Millets (pearl and finger) as nutritional interventions for COVID 19 with focus on Zimbabwe: mini review

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Abstract: Though COVID 19 vaccines have proved to work effectively against SARS-CoV-2, nutritional interventions are central in boosting the immune system and reduce SARS-CoV-2 effects. The review aims at exploring the link between millets bioactive compounds (nutritional and phytochemical composition) and human immune system, as well as COVID-19 prevention and treatment. This mini review is based on the literature survey in these data sources: web of science, Scopus, Google scholar, PubMed, and ResearchGate. Based on the nutritional value and their importance in nutritional security, increased consumption of millets can be beneficial in preventing SARS-CoV-2 infection and COVID-19 establishment. Small grains (pearl and finger millets) contain abundance of bioactive compounds such as carotenoids, phenols, proteins, vitamin E, and tannins with antioxidant properties. Results from the review indicated that finger millet-derived foods contain substantially higher content of micronutrients when compared with other cereals including wheat. Pearl millet another important Zimbabwean millet has a significantly high content of dietary fibres, starch, micronutrients, as well as antioxidants. Moreover, many of the millet-derived antioxidants, such as quercetin, and ellagic acid are known to mop up any foreign agents and toxins. This review addressed the link...
between millets (nutrients and bioactive compounds) and immune system as well as COVID-19 prevention and treatment. However, there is inconclusive data to explain the contributions of millets in COVID-19 prevention and treatment, and this calls for more randomized and controlled clinical trials to ratify their significance in infectious disease prevention and treatment.

**Keywords:** Anti-oxidant; bio-fortification; COVID-19; small grains; micronutrient; phytochemical; macronutrients

### 1. Introduction

COVID-19 is as a result of SARS-CoV-2 infection and has grown into a key public health problem. SARS-CoV-2 is among the pathogens that target the human respiratory system (Naja & Hamadeh, 2020). Moreover, SARS-CoV-2 binds to angiotensin-converting enzyme 2 receptors, resulting in the production of inflammatory reactions, according to molecular research (De Morais, 2021). COVID-19 symptoms include fever, lethargy, dry cough, anosmia, pneumonia with dyspnea, muscle and joint pain, headache, diarrhoea, and nausea (Arshad et al., 2020; Laviano et al., 2020). Severe pneumonia is one of these symptoms that has been linked to COVID-19-related mortality (Arshad et al., 2020).

*Eleusine coracana* is classified in Poaceae family, which originated in Ethiopia (Pradeep & Sreerama, 2015). According to the literature, finger millet (FM) is an annual grass that may grow up to 170 cm tall (FAO, 2018). FM is also known as *Zviya*, *Poka*, *Mazhovole*, *Rapoho*, *Ruwzea*, *Njera*, and *Uphoko* in Zimbabwe (Singh & Raghuvsansi, 2012). Pearl millet (PM) (*Pennisetum glaucum*) known as *mhunga* in Zimbabwe is an important cereal which is ranked number 6 after other cereals including sorghum and barley, with 31 million ha under cultivation (ICRISAT, 2020). PM is the most extensively produced millet grain in Africa, accounting for around 10% of total cereal production (Ramashia et al., 2019). There are several different cultivars of millets characterised by brown, light brown, and white seed colours (Kumar et al., 2016).

Millets are highly nutritious and climate resilient, thereby adaptable to diverse environmental stresses. Accordingly, PM contributes significantly to food security in many countries of the world including Zimbabwe (Vadez et al., 2012). Millets have been identified as important sources of protein, energy, micronutrients, fatty acids and several amino acids (threonine and lysine excluded; Khairwal et al., 2007). Apart from being used as tools in climate change adaptation and indicators of climate change resilience, millets are known to possess nutritional and phytochemical properties, which impact positively on human health (Rurinda et al., 2014). The phytochemicals in millets include carotenoids, phenols, and tannins which have high antioxidant activities. Antioxidant potential of millets is critical in reducing oxidative damage, hence impacting on oxidative stress within the body (Liang and Liang, 2019). Majority of the COVID-19 symptoms which include bronchitis, pneumonia, pulmonary inflammation, fever and fibrosis are mediated by cytokine pro-inflammatory, and therefore, these phytochemicals prevent these symptoms. Recently, there has been an increases focus on millet production as a result of the existing problems associated with sustainable crop production, climate variability, droughts, and rapid population growth (Hassan et al., 2021). However, more studies and clinical trials are required to validate the exploitation of millets as nutritional interventions in COVID-19 prevention and treatment, given the inconclusive data on this subject matter. The findings of such investigations would have a significant impact on the potential of millet-based nutritional interventions in the fight against COVID-19 and other infectious diseases. This review therefore aims at exploring the possibility of millets as nutritional interventions for COVID 19 and other infectious disease prevention and treatment.
2. Nutritional value of FM and PM

The inclusion and large-scale utilization of pearl and finger millets in the production of functional foods is based on their substantial and diverse nutrients (Ahmed et al., 2013). Due to their high quantities of calories, lipids, zinc (Zn), iron (Fe), calcium (Ca), and proteins of high quality, millets considerably contribute to the diets of humans. Additionally, they are substantial sources of phytochemicals, vitamins, and dietary fiber (Hassan et al., 2021). As indicated by their substantially high nutritive value, finger and pearl millet have been identified as important components of multigrain foods and gluten-free cereal products (Kumar et al., 2018). The nutrient content of FM and PM grains (Table 1) show that these millets are important sources of energy, macronutrients, and micronutrients. Among other millets, PM has a significantly high content of dietary fibers, phytochemicals, resistant starch, and minerals (Ahmed et al., 2013). According to mineral and nutrient analysis, PM was found contain approximately starch (63.2%), fiber (2.8%), protein (13.6%), and fat (7.8%) (Ali et al., 2003). On the other hand, FM grains normally contain minerals (2.7%), dietary fiber (18%–20%), protein (9.8%), fat (1%–1.7%), starch (65%–75%), and carbohydrate (81.5%) (Ahmed et al., 2013). In addition to proximate compositions, finger millet grains are rich in micronutrients including vitamin B (1.71 mg), calcium (344 mg/100 g), and iron (3.9 mg). Millets, apart from being drought resistant, are special crops as they are rich in important nutrients including protein, calcium, and critical components such as polyphenols and dietary fiber (Table 1).

2.1. Carbohydrates

The finger and pearl millet grains normally contain up to 65% carbohydrate, with a considerably high percentage of non-starchy polysaccharides and dietary fibre (Ahmed et al., 2013). Notably, the carbohydrate levels of millets vary due to content of amylose and amylpectin, which ranges from 16% to 28% and 72% to 84%, respectively (Rao et al., 2017). Carbohydrate concentration in FM and PM ranges from approximately 56.88 to 72.97 g/100 g (Ahmed et al., 2013). Of critical importance is the presence of relatively high amounts of non-starchy polysaccharides in finger millet grains, which provides both nutritional as well as functional benefits (Ramashia et al., 2019). FM and PM are important sources of dietary and crude fibre (Rao et al., 2017; Kumar et al., 2018). Dietary fibre exists in millets in several forms including cellulose, lignin, and pectin (Prashantha & Muralikrishna, 2014). PM has a significant potential as a source of food for humans since it is gluten-free and contain more nutritional fiber than other cereals such as rice.

2.2. Lipids

PM and FM lipid content is approximately between 1.43 and 6 g/100 g. However, when compared with all millets, FM has the lowest lipid content, while the highest was recorded for PM (Kumar et al., 2018; Singh & Raghuvanshi, 2012). In addition, FM have significant concentrations of fatty acids including palmitic and linolenic acids. Moreover, FM grains have significantly lower fat content of approximately 1%–2% in relation to other millets (Ramashia et al., 2019). The fat content of PM is approximately 5% to 7%, compared to 3.21% to 7.7% in corn (Ikram et al., 2010). Furthermore, it was reported that the approximate proportion of FM and PM lipid is 1% and 5%, respectively. PM primarily has a high proportion of fatty acids including stearic, linoleic acids, and palmitic, whereas Zea mays is associated with low levels of fatty acid and oleic acid (Adeola and Orban, 1995). PM grain has a greater concentration than all other millets and has available and restricted lipid concentrations in the range 5.6%–6.1% and 0.6%–0.9%, respectively. According to Hoseney (1994), PM lipids have been classified into three classes and exist as free or bound components: (1) monoglycerides, (2) diglycerides, and (3) triglycerides. Of the 5.2% overall lipid content in FM, only 2.2% is free, the rest is either bound (2.4 percent) or structural (0.6%) (Kunyang et al., 2013). Most of the fatty acids in FM are unsaturated (up to 74.4%), and the saturated ones only contribute approximately 25.6%. There are three predominant fatty acids found in FM, and these are palmitic, linoleic, and oleic acids (Hassan et al., 2021). The grains of PM have almost the same quantity of lipid as other cereals including maize.
### Table 1. Summary of nutritional composition of millets and the role of nutrients in COVID-19 prevention and treatment

| Nutrient category | Nutrient/mineral | Content | Important function in the body | Roles on immune system/ treatment/prevention of COVID-19 | References |
|-------------------|------------------|---------|--------------------------------|------------------------------------------------------|------------|
|                   |                  | Finger millet |                  |                                                      |            |
|                   |                  | Pearl millet |                  |                                                      |            |
|                   | Proximate (g/100 g) |                  |                  |                                                      |            |
| Protein           |                  | 7.7      | 11.6 -11.8        | • Growth, repair of worn-out tissues, production of enzymes, hormones and antibodies. |            |
|                   |                  |          |                  | • Key in immune system modulation, antibody and enzyme production thereby preventing infection e.g. SARS-CoV-2 infection. | Kumar et al., 2018 Naja and Hamadeh, 2020. Junaid et al., 2020. |
| Fat/ lipids       |                  | 1.8      | 4.5 - 5.0         | • Provision of energy, energy store, cushioning of delicate organs, Polyunsaturated fats lower blood cholesterol level. | Ahmed et al., 2013. Sarita and Singh, 2016. Rao et al., 2017. Ramashia et al., 2019. Farag et al., 2020. |
| Carbohydrates | 75.0 - 83.3 | 67 - 67.5 | • Soluble polysaccharides (SP) provide energy  
• slowly digestible starch, resistant starch and Complex unavailable polysaccharides are critical in preventing and managing diabetes and hyperlipidemia  
• Important energy sources that support the immune system  
• highly critical in immunity as they prevention decrease of number of cells conjoint to apoptosis.  
• Some reduces underlying conditions e.g. diabetes which increase the severity COVID-19 |
| --- | --- | --- | Ahmed et al., 2013. Dayakar et al., 2017. Rao et al., 2017. Ramashia et al., 2019. de Morais, 2020. |
| Dietary fiber | 15 - 22.0 | 11.3 | • Reduced risk of inflammatory bowel disease, constipation and bloating.  
• Reduces underlying conditions e.g. diabetes which increase the severity COVID-19 |
| Phenolic compounds and polyphenols | Ferulic and Phytic acid | - | - | • Have key function in decreasing body cholesterol.  
• Restricts damage of tissues and promotes tissue regeneration.  
• Reduces underlying conditions e.g. diabetes which increase the severity COVID-19 |
| Sarita and Singh, 2016  
Chandra et al., 2018 |
Table 1. (Continued)

| Micronutrients | Minerals | (mg/100 g) | Benefits |
|----------------|----------|------------|----------|
| Tannins, phytates, and phenol | - | - |  ● Essential in treating metabolic problems and degeneration.  
  ● Enzyme inhibition e.g. α-amylase thereby lowering Hyperglycemia after eating  
  ● Prevents incidences of cardiovascular diseases and tumor development, reduces chances of diabetes and hypertension  
  ● Reduces underlying conditions e.g. diabetes which increase the severity COVID-19 |
| Zinc | 2.3 | 3.1 |  ● Promotes the proliferation of immune cells, prevents respiratory infections.  
  ● Acts as an antioxidant thereby protecting the body against bacterial and viral infections.  
  ● Critical in the adaptive and innate immune cells pathway modulation.  
  ● Reduces RNA virus multiplication e.g., SARS-CoV-2.  
  ● Inactivates ACE2 receptors responsible for SARS-CoV-2 entry into host cells. |

Siwele et al., 2007  
Thilagavathi et al., 2015  
Kumari et al., 2017  
Ali et al., 2003.  
Oliveira et al., 2018.  
Nairz et al., 2018.  
Read et al., 2019
| Element | Value |  |  |  |  |
|---------|-------|---|---|---|---|
| Iron    | 3.3-14.89 | 8.0 | • Important in enhancing the immune system, reducing chances of anaemia and recurring acute respiratory tract infections.  
• Inhibits progressive inflammation and prolonged hospital stay | • Contribute critically to immune development and upregulation of the immune response.  
• Mediates in generation of hydroxyl radicals, which are central in stimulating the differentiation of T lymphocytes involved in elimination of viruses and bacteria | Ganz and Nemeth, 2015.  
Maywald et al, 2017.  
Mishra and Patel, 2020.  
Aman and Masood, 2020.  
Calder, 2020 |
| Magnesium | 78-201 | 137 | • Blood pressure reduction, reduced asthma incidences and the chances of heart attack. | • Involved in the development of immune responses against viral infections  
• Involved in production of antibodies, CD8+ and CD4+ adherence. | Makuvara, Cogent Food & Agriculture (2022), 8: 2111060.  
https://doi.org/10.1080/23311932.2022.2111060 |
| Vitamins       | mg/100g |  |
|----------------|---------|-----------------|
| **A (Retinol)** | 6.0     | -               |
| -              |         | • Significant for epithelial cell integrity and maintains healthy stomach, intestines and respiratory system. |
| -              |         | • Anti-inflammatory and improves differentiation of T helper 2 and immune responses. |
| -              |         | • Promotes interleukins 4 production (which decreases vulnerability of cells to SARS-COV-2 and down-regulates angiotensin-converting enzyme). |
| -              |         | • Significant for immune capacity of the mucosa hence reduces viral infection. |
| **Vit B1(Thiamine)** | 0.2- 0.48 | - |
| -              |         | • Plays a central role in muscle contraction, conduction of nerve signals and keeping nervous system, digestive system and skin healthy |
| -              |         | • Involved in the production of antibodies and in cellular immune defense |
| -              |         | • It is critical in cell metabolism and in the maintenance of immune homeostasis |
| **Niacin**     | 1.0-1.30 | -               |
| -              |         | -               |
|                |         | Brown and Noell, 2015 |
|                |         | Hemilä, 2017 |
|                |         | Carr, 2017 |
|                |         | Erkelsens and Mebius, 2017 |
|                |         | Aman and Masood, 2020 |
|                |         | Mishra and Patel, 2020 |
|                |         | Arshad, 2020 |
|                |         | Calder, 2020 |
|                |         | Oliveira et al., 2018 |
| Vitamin C | ≤1.0 | - | • Required in the formation proteins used to make skin, tendons, ligaments, and blood vessels
• Has an antioxidant activity hence prevent cancer, heart disease, and conditions including arthritis.
• It activates cellular function of innate and adaptive immune system.
• It is critical in antibodies, lymphocytes, and macrophages function.
• Stimulates of signalling molecules and interferon release, hence providing defense against viruses.
• Is a weak anti-histamine which provides relief from flu-like symptoms. |
2.3. Proteins
The protein composition of PM approximately ranges between 10% and 11%, whereas FM protein content was reported to be between 4.76 and 11.70 g/100 g (Kumar et al., 2018). Millet proteins have been identified as important and rich sources of amino acids (essential) and phytochemicals (Ahmed et al., 2013). Quite a number of these amino acids are present in FM grains constituting 0.45 of all the diet-derived amino acids (Kumar et al., 2018; Ramashia et al., 2019). Diet-derived amino acids in FM include methionine, cysteine and tryptophan, lysine, isoleucine, leucine, phenylalanine, and threonine (Ramashia et al., 2019; Sood et al., 2017). FM protein is preferable considering that it is associated with three critical essential amino acids: threonine, valine, and lysine (Ravindran, 1991). PM grain protein content was shown to be greater than that of maize, and this may promote PM diet formulations without protein augmentation, thereby lowering food costs (Hassan et al., 2021). Moreover, Adeola and Orban, (1995) discovered that PM proteins have higher percentage of amino acids including threonine, lysine, cysteine, and methionine when compared with proteins of other cereals such as corn and sorghum. Similarly, digestibility of the amino acids arginine, isoleucine, valine, and threonine were shown to be higher in PM than in cereals such as maize. However, the distribution of proteins in PM was found to be almost the same as that of maize (Hassan et al., 2021). Though PM is adapted to dry environments, the amino acid profiles of its proteins are almost the same as that of other cereals such as rice, barley, and wheat (Hoseney, 1994). Generally, PM has more critical amino acids like lysine, isoleucine, and leucine than conventional cereals like wheat (ICRISAT, 2020).

2.4. Micronutrient
Finger and pearl millets contain considerable levels of micronutrients, which are only needed in small quantities. The mineral content in finger and pearl millets ranges between 1.7 and 4.3 g/100 g as reported by Kumar et al. (2018). Both finger and pearl millets contain substantial levels of zinc (Kumar et al., 2018). FM grain is an important source of critical minerals including Fe, Ca, and P (Ramashia et al., 2019). Additionally, FM is considered to have highest calcium composition of about 34.4 mg/10 g among the millets (Rao et al., 2017). Phosphorus (P) levels in finger millet grain is quite considerable with a concentration of about 130.0–283.0 mg/g. Apart from phosphorus and calcium, finger millet grains contain other equally essential minerals including iron with a content of around 4%–21% and magnesium (Ramashia et al., 2019). On the other hand, PM is an important iron source (Kumar et al., 2018). FM contains important micronutrients such as vitamins that are fat and water-soluble (Ramashia et al., 2019). In addition to this, all finger and pearl millets contain substantial levels of β-carotene as well as B-vitamin complex (Kumar et al., 2018, Rao et al., 2017).
3. Phenolic compounds

Millets are excellent sources of phytochemicals such as pinacosanols, tannins, anthocyanins, and phenolic acids (Chandrasekara & Shahidi, 2010; Kumar et al., 2018). Of all these, phenolic compounds contribute the highest percentage in millets (Rao et al., 2017, Kumar et al., 2018). Moreover, millet kernels have phytochemicals (Figure 1) such as polyphenols, which varies between 0.2% and 0.3% (Shashi et al., 2007, Rao et al., 2017, Rathore et al., 2019). The antioxidant activity of millets is attributed to the presence of high polyphenol and tannin content (Rao et al., 2017, Rathore et al., 2019). It has been observed that the phenol-rich FM seed coat has antibacterial activity against bacterial species such as Bacillus cereus (Viswanath et al., 2009). Polyphenols have been demonstrated to inhibit some enzymes, such as pancreatic amylose and glucosidase, hence lowering hyperglycemia. Similarly, it has been shown that phenols generated from PM, such as p-coumaric and ferulic acids, greatly reduce tumor cells (Chandrasekara & Shahidi, 2011). Millet-derived phenols, according to Devi et al. (2014), offer various beneficial properties, including anti-oxidative capacities, antimicrobial activities, antiviral properties, anti-inflammatory effects, and celiac disease preventive capabilities. Normally, the quantity of free phenolic acids in millet grains is around 40%, and the remainder is immobilized (Hassan et al., 2020). The most prevalent group of millet-derived polyphenolic compounds in millets is hydroxycinnamic acids (Liang and Liang, 2019). In this group of phenols, the common antioxidant compound is ferulic acid. Besides ferulic acid, ferulate dimers identified from millets exhibit strong antioxidant potential (Liang and Liang, 2019). Notably, ferulic acids from millets and other cerea acids have higher antioxidant capacity in bound state (Călinoiu & Vodnar, 2018). Additionally, millet grains also contain a variety of flavonoids, including flavanols, anthocynidins, chalcones, flavones, and aminophenolics (Liang and Liang, 2019). Furthermore, millet grains of different cultivars are thought to contain condensed tannins (proanthocyanidins; Saleh et al., 2013).

Millet grains are enriched with polyphenols and phenols, which have been linked to improved health. According to Hassan et al. (2020), there are eight phenolic compounds found in millet cultivars grown in Zimbabwe. The phenols found in Zimbabwean and South African millets include benzoic acid derivatives, which include p-hydroxybenzoic acids. Apart from benzoic acid derivatives, flavonoids such as catechin and procyanidin B2 were discovered in Zimbabwean millets. Catechin is the most abundant phenolic compound in pearl millet, preceded by epicatechin. Catechin mean values varied between 2.50 and 12.6 mg/kg in pearl millet.
and 610.4 to 675.1 mg/kg in finger millet, while the epi-catechin mean values for pearl and finger millet varied from 1.2 to 1.8 and 99.1 to 139.5 mg/kg, respectively (Hassan et al., 2020). Procyanidins B1 and B2, protocatechuic (20.9, 23.7 mg/kg), and p-hydroxybenzoic (16.8, 13.5 mg/kg) acids were found solely in finger millet cultivars. Kaempferol glycoside (213.6 mg/kg), on the other hand, was exclusively found in pearl millets (Hassan et al., 2020). FM contains phytate, trypsin inhibitors, flavonoids, and phytic acid, which reduce bioavailability of minerals (Devi et al., 2014). The findings of this study support the idea that millets may be used as a source of useful phenolic compounds. However, polyphenols and tannins reduce nutrient digestibility and mineral absorption, thereby regulating these processes (Ramashia et al., 2019; Shashi et al., 2007).

4. Anti-nutrients, effects of anti-nutrients on nutrient availability and need for processing

Although finger and pearl millets are nutritious, they contain significant concentrations of anti-nutrients, which interfere with nutrient bio-accessibility of nutrients (Kumar et al., 2018; Palanisamy et al., 2012). Generally, the existence of millets anti-nutrients has been implicated for ingested mineral adsorption in the digestive tract. Polyphenols, saponins (0.36%), phytate (0.48%), tannins (0.04–3.47%), oxalate (0.27%), cyanide (0.17%), and phytate (0.48%) are anti-nutrients found in pearl and finger millet (Rathore et al., 2019). The presence of these anti-nutrients has resulted in the development of a myriad of millet processing and preparation techniques that can enhance the nutrient bioavailability in millet-derived foods (Ahmed et al., 2013; Kumar et al., 2018; Pradeep & Sreerama, 2015). Processing methods that are exploited in order to increase the physicochemical accessibility of micronutrients in millets include roasting, soaking, fermentation, malting, and mechanical processing (Ahmed et al., 2013; Kumar et al., 2018). Apart from increasing nutrient bioavailability of finger and pearl millets, processing increases shelf life of finger and pearl millet-derived foodstuffs through the reduction of anti-nutritional features (Rathore et al., 2019).

5. Health benefits of FM and PM

Millets provide a wide range of health advantages in addition to their nutritional value (Table 1), and these include prevention of cardiovascular diseases, blood pressure lowering, reduction of cholesterol, as well as fat absorption (Mathanghi & Sudha, 2012; Ramashia et al., 2019). Based on their high concentration of bioactive compounds such as polyphenols, finger and pearl millets are important in lowering fat absorption rate and slowing down the release of sugars (Saleh et al., 2013). These two features are linked to reduced incidences of (1) high blood pressure, (2) diabetes, and (3) heart disease (Figure 2; Ahmed et al., 2013; Saleh et al., 2013). Generally, millets contribute positively to human health through promoting the growth and repair of bodily tissue, improving digestive system, detoxifying the body, increasing immunity in respiratory health, increasing energy levels, and protecting against degenerative diseases (Rao et al., 2017). Based on the absence of gluten, millets are suitable for celiac disease patients (Rao et al., 2017, Sarita and Singh, 2016). Many of the millet-derived antioxidants such as catechins, quercetin, and ellagic acid are known to mop-up heavy metals and other toxins in the body (Rao et al., 2017).

6. Zimbabwean foods derived from millets and their uptake

In Zimbabwe, millets have been used to make porridge, sadza, alcoholic and non-alcoholic drinks. One of the most popular beverage prepared from millets in Zimbabwe is Masvusvu (sweet traditional beverage prepared from malted FM). The fermentation of sieved Masvusvu produces Mangisi (sweet-sour beverage). Although millets have been used in food preparation in Zimbabwe, customers are reluctant to use millet as a fundamental food sources, according to Phiri et al. (2019). They linked this to the millet’s color, flavor, and taste. Apart from this, typical habits and lifestyles of particular households in Zimbabwe has limited uptake of millets as primary sources of food. As a result, farmers are less eager to create additional millet goods, and the grain is now mostly grown and utilized to prepare classic beer brands like Chibuku (Phiri et al., 2019).
7. Immune system, nutrition and COVID-19

Human infection by viruses stimulates the immune system and an immune response is generated. Immune responses against viruses are essential in the eradication of viruses e.g., SARS-CoV-2 and prevent progression of viral-related infection (Wang et al., 2020). However, a weak immune system enhances SARS-CoV-2 propagation and tissue damage in specific organs, which possess ACE2 receptors (Calder et al., 2020). Invasion of host cells by the viruses is initiated through interaction between the receptor-binding domain and ACE2 receptors of host cells. Normally, antigen-presenting cells, macrophages included, are critical in viral multiplication prevention as they are central to T cells differentiation and activation (Calder et al., 2020; Wang et al., 2020). Equally important are mast cells, which are activated by viral infection and contribute to the intensification of immune responses against viruses. Moreover, CD8+ and CD4+ are central in the prevention of further SARS-CoV-2 host cell infection. CD4+ and CD8+ activate B lymphocytes to swiftly produce SARS-CoV-2-specific antibodies and directly kill SARS-CoV-2-infected cells. In a way to reduce infection, CD4+ additionally release chemical signals which stimulate monocytes and neutrophils to rush to the infected site (Junaid et al., 2020). However, release in large quantities of chemical signals (cytokines) is linked to acute respiratory distress syndrome and abnormally high COVID-19 fatality rate (Junaid et al., 2020).

An individual’s nutritional status is considered as the basis of a strong immune system and an indicator of resilience against infection (Naja & Hamadeh, 2020). Existing evidence has highlighted the correlation between diet and immune system or disease susceptibility (Naja & Hamadeh, 2020). Protein-energy malnutrition has been implicated in alteration of immune system and immune responses thereby increasing the risk of infection (Farag et al., 2020). Enough nutrients are required for a healthy immune system (Carr and Maggin., 2017; de Morais, 2020). Dietary nutrients directly contribute to the immune system through immune cell activation, regulating signalling molecule synthesis and gene expression (Table 1; Farag et al., 2020). Apart from prevention of COVID-19, micronutrients from millets have been identified as COVID-19 treatment options. For example, vitamin B complex has been identified as an anti-inflammatory agent (Erkelens & Mebius, 2017) and Read et al. (2019) reported that zinc is an inhibitor of RNA polymerase, an enzyme required in SARS-CoV-2 replication. Both macronutrients and micronutrients from millets generally lower probability of COVID-19 progression and improve covid-19 recovery.

7.1. Millets (FM and PM), underlying conditions, and COVID-19

Millet’s dietary fiber has been linked to improved digestive health, cholesterol reduction, cardiovascular disease prevention, diabetes prevention, cancer risk reduction, and an increase in energy levels (Amadou et al., 2013). In general, dietary fiber promotes bowel movement and, due to its slow digestion, prolongs transit time, reducing blood glucose levels, which is beneficial to type II diabetics (Hassan et al., 2021). Shobana et al. (2009) reported a lower diabetes incidence in people who eat millet-based diets. Furthermore, millet fiber suppresses bile acid production, thereby preventing the formation of gallstones in the body (Hassan et al., 2021). Millets were found to be rich in phenolic acids, both free and bound. Millets’ predicted glycemic index (GI) ranged from 42.7 to 58.3, making them ideal low GI dietary alternatives for diabetics (Bora et al., 2019). The effectiveness of millet-derived functional foods in lowering the severity of underlying conditions that increase COVID-19 occurrences, such as cardiovascular disease, obesity, diabetes, and hyperlipidemia, is crucial in preventing COVID-19 and other infectious diseases (Figure 2).

8. Conclusion

While research and nutritional therapies for COVID-19 and other infectious diseases are underway, nutritional interventions based on millets should be included in COVID-19 and other infectious disease prevention and treatment. This is anchored on presence of essential immune system boosters and antimicrobial micronutrients, macronutrients and secondary metabolites in millets. Millets contribute significantly to immune system enhancement and COVID-19 resistance. Nutrients derived from millets have a wide range of health benefits, including high antioxidant
activity, anti-inflammatory activity, anti-diabetes, obesity, and cardiorespiratory disease prevention. Furthermore, millets have an important role in immune system regulation, immunoglobulin production, and viral infection prevention. Millet-derived nutrients promote the development of T-lymphocytes and other immune system cells, resulting in the elimination of viruses and microorganisms. Several studies reported that millets’ nutrients and phytochemicals reduce the occurrence of underlying illnesses such as cardiovascular disease, obesity, diabetes, and hyperlipidaemia. Consequently, this has a direct impact on COVID-19 and other infectious diseases prevention and treatment. As a result, it is argued that including millets in daily diets will strengthen immune systems, minimize infections, and lower treatment costs. Transforming consumption habits to millets can save people and the country a lot of money in terms of medical expenses and pharmaceutical imports to address malnutrition-related diseases.

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References
Adeola, O., & Orban, J. I. (1995). Chemical composition and nutrient digestibility of pearl millet (Pennisetum glaucum) fed to growing pigs. Journal of Cereal Science, 22(2), 177–184. https://doi.org/10.1016/0733-5210(95)90048-9
Ahmed, A. S., Zhang, Q., Chan, J., & Shen, Q. (2013). Millet grains: Nutritional quality, processing, and potential health benefits. Comprehensive Reviews in Food Science and Food Safety, 12(3), 281–295. https://doi.org/10.1111/j.1541-4337.2012
Ali, M. A., El Tinay, A. H., & Abdalla, A. H. (2003). Effect of fermentation on the in vitro protein digestibility of pearl millet. Food Chemistry, 80(1), 51–54. https://doi.org/10.1016/S0308-8146(02)00234-0
Amadou, I., Gounga, M. E., & Le, G. W. (2013). Millets: Nutritional composition, some health benefits and processing - A <br> Review. Emirates Journal of Food and Agriculture, 25(7), 501–508. https://doi.org/10.9755/ejfa.v25i7.12045
Aman, F., & Masood, S. (2020). How Nutrition can help to fight against COVID-19 Pandemic. Pakistan Journal of Medical Sciences, 36(COVID19–54), S121. https://doi.org/10.12669/pjms.36.COVID19-S5.2776
Arshad, M. S., Khan, U., Sadiq, A., Khalid, W., Hussain, M., Yasmeen, A., Ashgar, Z., & Rehana, H. (2020). Coronavirus disease (COVID-19) and immunity booster green foods: A mini review. Food Science & Nutrition, 8(8), 3971–3976. https://doi.org/10.1002/fsn3.1719
Bora, P., Ragaei, S., & Marcone, M. (2019). Characterisation of several types of millets as functional food ingredients. International Journal of Food Sciences and Nutrition, 70(6), 714–724. https://doi.org/10.1080/09637483.2019.1570086
Brown, C. C., & Noelle, R. J. (2019). Seeing through the dark: New insights into the immune regulatory functions of vitamin A. European Journal of Immunology, 45(5), 1287–1295. https://doi.org/10.1002/eji.201344398
Calder, P. C., Carr, A. C., Gombot, A. F., & Eggersdorfer, M. (2020). Optimal nutritional status for a well-functioning immune system is an important factor to protect against viral infections. Nutrients, 12(4), 1181. https://doi.org/10.3390/nu12041181
Calinou, L. F., & Vodnar, D. C. (2018). Whole grains and phenolic acids: A review on bioactivity, functionality, health benefits and bioavailability. Nutrients, 10(11), 1615. https://doi.org/10.3390/nu10111615
Carr, A. C., & Maggini, S. (2017). Vitamin C and immune function. Nutrients, 9(11), 1211. https://doi.org/10.3390/nu9111211
Chandra, A., Singh, A. K., & Mohto, B. (2018). Processing and value addition of finger millet to achieve nutritional and financial security-case study. International Journal of Current Microbiology and Applied Sciences, 71, 2901–2910.
Chandrasekara, A., & Shahidi, F. (2010). Content of insoluble bound phenolics in millets and their contribution to antioxidant capacity. Journal of Agricultural and Food Chemistry, 58(11), 6706–6714. https://doi.org/10.1021/jf1008688
Chandrasekara, A., & Shahidi, F. (2011). Determination of antioxidant activity in free and hydrolyzed fractions of millet grains and characterization of their phenolic profiles by HPLC-DAD-ESI-TOF. Journal of Functional Foods, 3(3), 144–158. https://doi.org/10.1016/j.jff.2011.03.007
Dayakar Rao, B., Bhaskarachary, K., Arlene Christina, G. D., Sudha Devi, G., Vilas, A. T., & Tonapi, A. (2017). Nutritional and health benefits of millets (pp. 112). ICAI, Indian Institute of Millets Research (IIMR), de Morais, C. M. (2021). Nutritional therapy in COVID-19 management. Kompass Nutrition & Dietetics, 1(1), 10–12.
Devi, P. B., Vijaya Bharathi, R., Sathyabama, S., Malleshi, N. G., & Priyadarisini, V. B. (2014). Health benefits of finger millet (Eleusine coracana L.) polyphenols and dietary fiber: A review. Journal of Food Science and Technology, 51(6), 1021–1040. https://doi.org/10.1007/s11699-011-0584-9
Erkelenz, M. N., & Mebius, R. E. (2017). Retinoic acid and immune homeostasis: A balancing act. Trends in Immunology, 38(3), 168–180. https://doi.org/10.1016/j.it.2016.12.006
FAO. (2018). Agriculture organization of the United Nations.
Farag, H. A., Baqi, H. R., Hussein, Y. T., Shareef, O. H., Qadir, S. A., El Afifi, A., & El Bilbeisi, A. H. (2020). The role of nutrients in supporting the immune system against viral infection; newly emerged coronavirus (COVID-19): A narrative review. Kurdistan Journal of Applied
Makuvara, Cogent Food & Agriculture (2022), 8: 2111060
https://doi.org/10.1080/23311932.2022.2111060

health benefits. Comprehensive Reviews in Food Science and Food Safety, 12(3), 281–295.
Sarita, E. S., & Singh, E. (2016). Potential of millets: Nutrients composition and health benefits. Journal of Scientific & Innovative Research, 5(2), 46–50.
Shashi, B. K., Sharan, S., Shittalamani, S., Shankar, A. G., & Nagarathna, T. K. (2007). Micronutrient composition, antinutritional factors and bioaccessibility of iron in different finger millet (Eleusine coracana) genotypes. Karnataka Journal of Agricultural Sciences, 20(3), 583–585.
Shobana, S., Sreeerama, Y. N., & Malleshi, N. G. (2009). Composition and enzyme inhibitory properties of finger millet (Eleusine coracana L.) seed coat phenolics: Mode of inhibition of α-glucosidase and pancreatic amylase. Food Chemistry, 115(4), 1268–1273. https://doi.org/10.1016/j.foodchem.2009.01.042
Singh, P., & Raghuvanshi, S. (2012). Finger millet for food and nutritional security. African Journal of Food Science, 6(4), 77–84.
Siwela, M., Taylor, J. R., de Milliano, W. A., & Duodu, K. G. (2007). Occurrence and location of tannins in finger millet grain and antioxidant activity of different grain types. Cereal Chemistry, 84(2), 169–174. https://doi.org/10.1094/CCHEM-84-2-0169
Sood, S., Kant, L., & Pattanayak, A. (2017). Finger millet [Eleusine coracana (L.) Gaertn.: A minor crop for sustainable food and nutrition security. Asian Journal of Chemistry, 29(4), 707–710. https://doi.org/10.14233/ajchem.2017.20284
Thilagavathi, T., Banumathi, P., Kanchana, S., & Ilamaran, M. (2015). Effect of heat moisture treatment on functional and phytochemical properties of native and modified millet flours. Plant Archives, 15(1), 15–20.
Vadez, V., Berger, J. D., Workentin, T., Asseng, S., Ratnakumar, P., Rao, K., Gour, P. M., Munier-Jolain, N., Larmure, A., Voisin, A.-S., Sharma, H. C., Pandé, S., Sharma, M., Krishnamurthy, L., & Zaman, M. A. (2012). Adaptation of grain legumes to climate change: A review. Agronomy for Sustainable Development, 32(1), 31–44. https://doi.org/10.1007/s11593-011-0020-6
Viswanath, V., Urooj, A., & Malleshi, N. G. (2009). Evaluation of antioxidant and antimicrobial properties of finger millet polyphenols (Eleusine coracana). Food Chemistry, 114(1), 340–346. https://doi.org/10.1016/j.foodchem.2008.09.053
Wang, L., Wang, Y., Ye, D., & Liu, Q. (2020). Review of the 2019 novel coronavirus (SARS-CoV-2) based on current evidence. International Journal of Antimicrobial Agents, 55(6), 105948. https://doi.org/10.1016/j.ijantimicag.2020.105948

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