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Review

Consideration of Phytonutrients, Probiotics and Prebiotics for enhanced immunity during disaster relief situation – A review

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SUMMARY

Background: Disasters cause diseases, disrupt food supply systems, and expose people to food and nutritional instability. Malnutrition issues, recurrent infections, contaminated food, and inadequate access to essential resources make an already vulnerable population more vulnerable. For the first 15 days, emergency food assistance is of the utmost importance. Nutritional challenges become critical for vulnerable groups and patients for their specific dietary requirements. In addition, infections, foodborne illness, poor immunity is yet another challenge faced by affected population after any disaster.
Method: Relevant literature was searched using Google Scholar, PubMed and other international organization databases using keywords such as “disaster and public health”, “nutrition during disaster”, “food selection in disaster”, “biscuits or food bars for disaster”, “phytochemicals”.
Results: The current manuscript emphasizes on an analytical discussion of already available ready-to-eat foods that are now on the market as disaster relief products. Mortality during disaster is high in vulnerable groups due to their compromised immunity. These populations could be benefitted by providing a disaster relief food with additional immune-boosting nutraceutical properties such as

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phytochemicals, probiotics, and prebiotics. By providing disaster specific foods rich in probiotics, prebiotics and phytonutrients to the immune-compromised population, health consequences associated with disasters such as digestive issues, respiratory illnesses, and chronic diseases can be reversed.

Conclusion: Inclusion of phytochemicals and immunity boosting foods into the disaster relief program will help the population having compromised immunity or metabolic disorders to have better coping strength to the adverse disaster conditions. Although providing adequate amounts of macronutrients is the first practical consideration, phytonutrients and probiotics would be helpful to alleviate a variety of health complications during crises. Phytochemical-enriched ready-to-eat products can be used for additional immunomodulatory benefits in disaster relief. Food products having additional health benefits for disease-specific population should be developed and provided to them for better survival.

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1. Introduction

Natural disasters are disruptive events leading to destruction at levels beyond the coping capacity of the community. These events in one or other form occur year after year and affect the lives of millions of people. Globally, natural disasters are faced by 60,000 people per year and on an average decade are responsible for 0.1% of the total deaths [1]. As per reported, the evidence from 2003 to 2013 affecting approximately 2,50,000 people in 67 developing countries [2]; in 2018 and 2019 Kerala catastrophe led to migration of over 1.5 million people, moreover, having an adverse impact on over 60 villages and vegetation [3]. Natural calamities in Madagascar and Pakistan (in the year 2022) has not only destroyed the infrastructure, roads, and livelihood but also disrupted the production chain; thereby crumbling agricultural sectors, high food prices, and increased food insecurity [4,5].

Post-disasters challenges such as rapid spread of infections, poor food distribution are tougher, and need solid infrastructure [6]. The rapid spread of infectious diseases after a disaster can be attributed to poor hygiene, contamination of eatables during transportation and storage, poor immunity, limited access to healthcare, and vaccinations [7]. Moreover, loss of productivity coupled with the disrupted food system and broken supply chain often generates food shortage, therefore, increasing the risk of compromised nutritional security in vulnerable groups. Wasting is the predominant form of malnutrition in children under 5 years of age living in disaster-hit regions including low and middle-income countries [8]. WHO has declared covid-19 pandemic as a Global health emergency. As suggested by Fore, the first 12 months of covid-19 emergency could further shoot the global wasting rate up by 14.3% accompanied by complications like stunting, micronutrient deficiency, and overweight [9].

Shortage of food resources amplifies the demand for nutrient-dense ready-to-eat food [10]. A joint work done by UNHCR, UNICEF, WFP and WHO suggested use convenient, easy to distribute and shelf-stable food providing about 2100 kcal per individual per day [11]. Disaster relief food is defined as energy-dense convenient food specially designed for the adverse crisis. It is designed in such a way that it is ready-to-use, needs no preparation, shelf-stable, portable for transportation-distribution purposes, culturally acceptable and above all, it correlates with the nutritional needs of the survivors. The emergency food products consist of 10–15% protein, 35–45% fat, and 40–50 % carbohydrates [12]. Low food intake and frequent infections may lead to compromised immunity in affected population. Populations who are suffering from metabolic diseases have special nutritional needs which are not met by the available disaster relief food. Hence, addition of functional foods with their valuable nutraceutical properties could play a progressive role in the distribution programs to prevent infections, non-communicable disorders, and gut-associated complications. Figure 1 represents the need for the development of phytochemical enriched disaster relief foods. Very few studies emphasize the role of phytochemicals as a potential ingredient for an emergency food product. The primary focus of this review study is on the nutritional requirements of immune-compromised and vulnerable populations.

2. Methodology

To understand the basic concept of disaster food relief, studies based on a well-established systemic literature review was considered. This review used various searched databases and three website: Google Scholar, PubMed and other international organization databases including WHO, WFP, UNICEF and UNHCR. Synonyms and alternative words in each category were identified to obtain a current literature. Keywords were used such as “public health”, “disaster and infections”, “nutrition during disaster”, “food selection in disaster”, “biscuits or food bars for disaster”, “phytochemicals”, “immunity boosting food” and so on. The inclusion criteria has database been collected from 2016- 2022 articles consisting of emergency and immunity food related information. This review include all the studies done on public health in emergency, ready to eat food exclusively made for disaster, nutrients and their health in terms of immunity. Studies related to economic expenses and other finance related issues during disaster were excluded.

3. Effect of disaster on health status of population

The occurrence of these extreme events brings forth physical and psychological stresses to the affected population. Furthermore, anxiety, isolation, shortage of food and water, and news of death increase the risk of post-traumatic stress disorders [13]. During emergencies, trauma-related psychiatric disorders are the most prevalent in young children, adolescents, and pregnant and lactating women than in the general population. Indeed, limited access to healthcare units for pregnant women deteriorates maternal and neonatal health [14]. The compromised immune system unshielded the entry of pathogenic bacteria, viruses, and parasites which further elevates the chances of infectious

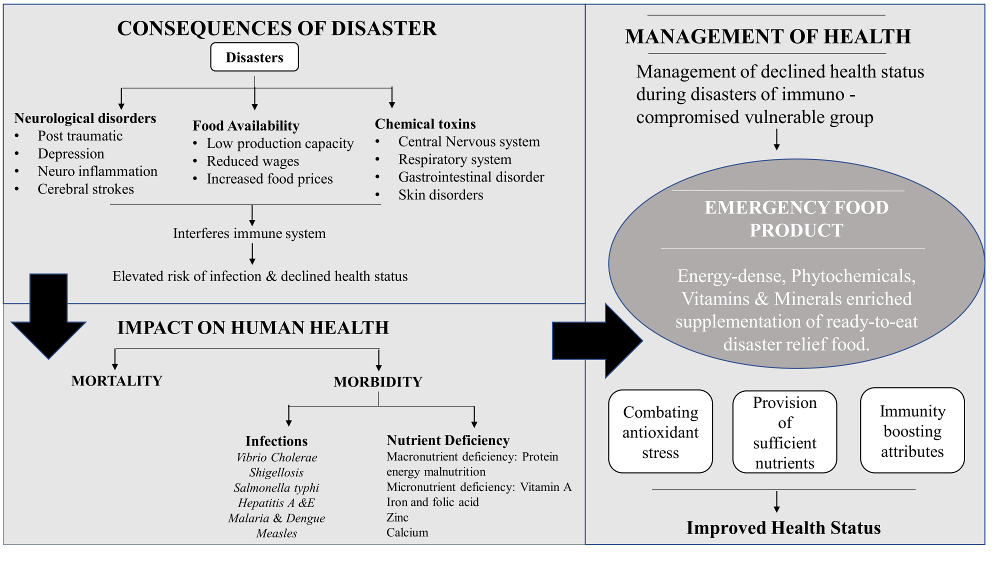

Figure 1. Consequences of disasters on health and its management through supplementation of phytochemical enriched emergency food product. Figure represents hazardous result of disaster imposing a negative impact on health status but it could be restore by emergency food aid enrich with phytochemical constituents.

diseases such as dysentery, diarrhea, typhoid, hepatitis, and cholera [15,16]. Water and foodborne ailments in the post-emergency period ensue from pathogenic dissemination such as *Vibrio Cholerae* (frequent watery stool), *shigellosis* (fever - acute biliary dysentery), *salmonella typhi* (typhoid) and *E. salmonella enterica serotype paratyphi A* (paratyphoid), Citrobacter (gastroenteritis), especially during hydraulic disasters [17]. The diarrheal complication is the cause of morbidity and mortality in children and pregnant women as it impairs metabolism, absorption, and electrolyte balance [18]. Frequent infections with the intake of low nutrient-enrich food exacerbate nutritional insecurity in the population already suffering from malnutrition and other traumas [19]. Therefore, the cyclic chain of low productivity and unavailability of nutritious food to poor health status tends to persist in the long run. However, demand for relevant nutritional intervention is required to optimize the health status of groups at higher risk.

4. Disaster-relief food product considerations for vulnerable group with compromised immunity

Malnutrition and infection create a vicious cycle of frequent diseases that deteriorate health status [20,21]. The emergency crisis and severe food insecurity increase the demand for high nutrient-dense emergency food, if unavailable, leading to worse health outcomes [22]. Hence, some considerations need to be taken care of while designing emergency foods as discussed below.

4.1. Nutritional requirement of the vulnerable group with compromised immunity

The at-risk population which primarily needs to be the focus centre during disaster is infants, pregnant and lactating women, old age, the sick, and the injured. Nutrition becomes challenging for vulnerable groups and patients with chronic diseases such as diabetes, hypertension, and many more having specific nutrient requirements [6,23]. Artificial feeding practices for young children in emergencies can be hazardous as they may lead to infections like diarrhea and malnutrition [24,25].

Age, sex, weight, and levels of physical activity of various groups are used to predict energy needs during a humanitarian situation. The initial step is to set a figure of the energy requirement under the influence of factors: temperature, nutritional status of the population, physical activity level, and demographic characteristics. The energy requirement for adults is 2100 kcal/person/day (obtained from 10% to 12% of protein and 17% in the form of fat). If the temperature of the location decreases, there is an increase of 100 kcal for every drop of 5º below 20ºC. In other words, these calories are added to the initial figure of energy (2100 kcal per person). The final energy requirement is not only affected by temperature but also by physical activity levels and health status. Pregnant women need an extra 285 kcal/day and lactating women require an extra 500 kcal/day than the normal requirement. Pregnant and lactating women are provided with fortified blended food commodities during emergencies for fulfilling their 2/3rd daily micronutrient requirements [11]. Breastfeeding mothers should have a safer environment and encouragement to feed their children, even in stressful conditions [26]. Breast milk has a tailored amount of nutrients for an infant (less than six months) then energy requirement increases at later stages of life owing to growth and development. Therefore, inclusion of complementary feeding along with breast milk becomes a vital part of their diet for extra energy. The complementary food needs to be easily digestible, contains energy 30–40 % from fats and 12% from protein. It is composed of cereals, pulses, oil enriched with vitamin-mineral, and energy supplements [11]. Energy requirements vary for children of different months as 6–8 months 200 kcal, 9–11 months 300 kcal, and 12–23 months of age 550 kcal [28]. Extra 500–700 kcal are given to younger children suffering from severe malnutrition [27]. WHO/UNHRC/WEF/UNICEF emergency guidelines state that older people who are over 60 years of age require fewer calorie intakes due to a decrease in basal metabolism and poor digestibility [11].

An appropriate quantity of micronutrients must also be ensured during infancy, pregnancy and lactation. For instance, WHO suggests high doses of vitamin A supplements during infancy to get rid of infantile mortality [29]; calcium supplements during pregnancy to prevent preeclampsia [26]. To rehabilitate nutritional security, certain micronutrient supplements (in the form tablets or paste) with their appropriate dosages are distributed among vulnerable groups during emergencies to restore their nutrition needs as shown in Tables 1 and 2.

Table 1
Energy and supplementary requirement for the vulnerable group during humanitarian emergency.

Groups	Energy	Supplements	Administration	General functions
Infant (0–6 month)	Exclusive breastfeeding	Zinc	10 mg of zinc dose per day for 10–14 days	Reduces diarrhea and restore water-electrolyte balance
		Vitamin A (if measles)	50,000 IU one dose in 24 h	If measles to provide additional source of immunity
Infant (6–11 months)	Breastfeed plus 550 kcal	Iron	Dose of 2 mg/kg body weight/day for 3 months	After 6 months it is vital to maintain iron stores in the body. Iron helps in the restoration of Hb levels or blood loss from parasitic infection.
		Vitamin A	10, 000 IU one dose per month	Vitamin A helps in providing immunity against viruses, protects from diseases like diarrhea, night blindness and exophthalmia.
		Zinc	20 mg per day for 10–14 days	Zinc reduces the incidence of diarrhea, pneumonia, protein synthesis, cell growth and differentiation
Older infant (12–23 months)	Breastfeed plus 550 kcal	Vitamin A	20,000 IU Every 4–6 months	Eliminate vitamin A deficiency in the geographical prevalent area.
		Zinc	Zinc dose 25 mg/day for 10–14 days	Improvement in gastrointestinal health.
PEM in infants	+500 to +700 kcal	Vitamin A (<6 months) (6–12 months) (>12 months)	50,000 IU/day 100,000 IU/day 200,000 IU/day	To improve vitamin A bio-availability, reduce mortality due to infection and sever acute malnutrition. To eradicate eye-related problems
		Iron	Dose of 2 mg/kg body weight/day for 3 months	
Pregnant woman (anemic women)	+285 kcal	Iron	30–60 mg elementary iron daily	To prevent iron deficiency at the gestational period and moderate to severe anemia.
		Folic acid	0.4 mg of folic acid daily	Folic acid prevents neural tube defect and also improves maternal and fetal outcomes.
		Calcium (area low in dietary Calcium)	1.5–2.0 gm/day	Reduce pre-eclampsia.
		Vitamin A	10,000 IU/day	Vitamin A helps in cellular and skeleton development in fetus, immunity against infection.
Pregnant non-anemic women	+285 kcal	Iron	120 mg elementary iron, once/ week	Iron and folic acid builds iron store in the fetal body, reduce anemia and other complication like nausea and constipation in mothers.
		Folic acid	2.8 mg, once/ week	Vitamin A helps in cellular and skeleton development in the fetus, immunity against infection.
		Vitamin A	10,000 IU/day	
Lactating woman (HIV positive)	+500 kcal	Iron and folic	Same as pregnant women	Maintenance and development of the maternal iron store.
		Vitamin A	20,0000 IU/dose	Provides immunity to infant and mother and prevent vitamin A deficiency.
		Iodine	250 μg/day 400 μg/year	Provision of iodine to infant exclusively on breastfeeding for growth and maintenance.
		Antiretroviral drugs	In exclusive breast feeding period	Improves neonatal outcomes and prevention of transmission of virus in infant body.
Elderly (+60 years)	<2100 kcal	fortified blended food	25 g per package	Fulfill dietary micronutrient deficiency.

Information updated from [11,25,26,29,107,109,110].

Table 2
Micronutrient requirement per day

Nutrients	Child (6–59 months)	Adults	Pregnant women	Lactating women
Vitamin A (μg)	400	500	100	350
Vitamin C (mg)	30	28	20	20
Thiamine-B1 (mg)	0.5	0.9	0.1	0.2
Riboflavin B2 (mg)	0.5	1.4	0.1	0.3
Niacin (mg)	6	12	1.1	2.7
Folic acid (μg)	150	160	250	100
Vitamin D (μg)	5	3.8	7.5	7.5
Iron (mg)	10	22	60–120	17
Iodine (μg)	90	150	50	50

Information updated from [11,110].

4.2. Identification of health-promoting constituents and ingredient selection for vulnerable group with compromised immunity

The primary prerequisite for food to be supplied for disasters is that it should be nutritionally rich, acceptable by local culture and religion, and a certified label for the safe-to-eat product [11]. In accordance with basic nutritional recommendations, it is essential to adopt a diversified diet that includes whole grains, legumes, fruits, and vegetables and limit the amount of food that contains excessively concentrated salt and sugar [30].

To select appropriate ingredients/food groups for the preparation of foods for disaster three-phase multidimensional approach has been proposed [31]. The authors identified and evaluated eleven food groups (dry cereals, nuts, dried fruits, grams, legumes, dried meat/fish, dry nonfat milk, eggs and fresh fruits, vegetable, meat, fish) based on Drewnoski's naturally nutrient-rich (NNR) score for nutrient density against 14 key bases (protein, calcium, folate, zinc, iron, monounsaturated, fatty acid, potassium, vitamin A, B1, B2, and B12) and then classified their utility as a component of disaster response diet. Out of these entire food groups, nuts and dried fruits received more acceptability via selection criteria based on aspects such as energy density, cultural acceptance, ease of storage and handling, ready-to-eat, and affordability.

However, specific ingredient selection for disaster relief foods must also focus on non-nutritive components such as phytochemicals, probiotics, prebiotics and their attributes. These components do not add to the nutrient value but exhibit various nutraceutical properties and health benefits.

4.2.1. Phytochemicals

Phytochemicals are secondary plant metabolites having high antioxidant activity, which is having the potential to prevent and combat communicable and non-communicable diseases in vulnerable group during disaster (Figure 2). The natural sources are vegetables, fruits, nuts, legumes, and whole grains [32]; which are associated with the treatment of chronic diseases such as cardiovascular diseases, diabetes, gut microbiota, oxidative stress, cancer [33], inflammatory bowel diseases, and obesity. These are flavonoids, terpenoids, carotenoids, phytosterols, glucosinolates, and fiber [34].

Flavonoids are polyphenolic compounds that are widely distributed in fruits, vegetables, cocoa, legumes, tea, and soy [35,36]. It possesses a broad spectrum of anti-inflammatory, anti-viral, antimicrobial, and antioxidant properties. Flavonoids are found in many different species of plants and can be subdivided into flavonols, flavones, flavanols, flavanones, anthocyanidins, proanthocyanidins, and isoflavones. A study reports that the consumption of flavonols such as quercetin and catechin can effectively suppress the risk of CVD, diabetes, cancer, cognitive problem [32], Parkinson's disease, Alzheimer's disease, metabolic syndrome, and upper respiratory tract infection [37]. Quercetin and vitamin C exhibit synergistic relations by re-oxidizing quercetin and enhancing its antiviral and immunomodulatory effects on the body [38]. Moreover, some animal model studies propose quercetin's prebiotic activity (bifidobacterium aldolescentis) that enhances the growth of probiotic (Lactobacillus rhamnosus), therefore, assisting in the removal of a pathogen (Salmonella Typhimurium) and inflammation caused by nitro-oxide inhibitors in the gut microbiota [39]. Dietary sources for quercetin are honey, apple, red onion, cherries, grapes, citrus fruits, and green leafy vegetables [40]. Foods

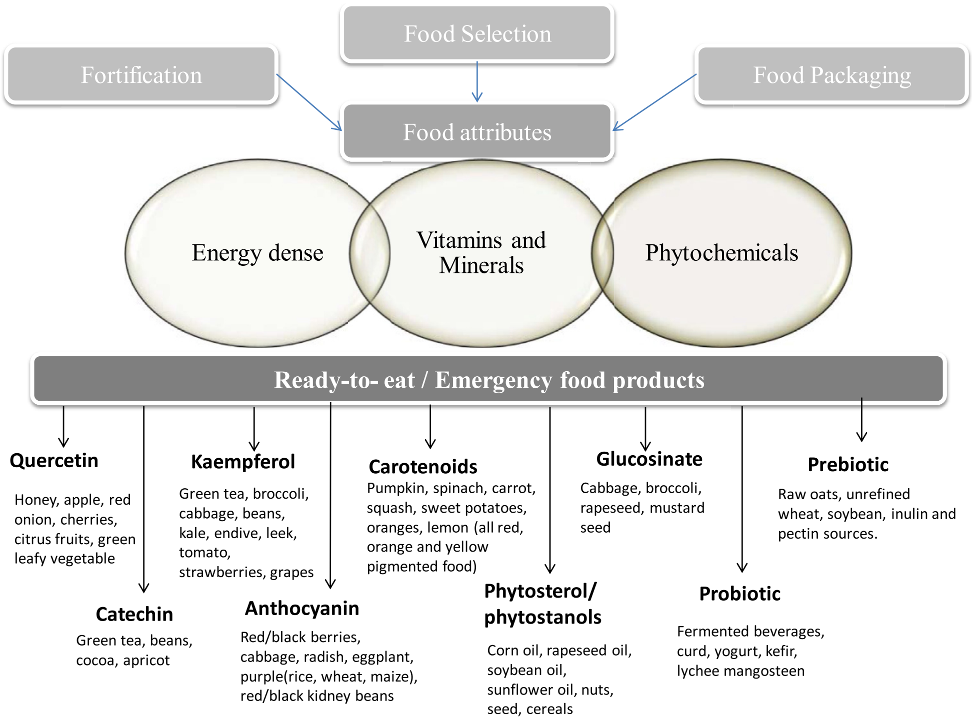

Figure 2. Sources for ingredient selection for designing immunity-boosting food for disaster relief. Consideration and ingredient selection for disaster relief food.

containing high amounts of catechin are green tea, beans, cocoa, wine, and apricot [41,42]. Catechin and anthocyanin are alternative sources to antibiotics as the study reports their antimicrobial effect against foodborne pathogens (Escherichia coli and Salmonella) [43].

Anthocyanin and flavonol present in pomegranate potentially increases the immune response against viral diseases related to foodborne/intestinal, HIV, Herpes and other viral diseases [44]. Foods containing high concentrations of anthocyanin are black carrot, berries (especially red and black current), red cabbage, radish, eggplant, purple or red rice, wheat and maize, black/red kidney beans [45,46]. A study show that resveratrol present in grapes could potentially decrease risk of chronic obstructive pulmonary disease [47] because it's strong antioxidant activity (produce GHS synthesis, TNF-alpha, TL-6, and TL-18 at inflammation area) [37] and Cranberry has antimicrobial and antioxidant properties, increases immunity [22,43], and hinders the attachment of H. pylori to the stomach wall [48].

Other flavonol-kaempferol work on allergic airway inflammation, decrease the infiltration of eosinophils in the airways and block their degranulation in the lung tissue [36]. Similarly, administration of 20 mg/Kg per body weight of kaempferol in guinea pigs has reduced inflammatory cytokines (IL5, IL-13, GM-CSF), eosinophil count in bronchoalveolar lavage (BAL) fluid, and TGF-ß1 protein level in lung tissue [49]. Thus, it increases the lymphocytic concentration in the blood to revert infections such as the common cold, especially among old aged people experiencing immune-senescence [48]. A study reports that 0.1–0.3% of kaempferol pre and post-fed mice progressively decrease ulcerative colitis. Foods rich in kaempferol are tea, broccoli, cabbage, beans, and kale [50].

Phytosterols and phytostanols are not commonly produced in the human body because they are not absorbed in the intestinal cells [33] but are taken through external dietary sources. Sitosterol, campesterol, sitostanol, and campestanol are the broad categories of phytosterols and phytostanols. It is present in vegetable oil such as corn oil, rapeseed oil, soybean oil, sunflower oil, nuts, seeds, and cereals. This phytonutrient inhibits cholesterol absorption, thus, reducing the carcinogenic activity of cells [50]. Although some studies demonstrate phytosterol's positive effect on insulin levels, the dose for such components is higher (approximately 1–2 g/day) than the recommended dietary allowance (200–300 mg/day) [52].

Carotenoids are present in red, yellow, and green-colored fruits and vegetables, namely, pumpkin, carrot, broccoli, squash, spinach, and sweet potato. Alpha-carotene, beta-carotene, lycopene, zeaxanthin and lutein are some types of the carotenoid [53]. Xanthophyll, yellow pigment, does not serve provitamin A content but eradicate the risk of cancer, tumor growth, CVD, dysbiosis, age-related degeneration, inflammation [33]. According to Dhinaut et al., proactive vitamin A functions as a possible antioxidant, lowers tissue damage and cellular damage in response to high oxidative stress, as well as anorexia, pneumonia, measles, diarrhoea, and eye-related disorders [54]. The recent study elucidates the beta-carotene benefits against the severity of ulcerative colitis in dextran sulfate sodium-induced rats-the most significant changes observed by body weight and microbiome proliferation of *Faecalibacterium*, the levels of which negatively correlated with the level of pro-inflammatory cytokines [55]. Another study reports that carotenoid-rich foods intake has increased serum immunoglobulin levels in rabbits. Thus, this activates innate and humoral immunity and ameliorates the mechanistic defense [56].

Curcumin is now studied to be an effective food that can have potential benefits to the SARS-coV-2. As it has been reported antiviral in nature, this bioactive component hinders invasion of the virus into healthy cells by increasing levels of interferons in the body. Curcumin is extracted from turmeric plant (*Curcuma longa*), an antiviral agent, has been able to suppress several viruses such as influenza, hepatitis and HIV, and could reduce the activity of covid-19. Curcumin and zinc together form an ionophore complex that alleviates viral activities [57]. Several studies report that the addition of curcumin nanoemulsion enhanced its oral bioavailability, allowing its use as a phytochemical in individuals [58]. Numerous studies also showed that the integration of curcumin nanoemulsion enhanced its oral bioavailability, allowing its use as a phytochemical in people. A study found that giving diabetic rats treated with alloxan and different doses of turmeric extract—100, 300, and 500 mg—significantly decreased their blood glucose levels while increasing their serum insulin levels [59]. Various recent researches have proven that this substance has anti-diabetic properties [60–63].

Glucosinolate is present in the cruciferous family of vegetables, especially the Brassica spp. (e.g. cabbage, broccoli), oilseeds such as rapeseed and in condiments such as mustard seed [34]. The daily intake of glucosinolates is in the range of 10–50 mg and for vegetarian or vegan diets, it must be as high as 100 mg/d [33]. Allyl isothiocyanate is a bioactive compound that possesses anti-tumor, antimicrobial, and anti-fungal properties which prevent parasitic infection and spoilage of the food product from microbial attack [64].

Thus, inclusion of above discussed phytochemicals could prove to be a great weapon in preservation the health if included in disaster relief food for vulnerable groups.

4.2.2. Probiotic and prebiotics

Probiotic and prebiotics have a significant role to play in maintaining for body's immunity against gut infections. The most well-known species of probiotic microorganisms that affect the gut-associated immune system are streptococcus, bifidobacteria, lactobacillus rhamnosus, and lactobacillus reuteri during disaster. Traditional probiotic food considers some of the beverages, salty fishes, fermented milk, and products like yogurt, a variety of cheese, and kefir [65]. *Saccharomyces boulardii*, a probiotic yeast, found in lychee mangosteen fruits is associated to reduce diarrhea and other gastrointestinal complication in children (6 months–5 years of age) [66]. By forming a biofilm (soluble protein) between the cells of the intestinal epithelium to prevent the attachment of the pathogenic bacteria, Lactobacillus (LGG) modifies the gut microflora. Interleukin (IL)-10, IL-12, TNF-alpha, and macrophage production are consequently encouraged. In addition to being able to get rid of entero-pathogenic bacteria like Escherichia coli and vibrio cholera through defecation, Saccharomyces boulardii also produces IgA, IgM, cytokines, and kuffer cells. Antibiotic-related diarrhea is prevented by kefir beverages made from kefir grain [67]. Prebiotics can be found in breast milk, soy, inulin-rich foods, raw oats, unprocessed wheat, and other foods. For instance, inulin and pectin are the soluble fibre promotes probiotic proliferation in the ileum and ascending colon. They are also linked to decreased frequency and length of diarrhea while enhancing the body's ability to absorb and utilise nutrients [68].

While formulating a food product for disaster management some food attributes are taken under account such as nutrients composition, food fortification and durable package [69]. Both nutritive and non-nutritive bio-active components can be found in foods such grains, legumes, nuts, vegetables, fruits, and fermented foods. The main emphasis is on specific foods that, in addition to providing energy, have a significant impact on boosting immunity and recovering from nutritional deficiencies due to their high concentration of phytochemicals and probiotics. Immune-compromised conditions as digestive problems, respiratory disorders and chronic diseases can be reversed by the use of nutrients like anthocyanin, quercetin, catechin, kaempferol, carotenoid, curcumin, phytosterol/phytostanol, *Saccharomyces boulardii*, inulin and pectin. Inclusion of Antioxidants and Polyphenols could exert health benefits to effected populations having co-morbidities. Since, not all food ingredients contain all the essential nutrients and nutraceutical compounds, efforts must be taken to incorporate these together into a single formulated product.

5. Nutraceutical compound enriched disaster relief food for vulnerable group with compromised immunity

Several processed food products have been formulated and scientifically tested by food technologist for its nutritional and nutraceutical health benefits, which has the potential to be incorporated in disaster-relief foods. Considering the prerequisites as discussed in previous section, these food products are discussed in this section.

Biscuits and cookies have been used in feeding programs for a long time as they are easy to carry, have a high shelf-life, and are tasty. The development of low-cost high-calorie biscuits were used to eliminate prevailing PEM in Ethiopian children in 1985 [70]. Biscuits can easily be fortified with various flour and other ingredients to enrich the nutritional value of the product (Table 3). Koya was used into the biscuit mix to boost the protein content. In Indonesia, snakehead fish is the primary source of koya [71]. Another formulation involved the biscuit made from fresh white oyster mushroom using different fats. This study aimed to increase energy from protein rather than fat to meet the basic requirement of emergency food [72]. Apart from this, these mushrooms also contain 32 bioactive compounds and rich phytochemicals: saponin, flavonoids and steroids [73,74]. In a recent study, researchers evaluated the phytonutrients (alkaloids, flavonoids, saponins, and tannins) in plantain flour and found that oven drying is preferable to sun drying for improving quality [75]. The preparation oven baked plantain cookies with 15% bambara groundnut protein concentrates have significantly enhanced crude protein, fiber and energy of the cookies [76]. Similarly, the addition of 10% whey protein concentrate in wheat flour biscuits improves the protein, fat, and mineral content of the biscuits. This formulation can effectively be used in a child feeding program to combat protein-energy malnourishment in 4–8 years of children [77]. Akande et al. incorporated 15% of edible insect powder made from freshly harvested mulberry silkworm pupae and frozen locust into biscuits to increase protein content and vitamin minerals like vitamin A, vitamin C, calcium, potassium, iron, and phosphorus [78]. These biscuits contain protein, fat, energy, and are slightly rich in fiber, ash, and carbohydrate; moreover, it scored satisfactory results in the sensory analysis. Energy-dense rice biscuits and cakes are prepared with high-yield varieties of rice (BRRI). It meets the nutritional and phytochemical (flavonoids, phenolic content and antioxidant) requirement of an emergency food product and prevents malnutrition and non-communicable diseases. The product got approved as emergency food in Bangladesh by WFP [79,80].

The food bar is another form of convenient food for disaster relief because it has a firm texture, low water activity, easy handling and distribution [81]. Food bars are manufactured commercially using different ingredients to enhance the nutrient bioavailability, palatability, and satiety level of the product. Zahra et al., formulated a low-cost nutrient-rich food bar using dried apricot paste, roasted chickpea and barley, and puffed rice as main ingredients [82]. While this is going on, numerous research [83–88] evaluated the existence of phenolic acid, -carotene, -carotene, -cryptoxanthin, and zeaxanthin contents, quercetin, glycoside rutin, resveratrol, and vanillin. The barley samples contained 64 different chemicals that could be identified, which contained 27 anthocyanins, 19 phenolic acids

Table 3
Nutritional composition of different emergency food products

Food product	Main ingredients	Composition (100 g)	Energy (kcal)	Carbohydrate (g)	Protein (g)	Fats (g)	Micronutrients	References
Proso millet and Snakehead fish biscuit	Proso millet, koya, tapioca flour	40 and 10 respectively	503.3	56.3	12.5	26.3		RBK Anandito et al., 2015
White oyster mushroom biscuit	White oyster mushroom with palm oil	25	241.5	56.7	13.1	22.6	Calcium, phosphorus, potassium and sodium.	Cornelia et al., 2019
Wheat whey protein biscuits	Wheat flour and whey protein concentrates	90 and 10 respectively	360.3	65.67	20.12	1.91	magnesium, potassium, phosphorus, calcium and sodium	Ahmed et al., 2019
Locust powder insect based Silkworm powder base biscuit	Silkworm powder, locust powder, high protein quality maize, orange-fleshed sweet potato	45, 120 and 36 g respectively	438.8 484.2	44.9 34.1	25.1 28.2	17.6	vitamin A, vitamin C, calcium, potassium, iron and phosphorus	Akande et al., 2020
Energy dense rice biscuit	Broken rice or unparboiled milled rice flour, sagu	30–35 g rice flour	559	4.7	10	36	Zinc, iron, calcium and phosphate.	Shozib et al., 2018
Energy dense rice cake	powder, rice bran oil, xanthan gum		550	48	10	30	zinc, calcium and phosphate	
Plantain cookies	Plantain flour and bambara groundnut protein concentrate	170 and 30 g respectively	458.6	48.3	14.6	23.4		Kabari et al., 2015
Banarsi bar	Sweet potato flour with BAL, omega-3, omega-6, iron and zinc	0.1% of BAL, Fortified with 98 mg omega-3, 1.9/gm omega-6, 5 mg zinc oxide, 6 mg ferrous sulphate					omega-3, omega-6, iron and zinc	Rachmat et al., 2019
Nutri-bar	Dried apricot paste, roasted barley powder, roasted chickpea powder	8, 1.5, 1.5 g respectively	339.8		9.4	6.8		Zahra et al., 2014
Red rice flour and yellow pumpkin flour bar	Red rice flour and yellow pumpkin flour	50 and 50 g	144.2	26	2.1	4.5	Calcium, phosphorous, vitamin A, C and B1.	Miranti et al., 2016
Nike flour bar	Nixtamalised cornmeal, nike powder and corn flour	2.77, 6.69 and 9.37 respectively	469.8	64.4	7.1	20.2	Calcium and niacin	Kasim et al., 2017
Mangrove bar	Mangrove flour, broccoli flour and soybean flour		495	60.4	3.8	24.2		Fatmah et al., 2021
Mushroom moringa leaf soup	Soy flour, mushroom and moringa leaf powder	10,5 and 8.5 g respectively	386.7	58.8	16.3	6.3	Vitamin D, C, sodium, potassium, manganese, iron and zinc.	Farzana et al., 2017
Fish powder soup	Fish powder and corn flour	10 and 34 g		65.7	9.3	1.4		

						Rahman et al., 2012
Super cereal plus CSB+ (acute malnutrition in 6–23 months children)	Corn/wheat/rice soya, milk powder, sugar, oil, vitamin and minerals.	100–200 g	394–787	16–33	10–20	WFP (2013)
Super cereal plus (acute malnutrition in pregnant lactating women)	corn/wheat/soya/rice and vitamin and mineral mix	100–200 g	376–752	15–31	8–16	
Plumpy'sup (moderate acute malnutrition)	Peanut, sugar, whey, vegetable oil, milk, soy protein, cocoa and vitamin and mineral	92 g sachet	500	13	31	
Wawa Mum (children 6–23 months suffering from acut malnutrition	Chickpea, sugar, vitamin, mineral, vegetable oil, milk powder and soya lecithin	100 g sachet	520	13	29	
Acha Mum (children 6–59 months suffering from moderate acute malnutrition)	Chickpea, sugar, vitamin, mineral, vegetable oil, milk powder and soya lecithin	100 g sachet	520	13	29	

and aldehydes, 9 flavan 3-ols, and 9 flavone glycosides [88]. Development of bar to increase protein bioavailability from local ingredients-like flour made from nike fish and nixtamalization corn flour; is not only a good source of minerals (calcium and niacin) [81] but also anthocyanin (cyanidin-3-O-glucoside) [89]. Another bar prepared using red rice flour and yellow pumpkin flour is more applicable for survivors with chronic disorders. The product contains sufficient amounts of energy, fiber, antioxidants, and vitamin A, C, and calcium that help in the prevention of gastrointestinal and non-communicable disorders [90]. Red rice has the highest quantity of tocotrienols and tocopherols compared to black, brown polished rice, and it also has the highest flavonoid content [91]. The formulation of three different types of soy bars - high fructose corn syrup and crystalline fructose (HFCS/CF), Corn syrup/granulated sugar (CS/GS), and corn syrup/high fructose corn syrup (CS/HFCS). Based on proximal, chemical, and organoleptic analysis CS/GS receives higher acceptability. The product resulted in protein 18.3 g, fat 23.9 g, ash 4.8 g, vitamin A 372.8 IU, and folic acid 1.1 mg but some vitamins such as thiamine and ascorbic acid were lost during the baking method [92]. To resolve malnutrition and stunting in toddlers, Banaras bar was prepared using sweet potato flour fermented with *Lactobacillus bulgaricus*, Lactic Acid Bacteria and further fortified with iron, zinc, and Omega-3 and Omega-6. The resultant bar is soft and less compact than a regular bar, improved height and gut activity in children, and increased availability of omega 3, zinc, iron, and beta carotene [93]. Fatmah et al. carried a 15-day food interventional study by adding a food bar as a supplementary snack in older people's routine diet [94]. Keeping nutrition for old age as the main focus, the food bar was prepared using three basic flour-broccoli, soybean, and mangroves flour. The broccoli-soybean mangrove food bar is an energy-dense supplementary snack that has shown a slight improvement in body weight in underweight individuals and potentially meets 14–16% of the energy requirement of an old man or woman. In addition to this, the food bar got an overall organoleptic acceptance as disaster relief aids. Adlai, a Filipino cereal grain, is dense in energy, offers a fair quantity of protein, carbohydrates, dietary fibre, calcium, phosphorus, iron, niacin, thiamine, and riboflavin and may be the finest substitute for rice. Additionally, it satisfies the need for micronutrients that can be effectively used in disaster aid, such as calcium, iron, phosphorus, thiamine, and riboflavin [95].

The preparation of instant sweet potato cream soup made from beef broth, full cream milk powder, and dried sweet potato puree provides at least 30% of the protein requirement in 375 g of formulation for kid's breakfast [96,97]; phytochemical quality of sweet potato vary by food processing, even though it is a rich source of beta carotenoid [98]. Farzana et al., prepared vegetable soup using local ingredients-soybean flour, mushroom, and moringa leaf and are adequate for an emergency food product. The protein content of the soybean is higher than other plant resources and rich in essential amino acids like lysine and tryptophan. Mushroom is the richest source of protein, lysine, leucine and vitamin B1, B2, B12 (excellent source), folic acid, niacin, vitamin C and D. Moringa leaf is an excellent source of ß-carotene, protein, tocopherols, vitamins (A and C), minerals (calcium and potassium) and essential sulfur-containing amino acids [99]. Another quick mix vegetable soup was prepared for controlling diabetes by using sprouted horse gram and has a shelf life of up to one month [100]. Emergency food faces a shortage of problems for animal resources, incorporation of dried fish powder has been best included in the form of instant mix soup [101] and instant flour of tuna fish and tempeh flour [102]. This could be the best possible way for the availability of micronutrients and combat protein malnutrition [101].

Children who are suffering from wasting were furnished with therapeutic milk, ready-to-use therapeutic foods, ready-to-use supplemental food and micronutrient supplements during the recent pandemic covid-19 [103]. Ready-to-use therapeutic food (RUTF) formulation follows certain attributes such as non-water-based formula, providing adequate nutrients for the recovery, safely stored at room temperature, longer shelf life, acceptable, easy to use and can be used along with breastfeeding. RUTF use ingredients like peanut, oil, sugar, milk powder, vitamin and mineral supplements [27]. World food programme served 24 complementary foods for children in Pakistan called *Wawa Mum* or *Acha Mum* food that needs no preparation and is made from protein-rich locally available ingredient - chickpea paste [104,105]. Infant food formulation made of soya, maize, and sorghum has significantly reduced severe acute malnutrition and increased iron bioavailability for children of 6–59 months [106]. While providing children with high-protein, energy-dense foods in standardized serving sizes, such as lipid-based vitamin supplements and fortified blends, according to their age. Furthermore, small sachet of micronutrient powder added after preparation. Lipid-based nutrient supplements (LNS) product is a lipid based-paste or spread provided with different dosage according to the vulnerability of groups [107]. For instance, for severe acute malnutrition, a dosage of 200–300 g per day is given in large dose which follows up to 12 kg LNS in one-course treatment. This particular formulated dose provides about 200 kcal/kg body weight/day [108]. Fortified blend food is prepared using a mixture of cereals, pulses, oilseed like sunflower and sesame, sugar, and vitamin and mineral supplements are basic ingredients. There are many examples of fortified blend food as super cereal CSB+ (for pregnant and lactating women), CSB++ super cereal plus (for an infant) [11,21]. The detailed composition of several such foods is provided in Table 3.

A handful of the food items described above have elements that are naturally rich in nutrients and meet the needs of macro, micro, and phytonutrients. These include fresh white oyster mushrooms, plantain flour, red rice, high-yield rice grain (BRRI), nixtamalized maize flour, sweet potato puree, and moringa leaves, all of which have the potential to treat a variety of illnesses and are well suited for usage in food banks. However, there are not many products that offer the assertion to fix immunity-related issues. Therefore, this justification points to the need for emergency food items that include phytochemicals that successfully address public health problems.

5. Conclusion

Problems related to malnutrition, frequent infections, food contamination, and limited access to basic needs develop long-term onset for food and nutritional insecurity. This further elevates the rate of morbidity and mortality among the vulnerable group. Dependence on food aid increases the vulnerability of an already susceptible population. Ready-to-eat foods are the foremost priority that fits to run a practically successful disaster relief program. Currently available emergency food product mainly focuses on providing palatable, energy-dense food with a long shelf life. Phytonutrient and prebiotics and probiotics have shown to have potential health-promoting benefits and immune-modulatory effects. Incorporation of these immune-boosting, nutraceutical compounds would be beneficial to treat various health complication during an onset of disaster, which would further help in reducing the disaster induced mortality. Food industries should focus on developing phytonutrients and probiotic and prebiotics enriched ready-to-use immunity-boosting food products for the disaster relief program. This would help to enhance the nutritional status with additional health promoting benefits to immune-compromised and vulnerable population during disaster. Sendai framework for disaster has target 1 which aims for substantially reduce global disaster mortality by 2030, aiming to lower the average per 100,000 global mortality rate in the decade 2020–2030 compared to the period 2005–2015. In achieving the target, the above suggested considerations and recommendations would be an immense help in achieving the target of substantially reducing the global mortality in disaster and make our society more resilient during disaster.

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