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Fruits and their role in boosting the immune system : Article Review

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ABSTRACT
Despite the significant expansion in health and nutrition research, resulting in a large number of academic publications, previous studies have primarily focused on functional foods. Furthermore, most published research has concentrated on micronutrients, such as vitamins and minerals, and their role in influencing the immune response. Consequently, the recent trend has led to increased demand for immune-boosting foods. The use of natural fruits as immune modifiers is quite common and simply requires concrete scientific evidence to prove its effectiveness. Numerous studies have shown that fruits are rich in bioactive compounds such as vitamins (A, C, E, etc.), minerals, and phytochemicals (such as beta-carotene, flavonoids, and phenols). These components have the potential to enhance our immunity by supporting lymphocyte proliferation, eliminating free radicals, reducing oxidative stress, improving the anti-inflammatory mechanism and immune modulation, and supporting platelet aggregation. Therefore, adding an appropriate amount of fruit daily to the diet can support the body's natural defenses by strengthening our immune response. In this introduction, we attempt to summarize the important role that various phytochemicals and bioactive compounds in fruit play in boosting our immune system.

KEYWORDS: Fruits ,Immune System, Nutrition, Diet.

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الفاكهة ودورها في تعزيز الجهاز المناعي: مقالة مراجعة

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الملخص
على الرغم من التوسع الكبير في أبحاث الصحة والتغذية، والذي نتج عنه عدد كبير من المنشورات الأكاديمية، إلا أن الدراسات السابقة ركزت بشكل رئيسي على الأغذية الوظيفية.علاوة على ذلك، ركزت معظم الأبحاث المنشورة على المغذيات الدقيقة، مثل الفيتامينات والمعادن، ودورها في التأثير على الاستجابة المناعية. ولذلك، شهد الوضع الأخير زيادة في الطلب على الأطعمة المعززة للمناعة. يُعد استخدام الفواكه الطبيعية كمعدّلات للمناعة أمرًا شائعًا للغاية، ويحتاج فقط إلى أدلة علمية ملموسة لإثبات فعاليته. وقد أظهرت العديد من الدراسات أن الفواكه غنية بالمركبات النشطة بيولوجيًا مثل الفيتامينات (فيتامينات أ، ج، هـ، إلخ)، والمعادن، والمواد الكيميائية النباتية (مثل بيتا كاروتين، والفلافونويدات والفينولات، إلخ). تتمتع هذه المكونات بالقدرة على تعزيز مناعتنا من خلال دعم تكاثر الخلايا الليمفاوية، والتخلص من الجذور الحرة، وتقليل الإجهاد التأكسدي، وتحسين آلية مكافحة الالتهابات وتعديل المناعة، ودعم تراكم الصفائح الدموية. لذا، فإنّ إضافة كمية مناسبة من الفاكهة يوميًا إلى النظام الغذائي يمكن أن يدعم دفاعات الجسم الطبيعية من خلال تقوية استجابتنا المناعية. في هذه المقدمة، نحاول تلخيص الدور الهام الذي تلعبه مختلف المواد الكيميائية النباتية والمركبات النشطة بيولوجيًا في الفاكهة في تعزيز جهازنا المناعي.
الكلمات المفتاحية: الفاكهة، الجهاز المناعي، التغذية، النظام الغذائي.

INTRODUCTION

Boosting the immune system is crucial and can be achieved through a diet rich in immune-boosting foods. Fruits are rich in vitamins, minerals, and active compounds that are essential for enhancing the body's immune response. Moreover, ‘a person with suboptimal immune response is more prone to the infectious disease.’(Baidya and Sethy, 2020). On the other hand, nutrition, which is defined as a biological process whereby an organism assimilates food and uses it for growth,

maintenance and repair of tissues, is concerned with pivotal mechanisms. They include the synthesis and secretion of different substances for signaling purposes, the generation of free radicals, cell proliferation and immune-suppressive functions facilitate the understanding of the fact that the immune system of an individual can turn out to be far more productive if the immunity is adhered to (Percival, 2011).

It is also crucial to focus on the fact that 'nutritional deficiencies that give rise to specific diseases can impair immune status and render the human body more susceptible to infections. Overall, just like a balanced diet can keep a certain disease in check, it can also help the immune system perform all the necessary functions with optimal standards. 'Increased fruit consumption has been associated with a reduced risk of chronic diseases in numerous observational studies.'. 'Several biological mechanisms through which fruit consumption might protect against chronic diseases have been identified'. One of the reasons is that 'fruits are rich in essential vitamins, including vitamins A, C and E, important minerals and phytochemicals.'. 'A variety of plant chemicals have been identified in fruits that show potential health benefits'.:

- **Carotenoids**, such as beta-carotene, are found in apricots and mangoes.
- **Flavonoids**, such as quercetin found in berries; kaempferol found in apples and berries, and flavonoids found in general in citrus fruits and apples.
- **Phenolic acids**, such as ellagic acid found in berries, strawberries, pomegranates, and thuja, and phenols in apple and pear peels.
- **Catechins**, found in berries, grapes, apples, pomegranates, and persimmons.
- **Specialized vitamins**: such as ascorbic acid found in lemons and grapefruits, and folic acid found in oranges and papaya.

Thus, these compounds provide an opportunity to strengthen immunity due to the stimulation of lymphocyte proliferation and protection of the body from the damaging effects of reactive oxygen species. Second, these compounds allow for improved anti-inflammatory and immune-modulating mechanisms, as well as support platelet aggregation. Together, this information suggests that daily intake of fruit lets a person enhance the body's natural protection, trigger an immune response, and resist infections(Maheshwari et al., 2021; Ding et al., 2018; Pangrazzi, 2019). this review will present an overview of information to be learned and discovered surrounding the nutritional value and medicinal characteristics of fruits suitable for various regions of the globe.

DIET AND NUTRITION: THEIR EFFECT ON IMMUNE FUNCTION

Immunity is defined as the ability of an organism to resist a particular disease, particularly by preventing the development of pathogenic microorganisms or by diminishing the effects of their products. Fruit is the edible part of a plant that includes the seeds and the surrounding tissues. Fruits are vital sources of micronutrients and dietary fiber, and they play a crucial role in a healthy diet by

helping prevent serious diseases. Due to their health-promoting properties, they play an important role in nutritional guidance (Amao, 2018).

Components and types of the immune system: Immunity can be classified into two main types:

Innate immunity: Also known as nonspecific immunity.

Adaptive immunity: Also known as specific immunity (Singh et al., 2022).

The immune system comprises various anatomical and functional components, including the thymus, spleen, and lymph nodes, as well as specialized aggregates of lymphoid tissue, such as those in the gastrointestinal tract and bone marrow. It also encompasses a crucial group of cells, including phagocytes and lymphocytes—specifically B cells and T cells—as well as antibodies (Rakhi Sahu, 2022).

NUTRITION'S ROLE IN MODULATING IMMUNITY

Nutrition plays a crucial role in building human immunity. Consuming a diet that is rich in nutrients with immune-boosting properties is essential for strengthening the immune system. Diet includes a variety of ingredients that not only provide energy and help synthesize compounds but also contain non-nutritive elements. These components, along with essential nutrients, help regulate metabolic processes and biological signaling, including immune signaling, highlighting the significant role of diet in modulating the immune system (Pahwa and Sharan, 2020; Vishwakarma et al., 2022). Studies have shown that a low-fat, plant-based diet may enhance immune system function (Mishra & Patel, 2020). Conversely, malnutrition can impede immune system development, resulting in immunodeficiency that makes the body more susceptible to infection (Cooper and Ma, 2017), allergies, and chronic inflammation (Albers et al., 2013), confirming the importance of proper nutrition for maintaining optimal immune function.

THERAPEUTIC BENEFITS AND NUTRITIONAL SUPPLEMENTS

Immune-boosting nutrients and components, including antioxidants (carotenoids, vitamin C, vitamin E, folate, selenium, and phytochemicals), vitamin D, zinc, iron, dietary fiber, and omega-3 fatty acids, are essential for maintaining a healthy immune system.

Certain immune-boosting foods, including citrus fruits, avocados, kiwis, apples, berries, papayas, pineapples, and vanilla, are believed to positively impact overall health. These foods may benefit individuals with conditions such as cancer, diabetes, and heart disease, as well as support skin and vision health, bone health, blood pressure regulation, and brain development. Additionally, they possess various properties, including anti-stress, antimicrobial, antibacterial, antifungal, anti-aging, anti-allergy, antimalarial, antimutagenic, and anti-inflammatory effects (Bubnov et al., 2015; Jayewardena et al., 2020; Stephen et al., 2023). These influences emphasize the potential therapeutic benefits of incorporating specific foods into the diet to enhance immune function. For example, iron deficiency anemia can be addressed by consuming certain fruits that enhance the bioavailability of

iron in the blood (Shubham et al., 2020). In another instance, the combination of yogurt and bananas is important for supplying both probiotics and prebiotics. Prebiotics serve as food for beneficial bacteria, while probiotics introduce beneficial bacteria directly into the digestive tract (Natarajan et al., 2019).

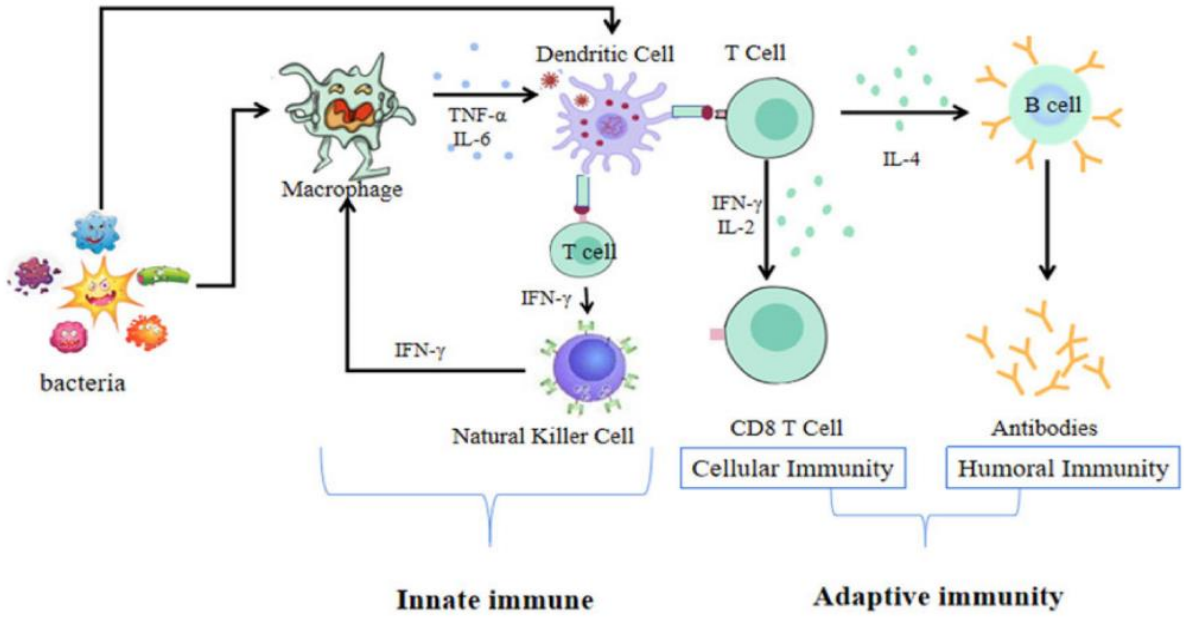


Figure 1. Human immune system (adapted from Jiang, 2019).

FRUITS AND THEIR ROLE IN IMPROVING THE IMMUNE SYSTEM

Fruits are a rich source of essential compounds that significantly enhance the body's immune response, as demonstrated by the specific properties of the following fruits:

1.Citrus fruits: *Citrus spp.*

Some fruits in this category include lemons, oranges, tangerines, and pomelo. These fruits contain flavonoids, which are believed to possess anti-cancer properties (Facts, 2018). Flavonoids are antioxidants that can neutralize free radicals, protect against heart disease, and improve blood flow through the coronary arteries (Kozlowska et al., 2018). Citrus fruits are excellent sources of vitamin C, as well as folic acid and thiamine. Vitamin C protects the body from free radicals that can cause damage. It also aids in wound healing and is crucial for strengthening blood vessels, tendons, ligaments, and bones. Thiamine plays an important role in metabolism, while folic acid is essential for cell division (Slavin and Lloyd, 2012; del Río-Celestino and Font, 2020). Both of these nutrients are important for enhancing immune system function (Guimarães et al., 2009).

The genus Citrus is known for its diverse range of antioxidant metabolites, nutritional components, and polyphenolic compounds. These substances not only help plants withstand challenging environmental conditions and improve their tolerance to both biotic and abiotic stresses, but they also offer numerous health benefits for humans, particularly by boosting immunity (Rakhi Sahu, 2022; Mazzoni et al., 2021).

2.Berries:

Studies show that berries are rich in antioxidants. The polyphenols in strawberries and the flavonoids in blueberries help reduce cellular damage, thereby enhancing immune function. Furthermore, these fruits are excellent sources of vitamin C, vitamin A, potassium, manganese, and fiber (Anurag, 2020). One of the key components of berries is anthocyanin, a significant polyphenol compound that interacts with γδ T cells. These specialized immune cells play a role in both adaptive and innate immunity. They are primarily located in the digestive and respiratory systems, helping to protect the body from pathogens that enter through these routes (Percival, 2009; Lachowicz et al., 2017).

Reactive oxygen species (ROS) are produced in the body during immune cell activity in response to pathogens. Anthocyanins, naturally found in berries, enhance immune function while protecting tissues from oxidative damage caused by ROS through their antioxidant properties (McAnulty et al., 2017). Research has demonstrated that the high levels of anthocyanins in blueberries contribute to increased levels of anti-inflammatory cytokines and reduced oxidative stress (Ma et al., 2018), suggesting that consuming foods rich in antioxidants can mitigate the harmful effects of inflammation

3.Apple: *Malus domestica*

Apples are a commonly consumed fruit rich in numerous phytochemicals. Many studies have demonstrated that consuming apples provides health benefits, including a decreased risk of cancer, diabetes, cardiovascular disease, and asthma. Apples possess strong antioxidant properties; they inhibit cancer cell growth, reduce lipid oxidation, and help lower cholesterol levels (Boyer & Liu, 2004). Apples are rich in polyphenols, a nutritional treasure that aids in the fight against chronic diseases. Specifically, phloretin, a compound within the polyphenol group, may inhibit the production of a specific protein that plays a role in the growth of cancer cells in some cancers, such as breast cancer (Boyer and Liu, 2004). Furthermore, quercetin, a major polyphenol in apples, has been shown to inhibit the growth and activity of human leukemia T cells during the G1 phase of the cell cycle (Lamson and Brignall, 2000). Research has demonstrated that consuming apples enhances the levels of antioxidant enzymes, such as superoxide dismutase (SOD) and glutathione peroxidase, within red blood cells and increases the overall antioxidant capacity of plasma. Higher levels of these enzymes indicate that regular apple consumption may help reduce oxidative stress. It is recommended that the average daily intake of apples should not exceed one apple (Hyson, 2011). Peeled apples have an antioxidant capacity comparable to 83 μmol of vitamin C, which means that the antioxidant capacity found in 100 grams of apples (about one apple) is roughly equivalent to 1500 mg of vitamin C. However, the vitamin C concentration in apples is only 5.7 mg/100 g (Eberhardt et al., 2000).

4.Kiwi: *actinidia deliciosa*

Kiwifruit, formerly known as Chinese gooseberry, is a rich source of vitamin C, vitamin E, folate, potassium, and various phytochemicals, as well as enzymes, particularly actinidin (Richardson et al., 2018). Scientific research indicates that kiwifruit supplements can offer several health benefits, including enhancing immune, digestive, and cardiovascular function (Baranowska and Dominik, 2019). Kiwifruit has shown immune-boosting properties; its consumption has been associated with reduced severity and duration of cold and flu symptoms in both older adults and children (Skinner, 2012). Plasma vitamin C concentration was found to increase with decreased purine and pyrimidine oxidation after kiwifruit incorporation into the diet. Thus, the antioxidant property of kiwifruit does not depend solely on vitamin C; other components, such as carotenoids, tocopherols, and flavonoids, also contribute to this effect, albeit at relatively low concentrations (Collins et al., 2001).

Kiwifruit is a rich source of vitamin C, as consuming one medium-sized fruit meets the daily requirement of this vitamin. Vitamin C plays a role in removing free radicals (ROS), including superoxide (O2.-), water, and hydroxyl radicals (HO·), thereby helping prevent cellular damage and oxidative stress (Cundra et al., 2020). A nutritional analysis revealed that the concentrations of certain nutrients vary among different kiwi varieties. Green kiwifruit contains high levels of vitamin C, vitamin E, and folic acid, with levels of 92.7 mg, 1.46 mg, and 0.025 mg/100 g, respectively. In contrast, golden kiwifruit boasts even higher concentrations of these vitamins, with values of 161.3 mg, 1.51 mg, and 0.031 mg / 100 g, respectively (Richardson et al., 2018). Additionally, kiwifruit possesses distinct health benefits. One study referred that kiwifruit seed oil may help improve obesity-related conditions by raising adipokine levels (Qu et al., 2019).

5.Papaya: *Carica papaya*

Papaya is primarily grown in tropical regions and is clinically used to treat a variety of ailments, including inflammatory conditions (Pandey et al., 2016). Compared to other commercial fruits, papaya is a rich source of iron and calcium and contains the highest levels of vitamin C and vitamin A. These antioxidant nutrients play a vital role in enhancing the immune system (Santana et al., 2019). The antioxidant phytochemicals in papaya reduced the consumption of antioxidant enzymes. Its extract has also been found to increase the amount of immunoglobulin, ultimately enhancing humoral immunity (Sadek, 2012). Additionally, the carpaine and folate compounds in papaya help slow the heart rate and lower blood pressure.

A study by Abdullah et al. (2011) demonstrated that papaya enhances human immunity through its many bioactive compounds, including alkaloids, carotenoids, phenols, flavonoids, saponins, and tannins. Papaya has the potential to reduce serious inflammation and its associated side effects by regulating the levels of harmful agents. Additionally, the proteolytic enzymes present in papaya, such as papain and chymopapain, exhibit anti-inflammatory and immunomodulatory properties (Mohr and Desser, 2013).

6.Pineapple: ***Ananas comosus***

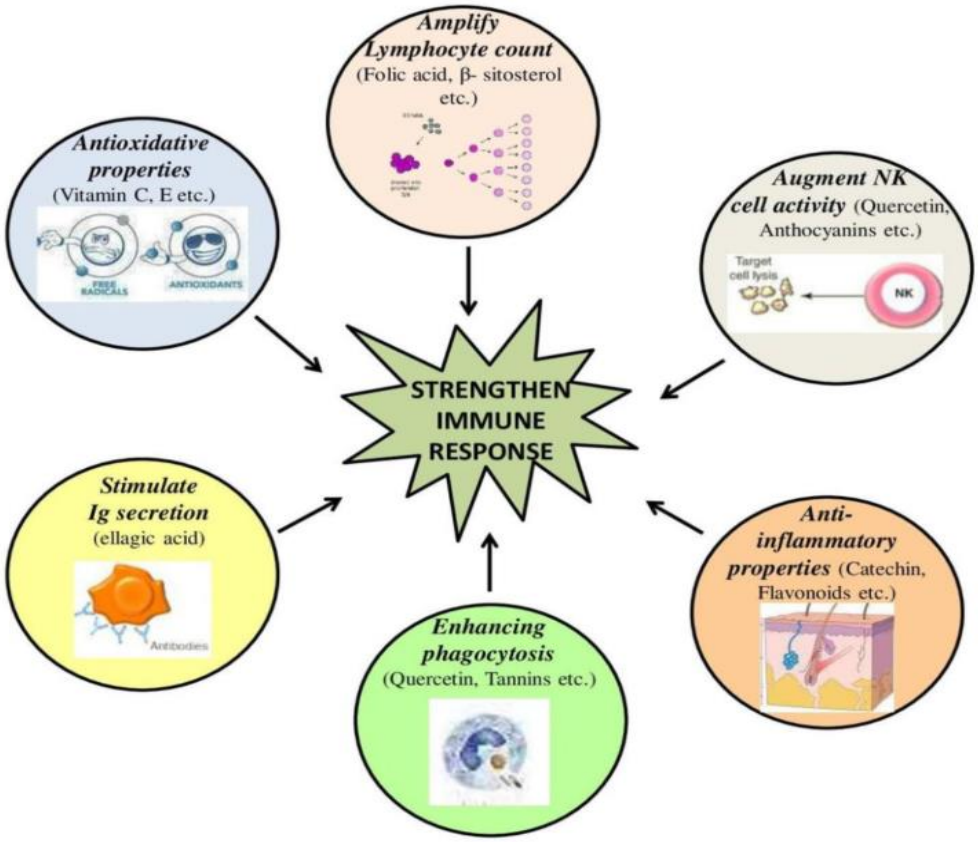
Pineapple is the third most important fruit in global production. It is a rich source of essential nutrients, providing the human body with valuable macronutrients and micronutrients, including calcium, carbohydrates, vitamins, minerals, fiber, enzymes, and bioactive compounds that aid digestion and promote overall health (Lalhruaitluangi and Mandal, 2022). Pineapple is often used as a nutritional supplement to support good health. One of its key components is the enzyme bromelain, which has been shown to possess anti-inflammatory, antibiotic, anticancer, and anticoagulant properties. Additionally, the antioxidants in pineapple help combat free radicals, reducing the risk of cancer and heart disease and lowering cholesterol levels (Hussein et al., 2015). Pineapple is rich in vitamin C, which plays a crucial role in supporting a strong immune system. Another important component found in pineapple is malic acid; this substance helps boost immunity and may also reduce the risk of toxic metal poisoning (Hendrickson, 2011). As one of the body's primary water-soluble antioxidants, vitamin C acts as a powerful defense against free radicals that can cause cell damage. Additionally, vitamin C is essential for the formation of collagen in bones, blood vessels, cartilage, and muscles, and it also enhances iron absorption. Furthermore, a higher intake of vitamin C has been associated with a reduced risk of certain cancers, including colon, esophageal, and stomach cancers (Debnath, 2012).

7.Aonla: ***Emblica officinalis***

Indian gooseberry, also known as Aonla, is abundant in various bio-active compounds that provide it with immunomodulatory, anti-tumor, antioxidant, and hepatoprotective properties. These compounds include flavonoid, polyphony, alkaloids, and flavonoids, all of which are linked to numerous health benefits. They can help improve memory and reduce the risk of chronic diseases such as heart disease, diabetes, and cancer (Gupta, 2017). Vitamin C, a key component of Aonla, acts as an excellent antioxidant by neutralizing harmful reactive oxygen species (ROS) generated in cells associated with the immune system (Venkatalakshmi et al., 2016). The Aonla fruit is not only highly nutritious but also has significant medicinal uses. It is renowned as the richest source of vitamin C; its juice contains approximately 20 times the amount found in orange juice (Singh, 2004).

Researchers have shown that vitamin C and several phytochemicals found in aonla fruit are effective antioxidants and provide immunomodulatory benefits (Hassan et al., 2016). According to Puranik et al. (2012), the vitamin C and total phenolic contents of aonla fruit are approximately 680 mg per 100 g and 24.5 g per 100 g, respectively. Aonla fruit demonstrates the capacity to enhance immunomodulatory activity; it stimulates the activity and efficiency of granulocytes and natural killer (NK) cells while promoting the production of various effective molecules secreted by activated cells. Additionally, various polyphenolic compounds in aonla, such as ellagic acid, corilagin, pyrogallol, shikimic acid, gallic acid, and quercetin, are associated with anticancer properties (Zhao et al., 2015;

Jyothi et al., 2013).



,.**Figure 2.** Immunomodulatory mechanisms of different fruit phytochemicals (Maheshwari et al (2022

Table 1. Main nutritional and functional components of fruits and their immune-boosting properties:

No.	Fruits		Nutrients	Mechanism	References
1.	Citrus fruits (Citrus spp.)	Lemons , Limes	Vitamin C, Folic Acid, Potassium, Pectin, Calcium, Magnesium, Oranges Fiber, Calcium, Magnesium, Potassium, Vitamin C	Anticancer and antioxidant, Helps the epithelial barrier function, and boost the development of lymphocytes and phagocytes	(Sissons, 2019) Boretti and Banik (2020)
		Oranges			
		Grapefruit	Fiber, Calcium, Magnesium, Potassium, Vitamin C		

2.	Berries:*(Morus alba)*	vitamin C, vitamin A, potassium, manganese, and fiber.polyphenol and flavonoids	Antioxidants,Reduces cell damage,Prevents body tissues from oxidative damage γδ T, anthocyanins, the main polyphenol compound found in blueberries, interact with cells	(Percival,2009; Lachowicz et al., 2017).
3.	Apples (Malus domestica)	Vitamin C, Epicatechin, Phloridzin, Chlorogenic acid, Quercetin glycosides, Rutin, Procyanidin B2, Catechin	Antioxidant, ROS scavenger, Protects cells from oxidative stress, improves quality of anti-inflammatory response, inhibits activity of human leukemic T-cells during G1, regulate aggregation of platelets, radical chelator of transition metal ions,	Boyer & Liu, 2004, Duda-Chodak et al., 2011,
4.	Kiwi (Actinidiaceae spp. L.)	Vitamin C, Vitamin E, Folate, β-Carotene, Lutein + zeaxanthin, γ-Tocophero, β-Cryptoxanthin**.**	Anti-inflammatory, Antioxidant, scavenger of free radicals and other reactive oxygen species, reduces oxidative stress,	Baranowska-Wójcik and Szwajgier (2019)
5.	Papaya (Carica papaya L.)	Vitamins A, B, And C, Carpaine, Folic Acid	Antioxidant, precursor of vitamin A, promotes lymphocyte and T-cell proliferation	(Aravind et al., 2013), Farhan Aslam et al. (2017)
6.	Pineapple: (*Ananas comosus*)	Vitamin C, Malic Acid, Bromelain	anti-inflammatory, reduces the risk of toxic, reducing swelling in inflammatory conditions	(Hendrickson, 2011). (Hossain et al., 2015)

7.	Aonla (Emblica officinalis)	Vitamin C, Gallic acid, Ellagic acid, Quercetin, Total phenolics, Total flavonoids.	Antioxidant, immunomodulatory properties, free radical scavenging property, Anticancer, anti-allergic, and anti-inflammatory activity, antimicrobial.	Hasan et al., 2016, Kumari et al., 2019

CONCLUSION

An optimal diet is crucial for achieving good health. It is essential to emphasize the consumption of foods rich in various compounds that help build and strengthen the immune system. Fruits are vital sources of antioxidants, vitamins, and minerals, making it important to consume them in adequate amounts for a balanced diet. The findings suggest that individuals who consume the recommended amount of fruit can improve their resilience to health challenges, as optimal immunity is a valuable strategy for preventing diseases. The fruits studied, along with their bioactive components, demonstrated a clear positive effect on the human immune response. Thus, any deficiency of fruit in the diet may lead to immunosuppression, making the body more vulnerable to disease.

RECOMMENDATIONS

Despite encouraging data highlighting the significant role of bioactive compounds in modulating the immune system, there remains a notable lack of research exploring the specific molecular mechanisms behind their biological activities. Therefore, further in vivo studies are urgently needed to enhance our understanding of how various phytochemicals function and their precise effects on immune function. Additionally, it is important to recognize that other food sources—such as vegetables, mushrooms, dairy products, meat, and eggs—can also boost the immune system, warranting further investigation.

REFERENCES

Abdullah, M., Chai, P. S., Loh, C. Y., Chong, M. Y., Quay, H. W., Vidyadaran, S., & Seow, H. F. (2011). *Carica papaya* increases regulatory T cells and reduces IFN-γ^+ $CD4^+$ T cells in healthy human subjects. *Molecular Nutrition & Food Research, 55*(5), 803–806.

Albers, R., Bourdet-Sicard, R., Braun, D., Calder, P. C., Herz, U., Lambert, C., Lenoir-Wijnkoop, I., Méheust, A., Ouwehand, A., Phothirath, P., Sako, T., Salminen, S., Siemensma, A., Van Loveren, H., & Sack, U. (2013). Monitoring immune modulation by nutrition in the general population: Identifying and substantiating effects on human health. *British Journal of Nutrition, 110*(Suppl. 2), S30–S45. https://doi.org/10.1017/S0007114513001505

Amao, I. (2018). Health benefits of fruits and vegetables: Review from sub-Saharan Africa. In *Vegetables – Importance of quality vegetables to human health*. InTech. https://doi.org/10.5772/intechopen.74472

Anurag, G. (2020). *Fruits that boost immune system*. Me N Mom Health.

Aravind, G., Bhowmik, D., Duraivel, S., & Harish, G. (2013). Traditional and medicinal uses of *Carica papaya*. *Journal of Medicinal Plants Studies, 1*(1), 7–15.

Baidya, B. K., & Sethy, P. (2020). Importance of fruits and vegetables in boosting our immune system amid the COVID-19. *Food Science Report, 1*, 50–55.

Baranowska, E., & Dominik, W. (2019). Characteristics and pro-health properties of mini kiwi (*Actinidia arguta*). *Horticulture, Environment, and Biotechnology, 60*(2), 217–225. https://doi.org/10.1007/s13580-018-0107-y

Baranowska-Wójcik, E., & Szwajgier, D. (2019). Characteristics and pro-health properties of mini kiwi (*Actinidia arguta*). *Horticulture, Environment, and Biotechnology, 60*(2), 217–225. https://doi.org/10.1007/s13580-018-0107-y

Boyer, J., & Liu, R. H. (2004). Apple phytochemicals and their health benefits. *Nutrition Journal, 3*, Article 5. https://doi.org/10.1186/1475-2891-3-5

Bubnov, R. V., Spivak, M. Y., Lazarenko, L. M., Bomba, A., & Boyko, N. V. (2015). Probiotics and immunity: Provisional role for personalized diets and disease prevention. *EPMA Journal, 6*(1), Article 14. https://doi.org/10.1186/s13167-015-0036-0

Collins, B. H., Horská, A., Hotten, P. M., Riddoch, C., & Collins, A. R. (2001). Kiwifruit protects against oxidative DNA damage in human cells and in vitro. *Nutrition and Cancer, 39*(1), 148–153. https://doi.org/10.1207/S15327914nc391_20

Cooper, E. L., & Ma, M. J. (2017). Understanding nutrition and immunity in disease management. *Journal of Traditional and Complementary Medicine, 7*(4), 386–391. https://doi.org/10.1016/j.jtcme.2016.12.002

Cundra, L. B., D'Souza, M. D. S. M., Parekh, P. J., & Johnson, D. A. (2020). The impact of kiwifruit on human health. *Gut and Gastroenterology, 3*, 001–010.

Debnath, P., Dey, P., Chanda, A., & Bhakta, T. (2012). A survey on pineapple and its medicinal value. *Scholars Academic Journal of Pharmacy, 1*(1).

del Río-Celestino, M., & Font, R. (2020). The health benefits of fruits and vegetables. *Foods, 9*(3), Article 369.

Ding, S., Jiang, H., & Fang, J. (2018). Regulation of immune function by polyphenols. *Journal of Immunology Research, 2018*, 1–8. https://doi.org/10.1155/2018/1264074

Duda-Chodak, A., Tarko, T., & Tuszyński, T. (2011). Antioxidant activity of apples: Impact of maturity stage and fruit part. *Acta Scientiarum Polonorum, Technologia Alimentaria, 10*(4),

443–454.

Eberhardt, M. V., Lee, C. Y., & Liu, R. H. (2000). Antioxidant activity of fresh apples. *Nature, 405*(6789), 903–904.

Farhan Aslam, M., Majeed, S., Aslam, S., & Irfan, J. A. (2017). Vitamins: Key role players in boosting immune response—A mini review. *Vitamins & Minerals, 6*(1), 1–8. https://doi.org/10.4172/2376-1318.1000153

Guimarães, R., Barros, L., Barreira, J. C. M., Sousa, M. J., Carvalho, A. M., & Ferreira, I. C. F. R. (2009). Targeting excessive free radicals with peels and juices of citrus fruits. *Food and Chemical Toxicology, 48*(1), 99–106.

Gupta, R. (2017). Amla: A novel ayurvedic herb with its health benefits. *International Journal of Advance Research and Engineering, 6*(9), 923–927.

Hasan, M., Islam, M., & Islam, M. (2016). Phytochemistry, pharmacological activities and traditional uses of *Emblica officinalis*: A review. *International Current Pharmaceutical Journal, 5*(2), 14–21. https://doi.org/10.3329/icpj.v5i2.26441

Hendrickson, K. (2011). *Citric acid in pineapple*. Healthfully.

Hossain, M. F., Akhtar, S., & Anwar, M. (2015). Nutritional value and medicinal benefits of pineapple. *International Journal of Nutrition and Food Sciences, 4*(1), 84–88. https://doi.org/10.11648/j.ijnfs.20150401.22

Hyson, D. A. (2011). A comprehensive review of apples and apple components and their relationship to human health. *Advances in Nutrition, 2*(5), 408–420.

Jayawardena, R., Sooriyaarachchi, P., & Chourdakis, M. (2020). Enhancing immunity in viral infections, with special emphasis on COVID-19: A review. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews, 14*(4), 367–382. https://doi.org/10.1016/j.dsx.2020.04.015

Richardson, D. P., Ansell, J., & Drummond, L. N. (2018). The nutritional and health attributes of kiwifruit: A review. *European Journal of Nutrition*. https://doi.org/10.1007/s00394-018-1627-z

Jiang, T. A. (2019). Health benefits of culinary herbs and spices. *Journal of AOAC*.

Jyothi, K. S., Rai, A., Rasmi, R. R., Somashekarappa, H. M., & Shenoy, K. B. (2013). Quantification of tannin content in *Phyllanthus emblica* using radiolabeled BSA by precipitation method.

Kozłowska, A., & Szostak-Węgierek, D. (2014). Flavonoids—Food sources and health benefits. *Roczniki Państwowego Zakładu Higieny, 65*(2), 79–85.

Kumari, P., Khatkar, B. S., & Duhan, A. (2019). Aonla phytochemicals: Extraction, identification and quantification. *Journal of Food Science and Technology, 56*(4), 2278–2286. https://doi.org/10.1007/s13197-019-03716-7

Lachowicz, S., Oszmiański, J., Seliga, Ł., & Pluta, S. (2017). Phytochemical composition and

antioxidant capacity of seven saskatoon berry (*Amelanchier alnifolia* Nutt.) genotypes grown in Poland. *Molecules, 22*(5), 853. https://doi.org/10.3390/molecules22050853

Lalhruaitluangi, N., & Mandal, D. (2022). Medicinal and nutritional characteristics of pineapple in human health: A review. *Journal of Postharvest Technology, 12*(2), 1–13. https://doi.org/10.48165/jpht.2024.12.2.01

Lamson, D. W., & Brignall, M. S. (2000). Antioxidants and cancer III: Quercetin. *Alternative Medicine Review, 5*(3), 196–209.

Łata, B., Trampczyńska, A., & Paczesna, J. (2009). Cultivar variation in apple peel and whole fruit phenolic composition. *Scientia Horticulturae, 121*(2), 176–181. https://doi.org/10.1016/j.scienta.2009.01.038

Ma, L., Sun, Z., Zeng, Y., Luo, M., & Yang, J. (2018). Molecular mechanism and health role of functional ingredients in blueberry for chronic disease in human beings. *International Journal of Molecular Sciences, 19*(9), 2785. https://doi.org/10.3390/ijms19092785

Maheshwari, S., Kumar, V., Bhadauria, G., & Mishra, A. (2022). Immunomodulatory potential of phytochemicals and other bioactive compounds of fruits: A review. *Food Frontiers, 3*, 221–238. https://doi.org/10.1002/fft2.129

Mazzoni, L., Ariza Fernández, M. T., & Capocasa, F. (2021). Potential health benefits of fruits and vegetables. *Applied Sciences, 11*(19), 8951.

McAnulty, L. S., McAnulty, S. R., Malone, N. M., Prigge, L. A., & Thompson, K. L. (2017). Bioactive properties and potential health benefits of blueberries and anthocyanins. *Medical Research Archives, 5*(2).

Mishra, S., & Patel, M. (2020). Role of nutrition on immune system during COVID-19 pandemic. *Journal of Food Nutrition and Health, 3*(2), 1–6.

Mohr, T., & Desser, L. (2013). Plant proteolytic enzyme papain abrogates angiogenic activation of human umbilical vein endothelial cells (HUVEC) in vitro. *BMC Complementary and Alternative Medicine, 13*(1), 231.

Natarajan, T. D., Ramasamy, J. R., & Palanisamy, K. (2019). Nutraceutical potentials of synergic foods: A systematic review. *Journal of Ethnic Foods, 6*(1), 1–7. https://doi.org/10.1186/s42779-019-0033-3

Pahwa, H., & Sharan, K. (2022). Food and nutrition as modifiers of the immune system: A mechanistic overview. *Trends in Food Science & Technology, 123*, 393–403. https://doi.org/10.1016/j.tifs.2022.03.017

Pandey, S., Cabot, P. J., Shaw, P. N., & Hewavitharana, A. K. (2016). Anti-inflammatory and immunomodulatory properties of *Carica papaya*. *Journal of Immunotoxicology, 13*(4), 590–602. https://doi.org/10.3109/1547691X.2016.1149528

Pangrazzi, L. (2019). Boosting the immune system with antioxidants: Where are we now? *Immunology*, 42–44. https://doi.org/10.1042/BIO04101042

Percival, S. S. (2009). Grape consumption supports immunity in animals and humans. *The Journal of Nutrition, 139*(9), 1801S–1805S. https://doi.org/10.3945/jn.109.108324

Percival, S. S. (2011). Nutrition and immunity: Balancing diet and immune function. *Nutrition Today, 46*(1), 12–17. https://doi.org/10.1097/NT.0B013E3182076FC8

Puranik, V., Mishra, V., Yadav, N., & Rai, G. K. (2012). Bioactive components retention in processed Indian gooseberry products. *Journal of Food Processing and Technology, 3*(12), 194.

Qu, L., Liu, Q., Zhang, Q., Tuo, X., Fan, D., Deng, J., & Yang, H. (2019). Kiwifruit seed oil prevents obesity by regulating inflammation, thermogenesis, and gut microbiota in high-fat diet-induced obese C57BL/6 mice. *Food and Chemical Toxicology, 125*, 85–94.

Sahu, R., Pandey, A., Tiwari, M., Mishra, N., & Varshney, A. (2022). Effects of citrus fruit and their bioactive components on immunity. *World Journal of Pharmaceutical Sciences, 10*(4), 32–37. https://doi.org/10.54037/WJPS.2022.100404

Sadek, M. K. (2012). Antioxidant and immunostimulant effect of *Carica papaya* Linn. aqueous extract in acrylamide intoxicated rats. *Acta Informatica Medica, 20*(3), 180–185. https://doi.org/10.5455/aim.2012.20.180-185

Santana, L. F., Inada, A. C., do Espírito Santo, B. L. S., Filiú, W. F. O., Pott, A., Alves, F. M., de Guimarães, R. C. A., de Freitas, K. C., & Hiane, P. A. (2019). Nutraceutical potential of *Carica papaya* in metabolic syndrome. *Nutrients, 11*(7), 1608. https://doi.org/10.3390/nu11071608

Shubham, K., Anukiruthika, T., Dutta, S., Kashyap, A. V., Moses, J. A., & Anandharamakrishnan, C. (2020). Iron deficiency anemia: A comprehensive review on iron absorption, bioavailability and emerging food fortification approaches. *Trends in Food Science & Technology, 99*, 58–75. https://doi.org/10.1016/j.tifs.2020.02.021

Singh, V., & Singh, P. (2004). A review on physico-chemical characteristics of aonla (*Emblica officinalis* Gaertn.) cultivars. *Journal of Eco Physiology, 7*, 73–76.

Singh, M. R., Yadav, K., Chaurasiya, N. D., & Singh, D. (2022). Plants and phytomolecules for immunomodulation. In N. S. Sangwan, M. A. Farag, & L. V. Modolo (Eds.), *Plants and phytomolecules for immunomodulation* (pp. 1–31). Springer. https://doi.org/10.1007/978-981-16-8117-2_1

Skinner, M. A. (2012). Wellness foods based on the health benefits of fruit: Gold kiwifruit for immune support and reducing symptoms of colds and influenza. *Journal of Food and Drug Analysis, 20*(1), 261–264.

Slavin, J. L., & Lloyd, B. (2012). Health benefits of fruits and vegetables. *Advances in Nutrition,*

3(4), 506–516.

Stephen, J., Manoharan, D., & Radhakrishnan, M. (2023). Immune boosting functional components of natural foods and its health benefits. *Food Production, Processing and Nutrition, 5*(1), 61.

Venkatalakshmi, P., Vadivel, V., & Brindha, P. (2016). Role of phytochemicals as immunomodulatory agents: A review. *International Journal of Green Pharmacy, 10*(1), 1–18. https://doi.org/10.22377/ijgp.v10i1.600

Vishwakarma, S., Panigrahi, C., Barua, S., Sahoo, M., & Mandliya, S. (2022). Food nutrients as inherent sources of immunomodulation during COVID-19 pandemic. *LWT – Food Science and Technology, 158*, 113154. https://doi.org/10.1016/j.lwt.2022.113154

Zhao, T., Sun, Q., Marques, M., & Witcher, M. (2015). Anticancer properties of *Phyllanthus emblica* (Indian gooseberry). *Oxidative Medicine and Cellular Longevity, 2015*, 950890.