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Delving the role of nutritional psychiatry to mitigate the COVID-19 pandemic induced stress, anxiety and depression

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ABSTRACT

Background: The distressing COVID-19 pandemic has had a substantial impact on public mental health, and the importance of food and nutrients in several aspects of mental health has been recognized. People in isolation or quarantine suffer from severe stress, anger, panic attack, and anxiety.

Scope and approach: Although, people who have improved and progressed through medications or vaccines have reduced anxiety levels to some extent yet the efficacy of these measures, in the long run, remains a question. The review depicts that such negative emotional reactions were particularly higher in elderly individuals in the first wave than in other phases. The emotional and behavioral response to the COVID-19 pandemic is multifactorial. From different research studies, it has been found that stress scores were considerably higher for those engaging in unhealthy eating practices. This factor relies not only on external components but on personal and innate ones as well. In the present pandemic, the sustainable development of the food system would have been a major issue; this should be carefully restored to avoid a food crisis in the future.

Key findings and conclusions: Changes in mind-body interactions are triggered by psychosocial stresses such as interpersonal loss and social rejection. Physiological response (in terms of psychological stress) in COVID-19 affected patients varies due to individual physical health status. This review explores the relationship between nutrition and mental health as what we eat and think is interlinked with the gut-brain-axis. The role of dietary components along with the Mediterranean diet, DASH diet and use of psychobiotics in improving psychological distress in pandemic induced stress, anxiety and depression has also been discussed.

1. Introduction

The novel Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) virus has swiftly spread around the world since the first incident of pneumonia of unknown source was discovered in Wuhan, China, in December 2019, and this pandemic constitutes one of the most serious international health concerns in living memory (Jianbo Lai et al., 2020). The disease itself, as well as the methods taken to combat the pandemic, have inflicted psychological stress in significant segments of the global population. As a result, research into the mental health effects of this pandemic is given top attention (Bendau et al., 2021). The unpredictable and growing Corona Virus Disease-19 (COVID-19) virus variants have highlighted the need for stress management and self-care for all the affected and non-affected persons (Lupe, Keefer, & Szigethy, 2020).

Considering the pandemic's magnitude and speed of transmission, increasing fear and concern among the public and healthcare personnel is reasonable (Jianbo Lai et al., 2020). There are several contributing causes, including lack of efficient control and recovery approaches, numerous deaths in various countries, including those with great health facilities, the susceptibility of healthcare professionals, and enormous economic consequences. On a personal level, many people have lost family members before their time and are terrified of losing more. In addition to the existing methods to prevent the spread, there are additional mental health concerns connected to isolation and loneliness (Kar,

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Kar, & Kar, 2021).

As can be seen, many people suffer from anxiety, sadness, and stress, as well as post-traumatic stress disorder (PTSD). A few studies have shown similar findings; however, the prevalence estimates have varied significantly. A systematic review indicates anxiety (6.33–50.9%), depression (14.6–48.3%), PTSD (7–53.8%) and psychological distress (34.43–38%) were all found to be common in general population studies. Students, 20- to 30-year-olds, those who were unmarried, and those with a university education were all shown to have a higher risk of mental health problems (Kar et al., 2021). Similarly, a study in the United Arab Emirates found that COVID-19 does have a psychological influence on adults and children. There was anxiety among three quarters (71%) of the adult population and moderate to severe anxiety among 38%. Half of the participants (49.8%) reported higher levels of anxiety when anxiety was classified by high and low, based on GAD-7 cutoff of 8 (Generalized Anxiety Disorder Assessment). Vitamin C, anti-inflammatory medicines and analgesics were more likely to be taken by highly anxious participants (Saddik et al., 2021).

These complications especially in virus affected people are thought to be linked to a phenomenon known as a cytokine storm i.e. over production of cytokines, which promotes more immune cells to be drawn to the wounded site, potentially causing organ damage. A strong, functional immune system is essential for infection prevention, and an appropriate and balanced diet is a vital basis for optimum immunological response. Proper nutritional intake is important for controlling inflammatory and oxidative stress states affecting the immune system (Jahns et al., 2018); Gabriele and Pucci, 2017). Omega-3 fatty acids, vitamin A, vitamin C, and a range of phytochemicals found in plant-based foods, such as polyphenols and carotenoids, are among the dietary and nutritional components known to have anti-inflammatory and antioxidant effects (Ma et al., 2008). While the vitamin A metabolite, retinoic acid, interacts with the retinoic acid receptor, which may play a role in immunity, vitamin D is thought to interact with its transcription factors (Iddir et al., 2020). Additionally, evidence supports that intake of certain types of micronutrients, including vitamin B complex, folate, zinc, magnesium, and selenium positively influence mood status and mental health, promoting stress prevention (Maffoni, Kalmpourtzidou, & Cena, 2020).

2. Pandemic chaos and effect on the mental health of different peer groups

Mood disorders such as anxiety, sadness, rage, and irritability have already been observed during quarantine periods in many investigations. An online poll found that over a thousand individuals in-home quarantine reported worse psychological conditions and contentment, as well as greater depression and the need for psychological help during the COVID-19 outbreak. Increased negative psychological impacts were linked to reduced physical activity and an upsurge in unhealthy diet behaviors (Amatori et al., 2020). Quarantine has a wide-ranging, significant, and long-lasting psychological impact. This is not to say that quarantine should be neglected; in fact, the mental consequences of unavailing quarantine time and letting illness spread may be more severe. If quarantine is necessary, then clear communication, maintaining important resources (such as water, food and medical provisions), and strengthening the sense of humanity that people should rightfully feel are all necessary (Brooks et al., 2020). Stress variables linked to COVID-19 have been linked to a high risk of negative mental health effects in different research investigations. There was a review study launched in May 2020 to investigate the psychological symptoms linked with the pandemic among the public and healthcare personnel (Mumtaz, Manzoor, Jiang, & Anisur Rahaman, 2021). Pandemic chaos has left a significant impact on people of different age groups (Table 1) owing to various stressors associated with stress, anxiety, and depression.

Table 1
Effect of COVID-19 pandemic on mental health in different age groups.

Age (years)	Perceived Stress (%)	Generalized Anxiety Disorder (%)	Major Depressive Disorder (%)	Reference
≤25	96.3	65.5	66.8	Nwachukwu et al. (2020)
26–40	91.1	58.6	50.9	
41–60	81.9	37.5	35.9	
>60	68.2	23.3	26.4	

2.1. Children and teenagers at risk

Children who live at home, away from their fellow students, may have a number of issues about the pandemic and seek answers from their parents and caregivers. Stress, discomfort, isolation, and associated anxiety affect children and parents in a variety of ways, with short- and long-term effects on a child's mental development (Liu, Bao, Huang, Shi, & Lu, 2020). Excessive weeping and obnoxious conduct are two of the most common complaints. Sadness, melancholy and worry are all on the upswing these days as are sudden headaches and discomfort all over their bodies (Liu et al., 2020).

2.2. Elders and people with disabilities at risk

Most of the research usually focused broad audience rather than a specific age range. COVID-19 is more likely to affect elderly persons who have numerous risk factors, such as old age stigmatization, chronic morbidity, lack of social support, living alone, and a greater level of depression (Mumtaz et al., 2021). The elderly are the most vulnerable to the COVID-19 pandemic for both clinical and social reasons, such as a weakened immune system or other underlying health conditions, as well as separation from family and friends owing to their busy schedules (Javed, Sarwer, Soto, & Mashwani, 2020). Isolation may be harmful to a family structure since elderly folks rely on their kids for their daily needs. Residents of nursing homes, particularly the elderly and disabled, may have serious mental health issues. In elderly people who already have mental health issues, COVID-19 may induce increased tension, anxiety, and sadness (Javed et al., 2020). During the COVID-19 epidemic, women were reported to be more distressed. As a result, to safeguard the elderly from the pandemic's negative impacts, it's critical to investigate the potential mental health issues that may arise in this population and take the necessary precautions (Mattioli, Sciomer, Maffei, & Gallina, 2021).

2.3. Health workers at risk

On the front lines of the COVID-19 pandemic, doctors, nurses, and paramedics may be more prone to mental health concerns. Long work hours, a lack of safe essential clothing and equipment, an increasing care load, an absence of effective medication, the death of a coworker following COVID-19 exposure, social distancing, isolation from loved ones, and the difficult situation of their patients may all have a significant negative impact on health workers' psychological health. As the epidemic spreads, health workers' performance may steadily deteriorate (Javed et al., 2020).

2.4. Pregnant women

Pregnant women also faced psychological problems because of the COVID-19 pandemic. During the COVID-19 outbreak, pregnant women's anxiety and depression symptoms intensified. Depression, anxiety, and stress are frequently undiagnosed and untreated during pregnancy. The COVID-19 pandemic caused social and economic stress, and both are risk factors for preterm birth and giving birth to newborns with growth restrictions (Effati-Daryani et al., 2020).

3. Main stressors affecting psychological health during COVID-19 pandemic

Social isolation or either rejection are two forms of stress that are particularly significant in this context, especially considering research indicating that loneliness and long-term social exclusion have been significant consequences of COVID-19 prevention measures (Miller, 2020). In response to this pandemic, dietary practices are affected in both positive and negative ways because of various related factors or stressors. The major influence observed was owing to quarantine (staying at home for smart working, digital education, limitation of outside visits and in gyms for physical activity). Food insecurity is due to stockpiling food because of restrictions in grocery shopping. In addition, it results in boredom, which in turn is associated with a greater energy intake (Moynihan et al., 2015). Reading and hearing about the COVID-19 from the media might be distressing, adding to the fatigue. Trauma and stress cause people to overeat, particularly sugary "comfort foods". These foods, which are mostly high in simple carbs, can help to relieve stress by promoting serotonin production, which has a positive influence on mood (Di Renzo et al., 2020). Likewise, restricted access to regular grocery shopping may lead to a shift away from fresh foods like fruit, vegetables, and seafood and toward highly processed meals like frozen meals, junk food, snacks, and ready-to-eat cereals, which are rich in sugars, salt, and fats (Di Renzo et al., 2020). Various stressors responsible for influencing psychological health during COVID-19 pandemic are shown in Fig. 1.

Limited availability and increasing price were the most common reasons for unfavorable changes in eating behaviors, and these were linked to bad food choices and mental health problems including sadness and anxiety (Sidor & Rzymski, 2020). It is also possible that additional lockdowns may occur, sustaining these changes in eating patterns. While some beneficial shift in dietary practices was observed during the first lockdown, it should be implemented in helping recovery and maintaining healthy lifestyle choices, to minimize long-term health impacts of the pandemic (Bennett, Young, Butler, & Coe, 2021).

In addition, increased screen exposure in children and teenagers may increase the risk of attention deficit hyperactivity disorder, anxiety, sadness, and suicidal behavior. The results of an epidemiological online cross-sectional survey conducted in the United Kingdom (UK) during the COVID-19 outbreak also indicated a connection between daily screen use and depression (Lee Smith et al., 2020). Individuals with massively increased screen time should be monitored for the extent of social isolation, sleep patterns and dietary behavior. According to the findings of a Canadian survey with over 4500 participants performed in spring 2020, reducing the amount of time spent watching television, surfing the internet, or playing video games while confinement may improve mental and overall health (Colley, Bushnik, & Langlois, 2020). Sleep might be negatively influenced by the short wavelength-enriched light emitted by technological gadgets. Sleep is a key component of the operation of the immune system. Sleep appears to be an important part of the immune system's function. Immunity and sleep are connected in a bidirectional way; although immune system activity can affect sleep, sleep has an impact on the adaptive and innate immune systems (Lange & Nakamura, 2020). These stressors predominantly affect the dietary pattern due to excessive snacking and an unhealthy selection of foods.

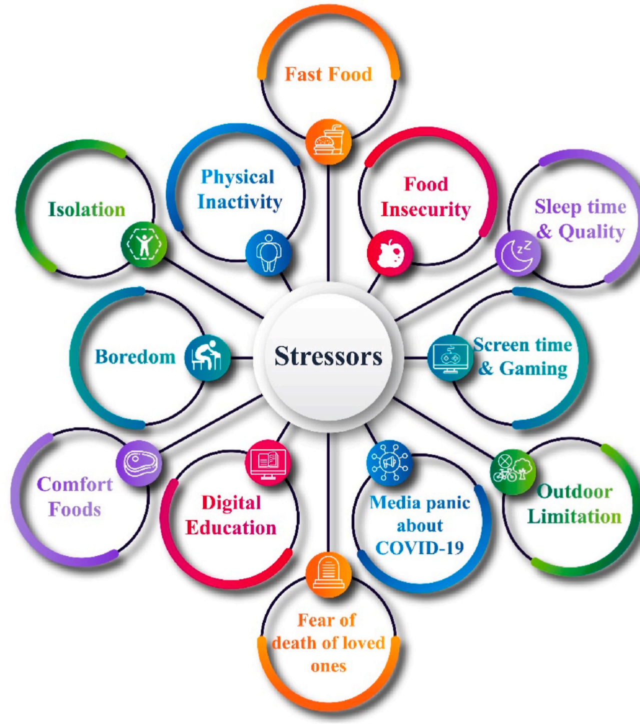

Fig. 1. Stressors affecting psychological health during COVID-19 pandemic.

4. Food security scenario through a window

During the pandemic, poor families are more prone to the risk of food insecurity. Not only are isolation measures linked to psychological distress, but economic stress, job loss, and the responsibility of childcare can all exacerbate psychiatric problems. Low-income households are more severely food insecure during the epidemic (Cannuscio et al., 2013). Low-income families frequently travel greater distances to obtain food and rely largely on public transportation, which becomes restricted or impossible during severe lockdown tactics. Children who depend on school meals are more likely to be hungry because of school closures (Fang, Thomsen, & Nayga, 2021). Food insecurity can lead to feelings of estrangement, concern, guilt, anger, and humiliation, which can lead to other psychological issues. In the context of poor countries, food poverty has historically been linked to psychological illness. Food insecurity during a pandemic is strongly linked to mental health issues such as anxiety and sadness. It is noteworthy that the impact of food scarcity during the pandemic is three times greater than the impact of losing a job (Fang et al., 2021).

By weakening different informal food supply channels, the COVID-19 pandemic is reportedly worsening food security. The COVID-19 pandemic presents opportunities for long-term agri-food production, while multi-agency converging innovation centers can speed up socio-economic recovery (Rowan & Galanakis, 2020, p. 141362). The ability to order groceries and household products via mobile devices has increased. However, it also highlights the significant disadvantages of marginalized individuals as well as the divisive character of cultural oppression (O'Hara & Toussaint, 2021). The impacts of COVID-19 on traditional and developing food systems, such as households, small and middle-class enterprises, and public markets, are expected to be severe (C. B. Barrett, 2021). Food chain systems in gulf countries have performed well in ensuring food accessibility during this epidemic. Policy participation necessitates public awareness initiatives to provide nutrient-dense food. The availability of food for migrant workers and other vulnerable groups is also a source of worry. This would necessitate improving current work laws and safety systems (Karasapan, 2020). The effects of a pandemic on sustainability have had an impact on a specific food health indicator, such as production, storage, and consumption. It also has an impact on long-term food and nutrition security, accessibility, and availability, as well as lifestyle, trade, and political cause (Sarkis, Cohen, Dewick, & Schröder, 2020). Most agricultural households have reduced access to healthy foods. The COVID-19 has sent millions of families into financial ruin and has been dubbed "even more deadly" than the global economic crisis of 2008, followed by the European debt crisis, United States home mortgage debt relative to gross domestic product (GDP) increase, increase in cash-out, refinancing, plummeting stock and commodity prices. According to estimates, half a billion people might be pushed into poverty (Akseer, Kandru, Keats, & Bhutta, 2020). A supply chain is necessarily required that can deliver a better diet with regulated bioactive components to help people enhance their immunity and food security (Galanakis, Aldawoud, Rizou, Rowan, & Ibrahim, 2020). In the present pandemic, the long-term growth of the food system would have been a major issue; this should be carefully restored to avoid a food problem in the future. To avoid food shortages and allow mobility to keep food supply chains and deliver adequate meals to the population, the current situation necessitates governmental actions and regulations (Rahaman et al., 2021).

5. Dietary habits during lockdown and COVID-19 pandemic

Scientific evidence providing an understandable relationship between diet and mental health is still emerging. Nonetheless, studies examining the dietary habits during this pandemic are limited owing to the nature of study design, analysis, sample size, gender, and ethnicity. However, consumption of various food groups during this pandemic has been observed in some of the studies evaluating dietary habits (Table 2). Unhealthy dietary practices during the lockdown were particularly observed in terms of fast-food consumption. Due to the closure of restaurants or restriction of dine in during partial lockdown, online food ordering systems are specifically involved in altering food habits.

In the first wave of the COVID-19 pandemic, healthy eating habits included increased use of fresh products, particularly vegetables and fruits, and promoted home cooking in the lockdown. People reported more willingness to consume foods that have a positive impact on the immunity of the people (Ali et al., 2021). In previous studies, the consumption of vegetables and fruits has been found to have an inverse relationship with depression. Nuts high in unsaturated fatty acids, polyphenols, and vitamins may also help to prevent mood and cognitive impairments (Amatori et al., 2020).

Table 2
Eating habits during Covid-19 crisis and lockdown.

Food group	Items	Rate of change in consumption	Possible causes	Region	Citation
Sweets and Oils	Fast food	82.2%↓	Lockdown, restaurants closed	Kuwait	Husain and Ashkanani (2020)
		13.7 consumed	Stress induced by quarantine	Italy, Spain, Chile, Colombia, and Brazil	Ruiz-Roso et al. (2020)
	Alcohol	36.8% ↓	Younger participants have less access during the lockdown	Italy	(Scarmozzino & Visioli, 2020)
		10.1% ↑	Increase was intentionally due to anxiety and depression	Spain	Ammar et al. (2020)
	Fried food	36.7% ↑	Anxiety and idleness	Palestine	Allabadi, Dabis, Aghabekian, Khader, and Khammash (2020)
	Chocolates, ice-creams, deserts	↑ 50%	To cope with stress, anxiety	Spain,	Romeo-Arroyo, Mora, and Vázquez-Araújo (2020)
		↑ 46.7%	Stress and anxiety	Italy	(Scarmozzino & Visioli, 2020) (Pellegrini, et al., 2020)
		↑ 20%	Stress	Australia	Gallo, Gallo, Young, Moritz, and Akison (2020)
		↑ 46.5%	Discomfort	Palestine	Allabadi et al. (2020)
Fruits and Vegetables	Vegetables	13.86% ↓	Difficulty in finding	Spain	Rodríguez-Pérez et al. (2020)
	Fruit and vegetables	27% ↓	Unavailability, increase in prices	India	Mehta (2020)
	Vitamin A rich fruit and vegetables	57.8% ↓	Poorer access to food stores, increase in food price	Zimbabwe	Matsungo and Chopera (2020)
	vegetables and fruits	↑ 21.2%	WHO Promotion of the importance of fruits and vegetables but some find them not appealing	Palestine	Allabadi et al. (2020)
		15%	Quarantine	Italy	Di Renzo et al. (2020)
		21.2%	Limited access to daily grocery shopping	Italy	Scarmozzino and Visioli (2020)
		Inadequate intake	Use of fast-moving consumer goods	Italy	Bracale and Vaccaro (2020)
Meat And alternatives	Meat	23.83% ↓	Difficulty in finding	Spain	Rodríguez-Pérez et al. (2020)
	Fish	12.11% ↓	Difficulty in finding	Spain	Rodríguez-Pérez et al. (2020)
		33% decreased consumption	Quarantine	Spain	Romeo-Arroyo et al. (2020)
	Nuts and seeds	45% ↓	Increase in prices, elevated stress, disrupted diet and consumption	Zimbabwe	Matsungo and Chopera (2020)
	Eggs	41.8% almost remained same	Individual perception	Zimbabwe	Matsungo and Chopera (2020)
Cereals	Cereals, breads, tubers	41.1% ↓	Extortionate prices	Zimbabwe	Matsungo and Chopera (2020)
Dairy Products	Milk and yoghurt	44.9% ↓	Lockdown	Zimbabwe	Matsungo and Chopera (2020)
Complementary Foods	Vitamin C and Vinegar	37.7% increase	People thought these would help them against covid-19	China	Zhao et al. (2020)
	Supplements	18.2%	To prevent COVID-19 symptoms	China	Zhao et al. (2020)
	Chinese herbs	16%	To cope COVID-19	China	Zhao et al. (2020)

In many observational studies, COVID-19 lockdown has been demonstrated to impact dietary patterns. To date, all aspects of people's lives have been seriously compromised and impaired, leading to increased awareness regarding emotional and mental stress induced by COVID lockdown since the psychological states of human beings are a fundamental part of life (Clemente-Suárez, Dalamitros, Beltran-Velasco, Mielgo-Ayuso, & Tornero-Aguilera, 2020). Di Renzo et al. (2020) observed improved dietary habits during the COVID-19-induced restrictions; a study involving 3533 Italian participants aged 12–86 years, 76.1% of whom were females, tended to adhere to the Mediterranean diet, especially those between the ages of 18 and 30, with an increased uptake of organic foods. According to research done in Kuwait, improvements in eating habits were seen in a study involving 415 individuals aged 18–73 years, including decreased intake of fast food and junk food and increased consumption of fresh, nutritious foods like fish and shellfish (Husain & Ashkanani, 2020). Psychological changes can be difficult to understand since they represent attempts and efforts to cope with challenging and unexpected conditions (Knell, Robertson, Dooley, Burford, & Mendez, 2020).

House confinement has a detrimental influence on stress, concentration, and healthy behaviors. Znazen, Slimani, Bragazzi, and Tod (2021) studied the correlation between cognitive function and lifestyle behaviour during COVID-19 mediated house confinement among 144 students aged 18–22 years with 62.5% of the population being females and observed that just 2.8% of people maintained appropriate eating habits, consuming healthy meals, whereas 69.4% and 27.8% took poor and unhealthy foods. However, there are currently no particular dietary recommendations for post-COVID-19 mental health patients. Unbalanced meals can have a deleterious influence on cognitive and mental health and eating habits can alter cognitive ability (Crispo et al., 2021). There are various drawbacks to web-based surveys, and those who have previously been diagnosed with mental health difficulties fall into the same group. Assessing the influence on cognitive functions and self-reported responses simultaneously may not be the optimal way to ensure that the findings are consistent (See Fig. 2).

6. Physiological consequences and individual immune response

Unhealthy dietary practices especially high in saturated fat consumption stimulate the innate immune system via activation of toll-like receptor 4 (TLR-4) expressed on macrophages, dendritic cells, and neutrophils. TLR-4 stimulates the production of proinflammatory transcript factors such as Nuclear Factor Kappa B (NF-κB) through MyD88-dependent and/or MyD88-independent pathways. It plays a crucial role in developing poor host response against viruses and the progression of diseases with persistent inflammation and (Rocha, Caldas, Oliveira, Bressan, & Hermsdorff, 2016). Furthermore, peripheral inflammation produced by COVID-19 may have long-term effects in individuals that recover, resulting in persistent medical problems such as dementia and neurodegenerative illness, presumably through neuroinflammatory processes that can be exacerbated by a poor diet (Butler & Barrientos, 2020). Pathological levels of neuroinflammation have long been linked to neurodegenerative illnesses including Alzheimer's disease and other kinds of dementia. As a result, severe immune system challenges like COVID-19 may exacerbate the neuroinflammatory response and illness development in sensitive people. There have been cases of dementia in the elderly following viral illness, especially respiratory viruses like influenza, which also corroborate this theory (Honjo, van Reekum, & Verhoeff, 2009).

The interactions of psychological variables with the neuroendocrine and immune systems, as well as the repercussions for higher brain function and human behavior, are studied in psychoneuroimmunology. Individual variations in stress physiology are linked to the brain, which plays a crucial role in evaluating stressors and regulating immune system reaction to physical and social threats, among other variables (Slavich & Irwin, 2014). Furthermore, some aspects of such a scenario, including the stressor's intensity, severity, and predictability, are linked to higher stress reactions. Even after repeated exposure to the same stressor, the physiological stress response is obvious (Seiler, Fagundes, & Christian, 2020).

It's also worth noting that certain social stresses have been linked to alterations in mind-body connections that might have a negative impact on health. The human bodies' physiological response is to increase

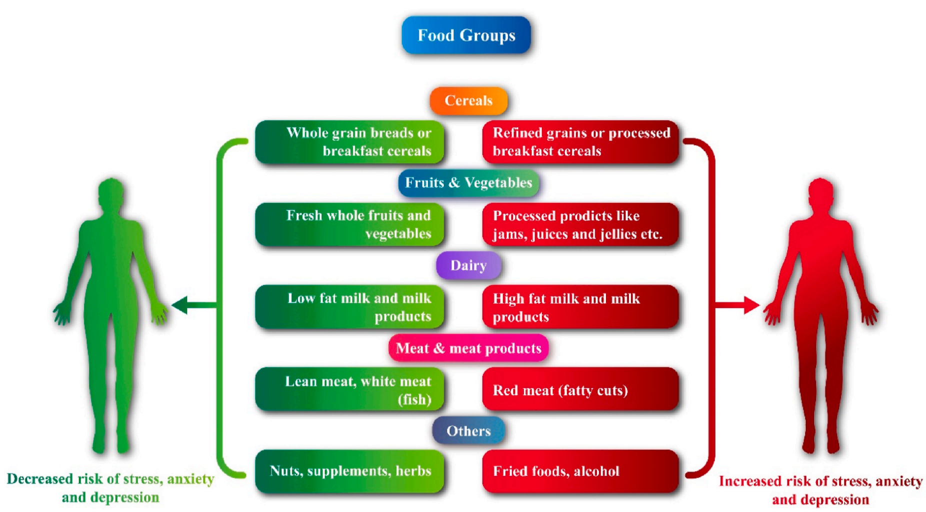

Fig. 2. Dietary behaviors and risk of stress, anxiety, or depression.

alertness and activity (e.g., fight-flight reaction) to enhance survival during the acute stress of COVID-19. Stress hormones from the hypothalamic–pituitary–axis (HPA), such as glucocorticoids and catecholamines (adrenalin/noradrenalin/dopamine), activate the sympathetic nervous system and prepare the body for the stress response (Lupe et al., 2020). Surprisingly, psychosocial stress exposure, such as relational loss and social rejection, might cause changes that can be similar to the disease in the mind-body linkages. Increased activity and response to the hypothalamic–pituitary axis, activation of the innate immune system and generation of pro-inflammatory cytokines can all contribute to systemic chronic inflammation. These dynamics are particularly important about the COVID-19 epidemic, as there are common psychological stresses caused by many individuals, including health, housing, financial, employment and relational losses (Nelson, Pettitt, Flannery, & Allen, 2020).

Social isolation has also been linked to increased (hyper) HPA axis activation and delayed cortisol recovery after stressful situations (Dickerson & Kemeny, 2004). Meta-analyses have linked IL-6 and TNF-levels to the severity of various diseases, including depression, psychosis, and sleep problems. Increased inflammatory activity, as measured by Interleukin-6 (IL-6), Tumor Necrosis Factor (TNF), and C-reactive protein (CRP), has been linked to social isolation. This might explain why previous SARS-CoV-2 transmission in lockdowns has been linked to an increase in the frequency of sadness, anxiety, and other mental problems (Javed et al., 2020). The mental healthcare system is predicted to be burdened due to the large scale and rapid spread of SARS-CoV-2 and the severe life stresses produced by the accompanying public health measures, even if only a small percentage of COVID-19 survivors develop psychopathology (Dedoncker, Vanderhasselt, Ottaviani, & Slavich, 2021).

However, due to individual health states, physiological changes in response to psychological stress in COVID-19-affected people are evident. Stress has also been identified as a risk factor for cardiovascular disease, particularly in women. Stress and depression are linked to immune system inflammation and depression in both COVID-19 and cardiovascular diseases (Mattioli et al., 2021). The inflammatory state features of obese people might aggravate inflammation in COVID-19 patients, exposing them to greater levels of pro-inflammatory cytokines than normal-weight people (Di Renzo et al., 2020).

7. Role of dietary constituents for reducing stress

Poor lifestyle adaptations, anxiety, and quarantine have some long-term impacts on mental health. Following quarantine, a global effort to promote a healthy diet and physical activity may help individuals to return to a healthy living pattern to improve mental health and cope with the stressful post-pandemic era. During adulthood, a higher-quality diet has been linked to a lower incidence of cognitive deterioration. A nutritious diet is an important factor in determining one's overall health as well as a key determinant of mental well-being as endorsed by epidemiological and intervention studies (Emerson & Carbert, 2019; Yang, Kim, & Je, 2018).

Because of the indirect link between improved nutritional status and the prognosis of combating COVID-19 (Li et al., 2021), numerous dietary-nutritional factors can be improved. Appropriate nutrition, as well as physical activity, is recommended to potentially lower the risk of chronic disease and improve the likelihood of having a strong immune system, which may assure rapid recovery and preparedness for a recurrence of COVID-19 or any other respiratory infections (Clemente-Suárez et al., 2020). However, a study reported that anxiety, depression, and insomnia were found to be prevalent in 25.4, 27.7, and 19.6% of the individuals recruited in the study, respectively. Moreover, a study also elaborates on the use of multivitamins, vitamin D, vitamin C, zinc, and selenium in certain populations to cope with stress, anxiety and depression induced during this pandemic (Alfawaz et al., 2021).

According to multiple studies, anti-inflammatory characteristics of very long-chain omega-3 fatty acids such as eicosapentaenoic acid (EPA) and docosahexaenoic acid levels (DHA) are linked to immunomodulation. These may decrease morbidity and mortality associated with COVID-19 infection due to its role in innate or adaptive immune responses. DHA and EPA function by incorporating into the cell membrane and regulating TLR-4 clumping, inhibiting signals that activate NF-κB and thus helping to alleviate COVID-19 complications by producing reduced pro-inflammatory mediators (Hathaway III et al., 2020). An Omega-3 Index (Red blood cells EPA + DHA) in banked blood samples obtained at hospital admission in pilot research of 100 patients was tested. Results suggest that the Omega-3 Index is negatively related to the risk of COVID-19 mortality (Asher and colleagues, 2021). An omega-3 fatty acid is a natural, cheap supplement with anti-inflammatory, immunomodulatory, and other diverse therapeutic characteristics that might play a role as a healthier supplement during this continuing pandemic crisis. Because of changes in the composition of the cell membrane lipid layer, omega-3 fatty acid helps macrophages increase their phagocytic capability. In both the innate and acquired immune systems, omega-3 fatty acids have a role in modulating inflammatory processes and immunomodulation (Gutiérrez, Svahn, & Johansson, 2019). According to the inflammatory theory of depression (Gałecki & Talarowska, 2018), researches conducted within the last decade have revealed that both psychological and physical stresses increase the risk of mental disorders (including depressive disorders) due to the action of several biochemical and hormonal mechanisms, as well as epigenetic mechanisms. The inflammatory theory of depression and higher levels of inflammation in depressed individuals reflects BDNF (Brain-Derived Neurotrophic Factor) as a useful measure for the differentiation between healthy and depressed individuals (Carniel & da Rocha, 2021). In animal studies, omega-3 treatment was found to enhance BDNF levels. A rise in depression has been linked to switching to a diet high in omega-6 fatty acids as evidenced by epidemiological studies (McGrath-Hanna, Greene, Tavernier, & Bult-Ito, 2003). Furthermore, people with depression have decreased amounts of omega-3 polyunsaturated fatty acids (Lin, Huang, & Su, 2010). In a related study, omega-3 PUFAs (polyunsaturated fatty acids) were observed to be helpful in reducing schizophrenia precursors and their early symptoms (Chen, Chibnall, & Nasrallah, 2015). Among PUFAs in treating mental health disorders, EPA is thought to be more effective than DHA. Thereby, optimized omega-3 polyunsaturated fatty acids status could be helpful to prevent infectious diseases, including COVID-19 (Yonezawa et al., 2020). However, insignificant results for treating mental illnesses in transition to psychosis after providing PUFAs to young people were also observed (Davies et al., 2018).

Although people who suffer from depression, anxiety, or sleeplessness take substantially more vitamin D, previous interventions have demonstrated the influence of vitamin D insufficiency on depression but there have been a few studies to establish the link between anxiety disorders and vitamin D levels in the blood (Alfawaz et al., 2021). Vitamin D supplementation, on the other hand, is highly suggested for lowering the risk of COVID-19. Several clinical trials are under underway to evaluate the potential preventive effects of vitamin D supplementation against COVID-19 at various doses and duration (Woods et al., 2020).

Biological variables such as low serum vitamin D levels were also linked to increased psychological discomfort in COVID-19 individuals with mood disorders (Akalu et al., 2021). Vitamin D, through modulating serotonin metabolism contribute to enhance serotonergic neurotransmission in an animal model of depression. The active form of vitamin D, 1, 25-dihydroxyvitamin D3, signals through the vitamin D receptor, inducing the expression of tryptophan hydroxylase-2 and influencing the expression of serotonin reuptake transporter as well as the levels of monoamine oxidase-A and the enzyme that catabolize serotonin. Vitamin D also has a relationship to chronobiological interaction, which may affect the development of depression symptoms when light-dark cycles are out of balance (Ceolin et al., 2021). Although the evidence is varied, one research on vitamin D and anxiety and affective disorders also revealed that age-matched patients with anxiety disorders had lower levels of calcidiol (a vitamin D product generated in the body) (Bicikova et al., 2015).

High-dose vitamin C can be given intravenously or orally and has been shown to protect against COVID-19 without causing serious complications. Furthermore, intravenous administration of a high dose of vitamin C was observed to decrease COVID-19 patients intensive care unit stays by 7.8% and significantly lowered fatality rates (Ceolin et al., 2021). Although vitamin C is an effective antioxidant, it also functions as a cofactor for a variety of biosynthetic and gene regulatory monooxygenase and dioxygenase enzymes, suggesting immune-modulating properties. In a relevant study, Vitamin C supplementation was observed to decrease anxiety levels in a small randomized, double-blind, placebo-controlled trial of 42 high school pupils (Ribeiro, 2015). Although the previous research showed that ascorbic acid has a positive effect in terms of minimizing depression symptoms, reports of unfavorable outcomes are also evident as even after 8 weeks of ascorbic acid (1 g/day) therapy, there was no significant improvement in depression symptoms as measured by the Hamilton scale in individuals taking citalopram (Sahraian, Ghanizadeh, & Kazemeini, 2015). More research on the efficacy of combining ascorbic acid with standard depression therapy is needed, even though the literature supports the idea of utilizing ascorbic acid as an adjuvant in depression treatment.

Vitamin E is an antioxidant, and its deficiency impairs humoral and cellular immunity. Vitamin E supplementation has been shown to protect against hepatitis B virus infection and bacterial pneumonia infection (Woods et al., 2020). Vitamin E is also crucial for the central nervous system, and it has been hypothesized that it may have a role in the prevention and/or treatment of various neurological disorders. Data from clinical trials showed a link between low vitamin E levels and symptoms of severe depressive illness. Vitamin E has been shown to have a positive effect on people's oxidative and inflammatory statuses, which might explain why depressive symptoms are minimized. Vitamin E's antidepressant-like response has been confirmed in preclinical investigations, and the mechanisms behind its action appear to be linked to the regulation of oxidative stress and neuroinflammation (Manosso, Camargo, Dafre, & Rodrigues, 2020).

Vitamin B2 has been shown to lower Middle East respiratory syndrome (MERS) virus titers in human plasma (Keil, Bowen, & Marschner, 2016). Likewise, using an in vitro plaque test, vitamin B2 and ultraviolet (UV) light successfully lowered the titre of SARS-CoV-2 in both human platelet and plasma products to below the detection limit (Keil et al., 2020). Vitamin B3 administration greatly reduced neutrophil infiltration into the lungs in virus-induced lung injury, even on a ventilator, and triggered a strong anti-inflammatory effect, suggesting that it should be ultimately included in the diet during this severe viral pandemic (Woods et al., 2020). A meta-analysis comprehensive assessment of older individuals' micronutrient consumption found that riboflavin and thiamin insufficiency were associated with poor cognitive results (ter Borg et al., 2015).

In addition, vitamin B6 deficiency is known to weaken the host immune response (Woods et al., 2020). Vitamin B6 (pyridoxine, pyridoxal, and pyridoxamine) has a role in brain function and mood control; neurotransmitters, which govern sadness, pain perception, and anxiety, are positively improved by vitamin B6. High homocysteine levels are a consequence of its insufficiency, which has been related to seizures, migraines, and depression. In a related study, a strong link between depression and low plasma pyridoxal levels was observed in 140 people being examined (Hvas, Juul, Bech, & Nexø, 2004). Vitamin B6 supplementation improves mood, psychotic symptoms in schizophrenia, fatigue, cognitive performance, and depression by lowering homocysteine levels in the blood (Malouf & Evans, 2003).

Evidence supports that folate insufficiency could increase the risk of depression during this pandemic (Maffoni et al., 2020). It has been found that there was a low prevalence of serious depression among individuals from Hong Kong and Taiwan with high folate diets. Low folate levels are common in patients who do not react well to antidepressant treatment; folic acid supplementation enhances drug responses (Coppen & Bolander-Gouaille, 2005). Folate supplementation was shown to have an inverse and linear relationship with depression symptoms in 517 Japanese adults (aged 21 to 67), but not in females (Murakami et al., 2008). In a study involving 2682 Finnish men, researchers discovered that individuals with the lowest folate consumption had a greater risk of depression than those with the greatest folate intake (Tolmunen et al., 2003).

Another essential trace element for immune system development and maintenance is zinc. Previous research on the 2003 SARS coronavirus (SARS-CoV) pandemic concluded that a combination of low zinc and pyrithione concentrations impeded coronavirus reproduction. Zinc supplementation has a strong potential for preventing COVID-19 since the SARS-CoV-2 virus belongs to the same coronavirus family as SARS-CoV. Because of the potential action of zinc against COVID-19, combining zinc with chloroquine and hydroxychloroquine has enhanced COVID-19 therapy outcomes (Woods et al., 2020).

Zinc's relationship with depression has been widely studied in both animals and people. Blood zinc concentrations have been observed to be 0.12 g/mL lower in depressed patients than in control participants, according to a meta-analysis of 17 observational studies (Swardfager et al., 2013). Zinc has been shown to have antidepressant-like and mood-enhancing properties in both people and rats in intervention trials utilizing dietary or supplementary zinc (Jun Lai et al., 2012; Sawada & Yokoi, 2010). Similarly, therapy with zinc (30 mg/kg) or imipramine, a conventional antidepressant, reduced depression symptoms generated in mice by chronic restraint stress (Ding et al., 2016).

Trace elements like selenium and zinc are other minerals that help to boost immunity. Selenium levels of COVID-19 patients are linked to their cure and mortality rates. A high level of selenium in the hair has been linked to better therapeutic efficacy in COVID-19 patients. The selenium-dependent enzyme glutathione peroxidases, which is a key antioxidant enzyme for reducing reactive oxygen species and oxidative stress, is believed to be involved in the protective effect of selenium (Woods et al., 2020). Research has also looked at a link between selenium levels and depression because of its neuro-modulatory involvement in brain function. Rodent research revealed a link between selenium insufficiency and lower BDNF levels. As a neurotrophic factor, it has been linked to the pathophysiology of major depressive disorder considerably (Björkholm & Monteggia, 2016). BDNF levels may play a role in mediating the link between selenium insufficiency and depression. Brüning, Souza, Gai, Zeni, and Nogueira (2011) found that administering *m*-trifluoromethyl-diphenyl diselenide, a multi-target selenium-based compound, reduced depressive symptoms in female mice as measured by immobility time in a forced swimming test, indicating that selenium may have an antidepressant effect.

8. Mediterranean diet as a nutritional approach for psychological distress

Diet is a significant predictor of an individual's health, and pandemic-related stress is influencing people's eating habits. Long-term conservation of bad eating habits can put a strain on one's health, especially for individuals who are more susceptible to stress and starvation (Khubchandani, Kandiah, & Saiki, 2020). The Mediterranean diet is now widely regarded as one of the healthiest dietary patterns in the world. Those who are predisposed to COVID-19 infection and associated consequences benefit from following the Mediterranean diet which includes consumption of a wide variety of fruits and vegetables, as well as legumes, whole grains, nuts, seeds, and fragrant herbs, as well as the use of extra virgin olive oil as the primary source of fat. This diet contains high levels of antioxidants, anti-inflammatory compounds, and antibacterial elements. The immunomodulatory characteristic of this diet is a feasible and very simple way to reduce the severity of COVID-19 infection. More *in vivo* experiments and possibly the best clinical trials are in prompt need to investigate the ultimate potential benefits of the Mediterranean diet and/or some of its essential aspects, such as nuts, dried fruits, and olive oil, in preventing COVID-19 infection and/or improving disease-related consequences (Angelidi, Kokkinos, Katechaki, Ros, & Mantzoros, 2021). Individually and worldwide, the COVID-19 pandemic has resulted in significant changes in eating preferences and nutritional practices. According to a major Italian population study, during the COVID-19 lockdown, 35.8% of the surveyed respondents ate fewer nutritious meals and 48.6% gained weight. The Mediterranean diet might be a strategic treatment approach for addressing both short- and long-term problems linked to COVID-19 infection and severity, as well as improving mortality and general well-being in affected populations (Angelidi et al., 2021).

It's worth noting that novel huge research called PREDI-DEP (Prevención con Dieta Depresión/Nutritional Intervention with Mediterranean Diet in the Prevention of Recurrence of Depression) has been initiated to see if a Mediterranean diet supplemented with extra virgin olive oil or nuts may reduce the incidence of unipolar depression relapse during two years of clinical follow-up (Sánchez-Villegas et al., 2019). This might contribute to the findings that the Mediterranean diet reduces the link between comorbidities and depressive symptoms in individuals with severe depression, as reported by an Italian research group in 2020 (Vicinanza et al., 2020).

9. DASH diet implications and psychological health

In the post-COVID syndrome, mental problems, and their symptoms, such as sadness, anxiety, and aggressiveness, are linked to an elevated risk of death. Previous research has indicated that the DASH (Dietary Approaches to Stop Hypertension) diet has beneficial benefits on a variety of illnesses, including diabetes, metabolic syndromes, hypertension, and cardiovascular disease. There have been some researches on the link between such a diet and psychological problems (Daneshzad & Azadbakht, 2018). To identify diet–disease relationships, nutritional epidemiologists now recommend utilizing an overall dietary pattern approach rather than specific nutrients or foods. Such guidelines would help to mitigate the co-linearity issue that might arise when evaluating food and nutrient consumption. However, virtually all prior studies in this sector have focused on the Mediterranean diet, the Healthy Eating Index, or followed local dietary standards, and currently, no known research has been found that has observed the link between the DASH eating plan and psychiatric disorders (J. S. Lai et al., 2014). The DASH diet is a nutritious meal pattern that emphasizes fruits, vegetables, low-fat dairy, and plant proteins from nuts and legumes while limiting red meat, sweets, and sugar-sweetened drinks. This eating pattern has been found to reduce blood pressure in both hypertensive and normotensive people. However, it has also been linked to improvement in obesity, metabolic syndrome, gestational diabetes, type 2 diabetes, stroke, and coronary heart disease. The methods through which the DASH diet may affect mental health are unclear. Given the role of inflammation and oxidative stress in the development of symptoms of depression, the DASH-style diet's positive impact might be related to its ability to reduce oxidative stress and inflammation owing to the high antioxidant content of fruits and vegetables (Valipour et al., 2017).

According to the findings of a meta-analysis, following a healthy eating pattern with high intakes of vegetables, whole grains, fruit, and fish may be linked to a lower risk of depression (J. S. Lai et al., 2014). The DASH diet, which includes high consumption of whole grains, fruits, vegetables, legumes, and nuts, as well as moderate amounts of low-fat dairy, red or processed meats, sweets, and sweetened drinks, has been linked to a decreased risk of depression. DASH diet may be regarded as a viable way of avoiding or treating depressive disorders, given the high incidence of depression and the outcomes of the current study (Khayyatzadeh et al., 2018).

Table 3
Psychobiotic strains used in different neurological conditions.

Neurological Conditions	Psychobiotic Strains	References
Stress	*Lactobacillus helveticus R0052*	Messaoudi et al. (2011)
	Bifidobacterium longum R0175	
	Lactobacillus plantarum PS128	(Y.-W. Liu, Yan, Li, & Zhang, 2016)
	Lactobacillus casei Shirota	Kato-Kataoka et al. (2016)
	Lactobacillus rhamnosus	Bravo et al. (2011)
	Bifidobacterium infantis	Akkasheh et al. (2016)
Depression	*Bifidobacterium infantis*	Desbonnet et al. (2010)
	Bifidobacterium bifidum	Akkasheh et al. (2016)
	Bifidobacterium longum R0175	Messaoudi et al. (2011)
	Bifidobacterium bifidum W23	(E. Barrett, Ross, O'Toole, Fitzgerald, & Stanton, 2012)
	Bifidobacterium lactis W52	(E. Barrett et al., 2012)
	Lactobacillus acidophilus W37	Selhub, Logan, and Bested (2014)
	Lactobacillus brevis W63	Steenbergen, Sellaro, van Hemert, Bosch, and Colzato (2015)
	Lactobacillus helveticus NS8	Liang et al. (2015)
	Lactobacillus lactis W19	(E. Barrett et al., 2012)
	Lactococcus lactis W58	Tillisch et al. (2013)
	Lactobacillus casei	(E. Barrett et al., 2012)
	Lactobacillus casei Shirota	(E. Barrett et al., 2012)
	Lactobacillus casei W56	(E. Barrett et al., 2012)
Anxiety	*Bifidobacterium breve* 1205	Savignac, Kiely, Dinan, and Cryan (2014)
	Bifidobacterium infantis	Desbonnet et al. (2010)
	Bifidobacterium longum 1714	Savignac et al. (2014)
	Bifidobacterium longum NCC3001	Bercik et al. (2011)
	Bifidobacterium longum R0175	Messaoudi et al. (2011)
	Lactobacillus rhamnosus JB-1	Bravo et al. (2011)
	Lactobacillus helveticus ROO52	Messaoudi et al. (2011)
	Lactobacillus fermentum NS9	Davari, Talaei, and Alaei (2013)
	Lactobacillus *casei* Shirota	Benton, Williams, and Brown (2007)

10. Psychobiotic products and impact on mental health

A psychobiotic is described as "a living organism that delivers health advantages in individuals suffering from the psychiatric disease when consumed in appropriate proportions" (Tang, Reddy, & Saier Jr, 2014). The gut microbiota is associated with the brain in a bidirectional linkage, which is known as the microbiome–gut–brain axis. This axis appears to be important in the regulation of brain function and behavior in preclinical studies (Bear et al., 2020). Psychobiotics are a type of probiotics that affect central nervous system functions and behaviors via immunological, humoral, neuronal, and metabolic pathways, improving not only the gastrointestinal function but also antidepressant and anxiolytic capability. They are mediated by the gut-brain axis. The use of psychobiotics has encouraged researchers to focus on a new field in neuroscience as a unique class of probiotics (Cheng, Liu, Wu, Wang, & Tsai, 2019). Some psychobiotic strains (Table 3) have been found to suppress inflammation and lower cortisol levels, resulting in an improvement in anxiety and depression symptoms. Gut microbiota can play an essential role in brain activity and cognitive development by synthesizing hormones, immunological factors, and metabolites, according to data obtained from animal and human research (Misra & Mohanty, 2019).

The intestinal microbiome is identified as a critical connection between the gut and brain growth, mounting evidence points to its major role in stress and affective disorders such as anxiety, depression, and cognition (Bastiaanssen, Cowan, Claesson, Dinan, & Cryan, 2019). It's also been proposed that healthy gut flora is important for serotonin metabolism control. Furthermore, stress can disrupt the gut flora and has a detrimental influence on digestive health. As a result, a high-quality diet may aid in the regulation of the gut microbiota, the reduction of stress and inflammation in the brain, and the maintenance of healthy cognitive function throughout life (Haghighatdoost et al., 2019). Diets rich in omega-3 polyunsaturated fatty acids as DHA, EPA and docosapentaenoic acid (DPA), as well as vitamin A, restored the negative behavioral, cognition, and neurotransmitter impacts of stressed adolescent rats, and led to changes in the microbiome (Provensi et al., 2019).

While the host's genetics and extrinsic variables (such as lifestyle) influence gut microbiota function and structure, the major drivers of gut microbiota structure and function remain dietary elements. The necessity for mechanistic research aiming at identifying the underlying molecular mechanisms of the impact of the gut microbiota on centrally controlled activities is critical. Diets that can influence brain function via bacterial strains generating centrally active metabolites should be investigated in detail in future studies (Adan et al., 2019). The primary benefits of utilizing psychobiotics to sustain mental health during crises like COVID-19 are that, unlike psychotropic medications, they are microorganisms that belong to microbial genera normally prevalent in the digestive system; thus, they may provide a reduced risk of allergies and less reliance on other treatments. Supplementing strains with psychobiotic characteristics would undoubtedly help the host, but future clinical trials will be required to determine their efficacy in treating emotional and behavioral problems especially in this era caused by the COVID-19 pandemic. Effective delivery approaches of these microbial strains must be considered for efficient results. Microencapsulation, the production of edible bars and functional drinks enriched with psychobiotic microorganisms, and the development of appropriate excipients are all possible techniques (de Araújo & de Paulo Farias, 2020).

The presence and makeup of the gut microbiota have been found to affect emotional behavior in animals in several studies. In mice, gastrointestinal infections or inflammation increased anxiety-like behaviors, such as decreased exploration and high behavioral inhibition (Bercik et al., 2010). On the contrary, stress-resilient mice were compared with control (stress-sensitive) mice in a similar study. The stress-resilient animals had more *Bifidobacterium* spp as compared to stress-sensitive control mice. Since various *Bifidobacterium* strains are considered psychobiotic, a rise in their abundance in some of the rats appeared to increase stress resistance (Bear et al., 2021).

Although evidence for the role of the microbiota in the interface between diet and brain processes is growing, and compelling results are available, particularly from animal studies, this field of research is still in its early stages, and one should proceed with caution and not misinterpret the findings. Similarly, diet-related research in animal models may not necessarily be implicated to human populations since the animal food formulations employed in the studies frequently offer dosages that are incompatible with human daily consumption, therefore the translational capacities of these trials or further clinical studies must be considered (Berding et al., 2021). Some limitations in clinical studies include the short length of the intervention and the inability to investigate the effect of probiotic supplementation on inflammatory and oxidative stress indicators. While mixed strains can be openly employed in research, this creates uncertainty in probiotic strain specific activity (Akkasheh et al., 2016). However, more thorough research, including non-stressed treatment groups in some trials, is needed to confirm these findings and draw more clear conclusions about the mechanisms involved in the central effects of probiotics (Desbonnet et al., 2010).

11. Conclusion and future trends

Psychiatric morbidity and dietary changes are evident in different peer groups especially young people during the COVID-19 pandemic. In these challenging times, psychological well-being and dietary habits are crucial but frequently ignored components of well-being. Despite the scientific community's best efforts, which resulted in a plethora of publications of different qualities, significant research on the psychological implications has yet to be completed. COVID-19 and stress or depression as a syndemic affecting the quality of life and the fact that proper nutrition is a critical component in strengthening the immune system against COVID-19 and simultaneously improving mental health. Various nutrient recommendations have been made to adopt a healthier eating behavior, with the Mediterranean diet, DASH diet, and psychobiotics being the most appropriate strategies. Following these recommendations, however, does not appear to be easy, especially given the general public's stress and anxiety, where eating unhealthy but highly tasty foods appears to be the alternative to reduce the chaos and unpleasant mood states in the prevailing COVID-19 pandemic. However, in future aspects, there is a need to understand the role of specific dietary components to mental health issues due to COVID-19 and post-COVID-19 effects taking into consideration of different physiological, psychological, and immunological aspects.

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