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## Functional dairy foods: The way forward after COVID-19

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### Abstract

The whole world is suffering from the severity caused due to the outbreak of novel coronavirus since last year. During this period, the relation of functional foods in combating and reducing the risk of this outbreak came to the light. Functional dairy products are in high demand due to their health-promoting effects and ability to incorporate diverse bioactive ingredients. The different herbs and nutraceuticals contain varieties of bioactive that can be conveyed through food to confer a health benefit to the consumer. Milk serves as the most efficient carrier for these functional ingredients for targeted health benefits. This review tends to explore the potential of various functional dairy foods in combating COVID-19 and its way forward in the market in near future.

### 1. Introduction

The global COVID-19 pandemic has swept the world through increasing morbidity and mortality rate with a distressing impact on the community and human health. Because of the soaring number of positive cases, health professionals are looking for an effective cure for this disease. The immunity of the host greatly affects the impact of this virus in terms of severity, symptoms, and outcomes of the disease (Han and Hoang, 2020). This has brought a shift in consumer food choices towards food products with immune-boosting and functional properties (Kanekanian, 2014). The urgent need for products with immune-boosting and health-promoting effects has been on an unprecedented rise in the market and has put nutraceuticals and functional foods on the front amid this pandemic (Ayseli *et al.*, 2020). Dairy products have been widely explored for this purpose because of their high nutritional value and demand in the market. The advent of various extraction and encapsulation technologies has further encouraged the functionalization of dairy products to offer a targeted release of the bioactive constituent. Food ingredients like herbs, spices, plant extracts, probiotics, and prebiotics have been effectively incorporated to produce functional dairy products (Martins *et al.*, 2018).

Herbs have been widely used for medicinal purposes from ancient times. They contain a diverse assortment of bioactive compounds such as flavonoids, terpenoids, lignans, sulfides, polyphenols, carotenoids, coumarins, saponins, plant sterols, curcumins, and phthalides (Bais, 2018). The presence of these compounds in herbs

has encouraged their tremendous exploration as a functional ingredient in foods against various diseases like CVDs, cancer, diabetes, *etc.* But now, the trend has shown a leaning outlook towards the role of herbs and herbs-based formulation against COVID-19 virus as they possess antiviral, antibacterial and, immune-stimulating properties that may be beneficial in lowering the risk of COVID-19 along with other severe infections and diseases (Khanna *et al.*, 2020). Polyphenolic compounds derived from plant extracts and food by-products are well-known for their antioxidant, antimicrobial and antiviral properties (Galanakis *et al.*, 2020). Presently, the dairy industry is manifesting a humongous interest in making functional dairy products by incorporating bioactive ingredients. Milk and milk products are already in demand due to their health promoting effects as well as they have an already established market. Dairy products are potential carriers of bioactive, phytochemical, and can act as the delivery system. Through this, the health-promoting functions of herbs and plant bioactives can be conveyed to a specific population group (Bais, 2018). Milk fat, especially ghee and butter, has the potential to captivate all the medicinal and functional characteristics of the incorporated bioactives, without disturbing their attributes. In view of the current situation of the COVID-19 pandemic, we would like to evaluate the potential of functional dairy products in combating COVID-19 and its way forward in the market. This review tends to provide a succinct overview of various functional dairy products, their potential against COVID-19 along with exploration of its prospects.

### 2. Functional foods as immune enhancer

Functional foods are described as “dietary products that have been modulated to perform one or more targeted functions in the body,” which means that in addition to providing nutrients and energy, they also perform other functions in the body. Many functional foods and components are naturally occurring compounds with immune-boosting properties that have been scientifically identified

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(Singh *et al.*, 2020). These compounds are not directly involved in inhibiting response to coronavirus but play an important role in prevention against COVID-19. Many prebiotics, probiotics, and ayurvedic products have been used as natural remedies in studies to improve the immune system. These products help to reduce stress in the body and improve the immune response of our body. Immune health has been related to micronutrients, probiotics, flavonoids, carotenoids, and herbs. Spices like turmeric, cumin, coriander, and garlic are also helpful to the immune system when used in cooking. These spices are considered health promoters because they facilitate monoamine and gamma-aminobutyric acid neurotransmission, both of which are important components of nutrition (Rajkumar, 2020). Golden milk is a milk-based drink that should be consumed once or twice a day (half teaspoon turmeric powder in 150 ml hot milk). It is said to raise immunity. Haridra (*Curcuma longa* Linn.), *i.e.*, turmeric, contains the active ingredient curcumin, which inhibits the release of cytokines, most notably interleukin-1, interleukin-6, and tumor necrosis factor, and is best taken with milk. It is comparable to COVID-19, in which a cytokine storm plays a key role in mortality (Sordillo and Helson, 2015). Flavonoids and carotenoids, which are naturally occurring functional food compounds, have been identified as potent antioxidants and anti-inflammatory agents that help to improve the immune system (Singh *et al.*, 2020). Antioxidant and anti-inflammation are two basic immune-boosting properties associated with fruits and vegetables, both of which are considered useful biomarkers for evaluating human health (Dangour *et al.*, 2010).

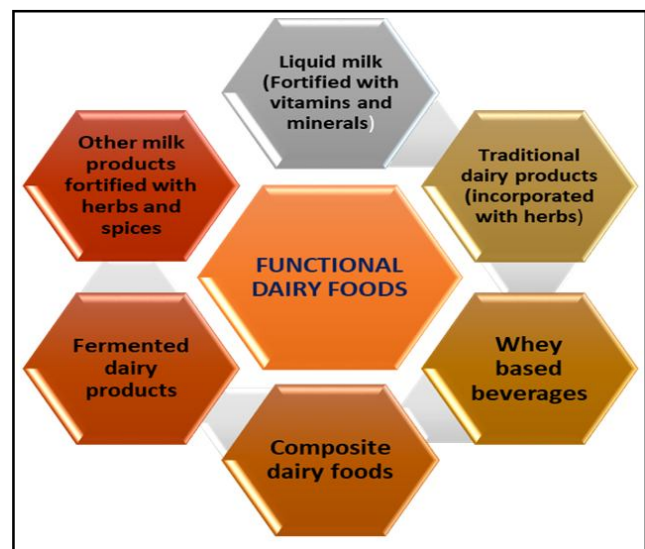
### 3. Why include milk in dairy diet?

Milk is a nutrient-dense food. The basic role of milk is to promote the growth of young ones as it contains a matrix of macro, micronutrients along with some growth-promoting factors like protein, fat, lactose, minerals, vitamins, CLA, *etc.*, and helps in the overall nourishment. It contains more utilizable calcium and good quality protein. Milk contains a branched chain of amino acids, leucine, isoleucine, valine in considerable quantity. It also helps in combating various diseases, and hence plays an important role in daily diet. As tryptophan and leucine present in milk activate the molecular signaling pathway for growth. Leucine activates mTORC1 which regulates T-cell. These T-cells play a critical role in the enhancement of immunity against autoimmune disorders, cancers, and pathogens (Ananieva *et al.*, 2016). Milk fat contains conjugated linoleic acid. Various *in vitro* and *in vivo* studies related to these naturally occurring substances demonstrated anticarcinogenic, antitumor, antimutagenic, and antioxidant activities. These substances showed a positive effect on the apoptosis of tumor cells (Dachev *et al.*, 2021). There are many more positive benefits of consuming milk in a daily diet as they contain more of the essential nutrients required for health than any other single food. Some bioactive components of milk like  $\beta$ -casomorphin, lactoferricin B are known for bracing immunomodulatory response. Lactoferrin, the bioactive peptide is mainly recognized for its iron-chelating ability. It also activates B cells by taking part in the stimulation of the K-light chain. Besides this, lactoferrin controls the function of killer cells present naturally by hindering granulopoiesis (Marccone *et al.*, 2017).

### 4. Milk as a source of functional foods

Milk is an immensely enriched source of nutrients. The fat portion is rich in various fat-soluble vitamins and phospholipids. They

contain high-quality proteins as casein and whey. It also contains minerals like calcium, phosphorus, magnesium, and potassium. Milk can be turned into a variety of dairy products, the majority of which have a well-known health-oriented image in the minds of consumers and have proven to be an excellent option for creating superior nutrition. Dairy foods can be classified into three categories: (a) basic products, such as milk, fermented milk, cheese, ice cream, and other dairy products, (b) goods with modified composition for value addition, such as lactose-free products, and (c) functional dairy products with an added ingredient to increase functionality such as probiotics, *etc.* Functional dairy products can be broadly categorized as (Figure 1).



**Figure 1: Categorization of functional dairy foods.**

Increasing awareness amongst the consumer about the role of diet in health and well-being has encouraged the need for a diet that greatly exerts a positive impact on the health and well-being of the people. Various products such as probiotics, prebiotics, synbiotics, and functional foods have received great attention as food with a special characteristic. Developing a functional dairy-based product means enriching the original base with a healthy ingredient. A food is said to be “functional” if it beneficially affects one or more of the characteristic functions in the body by providing an additional health advantage beyond basic nutrition. Milk has received great attention as a base material for the development of various dairy-based functional foods and has provided an excellent solution with superior nutrition (Nagpal *et al.*, 2012). The present scenario of a pandemic has further promoted these products because of their health-promoting and immunity-boosting properties.

### 5. Functional foods and nutraceuticals against COVID-19

Consumers and health practitioners are gradually embracing a proactive approach rather than a curative approach as a result of a rising pattern of health consciousness around the world (Nagpal *et al.*, 2012). The current pandemic scenario of COVID-19 has augmented the marketing and demand of immune-enhancing foods, supplements, and nutraceuticals. Food bioactive and nutraceuticals have been suggested as an alternative solution to COVID-19 disease, based on their anti-inflammatory properties as well as their ability to suppress virus activity (*e.g.*, SARS-CoV, MERS-CoV, and SARS-

CoV-2) by disrupting their protein envelopes. Several plant secondary metabolites can act as DNA intercalator (similar to the *in vitro* mechanisms of action suggested for chloroquine against malaria) that stops the virus from replicating (Galanakis *et al.*, 2020).

## 6. Herbs and spices in functional dairy products

Herbs and spices have been used to fortify foods as preservatives, flavorings, and medicinal agents throughout history. Several studies have suggested the use of dietary herbs and spices for their antimutagenic, anti-inflammatory, antioxidative, and immunomodulatory effects, which have been shown to enhance human health (El-Sayed and Youssef, 2019). Before the development of vaccines and till the vaccine reaches the whole population of the world, consumption of these herbs is the only way of protection against Novel coronavirus (Rahman *et al.*, 2021). Along with this the ministry of AYUSH, Government of India, recommended the consumption of kadha (AYUSH Advisory, 2020). As it improves immunity and reduces the harmful effect caused by COVID-19 catastrophe. This kadha is prepared from a combination of species and herbs. Nilavembu Kudineer can be used as a potent antiviral drug. As it shows immunomodulating activity against the ACE<sub>2</sub> enzyme receptor (Lekha *et al.*, 2020). Similarly, the herb *Curcuma longa* acts as a molecular blocker for viruses due to the presence of their bioactive components curcumin (Huynh *et al.*, 2018). *Ginkgo biloba* restricts the activation of the cell signaling pathway and arrests cell cycles by hindering the DNA and protein synthesis and their attachment to host cell receptors. It provides an inhibitory action and in studies proved to be potentially effective against Covid (Borenstein *et al.*, 2020). The bioactive components of *Allium sativum*, capsicum, *Mentha pulegium* restrained the synthesis of amino acids and stop the activity of the viral proteases enzyme. This study conducted by (Mohammadi and Shaghghi, 2020) using a molecular docking approach revealed the immunomodulatory mechanism of bioactive constituents of several herbs against coronavirus when consumed on daily basis. They provide a higher binding affinity towards viral and host macromolecular targets and other human pro-inflammatory mediators. In today's nutrition food system, dairy products are a special carrier that has been successfully used to distribute phytochemicals and other nutrients for health benefits (El-Sayed *et al.*, 2015). Furthermore, the addition of herbs, spices, or extracts to various dairy products turns these products into nutraceutical carriers. As a result, the dairy industry should come up with new ways to enhance the functionality of conventional dairy products, which could have significant value and have a positive impact on customers. Spices and herbs contain bioactive compounds that can reduce or prevent degenerative diseases like diabetes, obesity, cancer, and cardiovascular disease. Several herbs and spices in various forms (powder, raw, extract, essential oils, *etc.*) have been successfully identified in the functional application of dairy products (El-Sayed and Youssef, 2019). A study was conducted for the development of herbal lassi incorporated with ginger, turmeric, and carrot extracts @ 2% (v/v), 1% (v/v), and 15% (v/v), respectively using 1% commercial yogurt culture containing *Streptococcus thermophilus* and *Lactobacillus bulgaricus* and have found to exhibit good antioxidant activity (Maji *et al.*, 2020). The use of essential oils (EOs) from herbs and spices in processed foods is widely accepted (Moro *et al.*, 2015). In food items, the usual concentration of herbs and spices is between 0.05

and 0.1 per cent. However, their use in dairy products is subject to limits and limitations (Moro *et al.*, 2015) based on the assumption that dairy products are a good source of calcium (Tzima *et al.*, 2020). *In vitro* study was conducted using aqueous lyophilized extract of the optimized herbal mix (1g/100 g) including green mate (*Ilex paraguariensis*), lemongrass (*Cymbopogon citratus*), and clove (*Syzygium aromaticum*) through response surface technique. Incorporation of aqueous extract of clove (87.5% w/w) and green mate (12.5% w/w) into fermented milk manufactured without the use of any preservative improves the total phenolic content. It also enhances the antioxidant activity of fermented milk assessed through DPPH and FRAP methods. This drink attained more than 70% acceptability when a sensory test was conducted (Ramos *et al.*, 2017). Herbal extracts not only increase the bioactive compounds and antioxidant level but also improves the sensory acceptance of the product. Research conducted by Guo *et al.* (2018) on low-fat yogurt supplemented with either freeze-dried or oven-dried Jerusalem artichoke powder (*Helianthus tuberosus*) which is known for its various beneficial effects. Results verified that the addition of oven-dried JAP (4% w/w) into low-fat yogurt had similar textural and sensory properties to the full-fat control sample. It also showed better firmness and adhesiveness characteristics in comparison to freeze-dried JAP incorporated yogurt. So, it can be regarded as one of the beneficial prebiotic fat replacers in yogurt. Aqueous extract of olive, garlic, onion, and citrus added into yogurt containing (*Bifidobacterium animalis*, lactobacillus culture) was evaluated during a storage period of 29 days at 5° (Michael *et al.*, 2015). Results concluded that aqueous extract of these herbs improves the durability of probiotics by defending them from oxidative stress as these herbs exert a buffering capacity in the system. Similarly, turmeric, sage, or marjoram water extract (10%) was added to skimmed milk yogurt (@1%). The presence of turmeric extract showed more increment in the level of acid production and growth of bacterial compared to sage or marjoram. These herbs boost the antioxidant level in the product (Hasneen *et al.*, 2020). Yogurt fortified with Fuzhuan brick tea increased the proteolytic activity. It strengthens the β-galactosidase activity, viscosity, and total count of bacterial starter culture (*Lactobacillus acidophilus* and *Streptococcus thermophilus*). It lowers the syneresis problem along with this addition of this herb upgrade the shelf life and antioxidant activity of the prepared yogurt (Liu, 2018). The addition of the essential oil of ginger (0.2%) and chamomile oil (0.4%) into yogurt have improved the preservation activity due to the antimicrobial and antioxidant properties of ginger and chamomile (Yangilar and Yildiz, 2018). Some examples of functional herbal dairy products have been listed in Table 1.

## 7. Probiotics as functional dairy foods

Insight of current unprecedented COVID-19 pandemic threat where no effective preventive and remedial drug is available, building adaptive immunity against the virus serves as an imperative armamentarium. Probiotics are live microbes that have health benefits for the host when delivered in a sufficiently sufficient volume, and they include a range of bacteria and yeast genera, *Lactobacillus*, *Bifidobacterium*, *Leuconostoc*, *Pediococcus*, and *Enterococcus* are examples of probiotics. Microflora belonging to the genera, *Lactobacillus* and *Bifidobacterium* populate the natural gastrointestinal microflora of humans. They are healthy and popular in yogurt and other dairy products (López-Moreno and Aguilera,

2020). Some examples of probiotic dairy products have been listed in Table 2. Probiotics help to regulate the immune response of the host, enhancing mucosal barrier function and modulating the immune system (El Hage *et al.*, 2017). Probiotics support the host's health in several ways, including local immunity (by preserving gut health and gut wall integrity) and systemic immunity (by improving specific and non-specific immune responses). Probiotics are

effective and efficient for a variety of ailments, including virus infection (Sundararaman *et al.*, 2020). Many studies have shown that probiotics can help to improve and modulate the immune system's ability to combat diseases. In the case of dysbiosis, probiotics help to repopulate the gut with "good" bacteria, preventing pathogen replication and restoring eubiosis (Santacrose *et al.*, 2021).

**Table 1: Examples of some herbal dairy products**

| Product              | Herbal infusion  | Findings   | References                         |
|----------------------|--|--|------------------------------------|
| Herbal fruit yoghurt | <i>Ocimum sanctum</i> (Tulsi) Extract  | Increased antioxidant activity   | Mittal <i>et al.</i> , 2020        |
| Herbal paneer        | Ginger, Rosemary and Thyme Herbs   | Enhanced shelf life and food flavour due to bacteriostatic activity and occurrence of antioxidants | Yadav <i>et al.</i> , 2019         |
| Herbal lassi         | Turmeric Extract   | High phenolic content with good sensory property   | Maji <i>et al.</i> , 2018          |
| Herbal honey         | <i>Ocimum sanctum</i> Linn. and honey  | High score for flavour, colour and appearance and overall acceptability                            | Kumar <i>et al.</i> , 2020         |
| Yoghurt              | Fennel ( <i>Foeniculumvulgare</i> Mill) essential oil                                    | Improved microbiological properties  | Ben Abdesslem <i>et al.</i> , 2020 |
| Herbal milk          | <i>Aloe vera</i> ( <i>Aloe barbadensis</i> Miller) and Tulsi ( <i>Ocimum sanctum</i> )   | Improved acceptability and sensory quality   | Hingne <i>et al.</i> , 2020        |
| Ice cream            | <i>Ilex paraguariensis</i> , <i>Melissa officinalis</i> , and <i>Cymbopogoncitratu</i> s | Increased total phenolics and antioxidant activity   | Gremski <i>et al.</i> , 2019       |
| Herbal ghee          | Arjuna extract   | Phytosterols incorporated  | (Parmar and Khamrui, 2017).        |

**Table 2: Examples of probiotic dairy foods**

| Product                      | Probiotic strain   | Reference                    |
|------------------------------|--|------------------------------|
| Kalari cheese                | <i>Lactobacillus plantarum</i> , <i>Lactobacillus casei</i> , and <i>Lactobacillus brevis</i>                        | Mushtaq <i>et al.</i> , 2019 |
| Ricotta cheese               | <i>L. acidophilus</i> La-05 cell pellets   | Sameer <i>et al.</i> , 2020  |
| Probiotic ice cream          | <i>Lactobacillus acidophilus</i> (ATCC 4357D 5) and <i>Bifidobacteriumanimalis</i> subsp. <i>lactis</i> (ATCC 27536) | Ayar <i>et al.</i> , 2018    |
| Goat milk probiotic icecream | <i>Lactobacillus paracasei</i> , <i>Bifidobacteriumlongum</i> and <i>Bifidobacteriumbifidum</i>                      | Açu <i>et al.</i> , 2017     |
| Probiotic goat milk lassi    | <i>Lactobacillus casei</i>   | Adiver and Hiremath, 2021    |

## 8. Conclusion

The COVID-19 pandemic has spread quickly across the world, resulting in an ongoing public health crisis. To tackle the current pandemic, steps must be taken to minimize contamination and spread from person to person. To combat this pandemic situation, antiviral drug and vaccine production is needed. Immunosuppression, on the other hand, is another technique for treating this disease. Micronutrients, as well as functional food ingredients such as probiotics, spices, flavonoids, and carotenoids, can be considered natural immune booster foods. The immune system is boosted by these novel immune-boosting functional foods fortified with bioactive compounds and antioxidants. Finally, understanding the structural protein of SARS-CoV-2 may aid in the development of promising COVID-19 therapeutic drugs. The addition of herbs in dairy foods for the development of functional foods with immune-

boosting properties have gained tremendous attention in this time of the pandemic. Natural herbs are high in antimicrobial, antiviral, and immunomodulatory agents and they have no negative side effects. However, certain technical problems must be overcome during product production. Due to processing conditions, the addition of herbs or their decoction will alter the palatability of food. They can also interact with certain major or minor milk constituents, causing unfavorable effects. Also, their long-term everyday intake may have some negative health implications. The relationship of herbs and milk constituents during processing conditions needs to be studied to enhance their stability.

## Conflict of interest

The authors declare that there are no conflicts of interest relevant to this article.

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