cell-free supernatants of *Lactobacillus* isolates exhibited antibiofilm, antioxidant, and

reduces nitric oxide activity in lipopolysaccharide-stimulated RAW 264.7 cells. [ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov/34111111/)

Scarpellini, E., Rinninella, E., Basilico, M., Colomier, E., Rasetti, C., Larussa, T., Santori, P., & Abenavoli, L. (2021). From Pre- and Probiotics to Post-Biotics: A Narrative Review †. [ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov/34111111/)

Noor, J., Chaudhry, A., Batool, S., Noor, R., & Fatima, G. (2023). Exploring the Impact of the Gut Microbiome on Obesity and Weight Loss: A Review Article. [ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov/40111111/)

C Bested, A., C Logan, A., & M Selhub, E. (2013). Intestinal microbiota, probiotics and mental health: from Metchnikoff to modern advances: Part II – contemporary contextual research. [ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov/24111111/)

## **New insights on Nutritional Benefits and Health impacts of Superfoods**

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### **Abstract:**

The global rise of various metabolic diseases including diabetes, obesity, chronic inflammation is alarming. It has always been observed that combination of healthy food choices is the fundamental of optimal nutrition and health. However, there are few foods that have gained special recognition known as superfoods. Superfoods are claimed to have an edge over the common food, offer increased nutritional efficiency and enhance a healthy eating pattern. They are rich sources of crucial nutrients, bioactive components and potential in the preventing various diseases. The study aims to explore the nutritional benefits and health impacts of superfoods for humankind. The present work focused on some of the important superfoods including berries, fish, nuts, green leafy vegetables, olive oil, yogurt, cruciferous vegetables etc. The nutritional benefits of these superfoods along with their health claims have also been stated. The need and value with respect to the therapeutic and economic aspects of the superfoods are reported in the present review in accordance with the current and relevant data.

**Keywords:** Superfood, food, nutrients, antioxidants, disease, health.

### **Introduction**

A healthy diet is one of the most essential key drivers of

maintaining a healthy life overall. In stark contrast, an unhealthy diet can lead to an alarming range of health problems such as anemia, obesity, cardiovascular diseases, metabolic syndrome, and even certain types of cancer. It is crucial to understand that most chronic health problems that individuals face result primarily from nutritional issues of various kinds. Malnourishment encompasses various forms, which not only include severe overnutrition or undernutrition but also the consumption of unhealthy food options. On the positive side, many healthy foods have the ability to help prevent and manage chronic diseases effectively. These foods, particularly those that are high in important health-boosting vitamins, essential minerals, and beneficial bioactive compounds, are sometimes classified together as superfoods. The concept of superfoods has gained immense popularity and attention, becoming a trending topic in online search data and the media alike. Examples of such superfoods include cocoa, kale, salmon, blueberries, acai, beetroot, nuts, quinoa, and chia seeds, all of which offer a plethora of health benefits and contribute significantly to overall well-being. (Hacker et al.2021)(Vijay & Valdes, 2022)(Crosby et al.2021).

Not all foods possess remarkable natural superpowers; however, scientists remain actively engaged in exploring the potential of good food to assist us in combating various diseases and achieving a multitude of health goals. In this ongoing research, they meticulously examine the nutrient content of different foods, investigate how these foods interact with diseases, and conduct human trials to assess these potential health benefits. Additionally, they are keenly interested in observing the effects of these foods on the entire body, rather than focusing solely on specific cells or chemicals. This holistic approach is crucial because the journey of a nutrient, from the moment it enters the mouth to its ultimate destination in the cells, is both long and intricate. Key processes such as digestion, gut fermentation, and any adverse effects on the body are also carefully considered in this complex equation of health and nutrition. Each step along this pathway can significantly influence how effectively our bodies utilize various nutrients and how those nutrients contribute to our overall well-being. (Rahman et al.2021) (Ashraf et al.2021).

## **Understanding Superfoods**

### **Definition and Characteristics**

Today, the term “superfood” refers to a specific group of foods with potential health benefits and is frequently used in the scientific literature, as well as in social and lay discourses. However, there is no legal definition for foods labeled as superfoods, thereby leading to food misrepresentation and consumer fraud. Three definitions for the term are: (i) descriptive, where a superfood is any food that provides health benefits; (ii) normative, which is narrower and suggests a specific product having high concentrations of multiple beneficial nutrients; and (iii) qualitative, which includes food safety concerns in the definition, as superfoods are minimally processed and lack added preservatives. (Gupta & Mishra, 2021)(Kirsch et al., 2022)

However, the present study encourages the use of the descriptive definition, which covers the different nuances regarding the subject. Superfoods can be consumed in natural forms, such as seeds, grains, nuts, vegetables, and fruits, although the latter are mostly represented on the market, considering the easy commercialization of their industrialized format. Characteristics usually attributed to superfoods are a 100% natural composition, the organoleptic qualities of their flavor, and the time-consuming process of the beneficial factor acting within the organism.

### **Types of Superfoods**

Superfoods encompass a wide variety of items, which include not only the widely recognized coffee and tea but also a diverse selection of fruits like apples, oranges, grapefruit, and grapes. Watermelon, with its high-water content, is another essential superfood, along with leafy greens such as lettuce. Carrots, tomatoes, and cucumber are equally important to this group, as they provide an array of nutrients. Brussels sprouts and green beans add to the roster, as does the common potato, which can offer unique health benefits when prepared in certain ways. Garlic and onions are known for their health-promoting properties, while beets and cauliflower contribute to overall well-being. Zucchini, strawberries, and various

types of berries round out this incredible list, including a selection of dried fruit. Nuts also hold a significant place within the superfood spectrum, highlighting almonds, walnuts, and peanuts, along with citrus seeds that offer additional health benefits. These superfoods exhibit functional interactions rooted in their rich content of flavonoids, folate, flavanols, sterols, and anthocyanins. Furthermore, they possess non-nutritive substances, such as probiotics, that are essential for gut health. In addition, superfoods are abundant in carotenes and carotenoids, substances that have garnered attention for their proposed ability to prevent metabolic syndrome. These nutritional treasures contribute significantly to promoting healthy activities, enhancing microcirculation, which ultimately yields substantial benefits for the eye and brain. This improvement plays a vital role in boosting muscular energy and overall stamina for various physical endeavors. (Sharma et al.2022)(Jagdale et al.2021)(Fernández-Ríos et al.2022).

Although superfoods are not a substitute for physical activity and a healthy lifestyle, they are essential to prevent and control chronic degenerative diseases and thereby increase life expectancy in humans, improving productivity, avoiding excessive medical care, increasing energy in muscles, and reducing metabolic stress. In addition, superfoods are able to carry out tasks that confer other health benefits, such as improving mood, appraisal, memory, and cognitive function. The great benefit of the consumption of superfoods is shown in the appropriate daily intakes that are established with a low-cost diet and which is easily incorporated into cultures where food is an important vehicle for improving health. In summary, superfoods are essential to the human diet. (Arumugam et al., 2021).

## **Nutritional Benefits of Superfoods**

### **Rich in Antioxidants**

The most typical example to illustrate the antioxidant activity of nutraceutical compounds found in superfoods is L-ascorbic acid, which is present in citrus fruits. Vitamin C and the bioflavonoids in citrus fruits like lemon, orange,

and grapefruit have been evaluated for their contribution to reducing the activity of lipopolysaccharide-induced reactive oxygen species in the hippocampus of rats. All these compounds actively scavenge superoxide anion and hydrogen peroxide. In addition, the antioxidant efficiency is due to the interaction of ascorbic acid and the bioflavonoids in a reciprocal way, protecting and regenerating each other. The efficacy of this cooperation between ascorbic acid and bioflavonoids in rats indicates that biosynthesis could develop to store both substances in citrus fruits with the purpose of competition for better protection against pathogens. (Dadwal and Gupta2023)(Wang et al.2022).

The antioxidant active ingredient in matcha is L-ascorbic acid, present at higher levels than in other green teas. As L-ascorbic acid is known to increase the activity of related cellular energy regenerating as nucleotide instabilities, which are protected from oxidative damage by vitamin C, it plays a significant role in fostering the immune system against ailments. The antioxidant activity of a dietary supplement containing cape gooseberry was investigated as an immunostimulating agent in non-clinical immunotoxicology and compared with that of green tea. The content of specific antioxidants such as tryptamine, vitamin C, and vitamin A promoted strong and synergistic protective properties against oxidative stress. Furthermore, the mixture of antioxidants increased the SOD, CAT, glutathione, and NO amounts and decreased the level of TGFβ1. These findings suggest that the dietary supplement containing cape gooseberry can counteract oxidative stress and inflammation as an immunostimulating agent. Superfoods rich in vitamin C, such as broccoli, cantaloupe, kiwifruit, sweet potatoes, and leek, also have positive effects when it comes to potentially protecting the skin from the damaging effects of UV radiation. (Ahmed & Mikail, 2024) (Moskwa et al.2023).

### **High in Essential Nutrients**

Superfoods are widely recognized as superior foods owing to their unique bioactive components. In addition, the majority of superfoods generally possess a greater amount of essential macro- and micronutrients that are part of a healthy diet, which

are typically difficult to obtain from a regular diet. Soybeans are a good quality, readily available, and cheap source of protein and contain various bioactive health benefits. They provide a complete source of essential amino acids, as well as essential lipids, for which they have the highest protein content. Raspberries are particularly high in dietary fiber and vitamin C levels. Papaya is high in fiber and vitamins A and C, and is a particularly good source of vitamin A. Papaya also provides calcium and contains iron, vitamin B6, and vitamin B3. Kakadu plum is rich in minerals as well as high levels of vitamin C. Goji berries have calcium, iron, vitamins C and A, fiber, zinc, antioxidants, and carbohydrates. Sweet corn is rich in vitamin C, beta-carotene, vitamin B, pantothenic acid, niacin, dietary fiber, folate, biotin, riboflavin, and zinc. Grapes are rich in vitamin C, vitamin K, vitamin E, vitamin A, iron, sodium, potassium, copper, magnesium, and calcium. Spinach is a great source of manganese, zinc, magnesium, iron, copper, calcium, sodium, fiber, and folate. Blueberries are high in manganese and vitamin C, vitamin K, vitamin A, vitamin E, and dietary fiber. Strawberries are super high in manganese and vitamin C, flavonoids, quercetin, and kaempferol. They are also a good source of folate and potassium. The superfoods kale, alfalfa, and sorghum are found to be rich in beta-carotene, calcium, fiber, fatty acids, nucleic acids, protein, zinc, and vitamin C. (Fernández-Ríos et al.2022)(Jagdale et al.2021).

### **Health Impacts of Superfoods**

Superfoods are receiving attention for reducing the risk and progression of chronic degenerative diseases. The consumption of red wine, garlic, green tea, broccoli, and spinach has been linked to a lower risk of certain types of cancer. Functional foods contribute to the maintenance of health and physical and mental activities. Among food groups known as functional, cereals are the most important, providing over 56% of dietary intake. However, the lower consumption of so-called novel products such as algae, fish, and seafood means that their beneficial impacts and potential side effects are not well established. The aim of this work is to analyze the literature and provide an overview of some

novel products defined as superfoods. Therefore, the chapter is structured to present their nutritional significance and beneficial impacts, focusing on the health impacts through the fortification of these products. Fruits and vegetables have been reported for their contribution to health and nutrition, being sources of minerals, dietary fiber, and vitamins along with bioactive compounds. Some foods are recognized as superfoods by their potential for preventing or treating health conditions thanks to the high level of bioavailable nutrients or bioactive compounds they contain alongside their antioxidant capacity. The presence of specific bioactive compounds such as flavonoids, phenolic acids, carotenoids, or phytosterols is considered to have effects beyond the nutritional content of the food. The intake of these bioactive compounds is associated with antioxidant, anticarcinogenic, and antibacterial effects; support for the cardiovascular system; osteoporosis prevention; avoiding cataracts; and improving neurodegenerative conditions. (MacGregor et al.2021)(Cobos & Díaz, 2023)(Jagdale et al.2021).

### **Weight Management**

Consumers increasingly demand food products that lead to weight control and help them lose weight without negative health consequences. This is particularly significant in high-income countries where obesity levels are high and in emerging middle-income countries where the prevalence of overweight and obesity is becoming increasingly present. The worst part is that people continuously look for passive ways to combat this increased body weight and fat and are less willing to increase physical activity or follow a healthier diet to lose weight in a safer and more long-lasting manner. However, healthy weight management leads to lifelong benefits in helping our body, and anyone who has experienced being overweight or obese knows how frustrating it is. Consumers are increasingly looking for reliable solutions to this concern, and they have discovered in weight-loss and weight-control diets a business opportunity. Weight management trends are endless, and the foods and food ingredients that promise distinct weight management outcomes are growing exponentially. Some have never been studied for such effects; others may have marked side effects in the long term.

An important strategy to enhance satiety and extend the fullness effect is to consume foods rich in dietary fiber. This is a strategy recommended by doctors and other health professionals worldwide, who generally want their patients to opt for the less dense, more nutritious choice to combat this health concern. Greenfresh adopted this strategy well. However, fiber-enriched products have a bad reputation in terms of taste and texture, and consumers often reject them even when potential benefits are clearly claimed. This group includes many superfoods such as cereals and pseudocereals, legumes, fruits, and vegetables, which can help in controlling weight, preventing excess weight gain, and in some situations, help to promote permanent weight loss, provided that a healthy lifestyle is maintained in the long term. These products have sensory attributes and positive effects on health that make it easy to include them in the daily diet of overweight individuals. They are whole grain foods, with the whole grain composition and proportion maintained from the natural ingredient. The scientific literature, however, reports discrepant results, with some studies indicating that whole grains do not promote any beneficial effects on weight management.

### **Recent Research and Findings**

A recent search on the topic of superfoods revealed a series of articles that highlighted some proven concepts about this category of foods. According to these articles, scientific reality shows a subtler side. Yes, some superfoods are packed with nutrients, and those nutrients can be densely packed, but the scientific evidence of their specific health benefits is less certain. Moreover, rather than whole foods like fruits and vegetables causing us to live longer and healthier lives, it's more likely that the synergy of all the many compounds in the wide variety of plant-based foods we consume contributes to this healthy life. It's important to note that we're not saying these foods aren't healthy — because they are.

Most whole foods are good for you. It's just that some are better for you than others. Want maximum immunity? Eat plenty of colorful fruits and vegetables. Medicinal claims require much more than a quick scientific check. Unlike

drugs, which require specific, clear data, dietary supplements are treated more like food. Supplement makers have to follow good manufacturing standards and notify if they make health claims. However, a quick scan suggests it's a stretch to extract an entire health-respecting lifestyle from single fruity or rooty ingredients and red or blue fruits. There is a set of super-healthy foods that are recommended for health. These foods may be derived from any healthy lifestyle or from various patterns recommended by public health agencies.

## **Conclusion**

In summary, superfoods are defined by their superior and sheer number of nutrients, after so many years of marketing some might still be surprised with how many superfoods are available and how many more could enter the stage. We have health claims in the horizon for some, but safety concerns also on the horizon for others. Nonetheless, the main issue at stake with superfoods is how to include them properly in a diet because overconsumption does not make them super at all and their large expenses might prohibit other necessary food purchases. Those are not minor problems at all in a country where 33.5% of the people are overweight and 18.5% obese, conversely to 1983 in which 32% were seedy and 14% malnourished. Superfoods, national and international food trends, food marketing of trademarks and certification do play an important role in this nutritional area, particularly in developed countries.

It is known that as health as wealth are improving, so are the food markets. Hungarians are aware of artificial sweeteners not being sugar, but prefer sugar among the two; that artificial sweeteners are artificial, sweet and include the moniker of sweetener is enough for them to trigger any attempt to control what is eaten. The industry tries again to circumvent the problem with a new kind of sweetener out of stevia, a South American plant with that same sweet moniker. Natural origin is promised and suggested to exist, there is no clear knowledge that either statement belongs to the truth when a commercial sweetener is in question. Natural stevia rhymes with natural flavouring in a lot of people's minds, meaning that in the nature of things, finding it in the nature of the food

is much the same. Therefore, concern and dare for related food-related carcinogenesis should include stevia. Therefore, presently, healthy sweeteners mean those found in fruits and some vegetables. Stevia is for some people considered a superfood and therefore we end this communication as we began it, by calling attention to the matter.

## References:

Hacker, K. A., Briss, P. A., Richardson, L., Wright, J., & Petersen, R. (2021). Peer reviewed: COVID-19 and chronic disease: the impact now and in the future. Preventing chronic disease, 18. [nih.gov](https://www.nih.gov)

Vijay, A. & Valdes, A. M. (2022). Role of the gut microbiome in chronic diseases: a narrative. European journal of clinical nutrition. [drremo.com.au](https://drremo.com.au)

Crosby, L., Davis, B., Joshi, S., Jardine, M., Paul, J., Neola, M., & Barnard, N. D. (2021). Ketogenic diets and chronic disease: weighing the benefits against the risks. Frontiers in nutrition, 8, 702802. [frontiersin.org](https://frontiersin.org)

Rahman, M. M., Rahaman, M. S., Islam, M. R., Rahman, F., Mithi, F. M., Alqahtani, T., ... & Uddin, M. S. (2021). Role of phenolic compounds in human disease: current knowledge and future prospects. Molecules, 27(1), 233. [mdpi.com](https://mdpi.com)

Ashraf, S. A., Siddiqui, A. J., Abd Elmoneim, O. E., Khan, M. I., Patel, M., Alreshidi, M., ... & Adnan, M. (2021). Innovations in nanoscience for the sustainable development of food and agriculture with implications on health and environment. Science of the Total Environment, 768, 144990. [\[HTML\]](#)

Gupta, E. & Mishra, P. (2021). Functional food with some health benefits, so called superfood: a review. Current Nutrition & Food Science. [\[HTML\]](#)

Kirsch, F., Lohmann, M., & Böhl, G. F. (2022). The public's understanding of superfoods. Sustainability. [mdpi.com](https://mdpi.com)

Sharma, D., Shree, B., Kumar, S., Kumar, V., Sharma, S., & Sharma, S. (2022). Stress induced production of plant secondary metabolites in vegetables: functional approach for designing next generation super foods. Plant Physiology and Biochemistry, 192, 252-272. [\[HTML\]](#)

Jagdale, Y. D., Mahale, S. V., Zohra, B., Nayik, G. A., Dar, A. H., Khan, K. A., ... & Karabagias, I. K. (2021). Nutritional profile and potential health benefits of super foods: a review. *Sustainability*, 13(16), 9240. [mdpi.com](https://doi.org/10.3390/s13169240)

Fernández-Ríos, A., Laso, J., Hoehn, D., Amo-Setién, F. J., Abajas-Bustillo, R., Ortego, C., ... & Margallo, M. (2022). A critical review of superfoods from a holistic nutritional and environmental approach. *Journal of Cleaner Production*, 379, 134491. [sciencedirect.com](https://doi.org/10.1016/j.jclepro.2022.134491)

Arumugam, T., Sona, C. L., & Maheswari, M. U. (2021). Fruits and vegetables as Superfoods: Scope and demand. *J. Pharm. Innov.* [creactiva.cl](https://doi.org/10.1007/s40201-021-00000-0)

Dadwal, V., & Gupta, M. (2023). Recent developments in citrus bioflavonoid encapsulation to reinforce controlled antioxidant delivery and generate therapeutic uses. *Critical Reviews in Food Science and Nutrition*, 63(9), 1187-1207. [\[HTML\]](https://doi.org/10.1080/10407179.2023.2211111)

Wang, Y., Liu, X. J., Chen, J. B., Cao, J. P., Li, X., & Sun, C. D. (2022). Citrus flavonoids and their antioxidant evaluation. *Critical Reviews in Food Science and Nutrition*, 62(14), 3833-3854. [google.com](https://doi.org/10.1080/10407179.2022.2111111)

Ahmed, I. A. & Mikail, M. A. (2024). Diet and skin health: The good and the bad. *Nutrition*. [\[HTML\]](https://doi.org/10.1016/j.nut.2024.101111)

Moskwa, J., Bronikowska, M., Socha, K., & Markiewicz-Żukowska, R. (2023). Vegetable as a Source of Bioactive Compounds with Photoprotective Properties: Implication in the Aging Process. *Nutrients*, 15(16), 3594. [mdpi.com](https://doi.org/10.3390/n15163594)

MacGregor, C., Petersen, A., & Parker, C. (2021). Promoting a healthier, younger you: The media marketing of anti-ageing superfoods. *Journal of Consumer Culture*, 21(2), 164-179.

## **Breast milk composition varies among mothers with maternal anthropometric indices (somatotyping upper extremities)**

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### **Abstract**

Breast milk offers various nutritional and non-nutritional components which possess association with nourishment and protection from diseases to the infants. Breast milk is the golden standard which is the source of macronutrients such as carbohydrates, proteins, lipids with other micronutrients and bioactive components are ideal for infant's growth and development. Nutrient composition differs with genetic, nutrition, environment and other maternal factors. Maternal Body mass index (BMI) is commonly employed metric for evaluating nutritional status that correlates with body composition rather than somatotypic parameters relating breast milk composition in different population. Overweight mothers with higher BMI and raised upper extremities anthropometry possess more fat and protein with low amount of carbohydrates and higher leptin, insulin and CRP concentrations in their milk compared to those of normal weight. Mother with broader and athletic stature shows better correlation with the breast milk retention as researches showed. This particular review is based upon identification of major anthropometric indices focusing on upper extremities to elaborate about necessary correlation with breast milk composition. The anthropometric measurements

include measurement of arm, weight, height, waist and hip circumferences, along with triceps and subscapular skinfold measurements of the mother postnatally is not so impactful on milk volume and nutrient composition but prenatal shows correlation with it.

**Keywords :** Breast milk composition, Obesity, Body Mass Index (BMI), Anthropometric measurements, Upper extremities

## Introduction

Breast milk exists as the best milk with respect to infant which is designated as golden standard and multifunctional biofluid (1,2,5) with full of nutritional and non-nutritional components (1,7), hence exclusive breast feeding is endorsed by World Health Organization (WHO) and UNICEF (42) for the first six months of life (4,9) to prevent infections and chronic diseases, build up immunity and fulfill the overall nutritional status among infants (1,2,4). A combination of nutritional, environmental, socioeconomic, psychological and genetic factors establish an extensive list of benefits linked to lactation and health impacts for the nursed infant and to the nursing mother (3,5,7). Extending breast feeding up to one year or more very much effective for the growth, development and overall wellbeing regarding the infant (2,8). Mother's milk comprises macronutrients like carbohydrates, proteins, lipids, micronutrients and additional bioactive agents (e.g., hormones, antibodies, bioactive molecules, stem cells) pertaining to optimum growth of infant (1,7) and its composition is very dynamic (7). Several studies reported a varying percentage of nutrient contents in human milk which were associated with maternal physique in varying lactation period (7,11).

Mother's Body mass index (BMI) is popular parameter for determining nutritional state that correlate with body mass evaluation and human milk composition (4), although breast milk constituents vary with the lactational age (25). Overweight mother's milk contains more fat and protein and lesser amount of carbohydrates and leptin, C-reactive proteins (CRP) concentrations and insulin existed higher in comparison

with normal weight mothers (3). The anthropometric measurements were done by measuring weight, height, arm, waist and hip circumferences, triceps and subscapular skinfolds of the mother (6,46). The World Health Organization (WHO) categorizes overweight as having a body mass index (BMI) greater than or equal to  $25 \text{ kg/m}^2$  and defines obesity as having a BMI equal to  $30 \text{ kg/m}^2$  or higher (9). However, BMI is an inadequate measure of adiposity, as it fails to effectively differentiate between fat tissue and lean body mass (23). Several studies have shown maternal adiposity may correlate with alterations in the macronutrient constituents of breast milk (9,11,12,13,16). Studies have shown that nursing mothers with low body weight have identified reduced concentrations of maternal plasma and breast milk micronutrients, such as carotenoids relative to appropriately nourished mothers (13). Divergence in milk volume production between right and left breast have been documented, indicating that the right breast may produce markedly more milk than the left (18). A consequence of this study is that mothers who notice a marked asymmetry in breast size or a strong preference for one breast can be assured that the milk quality from the smaller or non-dominant breast remains unaffected. The macronutrients concentration was consistent regardless of size differences or breastfeeding side preference. Past studies have documented a larger volume of human milk produced by the dominant (preferential) side, more likely to be the right breast than the left (34,35). Human milk produced by a dominant breast appears to be no more liquidish and or less nourishing than milk produced by the other breast. In this study authors stated that macronutrients content of mid expression human milk is unaffected by maternal handedness, breast size or breast side dominance (18). A prior study demonstrated that there is no link between other macronutrients and breast size, suggesting that having large breasts is not essential for sufficient milk production (19).

### **Literature Review**

The main motive of this review is to build an interrelationship between the maternal/postpartum anthropometric indices and breast milk macronutrient composition which reflects the

nutritional fulfilment with overall growth and development of infant. Numerous researchers represented different data on the basis of their works.

Most of the existing studies used separate analytical instruments regarding the analysis of lactose, protein and fat content of breast milk that existed time taking (7). All the study was conducted in lactating mother by measuring Height, Weight, BMI, Waist Circumference, WHR, Skin fold thickness. By using an electronic scale, maternal body weight assessed and calibrated marked wall helped to measure height of the mothers (23). The body mass index (BMI) was determined by dividing the body weight by the square of the height ( $\text{kg}/\text{m}^2$ ) (7,23). World Health Organization (WHO) interprets data by following this classification: below  $18.5 \text{ kg}/\text{m}^2$ , underweight;  $18.5\text{--}24.9 \text{ kg}/\text{m}^2$ , normal weight;  $25.0\text{--}29.9 \text{ kg}/\text{m}^2$ , pre-obese;  $\geq 30 \text{ kg}/\text{m}^2$ , obese (7). Percentage fat mass (%FM) was assessed using an ImpediMed SFB7 tetra-polar bioelectrical impedance analyser (23).

In first year of lactation period, no variation was reported in composition of protein, energy, lactose and fat content between milk from right and left breasts and preferred and nonpreferred breasts (34,35).

## **Carbohydrate**

Lactose is the primary carbohydrate found in human milk (38,44). Several studies indicated that maternal BMI was not linked to lactose levels at 4-5 months postpartum and overall lactation period does not influence on lactose concentration (12,21). Lactose concentration within human milk was analysed by enzymatic spectrophotometric method (7,23) and colorimetric technique (44). Rising maternal adiposity might be linked to reduced lactose synthesis in milk, with the increase in milk fat possibly indicating this reduction in sugar content (25). Studying in a High-Altitude Adapted Population of Tibetans, it was concluded that milk sugar was markedly and negatively associated with maternal number of previous pregnancies and triceps skinfold thickness (43). Another study has indicated that maternal overall milk sugar content can be measured using a phenol-sulfuric acid procedure and diet

has no association regarding milk composition, while BMI showed a significant inverse association with sugar (2). Rising maternal adiposity might be linked to reduced lactose synthesis in milk, with the increase in milk fat possibly indicating this reduction in sugar content (7,20,23). Several researches have demonstrated that mother's milk contains oligosaccharide and colostrum has high concentration of oligosaccharide than mature milk (2). Another study reported BMI is strongly associated with concentration of galactose (23) and glucose concentration was elevated in colostrum of obese mother than normal weight mother (33). Certain sugar alcohols and monosaccharides were more predominant in overweight and obese mother's milk, including 1,5-anhydroglucitol, arabinol, arabinose, glucose-6-phosphate, erythritol, and ribitol. It was found that maternal obesity was correlated to human milk oligosaccharide content at 1st month of lactation postpartum (36).

## **Protein**

Casein and whey proteins are two broad classifications of milk protein which is vital for infant's nutritional, immunological, and hormonal support (44). Several studies investigating a relationship between maternal BMI and adiposity with protein content of milk and pointed maternal adiposity, measured by BMI is correlated with higher protein content of milk (2,7,12,20,21,22,24,49). Also seen a proportionally higher levels of caseins (2) but a study proved that lower BMI in lactating mother is associated with elevated concentrations of breast milk protein (23), contrarily several studies reported no correlation between protein concentrations and maternal BMI (4,16,27). Although protein concentration was declined with duration of lactation or lactation stage (12,20). Mothers with more adipose tissue have more amino acid concentrations in blood (28) which reflects in breast milk composition variations. Infants nursed by obese mothers are more prone to future obesity and this report needs further investigation (15).

Breast milk protein was analysed by using Bradford assay as stated in the methods of Mitoulas et al. (23). It was observed that BMI is not an exact tool to measure adiposity (7) and

researches showed higher maternal body fat composition was assuredly linked to elevated protein levels in milk (23,25). Using advanced techniques to assess mother's physique, it was stated that total protein percentage in breast milk was closely associated with maternal body composition like maternal weight, BMI, % fat mass and muscles and also reported an inverse relationship with percent total body water in the third month of postpartum (7). It has also been noted that several serum amino acid concentrations, especially branched chain amino acids (BCAAs), are elevated in mothers with higher adipose tissue, facilitating to pass more amino acids to the breast and also in breast milk. This may clarify a positive association between maternal fatness and milk protein content (15,21). Mother's preconception weight and height displayed a positive relationship with glutamic acid but not BMI whereas glutamine was positively associated with length of 4 months aged infant. Mothers who have higher weight and stature showed free glutamic acid in the breast milk (14).

## **Lipid**

Majority of studies reported that mother's higher BMI and adipose mass are favorably and significantly correlated with higher fat content in breast milk (4,7,11,12,17,20,21,25,37). In a study, maternal percent fat mass was measured using bioimpedance spectroscopy (23). Another study used well described methods such as creatatocrit method and the micro-Roese-Gottlieb method to analyse milk fat (44,45). Also it was reported that maternal obesity is strongly associated with higher fat percentage in colostrum (33) and transition milk than normal or overweight mothers (12,20). Triacylglycerides (96%) are the main form of breast milk lipid and remaining are the phospholipids and cholesterol (26). Higher intake of dietary fat predisposes high maternal Body Mass Index with dyslipidemia and triglyceridemia which results in increase breast milk fat concentrations (33). In case of fatty acid composition, a strong association was observed with mother's BMI. Breast milk from mothers who are obese possessed elevated concentration of omega-6 than omega-3 fatty acids and lesser content of alpha linolenic acid (ALA), docosahexaenoic acid (DHA), eicosapentaenoic

acid (EPA) and docosapentaenoic acid (DPA) in contrast to mothers with lower body weight (13). Using a beam balance and stadiometer, maternal weight and height were assessed, revealing a positive correlation between milk fat concentration and maternal body fat. Conversely, reduced levels of fat and energy in milk are more prevalent among malnourished women in Bangladesh, Gambia, Honduras, and Mexico (17). One study reported women with higher arm circumference and triceps skinfold thickness possess more fat percentage in mature milk (40).

Body circumferences at the arm, chest, waist, hip, thigh, and calf were measured twice using a non-stretchable measuring tape. Skinfold thicknesses were assessed using Lange calipers (Cambridge Scientific Industries, Cambridge, MD) at the biceps, triceps, subscapular, and suprailiac sites (17). Higher upper body measurements in mothers are associated with proportionally elevated levels of lipid (2) and saturated fatty acids (37) in breast milk, although dietary lipids influence the fatty acid profile of breast milk composition (2,37). In certain but not all previous studies, maternal body fat has been demonstrated to be a strong indicator of milk fat and energy content (11,25,26). BMI showed a positive correlation with protein and fat concentrations, and a negative correlation with lactose (20). It is concluded that human lactation performance is highly resilient and that BMI does not serve as a useful indicator of function based on the current study level (22,23). Besides higher maternal BMI, pregnancy weight gain and sampling methods significantly influence fat concentration of breast milk (24). Overweight and obese mother's milk have higher long chain fatty acids (LCFAs) content that may be due to maternal adiposity but there is no overall difference in the omega 3 and omega 6 long chain PUFA ratio (31). The fat concentration in hind milk was notably greater compared to fore milk, while no significant variations observed in either lactose or protein (34). It has also been established that the fat composition of mother's milk fluctuates based on mother's diet, hind or fore milk (12), timing of feeding (morning/night or day time/early evening) (35), and storage environment (12). In a population of Tibetan, it was examined that milk fat was positively associated with infant age and maternal

triceps skinfold thickness. They reported, measuring maternal triceps skinfold thickness is the more effective method than measuring maternal BMI to correlate milk fat, sugar, and energy with maternal postpartum upper extremities. Low triceps skinfold thickness of postpartum mothers denotes high milk fat (43). Similar correlations between macronutrient composition and triceps skinfold thickness were reported in other populations by some researchers (21,26,40).

### **Other factors**

Leptin, insulin (32, 48), and CRP levels were higher in overweight (OW) mother's milk than in normal-weight (NW) mothers (10,47,52). One study has reported the insulin concentrations in human milk (HM) are higher than those in maternal plasma and are associated with maternal BMI and insulin sensitivity (10). Infants of OW mothers were exposed to leptin and insulin concentrations 1.5 to 2.5 times higher than those of infants born to NW mothers (3). At two weeks, it was observed that mothers with increased BMI have higher insulin levels in milk (32). In one study, Obese mothers had higher serum CRP concentrations, but not in their colostrum (33). Several studies have reported the adiponectin concentrations in breast milk has positive association with maternal BMI (50,51).

### **Discussion**

In this study, we found that the composition of human milk is highly intricate (44) and among all the macronutrients, protein (2,7,12,20,21,22,24) and lipid contents (4,7,11,12,17,20,21,25,37) are highly correlated with maternal BMI and adiposity, depending on the lactation stage.

According to maternal somatotyping upper extremities there is no variations found in lactose content (12). Human milk represents the richest source of lactose compared to other animal milk (38). The concentration of lactose in milk shows a negative correlation with maternal body composition and lactation period has no effect on lactose concentration (12) but maternal BMI is strongly associated with high galactose content (23). Also one study report concluded that colostrum contains more concentrations of oligosaccharide than mature milk (2).

Casein and whey proteins are main two types of milk proteins (44) which have a strong relationship with maternal body fat or mass and adiposity (2,7,12,20,21,22,24) but contrary another study stated that lower BMI in lactating mother is associated with elevated level of breast milk protein (23). Contrarily, few studies reported no correlation between protein concentrations and maternal BMI (4,16,27). Mothers with higher adiposity shown a high level of amino acids in blood also in breast milk (28). Using advanced techniques of maternal body composition assessment, a study demonstrated that total protein percentage in human milk was highly associated with maternal body composition like maternal weight, BMI, % fat mass and muscles in the month three of lactation (7). Mother with more body fat composition exerts more BCAAs in blood which reflects in breast milk composition with higher BCAAs (15,21). A study reported that mother's prepregnancy weight and height have a positive association with glutamic acid but not in body mass index and maternal higher weight and stature possess free glutamic acid in breast milk (14).

The majority of studies which measured body circumferences at the arm, chest, waist, hip, thigh, and calf indicated that higher BMI and fat mass of lactating mothers are positively correlated with higher fat content in breast milk (4,7,11,12,17,20,21,25,37). Diet has a strong influence on maternal body fat composition with dyslipidemia and triglyceridemia predisposes breast milk fat composition (33). Compared to underweight mothers, obese mothers exhibit a higher omega-6 to omega-3 fatty acid ratio and reduced levels of ALA, DHA, EPA and DPA (13). Maternal higher arm circumference and triceps skinfold thickness are connected with more fat concentrations in mature milk (40). Overweight and obese mother's milk have higher content of long chain fatty acids (LCFAs) (31). Although fat composition in mother's milk varies depending on maternal diet, hind or fore milk, morning/night or day time/early evening feeding, and storage conditions (12,35). Maternal triceps skinfold thickness is the more effective assessment than BMI to correlate milk fat, sugar, and energy with maternal postpartum upper extremities in Tibetan mothers (43) and in other populations (21,26,40). Researcher showed low triceps skinfold thickness was associated with high milk fat (43).

The impact of maternal higher body weight and other anthropometric indices regarding human milk macronutrients is overall complex (44). One study's strengths include employing advanced techniques to evaluate maternal body composition and implementing a milk collection protocol that minimized errors in analyzing macronutrient compositions (7). Although infant's needs, the time of day, foremilk or hindmilk of a particular feeding are the different factors of fluctuation in breast milk volume and nutrient content (12). Further research documenting longitudinal changes in milk composition and maternal status is needed (20). Studies have also suggested impacts of several other factors to change the macronutrient composition of human milk (3,5,7).

A previous study has shown that there is no correlation between macronutrients and breast size, suggesting that having large breasts is not essential for sufficient milk production (19). Additionally, during the first year of lactation period, no variation was reported in composition of protein, energy, lactose and fat content between milk from right and left breasts & preferred and nonpreferred (34,35). Socioeconomic factors could potentially influence variations in the macronutrient content of breast milk (2).

Many studies have reported that insulin concentrations, leptin, CRP levels and adiponectin in human milk (HM) are higher in obese mothers than normal weight mothers (3,10,32,33,47,48,50,51,52).

## **Conclusion**

Investigating breast milk macronutrient composition in relation to maternal anthropometric indices, particularly somatotyping of upper extremities, reveals notable variability. In conclusion, this review underscores a significant relationship between composition of breast milk macronutrient like carbohydrates, proteins and fats and maternal body composition. Nearly, all studies employed BMI as a variable to categorize women into overweight, obese, normal and underweight classifications. While BMI is a widely used measure, it may not always precisely indicate maternal fat mass or body composition. Evidence suggests

that correlations between certain components of human milk and measures of maternal obesity may be more pronounced for fat mass than for BMI. According to the above discussion, we conclude that there is a positive and strong association between breast milk macronutrient composition and maternal body mass or adiposity and somatotypes. High-quality studies by using better analytical instruments and anthropometric indices or variables are required to enhance understanding of the connections between maternal adiposity and the composition of human milk. Adequate and balanced diet is an essential key of mother's health during preconception, pregnancy and lactation stage in influencing the balanced nutritional profile of breast milk composition. Further research on the volume and divergences in macronutrient composition of breast milk is vital due to invaluable nature of this biofluid as a consequence of its energy, lactose, essential amino acids and essential fatty acids value which are crucial for infant's growth and overall development for life long.

## References

Nicholas J. Andreas, Beate Kampmann, Kirsty Mehrling Le-Doare, Human breast milk: A review on its composition and bioactivity, *Early Human Development*, Volume 91, Issue 11, 2015, Pages 629-635, ISSN 0378-3782,

Koutsiafti, P., Soultani, G., Kechagias, S., Grivea, I., & Malissiova, E. (2021). Macronutrient composition of breast milk for full term and premature infants: Correlation to nutritional and socioeconomic factors. *International Journal of Caring Sciences*, 14(1), 608-616.

Sims, C. R., Lipsmeyer, M. E., Turner, D. E., & Andres, A. (2020). Human milk composition differs by maternal BMI in the first 9 months postpartum. *The American journal of clinical nutrition*, 112(3), 548-557.

Bzikowska A, Czerwonogrodzka-Senczyna A, Weker H, Wesołowska A. Correlation between human milk composition and maternal nutritional status. *Rocz Panstw Zakl Hig.* 2018;69(4):363-367. doi: 10.32394/rpzh.2018.0041. PMID: 30525326.

Shamir, R. (2016). The benefits of breast feeding. Protein in neonatal and infant nutrition: recent updates, 86, 67-76.

Gigante, D. P., Victora, C. G., & Barros, F. C. (2001). Breast-feeding has a limited long-term effect on anthropometry and body composition of Brazilian mothers. *The Journal of nutrition*, 131(1), 78-84.

Bzikowska-Jura, A., Czerwonogrodzka-Senczyna, A., Ołędzka, G., Szostak-Węgierek, D., Weker, H., & Wesołowska, A. (2018). Maternal nutrition and body composition during breastfeeding: association with human milk composition. *Nutrients*, 10(10), 1379.

Fields, D. A., Schneider, C. R., & Pavela, G. (2016). A narrative review of the associations between six bioactive components in breast milk and infant adiposity. *Obesity*, 24(6), 1213-1221.

World Health Organization (CH). Unicef (US). *Global Strategy for Infant and Young Child Feeding*. Geneva: World Health Organization;2003

Young, B. E., Patinkin, Z. W., Pyle, L., de la Houssaye, B., Davidson, B. S., Geraghty, S., ... & Krebs, N. (2017). Markers of oxidative stress in human milk do not differ by maternal BMI but are related to infant growth trajectories. *Maternal and child health journal*, 21, 1367-1376.

Leghi, G. E., Netting, M. J., Middleton, P. F., Wlodek, M. E., Geddes, D. T., & Muhlhausler, B. S. (2020). The impact of maternal obesity on human milk macronutrient composition: A systematic review and meta-analysis. *Nutrients*, 12(4), 934.

Chang, N., Jung, J. A., Kim, H., Jo, A., Kang, S., Lee, S. W., ... & Jung, B. M. (2015). Macronutrient composition of human milk from Korean mothers of full term infants born at 37-42 gestational weeks. *Nutrition research and practice*, 9(4), 433-438.

Panagos, P. G., Vishwanathan, R., Penfield-Cyr, A., Matthan, N. R., Shivappa, N., Wirth, M. D., ... & Sen, S. (2016). Breastmilk from obese mothers has pro-inflammatory properties and decreased neuroprotective factors. *Journal of Perinatology*, 36(4), 284-290.

Larnkjær, A., Bruun, S., Pedersen, D., Zachariassen, G., Barkholt, V., Agostoni, C., ... & Michaelsen, K. F. (2016). Free amino acids in human milk and associations with maternal anthropometry and infant growth. *Journal of pediatric gastroenterology and nutrition*, 63(3), 374-378.

De Luca, A., Hankard, R., Alexandre-Gouabau, M. C., Ferchaud-Roucher, V., Darmaun, D., & Boquien, C. Y. (2016). Higher concentrations of branched-chain amino acids in breast milk of obese mothers. *Nutrition*, 32(11-12), 1295-1298.

Bachour, P., Yafawi, R., Jaber, F., Choueiri, E., & Abdel-Razzak, Z. (2012). Effects of smoking, mother's age, body mass index, and parity number on lipid, protein, and secretory immunoglobulin A concentrations of human milk. *Breastfeeding Medicine*, 7(3), 179-188.

Barbosa, L., Butte, N. F., Villalpando, S., Wong, W. W., & Smith, E. O. (1997). Maternal energy balance and lactation performance of Mesoamerindians as a function of body mass index. *The American journal of clinical nutrition*, 66(3), 575-583.

Pines, N., Mandel, D., Mimouni, F. B., Moran Lev, H., Mangel, L., & Lubetzky, R. (2016). The effect of between-breast differences on human milk macronutrients content. *Journal of Perinatology*, 36(7), 549-551.

Babiszewska-Aksamit, M., Żelaźniewicz, A., Apanasewicz, A., Piosek, M., Winczowska, P., Barbarska, O., & Ziomkiewicz, A. (2024). Breast size in lactating women and the content of macronutrients in human milk. *American Journal of Human Biology*, 36(6), e24055.

Yang, T., Zhang, Y., Ning, Y., You, L., Ma, D., Zheng, Y., ... & Wang, P. (2014). Breast milk macronutrient composition and the associated factors in urban Chinese mothers. *Chinese medical journal*, 127(9), 1721-1725.

Nommsen, L. A., Lovelady, C. A., Heinig, M. J., Lönnerdal, B., & Dewey, K. G. (1991). Determinants of energy, protein, lipid, and lactose concentrations in human milk during the first 12 mo of lactation: the DARLING Study. *The American journal of clinical nutrition*, 53(2), 457-465.

Prentice, A. M., Goldberg, G. R., & Prentice, A. (1994). Body mass index and lactation performance. *European Journal of Clinical Nutrition*, 48, S78-86.

Kuganathan, S., Gridneva, Z., Lai, C. T., Hepworth, A. R., Mark, P. J., Kakulas, F., & Geddes, D. T. (2017). Associations between maternal body composition and appetite hormones and macronutrients in human milk. *Nutrients*, 9(3),

Grote, V., Verduci, E., Scaglioni, S., Vecchi, F., Contarini, G., Giovannini, M., ... & Agostoni, C. (2016). Breast milk composition and infant nutrient intakes during the first 12 months of life. *European journal of clinical nutrition*, 70(2), 250-256.

Quinn, E. A., Largado, F. E., Power, M., & Kuzawa, C. W. (2012). Predictors of breast milk macronutrient composition in Filipino mothers. *American journal of human biology*, 24(4), 533-540.

Villalpando, S., & Prado, M. D. (1999). Interrelation among dietary energy and fat intakes, maternal body fatness, and milk total lipid in humans. *Journal of mammary gland biology and neoplasia*, 4, 285-295.

Abranches, A.D.; Soares, F.V.; Junior, S.C.; Moreira, M.E. Freezing and thawing effects on fat, protein, and lactose levels of human natural milk administered by gavage and continuous infusion. *J. Pediatr.* 2014, 90, 384–388.

Xie, G.; Ma, X.; Zhao, A.; Wang, C.; Zhang, Y.; Nieman, D.; Nicholson, J.K.; Jia, W.; Bao, Y.; Jia, W. The metabolite profiles of the obese population are gender-dependent. *J. Proteome Res.* 2014, 13, 4062–4073.

Rudolph, M. C., Young, B. E., Lemas, D. J., Palmer, C. E., Hernandez, T. L., Barbour, L. A., ... & MacLean, P. S. (2017). Early infant adipose deposition is positively associated with the n-6 to n-3 fatty acid ratio in human milk independent of maternal BMI. *International journal of obesity*, 41(4), 510-517.

Storck Lindholm E, Strandvik B, Altman D, Moller A, Palme Kilander C. Different fatty acid pattern in breast milk of obese compared to normal-weight mothers. Prostaglandins, leukotrienes, and essential fatty acids. 2013;88(3):211-217.

Makela, J.; Linderborg, K.; Niinikoski, H.; Yang, B.; Lagström, H. Breast milk fatty acid composition differs between overweight and normal weight women: The STEPS Study. *Eur. J. Nutr.* 2013, 52, 727-735.

Ellsworth, L., Perng, W., Harman, E., Das, A., Pennathur, S., & Gregg, B. (2020). Impact of maternal overweight and obesity on milk composition and infant growth. *Maternal & child nutrition*, 16(3), e12979.

Fujimori, M.; França, E.L.; Fiorin, V.; Morais, T.C.; Honorio-França, A.C.; de Abreu, L.C. Changes in the biochemical and immunological components of serum and colostrum of overweight and obese mothers. *BMC Pregnancy Childbirth* 2015, 15, 166.

Mitoulas, L. R., Kent, J. C., Cox, D. B., Owens, R. A., Sherrieff, J. L., & Hartmann, P. E. (2002). Variation in fat, lactose and protein in human milk over 24h and throughout the first year of lactation. *British Journal of Nutrition*, 88(1), 29-37.

Kent, J. C., Mitoulas, L. R., Cregan, M. D., Ramsay, D. T., Doherty, D. A., & Hartmann, P. E. (2006). Volume and frequency of breastfeedings and fat content of breast milk throughout the day. *Pediatrics*, 117(3), e387-e395.

Isganaitis, E., Venditti, S., Matthews, T. J., Lerin, C., Demerath, E. W., & Fields, D. A. (2019). Maternal obesity and the human milk metabolome: associations with infant body composition and postnatal weight gain. *The American journal of clinical nutrition*, 110(1), 111-120.

Kim, H.; Kang, S.; Jung, B.-M.; Yi, H.; Jung, J.A.; Chang, N. Breast milk fatty acid composition and fatty acid intake of lactating mothers in South Korea. *Br. J. Nutr.* 2017, 117, 556-561.

Neville, M.C.; Allen, J.C.; Watters, C. The mechanisms of milk secretion. In *Lactation*; Springer: Berlin, Germany, 1983; pp. 49-102.

Gidrewicz, D. A., & Fenton, T. R. (2014). A systematic review and meta-analysis of the nutrient content of preterm and term breast milk. *BMC pediatrics*, 14, 1-14.

Brown, K. H., Akhtar, N. A., Robertson, A. D., & Ahmed, M. G. (1986). Lactational capacity of marginally nourished

mothers: relationships between maternal nutritional status and quantity and proximate composition of milk. *Pediatrics*, 78(5), 909-919.

Aleali, F., Fallahi, M., Kazemian, M., Fakhraee, S. H., & Afjeh, A. (2018). Longitudinal Changes in the Macronutrient Contents of Breast Milk in the Mothers with Preterm Delivery. *Iranian Journal of Neonatology*, 9(1).

Unicef (US). Infant and young child feeding [Internet]. New York (NY): Unicef;2014. cited 2015 June 1.

Quinn, E. A., Diki Bista, K., & Childs, G. (2016). Milk at altitude: Human milk macronutrient composition in a high-altitude adapted population of Tibetans. *American Journal of Physical Anthropology*, 159(2), 233-243.

Miller EM, Aiello MO, Fujita M, Hinde K, Milligan L, Quinn EA. Field and laboratory methods in human milk research. *Am J Hum Biol*. 2013; 25:1–11.

Adhikari, S., Kudla, U., Nyakayiru, J., & Brouwer-Brolsma, E. M. (2022). Maternal dietary intake, nutritional status and macronutrient composition of human breast milk: systematic review. *British Journal of Nutrition*, 127(12), 1796-1820.

Young, M. F., Faerber, E. C., Mehta, R. V., Ranjan, S., Shetty, S. A., Ramakrishnan, U., ... & Martorell, R. (2023). Maternal nutritional status and milk volume and composition in India: an observational study. *The American Journal of Clinical Nutrition*, 117(4), 830-837.

Hashemi Javaheri, F. S., Karbin, K., Senobari, M. A., Hakim, H. G., & Hashemi, M. (2025). The association between maternal body mass index and breast milk composition: a systematic review. *Nutrition Reviews*, 83(1), 83-111.

Ahuja, S., Boylan, M., Hart, S. L., Román-Shriver, C., Spallholz, J. E., Pence, B. C., & Sawyer, B. G. (2011). Glucose and insulin levels are increased in obese and overweight mothers' breast-milk. *Food and Nutrition Sciences*, 2(3), 201-206.

Bilgiç, F. Ş., & Bozkurt, G. (2024). The relationship between mothers' body composition and anthropometric characteristics of baby and breast milk nutrient content: A cross-sectional study. *Journal of Evaluation in Clinical Practice*, 30(7), 1396-1405.

Andreas, N. J., Hyde, M. J., Gale, C., Parkinson, J. R., Jeffries, S., Holmes, E., & Modi, N. (2014). Effect of maternal body mass index on hormones in breast milk: a systematic review. *PloS one*, 9(12), e115043.

Martin LJ, Woo JG, Geraghty SR, Altaye M, Davidson BS, et al. (2006) Adiponectin is present in human milk and is associated with maternal factors. *Am J Clin Nutr* 83: 1106–1111.

Savino F, Liguori SA, Petrucci E, Lupica MM, Fissore MF, et al. (2010) Evaluation of leptin in breast milk, lactating mothers and their infants. *Eur J Clin Nutr* 64: 972–977.

## **Quality enhancement of cereal-based products by enriching with plant-based components and their health benefits**

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### **Abstract**

Cereal-based products, such as bread, pasta, breakfast cereals, and snacks, constitute a fundamental component of diets worldwide due to their affordability, versatility, and availability. However, these products often have nutritional limitations, including deficiencies in essential amino acids, low dietary fibre content, and minimal levels of bioactive compounds such as polyphenols, vitamins, and minerals. Addressing these limitations has become a priority to meet growing consumer demands for healthier, functional foods. One promising approach is the incorporation of plant-based components, which offer a rich source of nutrients, bioactive compounds, and functional properties. The enrichment of cereal-based products with plant-derived ingredients impacts not only their nutritional profile but also their functional properties, including texture, flavor, and shelf stability. Enhanced water absorption, improved dough rheology, and antioxidant properties contribute to better product performance and longevity. From a sensory perspective, careful formulation is required to balance the enriched products' taste, aroma, and appearance to maintain consumer acceptability. The health benefits associated with these enriched products are extensive. High dietary fibre content supports digestive health and promotes gut microbiota diversity. Bioactive compounds like polyphenols and flavonoids reduce

oxidative stress and inflammation, decreasing the risk of chronic diseases such as cardiovascular disorders, diabetes, and certain cancers. Additionally, enriched products aid in weight management by enhancing satiety and contribute to glycemic control through slow-digesting carbohydrates. The fortification of cereal products with plant-based ingredients thus addresses nutritional deficiencies and plays a critical role in preventive healthcare. This review highlights the transformative potential of plant-based enrichment in cereal-based products, offering a sustainable and effective strategy to improve nutritional quality and deliver substantial health benefits. By bridging the gap between traditional cereal-based diets and modern functional foods, this approach contributes to addressing global nutritional challenges.

**Keywords:** Cereal-based products, plant-based enrichment, nutritional enhancement, dietary fibre, bioactive compounds, functional foods, health benefits, sustainable nutrition.

## Introduction

Cereal-based foods are a fundamental part of the human diet, supplying essential macronutrients and serving as staple foods across numerous cultures (Singh et al., 2023). These products, including bread, pasta, breakfast cereals, and baked goods, are primary sources of carbohydrates and dietary fibre but often lack sufficient levels of essential amino acids, vitamins, minerals, and bioactive compounds necessary for optimal human health (Patel & Shah, 2022). This nutritional shortfall has prompted a surge in interest towards enhancing the nutritional profile of cereal-based foods by incorporating plant-derived components such as legumes, seeds, fruits, and vegetables (Ahmed et al., 2024).

The global food industry has experienced a notable increase in the demand for functional foods, which not only fulfill basic nutritional requirements but also deliver additional health benefits (Lee et al., 2022). This shift is driven by heightened consumer awareness regarding the advantages of plant-based diets, which are associated with a reduced risk of chronic diseases like cardiovascular disease, diabetes, and obesity (Gupta & Kumar, 2023). In response, food scientists

and manufacturers are actively investigating methods to fortify cereal-based products with plant-derived ingredients to enhance their nutritional and functional qualities (Jain & Verma, 2024).

The integration of plant-based components into cereal products can significantly improve protein quality, boost dietary fibre content, and introduce beneficial bioactive compounds such as polyphenols and antioxidants (Martinez et al., 2023). For instance, the addition of legume flours, including chickpea, lentil, or soybean, can enhance protein digestibility and amino acid profiles, while seeds like flaxseeds and chia seeds contribute valuable omega-3 fatty acids and dietary fibre (Sharma & Singh, 2023). Moreover, the inclusion of fruits and vegetables can elevate the micronutrient content and introduce natural antioxidants that support overall health (Wang et al., 2023).

Nevertheless, the successful incorporation of plant-based components in cereal-based foods presents certain challenges, such as formulation complexity, sensory acceptability, and processing constraints (Kaur & Mehta, 2023). Although numerous studies have examined individual plant-based ingredients, comprehensive investigations into the synergistic effects of multiple plant components in cereal-based products remain relatively scarce (Rao et al., 2024). Additionally, consumer preferences and market trends require further exploration to ensure the widespread acceptance of these fortified foods (Patel et al., 2024). This study seeks to provide critical insights into the potential of plant-based enrichment to enhance the quality and health benefits of cereal-based products, thereby contributing to the advancement of functional food innovation (Singh et al., 2023).

### **Nutritional and Functional Properties of Cereals**

Cereal grains such as wheat, rice, maize, barley, oats, rye, sorghum, and millet form the cornerstone of global diets, supplying a substantial share of daily caloric intake and essential nutrients to populations worldwide (Smith et al., 2023). These grains are inherently rich in carbohydrates, proteins, dietary fibre, vitamins, and minerals, making

them critical for human nutrition (Kumar and Singh, 2024). However, conventional refining and processing methods often result in the loss of valuable micronutrients and bioactive compounds, thereby creating a need for targeted enrichment strategies to restore and enhance their nutritional quality (Patel et al., 2024).

## **Nutritional Composition of Common Cereals**

### **Carbohydrates**

Carbohydrates are the principal component of cereals, predominantly in the form of starch, which acts as a primary energy source. The starch content in cereals varies depending on the type of grain, and its digestibility can influence the glycemic index (GI). Whole grains, which retain their bran and germ, generally exhibit a lower GI than refined cereals. This slower release of glucose from whole grains contributes to better glycemic control, which is beneficial for managing blood sugar levels (Slavin, 2003).

### **Proteins**

Proteins found in cereals vary in their quality and composition. For instance, wheat contains gluten, maize contains zein, and rice has oryzenin. However, the protein content in most cereals is often deficient in certain essential amino acids, notably lysine and tryptophan. Consequently, cereal-based diets may not provide a complete amino acid profile, making it necessary to supplement these grains with other plant-based protein sources like legumes or seeds to meet nutritional requirements (Haug & Lantzsch, 1983).

### **Dietary Fibre**

Whole cereals are an outstanding source of dietary fiber, which plays a significant role in promoting digestive health. The fiber in cereals can be categorized into soluble and insoluble types. Soluble fibers, such as the  $\beta$ -glucans found in oats and barley, help to regulate cholesterol levels and stabilize blood sugar. Insoluble fibers, including cellulose and hemicellulose found in wheat bran, contribute to improved digestive function and prevent constipation by increasing stool bulk and frequency (Trowell, 1976).

## **Vitamins and Minerals**

Cereals contain a range of essential vitamins and minerals that are vital for maintaining health. B vitamins, including thiamine, riboflavin, niacin, and folic acid, are abundant in cereals and play critical roles in energy metabolism. Minerals such as iron, zinc, magnesium, and selenium are also present but are often bound by antinutritional factors like phytates and tannins, which can reduce their bioavailability. This limitation underscores the need for appropriate processing methods, such as soaking or fermentation, to enhance the absorption of these essential micronutrients (Bohn et al., 2008).

## **Bioactive Compounds**

In addition to their macronutrient content, cereals also contain various bioactive compounds, such as phenolic acids, flavonoids, and lignans. These compounds are known for their antioxidant and anti-inflammatory properties, which contribute to reducing the risk of chronic diseases, including heart disease and cancer. However, these beneficial compounds are primarily found in the bran and germ of the grain, which are often removed during the milling process (McCue & Shetty, 2004).

## **Functional Properties of Cereals in Food Processing**

The functional properties of cereals are critical in determining their suitability for various food formulations, as they directly impact texture, consistency, and stability in final products (Jones et al., 2023).

## **Water Absorption and Gelatinization**

Cereal starches absorb water during cooking, resulting in gelatinization, a process essential for achieving the desired texture in products like bread, pasta, and porridges (Patel & Kumar, 2024).

## **Dough Formation and Rheology**

Gluten-forming proteins in wheat provide the viscoelastic properties needed for dough formation, making it ideal for baking applications (Singh & Verma, 2024). In contrast,

gluten-free cereals like rice and maize often require the addition of hydrocolloids or plant-based proteins to enhance dough structure and rheological properties (Sharma et al., 2023).

### **Fermentation and Enzymatic Activity**

Cereals such as barley and rye contain natural enzymes that support fermentation, which improves the flavor, digestibility, and shelf life of products like sourdough bread and fermented porridges (Gupta & Mehta, 2024).

### **Limitations and Challenges in Cereal-Based Diets**

Despite their nutritional benefits, cereals alone cannot provide complete nutrition due to certain inherent limitations (Wang et al., 2024).

#### **Protein Quality Deficiency:**

Cereal proteins are generally low in essential amino acids, particularly lysine and tryptophan, necessitating complementation with protein-rich plant sources like legumes and seeds (Patel & Shah, 2024).

**Antinutritional Factors:** Compounds such as phytic acid, tannins, and enzyme inhibitors reduce mineral bioavailability, which can be mitigated through processing methods like soaking, germination, and fermentation (Rao et al., 2024).

**High Glycemic Index in Refined Cereals:** Processed cereals often cause rapid blood sugar spikes, increasing the risk of metabolic disorders, which highlights the importance of incorporating whole grains with lower glycemic indices (Lee et al., 2024).

### **Plant-Based Components for Enrichment**

Enriching cereal-based products with plant-based components is a promising strategy to enhance their nutritional and functional qualities (Patel et al., 2024). Various plant-derived ingredients, including legumes, seeds, nuts, fruits, vegetables, and herbs, can be incorporated into cereals to improve their protein content, dietary fiber, antioxidants, and essential micronutrients (Singh & Verma, 2024). This section examines

different plant-based components, their nutritional benefits, and their impact on the overall quality of cereal-based products (Sharma et al., 2023).

### **Legumes and Pulses**

Legumes, such as lentils, chickpeas, soybeans, peas, and black beans, serve as excellent plant-based protein sources, complementing cereals by providing essential amino acids, particularly lysine, which is typically limited in cereal proteins (Gupta & Mehta, 2024).

### **Nutritional Benefits**

Legumes and pulses generally have a high protein content, ranging from 20-40%, and are also rich in both soluble and insoluble dietary fiber (Rao et al., 2024). Additionally, these plants contain significant amounts of bioactive compounds, such as isoflavones in soy and saponins in lentils, which have been linked to improved gut health and reduced cholesterol levels (Wang & Chen, 2024).

### **Applications in Cereal-Based Products**

**Legume flour:** Legume flour can be used in bread, pasta, and biscuits to enhance the protein quality of them.

**Extruded Snacks:** Lentil or chickpea-based puffed snacks are increasingly popular for their high protein content and improved amino acid profiles, making them a nutritious alternative to traditional grain-based snacks (Patel et al., 2024).

**Fortified Breakfast Cereals:** Breakfast cereals enriched with soy protein or pea protein provide a protein boost while maintaining a balanced amino acid composition, addressing the protein quality limitations of conventional cereals (Singh and Verma, 2024).

### **Seeds and Nuts**

Seeds (chia, flax, sunflower, sesame) and nuts (almonds, walnuts, hazelnuts) provide essential fatty acids, proteins, vitamins, and minerals that improve the overall nutritional profile of cereal-based products.

### **Nutritional Benefits**

Rich in omega-3 and omega-6 fatty acids. They contain high-quality plant proteins and amino acids and are very high in dietary fibre, which supports digestion.

### **Applications in Cereal-Based Products**

**Ground flaxseed or chia seeds:** Added to cereal bars, muesli, and porridge for omega-3 enrichment.

**Nut flours:** Almond flour or walnut powder are used in gluten-free baked goods.

**Seed-based coatings:** Used for crunchy cereal coatings in granola bars.

### **Fruits and Vegetables**

Fruits and vegetables are valuable sources of vitamins, minerals, fibre, and antioxidants that enhance the health benefits of cereals. Dried fruits (dates, raisins, berries) and vegetable powders (spinach, beetroot, carrot) are commonly used in functional food formulations.

### **Nutritional Benefits**

Fruits and vegetables are rich in vitamins A, C, and various B-complex vitamins, which support immune function and metabolism (Slavin and Lloyd, 2012). They contain polyphenolic compounds, including anthocyanins, flavonoids, and carotenoids, which exhibit antioxidant and anti-inflammatory effects. They provide natural sugars and sweetness, reducing reliance on refined sugar.

### **Applications in Cereal-Based Products**

**Fruit powders:** Added to breakfast cereals, oatmeal, and smoothie bowls.

**Vegetable purees:** Incorporated into pasta and bread formulations.

**Dried fruit pieces:** Used in granola and energy bars for natural sweetness.

## **Herbs, Spices, and Functional Plant Extracts**

Herbs (moringa, mint, basil), spices (turmeric, cinnamon, ginger), and plant extracts (green tea, cocoa, spirulina) offer additional health benefits beyond basic nutrition.

### **Nutritional Benefits**

Rich in secondary metabolites such as polyphenols, flavonoids, and alkaloids that act as antioxidants and modulate inflammatory responses (Aggarwal et al., 2007). These nutritional components possess anti-inflammatory and antimicrobial properties. They can enhance flavour and can reduce the need for artificial additives.

### **Applications in Cereal-Based Products**

**Moringa powder:** Added to multigrain flour and protein bars

**Turmeric and cinnamon:** Used in spiced oatmeal, granola, and functional teas

**Green tea and cocoa extracts,** both high in catechins and theobromine, are utilised in functional breakfast cereals and energy bites targeting mental alertness and cardiovascular health (McKay and Blumberg, 2002).

### **Methods of Enrichment**

Enriching cereal-based products with plant-based components requires the use of appropriate processing and formulation techniques to ensure the retention of nutritional and functional benefits while maintaining desirable sensory attributes. Various methods, including fortification, blending, fermentation, and modern food processing techniques, are used to incorporate plant-derived ingredients into cereal products effectively (Sharma et al., 2020).

### **Fortification Techniques**

Fortification involves adding essential nutrients, such as vitamins, minerals, and proteins, to cereal products to improve their nutritional profile.

#### **Direct Fortification**

**Addition of plant-based protein isolates** (e.g., soy protein, pea protein) to cereal flour

**Micronutrients of plant origin**, like iron from moringa leaf powder or calcium from ground sesame seeds, can be blended into cereal formulations to address deficiencies commonly found in grain-based diets (Iqbal et al., 2006).

### **Microencapsulation**

Protects sensitive bioactive compounds (e.g., omega-3 from flaxseed, polyphenols from green tea)

Encapsulation enhances not only the stability and shelf life of these nutrients but also their **bioavailability upon digestion** (Dima and Dima, 2015).

### **Spraying and Coating**

This method ensures **uniform distribution** of vitamins and minerals and is particularly useful for **heat-sensitive micronutrients**, which would degrade during baking or extrusion (Jeyakumari et al., 2016) and also ensures uniform distribution and improved retention during storage

### **Blending and Formulation Strategies**

Blending different plant-based ingredients with cereal flours can improve the protein content, fibre levels, and antioxidant properties of the final product.

### **Composite Flour Technology**

1. **Mixing wheat or rice flour with legume flours** (chickpea, lentil) for enhanced protein quality
2. **Incorporating nut powders (e.g., almond or walnut)** enhances lipid quality and micronutrient density, especially in gluten-free products (Arora et al., 2011).

### **Extrusion Cooking**

1. High-temperature and high-pressure processing is used for fortified breakfast cereals and snacks
2. Enables incorporation of plant-based proteins, fibres, and bioactive compounds without compromising texture
3. The process also **denatures antinutrients** and helps in **binding functional ingredients without compromising product structure** (Singh et al., 2007)

## Functional Ingredient Formulation

1. **Addition of hydrocolloids and emulsifiers** (e.g., guar gum, pectin) to improve texture in gluten-free formulations
2. **Prebiotic fibers**, like **inulin extracted from chicory roots**, to support gut health and promote the growth of beneficial microbiota. These also act as fat replacers and moisture retainers (Roberfroid, 2007).

## Fermentation and Germination

Fermentation and germination are natural processing techniques that enhance nutrient bioavailability and improve the sensory properties of cereal-based products.

### Fermentation

1. Improves digestibility and reduces antinutritional factors (e.g., phytic acid in grains)
2. Enhances probiotic activity when using lactic acid bacteria or yeast
3. Fermented cereal products, such as **sourdough breads**, **probiotic porridges**, and kefir-like beverages, benefit from both **organoleptic improvements** and functional probiotic activity (Marco et al., 2017).

### Germination (Sprouting)

Germination Activates enzymes that break down starches and increase nutrient absorption. It increases the levels of bioavailable vitamins (e.g., vitamin C and B-complex). Some common applications of sprouted grain flour are for bread, cereal bars, and malted drinks

## Advanced Food Processing Technologies

Modern processing techniques help optimise nutrient retention and improve the quality of enriched cereal-based products.

### High-Pressure Processing (HPP)

1. Maintains the nutritional integrity of plant-based fortifiers while extending shelf life

2. Used for ready-to-eat breakfast cereals and functional beverages.
3. It is especially useful in the preparation of **functional beverages and minimally processed breakfast products**, where thermal degradation must be avoided (Rastogi et al., 2007).

### **Ultrasonication and Pulse Electric Field Processing (PEF)**

1. Enhances the extraction of bioactive compounds from plant sources for enrichment
2. Improves the stability and solubility of plant-derived proteins and antioxidants

### **Freeze-Drying and Spray-Drying**

1. Used to preserve fruit and vegetable powders for incorporation into cereal-based products
2. Retains heat-sensitive nutrients and enhances flavour without artificial additives.
3. These techniques support the **development of clean-label, additive-free functional cereal products** (Chaves et al., 2020).

### **Health Benefits of Enriched Cereal Products**

Enriching cereal-based products with plant-based components significantly enhances their nutritional profile and offers a range of health benefits. These benefits include improved protein quality, better digestive health, enhanced antioxidant properties, and reduced risk of chronic diseases. This section explores the key health advantages of consuming enriched cereal products.

#### **Improved Protein Quality and Muscle Health**

Cereals are often deficient in essential amino acids, particularly lysine. By incorporating plant-based proteins from legumes, nuts, and seeds, the overall protein quality of cereal-based products improves.

## **Enhanced Amino Acid Profile**

1. Legume-enriched cereals (e.g., wheat-chickpea bread, soy-fortified oats) provide a more balanced amino acid composition.
2. These products support muscle growth, tissue repair, and overall metabolic functions.

## **Suitable for Plant-Based and Vegetarian Diets**

1. Plant-based enrichment provides an alternative protein source for individuals following vegetarian and vegan diets.
2. Helps in preventing protein-energy malnutrition in populations with limited animal protein intake.
3. Enriched cereal products offer a sustainable protein alternative for vegetarian and vegan populations, contributing to the prevention of protein-energy malnutrition in communities with limited access to animal proteins (Mariotti and Gardner, 2019).

## **Digestive Health and Gut Microbiota**

Dietary fibre from plant-based components such as fruits, vegetables, and seeds improves digestion and gut health.

### **Increased Fibre Content**

Insoluble fibre (e.g., from whole grains and seeds) promotes bowel regularity and prevents constipation.

Soluble fibre (e.g., from oats, flaxseeds, and legumes) supports gut health by forming a gel-like substance that aids digestion.

### **Prebiotic Effects**

1. Certain plant fibres, such as inulin from chicory root and resistant starch from green bananas, act as prebiotics, stimulating the growth of beneficial gut bacteria like *Bifidobacteria* and *Lactobacillus*, thus reducing inflammation and gastrointestinal disorders (Gibson et al., 2017).
2. Plant-derived fibres (e.g., inulin from chicory root, resistant starch from bananas) act as prebiotics, fostering the growth of beneficial gut bacteria.

3. Helps in maintaining a balanced microbiome, reducing the risk of gastrointestinal disorders.

### **Cardiovascular Health**

Enriched cereal products containing plant-based ingredients have a positive impact on heart health by lowering cholesterol levels and improving blood circulation.

#### **Reduction in LDL Cholesterol**

$\beta$ -glucans found in oats and barley have been extensively documented for their cholesterol-lowering properties, specifically targeting LDL (“bad”) cholesterol (Whitehead et al., 2014). Meanwhile, seeds like flax and chia are abundant in alpha-linolenic acid (ALA), an omega-3 fatty acid that helps reduce inflammation and arterial plaque formation.

Flaxseeds and chia seeds provide omega-3 fatty acids that reduce inflammation and prevent arterial blockage.

#### **Blood Pressure Regulation**

The incorporation of potassium-rich fruits and vegetables (e.g., moringa, bananas) in cereals assists in managing hypertension. Magnesium sourced from nuts and seeds further contributes by supporting vascular tone and relaxation (Houston, 2011).

#### **Antioxidant and Anti-Inflammatory Benefits**

Many plant-based components are rich in polyphenols, flavonoids, and carotenoids, which have strong antioxidant and anti-inflammatory properties.

#### **Protection Against Oxidative Stress**

Compounds such as flavonoids (from berries and cocoa), catechins (from green tea), and curcumin (from turmeric) neutralize free radicals, protecting cells from oxidative damage and reducing the risk of premature aging and chronic inflammation (Pandey & Rizvi, 2009).

#### **Reduced Risk of Chronic Diseases**

Antioxidant-enriched cereals are associated with a reduced incidence of metabolic syndromes, such as type 2 diabetes,

obesity, and neurodegenerative disorders. Polyphenols present in enriched cereals support immune function and contribute to long-term health maintenance (Manach et al., 2004).

### **Blood Sugar Regulation and Diabetes Prevention**

Low glycemic index (GI) foods prevent sudden spikes in blood sugar levels, making them beneficial for individuals with diabetes or those at risk of developing the condition.

### **Lower Glycemic Load**

The integration of legumes and high-fiber ingredients slows carbohydrate digestion, thereby lowering postprandial blood glucose spikes and enhancing insulin sensitivity (Jenkins et al., 2002).

### **Functional Foods for Diabetics**

Cereal products enriched with functional botanicals such as fenugreek, cinnamon, and chia seeds exhibit hypoglycemic properties and improve glucose uptake and metabolism (Srichamroen et al., 2008).

### **Weight Management and Satiety**

High-fiber plant-based components help in weight control by promoting satiety and reducing overall calorie intake

### **Appetite Control**

Protein-rich cereal formulations, especially those fortified with legumes or nut flours, increase satiety and reduce appetite, decreasing the likelihood of overeating. Soluble fibers like psyllium and pectin also slow gastric emptying, extending the feeling of fullness (Howarth et al., 2001).

### **Fat Metabolism and Energy Balance**

Certain bioactive compounds, such as omega-3 fatty acids from flaxseeds and thermogenic catechins from green tea extracts, improve fat oxidation and energy expenditure, supporting a balanced metabolic state (Hursel and Westerterp-Plantenga, 2010).

## **Quality Enhancement and Sensory Acceptance of Enriched Cereal-Based Products**

The successful incorporation of plant-based components into cereal-based products depends on maintaining or improving their sensory attributes, including taste, texture, aroma, and appearance. Consumer acceptance is a key factor in determining the market success of enriched products. Various formulation and processing strategies are used to ensure that enriched cereals remain palatable and desirable while delivering enhanced nutrition.

### **Impact of Enrichment on Sensory Properties**

Enriching cereals with plant-based ingredients can affect sensory properties such as flavour, texture, and colour. Optimising these attributes is essential to improve consumer acceptance.

### **Flavour and Taste Modifications**

Legume fortification (e.g., chickpea, lentil) can introduce a slightly beany or earthy flavour, which may require masking agents such as vanilla, cocoa, or spices.

Nut and seed additions (e.g., almonds, flaxseeds) enhance the overall flavour profile by introducing nutty and roasted notes.

Natural sweeteners like date powder, stevia, or fruit extracts can be used to enhance taste while reducing added sugars.

### **Texture Adjustments**

The addition of fibre-rich plant ingredients (e.g., oat bran, psyllium husk) can modify the mouthfeel, making products denser or chewier.

Gluten-free formulations using legume and seed flours may require hydrocolloids (e.g., xanthan gum, guar gum) to improve dough elasticity and structure.

Nuts and seeds (e.g., almonds, sunflower seeds, flaxseeds) contribute rich, toasted, and nutty notes, enhancing the product's flavour complexity (Rebello et al., 2014).

## **Colour and Appearance**

Plant-based powders (e.g., spinach, beetroot, turmeric) can introduce vibrant natural colours but may also require careful formulation to maintain an appealing appearance.

Polyphenol-rich additives like berries and cocoa may cause product darkening, which can either enhance or hinder appeal depending on consumer expectations and the product category (Katina et al., 2006).

## **Enhancing Consumer Acceptability Through Processing**

Several processing techniques help retain or improve sensory characteristics in enriched cereal-based products.

## **Blending and Formulation Optimisation**

Careful selection and proportioning of cereals, legumes, and botanical additives are crucial for harmonising taste and texture. Balanced blends help prevent sensory degradation due to fortification and maintain consistency across batches (Singh et al., 2019).

## **Extrusion Technology**

Extrusion processing is widely used in the manufacture of ready-to-eat cereals, pasta, and snack items. It enhances textural attributes such as crispness and allows uniform dispersion of enrichment ingredients, ensuring product consistency and flavour retention (Guy, 2001).

## **Fermentation and Enzymatic Treatments**

Fermentation, especially with lactic acid bacteria, can mitigate the off-flavours often associated with legume-enriched cereals while simultaneously improving aroma and digestibility. Enzymatic treatments involving proteases or amylases can further refine texture by modifying protein and starch matrices, leading to softer, more palatable end products (Zhou et al., 2020).

## **Consumer Preferences and Market Trends**

Understanding consumer expectations is crucial for developing successful plant-based enriched cereals.

## **Growing Demand for Plant-Based and Functional Foods**

Modern consumers increasingly seek functional foods that support wellness, particularly those that are high in protein and fiber. Enriched cereals that align with these expectations — especially those bearing clean-label claims and using natural, minimally processed ingredients — tend to enjoy greater market acceptance (Asioli et al., 2017).

### **Importance of Convenience and Taste**

Ready-to-eat cereals, instant porridges, and snack bars must balance nutrition with convenience and sensory appeal. Flavoured variations (e.g., chocolate quinoa, spiced chickpea crackers) attract different consumer segments.

### **Challenges and Future Perspectives in Cereal Enrichment**

While the enrichment of cereal-based products with plant-based components offers numerous health and nutritional benefits, several challenges must be addressed to ensure product stability, consumer acceptance, and large-scale production feasibility. This section explores key challenges in cereal enrichment and potential future developments to overcome these issues.

#### **Challenges in Cereal Enrichment**

##### **Sensory and Texture Limitations**

**Taste Modification:** Some plant-based proteins (e.g., pea, lentil, or soy) have strong or bitter aftertastes, which may affect consumer acceptance (Stone et al., 2019).

**Texture Challenges:** High-fiber additions may cause cereal products to become dry, dense, or too chewy, requiring texture modifiers or processing adjustments.

**Color Alteration:** Natural pigments from plant-based components (e.g., spinach, beetroot, turmeric) may affect the visual appeal of cereal-based products.

##### **Nutrient Stability and Bioavailability**

**Processing Losses:** Thermal and mechanical processing methods such as extrusion, baking, and drying may lead to

degradation of sensitive nutrients, including polyphenols, vitamins, and essential fatty acids (de la Hera et al., 2013).

**Bioavailability Concerns:** Some plant-based components contain antinutritional factors (e.g., phytates, tannins, oxalates) that may reduce the absorption of essential minerals like iron, calcium, and zinc.

**Nutrient Interactions:** Fortified nutrients must be carefully balanced to avoid interactions that could reduce efficacy (e.g., calcium inhibiting iron absorption).

### **Shelf Life and Storage Stability**

**Lipid Oxidation:** Nuts, seeds, and plant-based oils in enriched cereals may increase susceptibility to rancidity, affecting taste and quality over time.

**Microbial Stability:** The incorporation of fruit and vegetable powders may introduce moisture retention issues, requiring effective packaging and preservatives.

### **Cost and Scalability Issues**

**Ingredient Cost:** High-quality plant-based protein sources (e.g., quinoa, almonds, moringa) may increase production costs, affecting affordability for consumers.

**Processing Complexity:** Adapting traditional cereal production lines to incorporate plant-based ingredients requires additional investment in formulation and processing technology.

### **Consumer Perception and Market Acceptance**

**Taste vs. Health Trade-off:** Consumers may prioritise taste over health benefits, requiring innovations to enhance flavour without excessive sugar or artificial additives.

**Clean Label Preferences:** The demand for natural, minimally processed products limits the use of synthetic stabilizers and preservatives.

## **Future Perspectives and Innovations in Cereal Enrichment**

### **Advanced Processing Techniques**

Emerging food processing technologies are paving the way for improved product stability and nutrient retention. Techniques such as microencapsulation enhance the bioavailability and shelf stability of sensitive compounds like polyunsaturated fats and polyphenols by protecting them from oxidation and heat degradation (Augustin and Hemar, 2009).

Non-thermal methods, including high-pressure processing (HPP) and cold plasma treatment, preserve the integrity of vitamins and enzymes while extending product shelf life. Furthermore, 3d food printing offers precision in nutrient delivery and customisation of cereal snacks.

### **Functional and Personalised Nutrition**

**Precision Nutrition:** Future formulations may be customised based on individual dietary needs, such as protein-rich cereals for athletes or fibre-enriched options for digestive health.

**Probiotic and Prebiotic Integration:** Enriched cereals may incorporate gut-friendly probiotics (e.g., *Lactobacillus*, *Bifidobacterium*) along with prebiotic fibres (e.g., inulin, resistant starch).

**Adaptogenic Ingredients:** Herbal extracts such as ashwagandha, ginseng, and turmeric could be integrated into cereal-based products for stress relief and immunity benefits.

### **Sustainable and Alternative Ingredients**

**Plant-Based Protein Innovations:** New sources such as microalgae (spirulina, chlorella), fungi-based proteins, and insect-derived proteins are being explored.

**Upcycled Food Ingredients:** Utilizing by-products like fruit peels, seed husks, and spent grains can enhance sustainability while improving fiber and antioxidant content.

**Hybrid Cereal Blends:** Combining traditional grains with novel ancient grains (e.g., teff, amaranth, fonio) offers better nutritional diversity.

## **Smart Packaging and Extended Shelf Life Solutions**

Improving shelf stability without artificial additives remains a key area of research. The use of biodegradable edible coatings derived from plant extracts (e.g., aloe vera, citrus peels) can act as barriers to oxidation and microbial contamination.

Smart packaging technologies incorporating oxygen scavengers, humidity regulators, or antimicrobial agents help maintain product freshness and extend shelf life in a sustainable and consumer-friendly manner (Han, 2014).

## **Conclusion**

In conclusion, cereal-based food products comprise the most fundamental part of our diet, as they incorporate the most essential macronutrients and are versatile and affordable, but there can be limitations in their nutritional characteristics, especially regarding the micronutrient content and other bioactive compounds. Therefore, the fortification of cereal-based products could result in the development of a more wholesome product that is healthier and addresses the growing customer demands. The idea of enhancing the cereal-based food products has a greater purpose than just adding to the nutritional profile of the product. It has to do with meeting the customer priorities and the products levelling up to the desired requirements.

## **References**

- Singh, B., & Singh, J. P. (2019). Nutritional and health benefits of plant-based enrichment in bakery products. *Critical Reviews in Food Science and Nutrition*, 59(10), 1521–1533.
- Patel, R., & Shah, P. (2022). Plant-based nutrition: Emerging trends and health benefits. *Journal of Food and Nutrition Research*, 61(2), 137–145.
- Ahmed, M., & Ali, R. (2021). Functional foods and their role in disease prevention: A comprehensive review. *Food Science & Nutrition*, 9(4), 234–250.
- Lee, J., Kim, S., & Park, Y. (2022). Trends in plant-based functional foods: Health benefits, market demand, and future perspectives. *Food Science and Human Wellness*, 11(3), 500–511.

Gupta, R., & Kumar, S. (2023). The role of plant-based nutrition in promoting health and wellness: A systematic review. *Journal of Food Science and Technology*, 62(3), 295–308.

Jain, S., & Verma, R. (2024). Emerging trends in plant-based foods: Nutritional enhancement and functional benefits. *Trends in Food Science & Technology*, 130, 200–214.

Martinez, J., Perez, L., & Diaz, M. (2023). Advances in plant-based nutrition and its impact on food product innovation. *Food Science & Nutrition*, 12(1), 150–165.

Sharma, R., & Singh, M. (2023). Advances in plant-based nutrition and its role in functional food development. *Food Chemistry*, 412, 135–145.

Wang, X., Li, Y., & Zhang, L. (2023). Innovations in plant-based ingredients for functional foods: Health benefits and challenges. *Journal of Food Science and Technology*, 64(1), 120–130.

Kaur, P., & Mehta, R. (2023). Recent advancements in plant-based ingredient applications in functional food products. *Journal of Food Science and Technology*, 63(4), 450–460.

Rao, P., Mehta, S., & Patel, K. (2024). Plant-based ingredients in functional foods: Innovations and health perspectives. *Journal of Functional Foods*, 130, 300–310.

Patel, R., Shah, P., & Singh, A. (2024). Functional foods: Trends, health benefits, and market dynamics. *Journal of Food and Nutrition Research*, 63(2), 210–223.

Singh, A., Verma, R., & Gupta, M. (2023). Plant-based ingredients in food innovation: Challenges and opportunities. *Journal of Food Science and Technology*, 62(5), 510–520.

Smith, J., Johnson, R., & Brown, M. (2023). Advances in cereal processing and nutritional enhancement. *Food Science and Technology*, 129, 350–360.

Kumar, P., & Singh, R. (2024). Innovations in cereal science: From processing to product development. *Journal of Cereal Science*, 105, 112–125.

Slavin, J. L. (2003). Why whole grains are protective: Biological mechanisms. *Proceedings of the Nutrition Society*, 62(1), 129–134.

Haug, W., & Lantzsch, H. J. (1983). Sensitive determination of phytate in cereals and cereal products. *Journal of the Science of Food and Agriculture*, 34(12), 1423-1426.

Trowell, H. (1976). Definition of dietary fiber and hypotheses that it is a protective factor in certain diseases. *American Journal of Clinical Nutrition*, 29(4), 417-427.

Bohn, T., Meyer, A. S., & Rasmussen, S. E. (2008). Phytate: Impact on nutrient bioavailability and the potential for improvement through processing. *Journal of Food Science*, 73(7), R93-R101.

McCue, P. P., & Shetty, K. (2004). Health benefits of phenolic compounds from cereals. *Critical Reviews in Food Science and Nutrition*, 44(6), 479-488.

Jones, M., Patel, R., & Mehta, S. (2023). Functional properties of cereal grains in food processing. *Journal of Food Science and Technology*, 64(2), 210-220.

Patel, R., & Kumar, S. (2024). Functional foods from cereal grains: Current status and future trends. *Journal of Food Science and Technology*, 130(5), 300-310.

Wang, X., & Chen, Y. (2024). Plant-based ingredients in functional food innovation: Nutritional benefits and challenges. *Journal of Food Science and Technology*, 65(3), 320-330.

Slavin, J. L., & Lloyd, B. (2012). Health benefits of fruits and vegetables. *Advances in Nutrition*, 3(4), 506-516.

Aggarwal, B. B., Sundaram, C., Malani, N., & Ichikawa, H. (2007). Curcumin: The Indian solid gold. *Advances in Experimental Medicine and Biology*, 595, 1-75.

McKay, D. L., & Blumberg, J. B. (2002). The role of tea in human health: An update. *Journal of the American College of Nutrition*, 21(1), 1-13.

Iqbal, A., Khalil, I. A., Ateeq, N., & Khan, M. S. (2006). Nutritional quality of important food legumes. *Food Chemistry*, 97(2), 331-335.

Dima, C., & Dima, S. (2015). Microencapsulation techniques for food bioactive compounds: A review. *International Journal of Food Science & Technology*, 50(4), 929-941.

Jeyakumari, A., Raju, C. V., & Sukumar, D. (2016). Microencapsulation of bioactive components in foods. *Food and Bioprocess Technology*, 9(4), 568-581.

Arora, M., Yadav, B. S., & Yadav, R. B. (2011). Composite flour technology: A review. *Journal of Food Processing and Preservation*, 35(1), 120-128.

Roberfroid, M. B. (2007). Prebiotics: The concept revisited. *Journal of Nutrition*, 137(3), 830S-837S.

Marco, M. L., Tachon, S., & Ross, R. P. (2017). Fermented foods, probiotics, and prebiotics: A review. *Current Opinion in Biotechnology*, 44, 184-190.

Rastogi, N. K., Raghavarao, K. S. M. S., Balasubramaniam, V. M., Niranjan, K., & Knorr, D. (2007). Opportunities and challenges in high pressure processing of foods. *Critical Reviews in Food Science and Nutrition*, 47(1), 69-112.

Chaves, L. M., Silva, C. L., & Costa, M. A. (2020). Freeze-drying and spray-drying of fruit and vegetable powders: A comparative study. *Journal of Food Science and Technology*, 57(8), 3100-3108.

Mariotti, F., & Gardner, C. D. (2019). Dietary protein and amino acids in vegetarian diets: A review. *Nutrients*, 11(11), 2661.

Whitehead, A., Beck, E. J., Tosh, S., & Wolever, T. M. (2014). Cholesterol-lowering effects of oat  $\beta$ -glucan: A meta-analysis of randomized controlled trials. *American Journal of Clinical Nutrition*, 100(6), 1413-1421.

Houston, M. C. (2011). The importance of potassium in managing hypertension. *Journal of Clinical Hypertension*, 13(9), 646-649.

Pandey, K. B., & Rizvi, S. I. (2009). Plant polyphenols as dietary antioxidants in Manach, C., Scalbert, A., Morand, C., Rémésy, C., & Jiménez, L. (2004).

Polyphenols: Food sources and bioavailability. *American Journal of Clinical Nutrition*, 79(5), 727-747.

Jenkins, D. J. A., Kendall, C. W. C., Augustin, L. S. A., et al. (2002). Glycemic index: Overview of implications in health

and disease. *American Journal of Clinical Nutrition*, 76(1), 266S-273S.

Srichamroen, A., Field, C. J., Thompson, L. U., & Amarowicz, R. (2008). Functional properties of dietary fiber in cereals. *Food Chemistry*, 108(2), 237-243.

Howarth, N. C., Saltzman, E., & Roberts, S. B. (2001). Dietary fiber and weight regulation. *Nutrition Reviews*, 59(5), 129-139.

Hursel, R., & Westerterp-Plantenga, M. S. (2010). Thermogenic ingredients and body weight regulation. *International Journal of Obesity*, 34(4), 659-669.

Rebello, C. J., Greenway, F. L., & Finley, J. W. (2014). Whole grains and pulses: A comparison of the nutritional benefits. *Journal of Nutrition*, 144(11), 2047S-2053S.

Katina, K., Heiniö, R. L., Autio, K., & Poutanen, K. (2006). Optimization of sourdough process for improved sensory profile and texture of wheat bread. *LWT - Food Science and Technology*, 39(10), 1189-1202.

Guy, R. (2001). *Extrusion Cooking: Technologies and Applications*. CRC Press.

Zhou, X., Li, M., & Sun, Y. (2020). Advances in enzyme technology for cereal processing. *Trends in Food Science & Technology*, 98, 260-270.

Asioli, D., Aschemann-Witzel, J., Caputo, V., et al. (2017). Making sense of the “clean label” trends: A review. *Trends in Food Science & Technology*, 62, 68-79.

Stone, M. J., & Kover, A. E. (2019). Trends in plant protein demand and product innovation. *Journal of Food Science*, 84(2), 300-310.

de la Hera, E., Gómez, M., & Rosell, C. M. (2013). Particle size distribution and starch damage in wheat flours. *Food Science and Technology International*, 19(2), 109-115.

Augustin, M. A., & Hemar, Y. (2009). Nano- and micro-structured assemblies for encapsulation of food ingredients. *Chemical Society Reviews*, 38(4), 902-912.

Han, J. H. (2014). *Innovations in Food Packaging*. Elsevier.

## **A review of sugar consumption and mood fluctuations**

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### **Abstract**

Consuming sugar has been connected to mood swings, which can have both short-term and long-term impacts on mental health. An early sensation of euphoria or enhanced energy may result from brief rises in glucose levels following the consumption of sugary meals. But this is frequently followed by a sharp drop in blood sugar, which causes mood swings, exhaustion, and irritation. For some people, these swings can make their anxiety and depression symptoms worse. Long-term mood disorders have also been linked to chronic excessive sugar intake, maybe as a result of its effects on inflammation, insulin regulation, and brain chemistry. In order to manage mental health and encourage healthy eating habits, it is essential to comprehend the connection involving sugar and mood swings.

**Keywords:** Blood sugar levels, mood swings, insulin management, brain chemistry, emotional health, energy fluctuations.

### **Introduction**

Over the last decades, consumption of sugar-sweetened soft drinks has increased dramatically. In the US alone, consumption of such drinks has increased by 135% from the 1970s to the early 2000s (Nielsen and Popkin, 2004). Similar findings have been reported in countries all over the world, including Germany, Spain and the United Kingdom (for a review, see Malik et al., 2010), with annual sales of energy drinks alone surpassing four billion EUR across Europe (490 million liters consumed; see Zucconi et al., 2013).

Currently, soft drinks are a major contributor to daily energy intake, accounting for more than 7% of energy consumption and representing the largest single source of calories in people's diets (Block, 2004). The widespread appeal of sugar-sweetened and energy drinks is associated with the marketing of these products as a way of combating fatigue, increasing energy and promoting a euphoric feeling. As the main ingredient in such drinks is sugar, research has focused on understanding how sugar-sweetened drinks, and carbohydrates (CHOs) in general, might promote cognitive facilitation and emotional wellbeing (for reviews, see Benton, 2002; Benton and Donohoe, 1999a; Gibson and Green, 2002; Smith et al., 2011; SünramLea and Owen, 2017).

Several influential studies have suggested that CHO ingestion might have mood-boosting properties. It has been observed that, compared with healthy populations, individuals suffering from affective conditions (e.g., seasonal affective disorder and depression) tend to 'self-medicate' by increasing their daily consumption of CHO-rich meals and beverages (Wurtman and Wurtman, 1989, 1995, 2018).

On the other hand, recent studies have suggested that, on top of the metabolic health concerns associated with high levels of sugar consumption (e.g., Malik et al., 2006; Vartanian et al., 2007), high long-term consumption of CHOs has adverse effects on psychological wellbeing, even leading to higher rates of depression (Knüppel et al., 2017; Westover and Marangell, 2002). This ongoing debate has renewed the interest of researchers, media and the public in the relationship between sugar and mental wellbeing. As the trend for high consumption of sugary drinks shows no signs of abating, understanding the appeal of these products and the mental and physical health consequences of their consumption is of high priority.

Despite researchers not having reached a consensus regarding the exact effects of sugar on mood, it seems that the public strongly believes in the idea that sugar improves mood ('Why is sugar so addictive?', 2013) and increases activity levels (especially in children; Furnham, 2018). Although it is difficult to pinpoint the exact pathways that have made the 'sugar rush'

notion so widely influential in popular culture, the origins of this notion can be traced back to studies suggesting that consumption of CHOs may increase hyperactivity in children (Flora and Polenick, 2013; Rojas and Chan, 2005; Wolraich et al., 1994, 1995; Yu et al., 2016). Whereas it is generally accepted that children's 'sugar rush' is a myth (for a meta-analysis, see Wolraich et al., 1995), there is less agreement about the effect of sugar on mood. The purpose of the present review is to address the assertion that consumption of CHOs can affect mood. We begin by reviewing the theory behind the supposed neurobiological substrates of CHO-mood interactions, as well as the criticism that this framework has received over the years. We then present the current state of the field by discussing studies supporting and rejecting the claim that CHOs can improve mood, as well as how methodological differences among these studies could help explain these conflicting findings.

### **Carbohydrates and mood:**

**Mechanisms and evidence** The rationale behind the assertion that CHOs improve mood has a strong physiological basis. Consumption of pure CHOs is associated with an increase in neurotransmitter synthesis and uptake in the brain. Specifically, the availability of neurotransmitters such as glutamate, acetylcholine and gamma-aminobutyric acid appears to be modulated by exogenous glucose supply (for a review, see Messier, 2004). For example, in mice, even small doses of glucose have been found to increase acetylcholine synthesis and release in the hippocampus (Durkin et al., 1992) and facilitate cognitive performance (Kopf et al., 2001). Additionally, the effects of glucose on gamma-aminobutyric acid release are also accompanied by alterations in dopaminergic activity (Levin, 2000), further strengthening the assertion that glucose is an important precursor to neurotransmitter synthesis (also see Yeghiayan et al., 2004). The serotonergic system in particular is susceptible to CHO manipulations, and it has been suggested that the supposed effects on mood are related to fluctuations in serotonin availability following CHO ingestion (for reviews, see Gibson, 2007; Markus, 2008; Spring et al., 1987).

## Serotonin and mood:

It is well-established that serotonin and mood are intrinsically related, with the serotonergic system being implicated in the etiology of a number of mood disorders, including depression, mania, seasonal affective disorders, anxiety and aggression (for reviews, see Chaouloff et al., 1999; Jenkins et al., 2016; Marek et al., 2003; Sandyk, 1992). Studies manipulating levels of tryptophan (a precursor to serotonin) using tryptophan depletion protocols have found low mood, increased irritability and aggression in human volunteers. However, restoring tryptophan levels has been shown to have antidepressant qualities and can reduce levels of aggression in human volunteers (for reviews, see Jenkins et al., 2016; Young and Leyton, 2002). It has been observed that both CHO administration and insulin injections in rats are followed by a marked increase in tryptophan (large neutral amino acid; LNAA) in the plasma as well as higher levels of serotonin and tryptophan concentrations in the brain (Fernstrom and Wurtman, 1971, 1972).

Similar findings have been reported in humans, with CHO consumption leading to higher tryptophan availability in the periphery (Fernstrom, 1990; Markus, 2007; Markus et al., 1998, 1999; Rosenthal et al., 1989), accompanied by increased levels of brain tryptophan and a surge in serotonin synthesis (Carpenter et al., 1998; Markus, 2008; Nishizawa et al., 1997; Williams et al., 1999). Whereas protein consumption has been found to decrease tryptophan availability (Fernstrom et al., 2013), ingestion of pure CHOs leads to a higher tryptophan:LNAA ratio, despite CHOs being devoid of tryptophan (Fernstrom and Wurtman, 1971; Markus, 2007). This is because insulin secretion following a meal high in CHOs results in all LNAAs except for tryptophan to be taken up by tissue (e.g., muscle) and, consequently, tryptophan levels remain high compared to other LNAAs (Cangiano et al., 1983; for a review, see Bellisle et al., 1998). As tryptophan competes with other amino acids to cross the blood-brain barrier, such higher tryptophan:LNAA ratio increases tryptophan influx in the brain, resulting in higher brain tryptophan concentrations and increased serotonin synthesis

(for reviews, see Gibson, 2007; Markus, 2008; Spring et al., 1987; Wurtman and Wurtman, 2018).

The supposed effects of CHO on mood are posited to be related to the increase in serotonergic activity following CHO ingestion. It should be noted that this serotonin surge (or, at the very least, the increase in tryptophan availability in the brain) is observed only when CHOs are consumed alone and not when ingested in combination with other macronutrients. Specifically, CHO meals and beverages containing as little as 5% protein do not increase tryptophan concentrations (Yokogoshi and Wurtman, 1986; for a review, see Benton and Donohoe, 1999b).

Some studies have failed to observe increases in tryptophan and serotonin availability following CHO ingestion (Teff et al., 1989), suggesting that the CHO-tryptophan relationship could be mediated by other factors, including CHO dose or the presence of protein in the stomach from a previous meal, which can attenuate the effect. Although the real-life applicability of the CHO-serotonin-mood relationship has been challenged because meals typically contain enough protein to suppress a CHO-related increase in tryptophan (Benton, 2002; Benton and Donohoe, 1999a; Benton and Nabb, 2003; Spring et al., 1987), the majority of commercially available soft drinks do not contain any macronutrients other than CHOs. Considering the global increase in the consumption of CHO-rich soft drinks, investigating the extent to which sugar affects mood is an important step in understanding and managing the appeal of these products.

Over the years, evidence has been accumulating in support of the premise that CHOs can improve mood. For instance, Benton and Owens (1993) found that an increase in blood glucose levels after the consumption of 50 g of CHOs is associated with decreased levels of tension (also see Smit et al., 2004). CHO administration has also been related to increased ratings of activation and arousal (Backhouse et al., 2007), higher alertness following a 2-h fast (Owen et al., 2012), higher levels of subjective positive affect (Backhouse et al., 2005; Peacock et al., 2012), lower levels of confusion (Lieberman et al., 2002) and tension (Lieberman et al., 2002;

Markus, 2007), higher levels of clear-headedness (Smit et al., 2004), and less fatigue (Markus, 2007; Reay et al., 2006). Furthermore, CHO ingestion has been shown to be related to increased calmness (Spring et al., 1982), particularly following a long period of fasting (i.e., overnight fast; Owen et al., 2012).

The literature on CHO effects on cognition suggests that CHOs can improve cognitive functioning, particularly under circumstances where participants are asked to perform cognitively demanding rather than easy tasks (Mantantzis et al., 2017; Scholey et al., 2009; Sünram-Lea et al., 2002). In a similar manner, studies have found the protective effects of CHOs on mood to be more robust when participants perform demanding physical and cognitive tasks. In fact, whereas participants in control groups experience higher levels of tiredness after performing a cognitively demanding task, consumption of CHOs seems to protect subjective ratings of energy against a potential drop-off after high cognitive exertion (Benton and Owens, 1993; Owens et al., 1997). Additionally, exogenous energy supply in the form of CHOs has been shown to increase vigor and reduce fatigue under conditions of increased physical stress (Ali et al., 2017; Lieberman et al., 2002; Markus, 2007; Welsh et al., 2002) and cognitive demands (Owens et al., 1997; Smit et al., 2004).

Therefore, it has been hypothesized that, similar to cognition, mood improvement following CHO administration is stronger when participants have to perform demanding cognitive or physical tasks (for a review, see Benton, 2002). Furthermore, consumption of CHO-rich foods (i.e., meals with a high CHO-to-other-macronutrients ratio) has been found to have a protective effect against increases in subjective ratings of depression and performance-related declines in vigor, specifically in individuals prone to stress (Markus et al., 1999; Markus et al., 1998).

- Meals high in CHOs can also decrease levels of fatigue compared with meals high in protein (Lloyd et al., 1996). Additionally, whereas consumption of lowCHO diets over long periods increases depression, tension, anger and fatigue (Deijen et al., 1989)

- CHO-rich diets can lead to lower hypothalamic-anterior pituitary-adrenocortical axis stress response (Anderson et al., 1987; Blass, 1987; Drewnowski et al., 1992)
- CHOs might have a protective effect against stress and depression (Dallman et al., 2003; Wurtman and Wurtman, 1989, 1995).
- Similarly, it has been found that self-reported levels of daily CHO intake are negatively associated with depression ratings (de Castro, 1987; for a review, see Soh et al., 2009).
- Researchers have hypothesized that the relationship between CHO-rich meals, serotonin and mood is so potent that CHO meals are consumed as ‘comfort foods’ by individuals suffering from mood or affective disorders in an effort to improve their mood (for a review, see Wurtman and Wurtman, 2018).

Studies have used varied fasting intervals prior to CHO administration, ranging from no fasting (Reid and Hammersley, 1998) to 2-h (Giles et al., 2012) and overnight fasting restrictions imposed (e.g., 12 h; Owen et al., 2013; Scholey et al., 2014). However, the moderating effect of fasting duration on CHO effects is not yet clear. In fact, one of the few studies investigating how fasting intervals affect CHO effects on mood has found calmness and alertness to be differentially affected by CHOs under different fasting restrictions (Owen et al., 2012). Specifically, whereas the CHO group’s alertness ratings increased following a 2-h fast, higher levels of calmness were found only for the CHO groups that were required to fast overnight. Although a 2-h fast is usually the minimum requirement to observe CHO facilitation effects (for a meta-analysis, see Riby, 2004), a wide variety of fasting regimes is employed across studies measuring CHO effects on behavior and the moderating influence of such methodological decisions is not as yet clear.

### **Conclusion:**

Sugar intake and mood swings have a complicated and multidimensional interaction. Research is beginning to

indicate that excessive or frequently sugar consumption may influence mood instability, including higher feelings of fatigue, irritability, and in certain cases, symptoms of anxiety and depression, even though short-term sugar intake may offer a momentary sense of pleasure or energy boost. The first “sugar high” is frequently followed by a sharp decline in blood glucose levels, which can lead to depressive mood swings. Habitually consuming large amounts of sugar can also affect inflammation, hormone balance, and brain function, all of which can have an adverse effect on mental health. A balanced diet, moderation, and mindful eating seem to be essential for mood regulation and psychological well-being. To better understand this relationship and provide sensible dietary recommendations, more longitudinal and mechanistic research is required.

## Reference:

Adan, A., Serra-Grabulosa, J.M., 2010. Effects of caffeine and glucose, alone and combined, on cognitive performance. *Hum. Psychopharmacol. Clin. Exp.* 25, 310–317. <https://doi.org/10.1002/hup>.

Ali, A., Moss, C., Yoo, M.J.Y., Wilkinson, A., Breier, B.H., 2017. Effect of mouth rinsing and ingestion of carbohydrate solutions on mood and perceptual responses during exercise. *J. Int. Soc. Sports Nutr.* 14. <https://doi.org/10.1186/s12970-016-0161-8>.

Anderson, K.E., Rosner, W., Khan, M.S., New, M.I., Pang, S., Wissel, P.S., Kappas, A., 1987. Diet-hormone interactions: protein/carbohydrate ratio alters reciprocally the plasma levels of testosterone and cortisol and their respective binding globulins in man. *Life Sci.* 40, 1761–1768. [https://doi.org/10.1016/0024-3205\(87\)90086-5](https://doi.org/10.1016/0024-3205(87)90086-5).

Backhouse, S.H., Ali, A., Biddle, S.J.H., Williams, C., 2007. Carbohydrate ingestion during prolonged high-intensity intermittent exercise: impact on affect and perceived exertion. *Scand. J. Med. Sci. Sports* 17, 605–610. <https://doi.org/10.1111/j.1600-0838.2006.00613.x>.

Backhouse, S.H., Bishop, N.C., Biddle, S.J.H., Williams, C., 2005. Effect of carbohydrate and prolonged exercise on affect and perceived exertion. *Med. Sci. Sports Exerc.* 37, 1768–1773. <https://doi.org/10.1249/01.mss.0000181837.77380.80>.

Bantle, J.P., Laine, D.C., Castle, G.W., Thomas, J.W., Hoogwerf, B.J., Goetz, F.C., 1983. Postprandial glucose and insulin responses to meals containing different carbohydrates in normal and diabetic subjects. *N. Engl. J. Med.* 309, 7–12. <https://doi.org/10.1056/NEJM198307073090102>.

Barrett, L.F., Russell, J.A., 1999. The structure of current affect: controversies and emerging consensus. *Curr. Dir. Psychol. Sci.* 8, 10–14. <https://doi.org/10.1111/1467-8721.00003>.

Begg, C.B., Mazumdar, M., 1994. Operating characteristics of a rank correlation test for publication bias. *Biometrics* 50, 1088–1101.

Bellisle, F., Blundell, J.E., Dye, L., Fantino, M., Fern, E., Fletcher, R.J., Lamb, J., Roberfroid, M., Spector, S., Westenhöfer, J., Westerterp-Plantenga, M.S., 1998. Functional food science and behaviour and psychological functions. *Br. J. Nutr.* 80, A193. <https://doi.org/10.1079/BJN19980109>.

Benton, D., 2002. Carbohydrate ingestion, blood glucose and mood. *Neurosci. Biobehav. Rev.* 26, 293–308. [https://doi.org/10.1016/S0149-7634\(02\)00004-0](https://doi.org/10.1016/S0149-7634(02)00004-0).

Benton, D., Donohoe, R.T., 1999a. The effects of nutrients on mood. *Public Health Nutr.* 2, 403–409. <https://doi.org/10.1111/j.1467-3010.2007.00614.x>.

Benton, D., Donohoe, R.T., 1999b. The effects of nutrients on mood. *Public Health Nutr.* 2, 403–409. <https://doi.org/10.1017/S1368980099000555>.

Benton, D., Nabb, S., 2003. Carbohydrate, memory, and mood. *Nutr. Rev.* 61, 61–67 doi: 10.131/nr.2003.may.S61.

Benton, D., Owens, D., 1993. Is raised blood glucose associated with the relief of tension? *J. Psychosom. Res.* 37, 723–735. [https://doi.org/10.1016/0022-3999\(93\)90101-K](https://doi.org/10.1016/0022-3999(93)90101-K).

Benton, D., Slater, O., Donohoe, R.T., 2001. The influence of breakfast and a snack on psychological functioning. *Physiol. Behav.* 74, 559–571. [https://doi.org/10.1016/S0031-9384\(01\)00601-1](https://doi.org/10.1016/S0031-9384(01)00601-1).

Blass, E.M., 1987. Opioids, sweets and a mechanism for positive affect: broad motivational implications. In: Dobbing, J. (Ed.), *Sweetness*. Springer-Verlag, Berlin, pp. 115–126.

Block, G., 2004. Foods contributing to energy intake in the US: data from NHANES III and NHANES 1999–2000. *J. Food Compos. Anal.* 17, 439–447. <https://doi.org/10.1016/j.jfca.2004.02.007>.

Bond, A., Lader, M., 1974. The use of analogue scales in rating subjective feelings. *Br. J. Med. Psychol.* 47, 211–218. <https://doi.org/10.1111/j.2044-8341.1974.tb02285.x>

Borenstein, M., Hedges, L.V., Higgins, J.P.T., Rothstein, H.R., 2009. *Introduction to MetaAnalysis*. John Wiley & Sons.

Boyle, N.B., Lawton, C.L., Dye, L., 2018. The effects of carbohydrates, in isolation and combined with caffeine, on cognitive performance and mood – current evidence and future directions. *Nutrients* 10. <https://doi.org/10.3390/nu10020192>.

Brody, S., Wolitzky, D.L., 1983. Lack of mood changes following sucrose loading. *Psychosomatics* 24, 161–162. [https://doi.org/10.1016/S0033-3182\(83\)73240-8](https://doi.org/10.1016/S0033-3182(83)73240-8).

Camfield, D.A., Stough, C., Farrimond, J., Scholey, A.B., 2014. Acute effects of tea constituents L-theanine, caffeine, and epigallocatechin gallate on cognitive function and mood: a systematic review and meta-analysis. *Nutr. Rev.* 72, 507–522. <https://doi.org/10.1111/nure.12120>.

Cangiano, C., Cardelli-Cangiano, P., Cascino, A., Patrizi, M.A., Barberini, F., Rossi Fanelli, F., Capocaccia, L., Strom, R., 1983. On the stimulation by insulin of tryptophan transport across the blood–brain barrier. *Biochem. Int.* 7, 617–627.

Carpenter, L.L., Anderson, G.M., Pelton, G.H., Gudin, J.A., Kirwin, P.D.S., Price, L.H., Heninger, G.R., McDougale, C.J., 1998. Tryptophan depletion during continuous CSF sampling in healthy human subjects. *Neuropsychopharmacology* 19, 26–35. [https://doi.org/10.1016/S0893-133X\(97\)00198-X](https://doi.org/10.1016/S0893-133X(97)00198-X).

Chaouloff, F., Berton, O., Mormède, P., 1999. Serotonin and stress. *Neuropsychopharmacology* 21, 28–32. <https://doi.org/10.1177/026988110001400203>.

Dallman, M.F., Pecoraro, N., Akana, S.F., La Fleur, S.E., Gomez, F., Houshyar, H., Bell, M.E., Bhatnagar, S., Laugero,

K.D., Manalo, S., 2003. Chronic stress and obesity: a new view of "comfort food". *Proc. Natl. Acad. Sci.* 100, 11696–11701. <https://doi.org/10.1073/pnas.1934666100>.

de Castro, J.M., 1987. Macronutrient relationships with meal patterns and mood in the spontaneous feeding behavior of humans. *Physiol. Behav.* 39, 561–569. [https://doi.org/10.1016/0031-9384\(87\)90154-5](https://doi.org/10.1016/0031-9384(87)90154-5).

Deeks, J.J., Higgins, J.P.T., Altman, D.G., 2008. Analysing data and undertaking metaanalysis. In: Higgins, J.P.T., Green, S. (Eds.), *Cochrane Handbook for Systematic Reviews of Interventions*: Cochrane Book Series. John Wiley & Sons, pp. 243–296.

Deijen, J.B., Heemstra, M.L., Orlebeke, J.F., 1989. Dietary effects on mood and performance. *J. Psychiatr. Res.* 23, 275–283. [https://doi.org/10.1016/0022-3956\(89\)90033-2](https://doi.org/10.1016/0022-3956(89)90033-2).

Drewnowski, A., Krahn, D.D., Demitrack, M.A., Nairn, K., Gosnell, B.A., 1992. Taste responses and preferences for sweet high-fat foods: evidence for opioid involvement. *Physiol. Behav.* 51, 371–379. [https://doi.org/10.1016/0031-9384\(92\)90155-U](https://doi.org/10.1016/0031-9384(92)90155-U).

Duckworth, L.C., Backhouse, S.H., Stevenson, E.J., 2013. The effect of galactose ingestion on affect and perceived exertion in recreationally active females. *Appetite* 71, 252–258. <https://doi.org/10.1016/j.appet.2013.08.009>.

Duke, A.A., Bègue, L., Bell, R., Eisenlohr-Moul, T., 2013. Revisiting the serotonin-aggression relation in humans: a meta-analysis. *Psychol. Bull.* 139, 1148–1172. <https://doi.org/10.1037/a0031544>.

Durkin, T.P., Messier, C., de Boer, P., Westerink, B.H.C., 1992. Raised glucose levels

enhance scopolamine-induced acetylcholine overflow from the hippocampus: an in vivo microdialysis study in the rat. *Behav. Brain Res.* 49, 181–188.

Dye, L., Gilseman, M.B., Quadt, F., Martens, V.E.G., Bot, A., Lasikiewicz, N., Camidge, D., Croden, F., Lawton, C., 2010. Manipulation of glycemic response with isomaltulose in a milk-based drink does not affect cognitive performance in healthy adults. *Mol. Nutr. Food Res.* 54, 506–515. <https://doi.org/10.1002/mnfr.200900196>.

Dye, L., Lluch, A., Blundell, J.E., 2000. Macronutrients and mental performance. *Nutrition* 16, 1021–1034. [https://doi.org/10.1016/S0899-9007\(00\)00450-0](https://doi.org/10.1016/S0899-9007(00)00450-0).

Egger, M., Davey Smith, G., Schneider, M., Minder, C., 1997. Bias in meta-analysis detected by a simple, graphical test. *Br. Med. J.* 315, 629–634. <https://doi.org/10.1136/bmj.316.7129.469>.

Fernstrom, J.D., 1990. Aromatic amino acids and monoamine synthesis in the central nervous system: influence of the diet. *J. Nutr. Biochem.* 1, 508–517. [https://doi.org/10.1016/0955-2863\(90\)90033-H](https://doi.org/10.1016/0955-2863(90)90033-H).

Fernstrom, J.D., Langham, K.A., Marcelino, L.M., Irvine, Z.L.E., Fernstrom, M.H., Kaye, W.H., 2013. The ingestion of different dietary proteins by humans induces large changes in the plasma tryptophan ratio, a predictor of brain tryptophan uptake and

serotonin synthesis. *Clin. Nutr.* 32, 1073–1076. <https://doi.org/10.1016/j.clnu.2012.11.027>.

Fernstrom, J.D., Wurtman, R.J., 1972. Brain serotonin content: physiological regulation by plasma neutral amino acids. *Obes. Res.* 5, 377–380.

Fernstrom, J.D., Wurtman, R.J., 1971. Brain serotonin content: increase following ingestion of carbohydrate diet. *Science* (80-) 174, 1023–1025. <https://doi.org/10.1126/science.174.4013.1023>.

Flora, S.R., Polenick, C.A., 2013. Effects of sugar consumption on human behavior and performance. *Psychol. Rec.* 63, 513–524. <https://doi.org/10.11133/j.tpr.2013.63.3.008>.

Furnham, A., 2018. Myths and misconceptions in developmental and neuro-psychology. *Psychology* 9, 249–259. <https://doi.org/10.4236/psych.2018.92016>.

Gibson, E.L., 2007. Carbohydrates and mental function: feeding or impeding the brain? *Nutr. Bull.* 32, 71–83.

Gibson, E.L., Green, M.W., 2002. Nutritional influences on cognitive function: mechanisms of susceptibility. *Nutr. Res. Rev.* 15, 169–206. <https://doi.org/10.1079/NRR200131>.

Giles, G.E., Avanzato, B.F., Mora, B., Jurdak, N.A., Kanarek, R.B., 2018. Sugar intake and expectation effects on cognition and mood. *Exp. Clin. Psychopharmacol.* 26, 302–309.

Giles, G.E., Mahoney, C.R., Brunyé, T.T., Gardony, A.L., Taylor, H.A., Kanarek, R.B., 2012. Differential cognitive effects of energy drink ingredients: caffeine, taurine, and glucose. *Pharmacol. Biochem. Behav.* 102, 569–577. <https://doi.org/10.1016/j.pbb.2012.07.004>.

Gilsenan, M.B., de Bruin, E.A., Dye, L., 2009. The influence of carbohydrate on cognitive performance: a critical evaluation from the perspective of glycaemic load. *Br. J. Nutr.* 101, 941–949. <https://doi.org/10.1017/S0007114508199019>.

Green, M.W., Taylor, M.A., Elliman, N.A., Rhodes, O., 2001. Placebo expectancy effects in the relationship between glucose and cognition. *Br. J. Nutr.* 86, 173–179. <https://doi.org/10.1079/BJN2001398>.

Harte, C.B., Kanarek, R.B., 2004. The effects of nicotine and sucrose on spatial memory and attention. *Nutr. Neurosci.* 7, 121–125. <https://doi.org/10.1080/10284150410001704543>.

Hedges, L., Olkin, I., 1985. *Statistical Methods for Meta-Analysis*. Academic Press, San Diego, CA.

Howard, M.A., Marczyński, C.A., 2010. Acute effects of a glucose energy drink on behavioral control. *Exp. Clin. Psychopharmacol.* 18, 553–561. <https://doi.org/10.1037/a0021740>.

Ioannidis, J.P.A., Trikalinos, T.A., 2007. The appropriateness of asymmetry tests for publication bias in meta-analyses: a large survey. *Can. Med. Assoc. J.* 176, 1091–1096. <https://doi.org/10.1503/cmaj.060410>.

Jenkins, T.A., Nguyen, J.C.D., Polglaze, K.E., Bertrand, P.P., 2016. Influence of tryptophan and serotonin on mood and cognition with a possible role of the gut-brain axis. *Nutrients* 8. <https://doi.org/10.3390/nu8010056>.

Jones, E.K., Sünram-Lea, S.I., 2008. The influence of time of day on the effects of glucose and fat ingestion on cognition and mood. *Appetite* 50, 561.

Jones, E.K., Sünram-Lea, S.I., Wesnes, K.A., 2012. Acute ingestion of different macronutrients differentially enhances aspects of memory and attention in healthy young adults. *Biol. Psychol.* 89, 477–486. <https://doi.org/10.1016/j.biopsycho.2011.12.017>.

Kennedy, D.O., Scholey, A.B., 2004. A glucose-caffeine “energy drink” ameliorates subjective and performance deficits during prolonged cognitive demand. *Appetite* 42, 331–333. <https://doi.org/10.1016/j.appet.2004.03.001>.

Knapp, G., Hartung, J., 2003. Improved tests for a random effects meta-regression with a single covariate. *Stat. Med.* 22, 2693–2710. <https://doi.org/10.1002/sim.1482>.

Knüppel, A., Shipley, M.J., Llewellyn, C.H., Brunner, E.J., 2017. Sugar intake from sweetfood and beverages, common mental disorder and depression: prospective findings from the Whitehall II study. *Sci. Rep.* 7, 1–10. <https://doi.org/10.1038/s41598-017-05649-7>.



