Traditional fermented foodsin Nigeria and Covid-19: A Possible Approach for Boosting Immune System

P.N. Anyiam[1*], P.N. Onwuegbuchu[2], C.L. Ekemezie[3]

[1]Department of Biochemistry, College of Natural Sciences, Michael Okpara University of Agriculture, Umudike, PMB 7262, Umuahia, Nigeria
[2]Department of Microbiology, Faculty of Biological Sciences, Abia State University, P.M.B 2000, Uturu, Abia State, Nigeria.
[3]Department of Microbiology, College Of Natural Sciences, Michael Okpara University of Agriculture, Umudike, PMB 7262, Umuahia, Nigeria

IJASR 2020
VOLUME 3
ISSUE 6 NOVEMBER – DECEMBER **ISSN: 2581-7876**

Abstract: Covid-19 has spread all over the world since itoriginated from Wuhan City, China in late 2019.While a careful search for an effective treatment is still on-going, nutritional strategies to promote immunity to possibly face the infection should not be ignored. Recently, there hasbeen anincreased interest on fermented foodsdue to their enhanced nutritional values and health benefits.In Nigeria, the most common of these traditional fermented foods are; tuber based fermented products (*Fufu, Garri, Lafun*), cereal based foods and beverages (*Kwunu, Pito, Agidi, Pap or Akamu*), vegetable-based fermented condiments (*Ogiri, Dawadawa, Ugba*) and animal fermented products (*Nono*and*Kilishi*). In addition to their improved nutritional quality, these fermented foods may also deliver viable microbes know as probiotics to balance the gut microbioataand therefore have the potential to boost immunity which in turn protects the body against infectious diseases like Covid-19 and other diseases.

Keywords: Covid-19, Fermented foods, Health benefits, Immune system, Nutrition, Probiotics

1. Introduction

Since the beginning of Covid-19 outbreakwhich is caused by a severe acute respiratory syndromecoronavirus 2 (SARS-CoV-2)-in late 2019 from Wuhan City,China, it has spread all over the world exhibiting large and significant geographical variations in the number of infected people and death rates between and within countries[1].Ithas also brought social and economic crisis not just in Nigeria but also in other developing countries, which is rapidly exacerbating theon-going food insecurity in the country.Malnutrition and other co-morbidities (such as Diabetes, cancer hypertension, tuberculosis, obesity) are considered risk factors for complications in people with Covid-19[2,3]mainly due to a compromised immune system with oxidative stress as a common pathway.

Thoughdemographic factors such as such as age, sex, occupation and education level, seasonal variations, immunity and timing of interventions are more relevant factors that are associated with increased incidence of Covid-19 and its mortality rate[4], other factors like nutrition, probiotics, nutraceuticals, environment and diet should not be ignored completely because these factors can as well beof interesting options in mitigating the impact of Covid-19 and preventing itscomorbidity.While a deep search for effective vaccines or drugswhich can be able to interfere with the SARS-CoV-2 pathway is on-going, nutritional strategies to boost the immunity against the infection and its spreadare imperative.

Certain fermented foods may deliver viable microbes with the potential of providing some health benefit to the host by boosting the immunity [4]. Such foods have long been an integral part oflocal cultures and traditions of human diet in developing countries [5,6]due to their nutritional and health benefits.Fermented foods are a very diverse family of foods, which differ in their nutritional values, microbiological compositions and metabolites with potential health effects[7]. Fermentation itself is a food processing technology whereby the growth and metabolic activities of microorganisms are used to transform and preserve foods. It is an inexpensiveand simple process that requires comparatively little energy, prolongs the shelf life of the original food, and making food nutrients more digestible[8-10]. Production methods of different traditional fermented foods were passed down to subsequent generations in different regions as family traditions where they are generally produced using plant or animalingredients in combination with microorganisms which are either sourced spontaneously from the environment, or carefully kept as starter cultures.

Mostrural communities in Nigeria are economically depending on fermented foods as the primary source of nutrition for nourishment, as well as for cultural traditional practices, since the major staples in the region (Cassava, yam, maize) though provide enough calories butthey are poor in essential nutrients needed to support life [8,11].Each region in Nigeria has its own distinctiveness in terms of food culture and heritage where fermented foods are included which depends on type of raw food material available in that particular place, which play very important role in the socio-economics development of the country as well as make major contributions to the protein requirements of the rural population which couldplay a mitigating role against the economic effects of Covid-19 especially on food security by reducing the rate of malnutrition and hunger in the region.

Despite the importance and potential health benefits of fermented foods in Nigeria, their preparation methodsstill remains a household art till date.Very little is known about these traditional fermented foods and their benefitsdue to scarcity of informationin the literature and the fact that they are only knownto those people residing in the area where such foods are produced and consumed. Therefore, this reviewis aimed at assessing the standard methods of preparation and consumption of common traditional fermented foods in Nigeria, and also discussed thehealth benefitsassociated with the consumption of these fermented foods.

1.1 Traditional fermented Foodsin Nigeria: Production methods

A wide range of fermented foods and beverages are produced in Nigeria. Such foodsare derived from the local staples (cassava, yam, rice, maize, wheat etc.) whichare prevalent in various localities within the country. Many names are applied to these traditional fermented foods throughout Nigeria which differ by region and ethnic groups. Most common fermented foods produced from these staples in Nigeria are; *Garri, Fufu, Lafun, Amala, Massa, Agidi*and *Ogi (Akamu).* Fermented beverages include *Kwunu, Mmanya-ngwo* (palm wine), *Pito, Burukutu* and fermented condiments include *Dawadawa and ogiri.*Fermented animal products include *Nono* (fermented milk), *Washainu*and*Kilishi* (fermented meat) (**Table 1**). These fermented foods are inexpensive and affordable for many individuals in the community.They are of sociocultural and nutritional value and are marketed for income generation. Most of the traditional fermented foods are primarily produced at household level usingN largely uncontrolled spontaneous inoculation methods in which microorganisms associated with the raw food material and the processing environment serve as inoculants [12]. The preparation method and mode of consumption of these fermented foods are highlighted according to food types;

1.2 Fermented Tubers (Cassava and yam meal)

1.2.1 *Garri*: Thisis a high energy food commonly consumed in Southern parts of Nigeria but it is also popular among the inhabitants of Northern and Eastern Nigeria. Itisa creamy-white granular flour with a slightly sour taste made from fermented gelatinized fresh cassava tubers. Nigeria is one of the leading producers of cassava in the world with an annual production of 35-40 million metric tons [9,12]. Over 40 varieties of cassava are grown in Nigeria and cassava is the most important dietary staple in the country accounting for majority of all food crops consumed in Nigeria [9,12]. Despite its vast potentials, the presence of hydrogen cyanide (HCN) is the most important problem limiting cassava utilization in the country [9]. Many varieties of cassava grown in the country are poisonous due to presence of HCN and would cause death in man and animals if consumed directly without fermentation which detoxifies HCN.

In preparation of *garri*from cassava, the tubers are harvested, cleaned, peeled and washed in clean water. The washed cassava is groundin a mill and the pulp is transferred into a cloth bag and tied before being subjected to heavy pressure at room temperature for 3 or 4 days to remove excess water and ferment. The fermented pulp is then sieved and dry-fried with or without palm oiladded (optional) to produce *garri* flour. The flour can be reconstituted in hot water into a paste, cooled and consumed with various soups and stews or it can be soaked in cold water with salt or sugar added before consumptionwith groundnut or coconut as snack.The flour, when properly fried and stored away from moisture, has a shelf life of about three months.

1.2.2 Fufu (Fermented Cassava meal)

Fufu is a fermented white paste made also from cassava which is ranked next to *garri* as an indigenous food of most Nigerians. It is widely consumed in Eastern Nigeria, especially among the Igbos but also available in the Western part of the nation. In preparation of *fufu,* thecassava tubers are peeled, washed, cut into thick chucks (say 20cm long) and soaked in water in earthen ware pots or plastic bucket for 4 to 5 days. During cold weather, the tubers

should be properly submerged in the waterand the container may be kept closer to the cooking stand in the kitchento fasten the fermentation and softening process.

During this period, the cassava tuber ferments and softens, releasing the poisonous hydrogen cyanide (HCN) in the soaked water and producing a characteristic flavor [9]. The softened tubers are then disintegrated in clean water, sieved and the starchy particles that go through the sieves are allowed to settle for about one or two hours. The water is decanted while the sediments is packed into a cloth and bag, tied, squeezed and subjected to heavy pressure to expel excess water. The resulting starch is rolled into balls, cooked in boiling water (100°c) for about 30 to 40 minutes. The cooked mass is pounded in a mortar with a pestle to produce*fufu* paste which can be eaten with sauce, soup or stew.

1.2.3 Lafun or Elubo (Cassava Flour)

Lafun is a fibrous powdery form of fermented cassava similar to *fufu but* the production process slightly differs from that of *fufu*. It is commonly produced and consumed in Western States of Nigeria and is also available in Eastern part of the country. *Lafun*is prepared from cassava tuber. Basically, the cassava tuber is peeled and soaked in water for 3 to 4 days to ferment. Afterwards, the soaked water is drained off and the fermented cassava dried in the sun. The dried product is ground in a mill into flour known as *Elubo*. The flour is added into boiling water with constant stirring until a smooth thick paste is formed. The paste is allowed to cool and is then served with any kind of vegetable sauce or soups.When properly stored, *lafun* have a shelf-life of up to six months [9].

1.2.4 Amala (Fermented Yam flour)

Amala is a popular food consumed in Western Nigeria. It is prepared from yam (*Discoreaspp*) tuber. Theyam tuber is washed and peeled, then cut into very thin slices and left in the sun on a tray or mat for 4 to 5 days to ferment and dry. The dried yam slices are milled into flour then cooked for few minutes in hot water with constant stirring until thick dark brown dough like paste (*amala*) is formed. The characteristic flavor and dark color of *amala* which is found objectionable by some people is due to enzymatic and non-enzymatic browning reactions and the presence of polyphenols in the yam [9], which can be minimized or prevented completely by blanching the yam slices in boiling water for 2 minutesbefore fermentation or drying to inactivate the enzyme responsible for the browning reactions.

1.3 Cereal based fermented food products

Generally, grains lack some basic nutrients such as essential amino acids and certain vitamins [9,10]. Fermentation of cereals is a simple way to improve their nutritional value as well as their sensory and functional qualities [10]. Fermentation decreases the level of carbohydrates and non-digestible polysaccharides and oligosaccharides in cereals and increases the synthesis of certain amino acids and the bioavailability of the vitamins [13]. In addition, fermentation also significantly reduces the content of non-nutrients in cereals, such as polyphenols, phytates and tannins [10]and increases the content of nutrients like free amino acids and their derivatives. The activities of some enzymes such as amylase, phytase, hemicellulase and protease increase, which results in improved shelf-life, digestibility and nutritional value [13]. It has been noted that during fermentation, cereals also have increased antioxidants activity [14]. Some of the cereal based fermented foods in Nigeria are as follows;

1.3.1 Ogi/Akamu/pap (Fermented maize starch)

Ogi (Akamu or pap) is another traditional fermented food consumed in Nigeria which is prepared from fermented maize (*Zea mays*). It is a staple cereal product of mainly the theYorubas, and is the first natural food given to babies at weaning [9]. The process of preparation basically consists of soaking the maize in water for one to three days to ferment and develop a characteristic odour. The softened maize is washed, ground into a meal with a blender or mill. The ground material is mixed with water and sieved to remove parts of the hull and other fibrous materials. The filtrate which is almost pure starch suspension is placed in a pot so that starchy material sediments at the bottom of the pot. The supernatant is decanted and the wet starch poured into cloth bags, squeezed and dewatered until a semi-solid corn starch is produced. This is stored in a cool place from where samples can be taken from the stock and cooked into *ogi or akamu* which is usually served hot with table sugar to enhance the taste and can be eaten with*akara* (bean cake), fried yam or bread.

1.3.2 *Massa* (fermented rice meal)

Massa is a fermented product made from rice or millet. It is consumed in various forms by all groups especially in Northern States of Nigeria. It is the principal ingredients for a variety of cereal-based foods and is a good source of income for the women who prepare the traditional product for sale. The problem of Massa apart from the short shelf-life is that of low protein content [9]. However, cowpea, groundnut or soybeans flour could be added into *Massa* during preparations to improveits nutritional quality. Basically, *Massa* is prepared from rice flour. The raw rice is firstly soaked in water for 8 hours or overnight and washed. Then blend together with already precooked rice with a gradual addition of water while controlling the texture and thickness. Add the yeast and set the mixture aside for 5 to 8 hours or overnight to ferment. After the fermentation process is completed, fry the batter in batches with little oil in a pan until they turn golden brown. Massa can be served with honey, sauce or any condiment of choice.

1.4 Fermented beverages:

1.4.1 Kwunu: This is a non-alcoholic fermented beverage prepared from millet andwidely consumed in Northern parts of Nigeria. To prepare *kwunu*, first, the millet is ground in a mortar with pestle to remove the husk and release the kernels. The kernels are washed and left to dry on a mat under the sun for 8-12 hours. The dried kernels are then ground into flour and mixed with little cold water before pouring it into a pot of hot water with constant stirring until a thick smooth paste is formed. The paste is left to ferment for 1 to 3 days so as to develop a sour flavor after which it can be consumed. The flour can also be made into a watery gruel known as *kwunuzaki* and consumed hot or cold with ginger, pepper and sugar to taste. The product has a shelf-life of about 24 hours at ambient temperature, which can be extended to 8 days by pasteurization at 60 ^{0}C for 1 hour [9] and stored under refrigeration condition.

1.4.2 Pito/burukutu

Pito is cream colored liquor while *burukutu* is a brown colored suspension, both of which are brewed from sorghum, millet, maize or a mixture of these cereals. Both drinks are brewed concurrently by fermentation of malted or germinated cereals. For instance, sorghum grains are soaked in water for 24hrs, drained and kept for 2 days to germinate. After sprouting, the grains are sun dried and ground into flour. The flour is mixed with water and boiled for 3 to 4 hours to form slurry. The boiled mash is allowed to settle at the bottom and water is decanted while the sediment which is a thick brown suspension is known as *burukutu.* Each fraction is decanted into a clean calabash pot where it is allowed to stand and ferment for 24 hours at room temperature for proper flavor development, after which the drink can then be consumed. *Pito* and *burukutu* are widely consumed in Northern Nigeria. The alcoholic content of *burukutu* is slightly higher than that of *pito.*

1.4.3 Mmanya-ngwo (Palm wine)

Thisis the fermented sap of palm tree which is obtained in Nigeria by the tapping of the inflorescence of the palm tree. The wine is a milky suspension of microorganisms (especially yeasts) in a fermenting palm sap. It is a popular refreshing and nourishing beverage consumed in most parts of Nigeria, especially Southern and Eastern Nigeria, and is also a major ingredient in the manufacture of local bread because of its naturally high content of yeasts. Fresh palm wine is sweet and has virtually zero alcohol contents, but the palm sap ferments easily and become sour in few hours after collection.

1.5 Fermented condiments

The fermentation of fruits and vegetablesis very popular as a means of preservation in various local communities in Nigeria, because untreated fruits and vegetables are highly perishable.The fermentation of fruits and vegetables is mainly by lactic acid fermentation that acts spontaneously when conditions are favorable for the fermenters, especially lactic acid bacteria, which are the dominant microorganism in this type of fermentation [8, 15, 16]. The conventional substrates for condiments productions from vegetables are diverse and each can be produced from more than one raw material. The methods employed in the production of these condiments foods differ slightly from one region of the country to another because these processes are based on traditional systems. Common traditional fermented condiments in Nigeria are as follow;

1.5.1 *Dawadawa or Iru:*

This is an important fermented food condiment and protein source produced from African locust bean (*Parkiabiglobosa*) and consumed extensively throughout Nigeria as a condiment to add flavor to various dishes and

soups. In the unfermented state, African locust bean is non-edible because it contains high quantity of trypsin inhibitors and flatulence causing oligosaccharides which are anti-nutrients [8,9]. After fermentation, the hard inedible beans are converted into a soft and palatable nutritious condiment with a sweet pleasant flavor and improved vitamin content. Basically, production of *Dawadawa* consists of boiling the locust bean seeds for 1 to 2 days to soften the hard seed coat.

After softening, the seed coats are removed by finger pressure, releasing the cotyledons which are reheated for up to 2 hours. After the second boiling, the cooked water is decanted and the cotyledons spread in basket lined with blanched banana leaves. The seeds are also covered with several layers of banana leaves and left 2 or 3 days to ferment in the natural heat of the tropics. Wood ash may also be added which is then sun dried for 2 days before consumption. When properly dried, *Dawadawa* can be kept for up to a year in a shelf under tropical conditions [8]. Production of *Dawadawa*provides useful nutritional supplements in a nutrient deficient region at a little cost in capital among traditional processing techniques. In poor families, it can be consumed generously as a low cost substitute to meat.

1.5.2 Ogiri:

This is also a fermented condimentprepared from the castor seed (*Ricinuscommunis*) which is a major oil seed common in Africa and other parts of the tropics [8]. Different types of *ogiri* exist depending on the starting raw. Such as *Ogiri-ugu*which is made from fluted pumpkin (*Telfaireaoccidentalis*) seeds whereas *Ogiri-egusi* is prepared from melon (*citrullus vulgaris*) seeds. All types of *ogiri*have similar preparation method. Raw castor seed is not edible because of its toxic constituents such as ricin and hemagglutinis as well as trypsin inhibitor [9]. However, the seed can be fermented and detoxified into a seasoning called *Ogiri*, used as a condiment in soups or stews. Basically, the preparation consists of dehaulling the castor seeds, wrapping the dehaulled seeds in blanched plantain leaves and boiling for to 8 hours and allowed for 4 days to ferment. Later, the seeds are mixed with ash from burnt palm leaves and then ground into a paste. The resulting paste is rewrapped and left for another 3 days to complete the fermentation process. Heat and characteristic foul odour from the product indicates that fermentation has been completed.

1.5.3 Ugba (fermented African oil bean)

Ugba is prepared from oil bean (*Pentaclethramacrophylla)* seeds and are eaten by many people in Eastern Nigeria, which comprises mainly the Igbo ethnic groups as well as other ethnic groups in Southern Nigeria. The condiment is produced in a traditional way at home with rudimentary utensils and can be also consumed either as snacks, salads or as a soup flavor. The unfermented oil bean seed is bitter to taste and contains a toxic alkaloid. Fermentation renders the *Ugba* seed nutritious and non-toxic [9].

To prepare *Ugba*, the seeds are boiled in water for over 12 hours to soften the hard seed coats. The boiled seeds are then dehaulled to produce the cotyledons or kernels while the seed coats are discarded. The kernels are cut into long narrow slices (about 0.2 cm thick), washed, boiled for 1 or 2 hours to remove the bittering substances and the cook water discarded. Then the *Ugba* slices are soaked overnight (12 hours) in a pan fully covered with water. The soaked water which also contains part of the bitter substance is now discarded and the sliced samples washed and placed in a basket to drain completely. Then the *Ugba* is placed in small portions in blanched banana leaves, wrapped and left to ferment for 2 to 3 days at room temperature. Fermentation for more than 4 days produces very soft Ugba used only in soups.

Table 1: Traditional fermented foods in Nigeria

Fermented food	Raw material	Location	Type of product
Ogi/Akamu/pap	Maize	West	Beverage
Kwunu	Millet	North	Beverage
Fufu	Cassava tuber	East/South	Food
Garri	Cassava tuber	All region	Food
Lafun	Cassava tuber	West	Food
Massa	Rice or Maize	North	Food
Ugba	Oil bean	East/South	Food
Dawadawa	African Locust bean	West	Condiment

Ogiri	Castor or Melon seed	East/south	Condiment
Mmanya-ngwu	Palm sap	East	Beverage
Pito/burukutu	Maize/Millet	West	Beverage
Nono/washainu	Cow milk	North	Beverage
Kilishi	Cow meat	North	Meat

1.6 Fermented Meat products: *Kilishi*

Fermentation of meat produces desirable organoleptic properties, such as aroma, texture and taste [17], good nutritional valueand important health benefits [18]. A popular Nigerian locally prepared meat product is known as *Kilishi*.It is the most popular traditional dry-cured semi-fermented meat product in Nigeria which is made from whole muscle of cow. It is the cheapest means of preserving meat and widely consumed and enjoyed by mostly Northern Nigerians. The production of*Kilishi* involves drying, curing and pressing the meat and then adding a *cemen*powder-which is a traditional spice made from the combination of red pepper and garlic [9]. Many physical, microbial, biochemical and organoleptic changes occur during the production of *kilishi*, such as proteolysis, which increases the levels of free amino acids, and the addition of cemenimproves the taste and flavor of *Kilishi*

1.6.2 *Nono/Maishanu*

Nono is a cow milk-based fermented delicious and refreshing beverage which is widely produced in Northern Nigeria for nutrition and income generation. It varies according to sociocultural and taste preferences and generally practiced among the Fulani herdsmen. Traditionally, milk is obtained freshly from cow and boiled for 3hrs and inoculated with a little of leftover as starter and then is allowed to ferment for 24 hours at room temperature. During fermentation, some of the lactose is converted to lactic acid by the fermenting microorganisms. At the end of the fermentation, the milk butter (*Maishanu*) is removed by churning for further use and the remaining sour milk which is *nono* has youghurt-like taste and is usually taken with sugar. It is an excellent source of proteins and minerals especially, calcium, phosphorous and vitamins [9]. It is more readily available in the northern states of Nigeria. The collected *Nono* can also be molded into *Wara* (soft cheese) which is also delicious.

2.1 Nutritional benefits of fermented foods

Nutritional benefits associated with food fermentation include extension of shelf life, enhancement of food quality and nutrients, improving digestibility and bioavailability of nutrients, enhancement of the sensory properties (flavor, aroma and texture, taste, colour), reduction in toxic and anti-nutritional factors, decreases in cooking time and energy requirement and delivery of probiotic bacteria [4,10,19]. Lactic acid bacteria and yeast create a low moisture content and pH which are unfavorable conditions for growth of spoilage and pathogenic microorganismsthat may decompose or spoil the food, thereby extending the shelf-life of the foods, especially for highly perishable foods.

Fermentation can also enhance nutritional properties in a safe and effective manner. The enzymatic activity of the raw material and the metabolic activity of microorganisms in fermented food can change the nutritive and bioactive properties of the food matrices in a manner that has beneficial consequences for human health.Traditional fermented foods are among the most affordable sources of vitamins, minerals and plant-based proteins, which are essential for good health [10]. During fermentation, bacteria synthesize vitamins, minerals, organic acids and produce biologically active peptides with enzymes such as proteinase and peptidase and remove some non-nutrients [9,10].The B-vitamins including folate (B_9), riboflavin (B_3), and cobalamin (B_{12}) are synthesized from various non-vitamin precursors by certain bacteria during fermentation [20,21]. The microorganisms involved in the fermentation of indigenous foods also improve the sensory properties by producing favorable volatile end products which promote the growth of fermenting bacteria and protect against pathogenic microorganisms [22].

Also during fermentation, microbial amylase hydrolyses carbohydrate into sugars which are then readily digestible by humans. Galactinase, (another microbial enzyme) soften the texture of the seeds and liberate sugars for digestion [23]. Most legumes which contain large amount of non-digestible carbohydrates are associated with abdominal distention and flatulence in humans but fermentation reduces the total flatus in legumes [10]. In most fermented high protein products, the extent of protein hydrolysis is one of the most important factors responsible for texture and flavor seen after fermentation. Soluble low molecular weight peptides and amino acids that contribute to flavor are also produced through the enzymatic breakdown of proteins [10,24]. Some polysaccharides produced

duringfermentation act as prebiotics which are further fermented by the microbiota in the colon to favorable short chain fatty acids with health benefits.

Additionally, fermentation results in the removal of toxic or undesirable food constituents such as phytic acid (9,10] which is an anti-nutritional compound that chelates divalent importantmetal ions reducing their absorption and bioavailability. The reduction of pH as a result of lactate production during fermentation optimizes endogenous phytase activity thus removing most phytate and increase the bioavailability of essential mineralsthat helps maintain immune system.

2.2 Fermented foods and probiotics

Microorganisms contributing to the food fermentation process have recently been associated with many health benefits and these microorganisms (probiotics)have become another focus of attention in nutrition and wellbeing. By definition, probiotics are live microorganisms that when administered in adequate amounts confer a health benefit on the host [25,26]. Studies have found that the intake of probiotics resulted in minor but consistent improvements in several metabolic risk factors in subjects with metabolic diseases and particularly in insulin resistance [1,4,27].

Different types of bacteria (e.g, *Lactobacillus, Bifidobacterium, Streptococcus, Bacillus*) and *yeast* or *mold* (e.g, *Saccharomyces, Aspergillus, Candida*) are used as probiotics [28]and studies showed that indigenous fermented foods and beverages may serve as a suitable carrier for these probiotics. Many fermented foods and beverages products are processed such that viable microorganisms are present at the time of consumption and a relatively large fraction of those microbes survives passage through the human digestive tract [29,30]. The ingestion of fermented foods containing probiotics potentially increase the numbers of microbes in the diet by up to 10, 000-fold [31] and consuming these fermented foods could be equivalent to introducing new beneficial microorganisms into the intestinalmicrobiota.

It is very important to note that fermented foods are not same as probioticsbecause not all fermented foods contain live microorganisms. Taking beer and wine as example, which undergo further steps after production that removes the organisms and other fermented foods such as bread are heated at higher temperature which inactivates the microorganisms in the food. Therefore, the strain composition and stability of the microorganisms in traditional fermented foods arenot clearly understood [7]. However, when fermented foods and beverages are supplemented with probiotic bacteria, they serve as nutraceuticals and provide numerous extra nutritional and health benefits.

2.3 Health Benefits Associated with Fermented Foods

In the past, the health benefits of fermented foods were unknown and so many people primarily used fermentation only to preservefoods and improve theirsensory qualities.Recently, it is increasingly understood that these fermented foods also promote human health in ways that are not directly attributable to the starting unfermented food materials. Nowadays, fermented foods have become an important part of the diet in many cultures and have recently emerged as a novel functional food with many health benefits that gobeyond basic nutrition. Fermented foods generally have the potential to lower the risk of carcinogenesis, atherosclerosis, oxidation, tumors, obesity [32], inflammation [27], mutagenesis, hypercholesterolemia effects [33], stimulating the immune system [34,35]and alleviating the symptoms of lactose intolerance [36].

Recent human clinical studies on fermented foods support this possibility. For instance, large cohort investigations revealed strong associations between consumption of fermented foods and weight maintenance [37,38].Another long-term prospective study shows reductions in risk of cardiovascular diseases and overall mortality from frequent yogurt consumption [39]. Similarly, An *et al*.,[40]and Choi et al., [33] showed that *kimchi* (a fermented food) possesses health beneficial effects especially on people with pre-diabetes by inducing insulin sensitivity and decreasing insulin resistance.In addition,fermented rice has been shown tohave beneficial effect on hypertension and metabolic syndrome and may prevent some lifestyle diseases [41]. Another similar study showed thatfermentedfoodsreduce fatigue and stresses [42] and protects against oxidative stress induced by DNA damage [43]. Also, fermented foods have been proved to help the liver against the free radicals produced by copper accumulation [44].

The health benefits provided by fermented foods could be attributable to the bioactive compounds formed during fermentation process and other metabolites produced by the microorganisms responsible for fermentation [45].Physiologically-active peptides with different functionalities, phytochemicals, free amino acids and their

derivatives,volatile compounds and organic acids are all produced by various microorganisms during the food fermentation [9,10]. Due to their bioactivities, these peptides possess the potential to be used in the formulation of health enhancing nutraceuticals that may play different physiological roles in the body. For instance, conjugated linoleic acidwhich is a metabolite produced during fermentation; have a blood pressure lowering effect [46]. Another bioactive compound called exopolysaccharideisnatural polymer of sugars that are produced biologically by various microorganisms during fermentation [47,48]. Due to the potential health benefits associated with exopolysaccharides, which include anti-oxidant, anti-diabetic, anti-carcinogenes, cholesterol lowering and immunomodulatory properties, the compound has recently become a focus of interest by researchers [49,50].

Free amino acids and its neurotransmitter derivatives (Gama-aminobutyric acid-GABA) which regulate blood pressure against cardiovascular and cancer and also possessimmuno-modulatory function are synthesized during fermentation [51]. The free amino acids and GABA contents of fermented foods also contribute to its anti-diabetic and anti-oxidant properties [52] and havealso been shown to have potential chemo-preventive[53], hypolipidemic and anti-inflammatory effects [54]. Lactic acid (a major end-product of food fermentation) has been reported to reduce pro-inflammatory cytokine secretion in a dose dependent manner [55]and also alters redox status by reducing the reactive oxygen species burden in intestinal enterocytes [56].

Apart from the bioactive compounds which are produced during food fermentation, several studies have shown that probiotics contained in fermented foodsalso provides several health benefits [10,24,28]. For example, ingestion of vibrant probiotics through fermented foods is found to cause significant positive improvements in balancing intestinal permeability [57], having direct effects on metabolic syndromes, atherosclerosis, inflammatory bowel diseases [27], colon cancer enhanced immune system and improve gastrointestinal function [4,10]and indirect effects on depression, anger, anxiety and levels of stress hormones [58].Studies have revealed that *Lactobacillus spp*which are common organisms in fermented foods could reduce the risk of infections, including bacterial vaginosis [59,60]. It could also reduce the occurrence of gonorrhoea, chlamydia, and other sexually transmitted diseases and diarrhoea [61]. Many fermented foods are high in vitamin C and iron, both of which help the body to fight against infection by contributing to a healthy immune system.

2.4 Effect of fermented foods on human immune system

Imbalance in the gut microbiota is associated with the pathogenesis of various diseases [1,62,63], including hypertension, diabetes mellitus, cancer, obesity and cardiovascular diseases which are considered risk factors for complications in people with Covid-19. Different levels of evidence have supported the role of nutrition and fermented foods in balancing and promoting immunity [1,4,28,64,]andrecent reports have shown that some of the countries with low Covid-19 mortality rate are those with a relatively high national consumption of traditional fermented foods [3,4]. The human gut is home for over 200 species of bacteria collectively known as the gut microbiotawhichlive mutually in gut of humans [62]. These microbes help break down food in the intestines, aid in the digestion process, help fight off disease, and boost the immune system [3,63]. The immune isthe group of cells and molecules that protect us from disease by monitoring our body and responding to any foreign substances they perceive as threats, particularly infectious microbes [10].

Recently, fermented foods have regained popularity as part of diets due to the interest in their significant impact on the gut microbiota balance and immune system. The importance of the interactions between the gut microbiota and the immune system is clearly highlighted by the fact that majority (about 80 per cent) of the body's immune cells are found in the human gut[4,63]. As a consequence, the immune system and the gut microbiota developed a mutualistic relationship regulating one another and cooperating to support each other.This means that when gut health is imbalanced, it is difficult for the body's immune system to function properly [65,66] and this may increase predisposition to inflammatory and immune-mediated diseases.According to Stiemsma*et al.,*[67], frequent consumption of fermented foodswhich contain probiotics may help improve the immune system's function by balancing the human gut microbiota.

The administration of probiotics through fermented foods has been shown to alter the composition and functionality of the gut microbiota thereby modulating the immune system to fight infections and diseases [4,10,65]. Moreover, having an active and natural variety of microorganisms in the gut may improve general health since the good and healthy microorganisms in the gut make food more digestible through their enzymes which also help also to maintain immune system [65]. Therefore, probiotics contained in fermented indigenous food may restore the

composition of the gut microbiome and introduce beneficial functions to gut microbial communities and thereby boosting the immune system to fight infections [67].

Apart from the effects of probioticson gut bacteria, the systemic effects of bioactive peptides which are produced during fermentation also possess some immuno-modulatory effects [10]. In a study to determine the serum cytokine profiles of healthy volunteers after consuming *Kefir* (fermented beverage), it was reported that immune cells (TNF-α) levels were increased with *Kefir* consumption, though the increase was not significant [68]. Again, consumption offermented foods and beverages improves the bio-accessibility and bioavailability of food bioactive components, supplying dietary fibers, essential micronutrients, enzymes and organic acids, all of which are crucial in boosting the immune system. Short chain fatty acids which are produced from insoluble dietary fibers by certain microbial species in fermented foods also promote the activity of regulatory T-cells which prevent inflammatory reactions by suppressing the abnormal activation of other immune cells [1], thereby playing a very important part in maintaining immune tolerance and self-antigens.

In fact, the human microbiotawhich is related to immunity is a key contributor to many aspects of human health and its composition is largely influenced by diet we eat [69]. A healthy interaction between the immune system and the gut microbiota is crucial for the maintenance of the body's homeostasis, immunity and wellbeing [65]. If we eat nothing but overly processed and difficult to digest foods, then the fermentation process will occur within the gastrointestinal track resulting into gas, bloating, diarrhea, and constipation which might possibly lead to other diseases like cancer. However, providing the body with predigested foods such as fermented foods will help the existing microbes within to do the job they need to do, which includes stimulating the immune system to function properly. This is why it is important to take good care of our gut and this starts with what we eat [69]. Taking into considerations the benefits of these traditional fermented foods, utilizing them properly at larger scale could mitigate the economic effects of Covid-19 especially on food security and also help boost the immunity to possibly face the infection.

3. Conclusion

Fermented foods are increasingly understood for their properties that extended well beyond preservation and sensory attributes. They offer additional health benefits and enhanced nutrient availability far beyond the unfermented material. Fermented foods have the potentials to boost the immune system to possibly face the infection by balancing the gut microbiota which is linked with immunity. Nigerian traditional fermented foods and beverages if properly developed as standard commercial products could also play a major role in the national food security especially during and post Covid-19 by mitigating the economic effects of the pandemic in the country. Without being a promise of efficacy against Covid-19, incorporating these locally fermented foods and beverages into diets may help to minimize gut inflammation and enhance immunity to possibly lower the severity or the duration of infection episodes pending when an effective vaccines or drugswhich can interfere withthe virusmetabolismsis discovered.

4. Acknowledgement

The authors are thankful to the *MobilitéUniversitaire en Afrique (MOUNAF)* projectof the Intra-Africa Academic Mobility Scheme of European union for the financial support.

Ethics statement

There are no ethical concerns in thisreview article

5. Author contributions

P.N.A reviewed the literature and wrote the manuscript. P.N.O and C.O.E read and revised the manuscript. P.N.A wasresponsible for the concept, preparation and submission of the final article.

6. Conflict of Interest

The authors declare no conflicts of interest

Reference

1) Adriane E C Antunes, Gabriel Vinderola, Douglas Xavier Santos, Katia Sivieri (2020) Potential contribution of beneficial microbes to face the Covid-19 pandemic, *Food Research International*; 156, 109577
2) Zabetakis I, Lordan R, Norton C, Tsoupras A (2020) COVID-19: The Inflammation Link and the Role of Nutrition in Potential Mitigation. *Nutrients*. 2020;12(5).
3) Bousquet J, Anto J, Iaccarino G, Czarlewski W, Haahtela T, Anto A, et al (2020). Is diet partly responsible for differences in Covid-19 death rates between and within countries? *ClinTransl Allergy.2020*.
4) Susana C Fonseca, Ioar Rivas, Dora Romanguera, Marcos Quijal, WiencyyslawaCzarlewski, Alain Vidal *et al* (2020) Association between consumption of fermented vegetables and Covid-19 mortality at a country level in Europe.
5) Borresen E C, A J Henderson, A Kumar, T L Weir, E P Ryan(2012) Fermented foods: patented approaches and formulations for nutritional supplementation and health promotion. *Recent Patents on Food, Nutrition & Agriculture* 4 (2):134–40.
6) Narzary Y, Brahma J, Brahma C, Das S (2016). A study on indigenous fermented foods and beverages of Kokrajhar, Assam, *India. Journal of Ethnic Foods;*3(4):284–91.
7) Tamang J P (2010) Diversity of fermented foods. Fermented Foods and Beverages of the World, eds. pp. 41–72. *CRC Press: New York*.
8) Achi O K (2005)Traditional fermented protein condiments in Nigeria. *African Journal of Biotechnology*; vol., 4 (13), 1612-1621
9) Egwim Evans, Amanabo Musa, YahayaAbubakar, Bello Mainuna (2013) Nigerian indigenous fermented foods; process and prospects. *Intech*; 153 -180
10) Maria L Marco, Dustin Heeney, SylvicBinda, Christopher J. Cifelli*et al*., (2017) Health benefits of fermented foods: Microbiota and beyond. *Current opinion in Biotechnology*, 44: 94-102
11) Anukam KC, Reid G (2009) African traditional fermented foods and probiotics. *J. Med. Food*; 12, 1177–1184
12) Food and Agriculture Organization of the United Nations. (2017) "Nigeria at a glance". FAO; Available at *http://www.fao.org/nigeria/fao-in-nigeria/nigeria-at-a-glance/en/*
13) Blandino A, Al-Aseeri M,Pandiella S, Cantero D, Webb C(2003) Cereal-based fermented foods and beverages. *Food Research International;* 36 (6):527–43.
14) Đorđevic TM, Siler-Marinkovic SS, Dimitrijevic-Brankovic SI (2010) Effect of fermentation on antioxidant properties of some cereals and pseudo cereals. *Food Chemistry;* 119 (3):957–63.
15) Gupta S, Abu-GhannamN (2012) Probiotic fermentation of plant based products: possibilities and opportunities. *Critical Reviews in Food Science and Nutrition*;52(2):183–99.
16) Nguyen DT L,VanHoorde K, Cnockaert M, De Brandt E,Aerts M, Vandamme P(2013)A description of the *Lactic acid bacteria*microbiota associated with the production of traditional fermented vegetables in Vietnam. *International Journal of Food Microbiology* 163 (1):19–27.
17) Giyatmi,Irianto H (2017) Enzymes in Fermented Fish. Advances in food and nutrition research, marine enzymes biotechnology: production and industrial applications, part III application of marine enzymes, *eds.K.Se-Kwon and T.Fidel,Academic Press* vol.80,199–216.
18) Adjou E S, Degnon R G, Dahouenon-Ahoussi E, Soumanou MM, Sohounhloue DC (2017) Improvement of fermented fish flour quality using essential oil extracted from fresh leaves of *Pimentaracemosa* (Mill.) JW Moore. *Natural Products and Bioprospecting*;7(4):299–305.
19) Hwang J, Kim J, Moon H, Yang J, Kim M(2017) Determination of sodium contents in traditional fermented foods in Korea. *Journal of Food Composition and Analysis;* 56:110–4.
20) Chamlagain B, Edelmann M, Kariluoto S, Ollilainen V, Piironen V (2015) Ultra-high performance liquid chromatographic and mass spectrometric analysis of active vitamin B_{12} in cells of *Propionibacterium*and fermented cereal matrices. *Food Chem*;166; 630-638.
21) Russo P, CapozziV, Arena MP, Spadaccino G, Duenas MT, Lopez P, Fiocco D, Spano G (2014) Riboflavin-overproducing strains *of Lactobacillus fermentum* for riboflavin-enriched bread. *ApplMicrobiolBiotechnol*; 98:3691-3700.
22) Bleve G, Tufariello M, Durante M,Perbellini E,Ramires FA, Grieco F, Cappello MS, De Domenico S,Mita G *et al*., (2014)Physico-chemical and microbiological characterization of spontaneous fermentation of *Cellina di Nardo and Leccino* table olives. *Frontiers in Microbiology* 5:570.
23) Kiers JL, Van Laekan AEA, Rombouts FM, Nout MJR (2000)*In vitro* digestibility of *Bacillus* fermented soya bean. *Int. Food Microbiol.* 60:163-169.

24) NevinSanlier, BusraBasarGokcen, AybukeCeylunSezgin (2017) Health benefits of fermented foods. *Critical Reviews in food science and nutritional*; vol.1, 1 to 22
25) Flavera C Prado, Jose LParada, Ashok Padey, Carlos R, Soccal (2008) Trendsinnon-diary probioticbeverages. *Food research international*; vol. 41 (2), 111-123
26) JPTamang (2009)Himalayan Fermented Foods*:* Microbiology, Nutrition and Ethnic Values, *CRCPress*, NewDelhi, India.
27) LoreaBaroja M, Kirjavainen PV, Hekmat S, Reid G (2007)Anti-inflammatory effects of probiotic yogurt in inflammatory bowel disease patients. *ClinExpImmunol*; 149:470-479
28) Gille D, Schmid A, Walther B, VergèresG (2018) Fermented Food and Non-Communicable Chronic Diseases: A Review. *Nutrients*2018, 10, 448.
29) Derrien M, van HylckamaVlieg JET (2015) Fate, activity, and impact of ingested bacteria within the human gut microbiota. *Trends Microbiol*; 23:354-366
30) Kim JY, Choi EY, Hong YH, Song YO, Han JS, Lee SS, Han ES, Kim TW, Choi IS, Cho KK (2016) Changes in Korean adult females' intestinal microbiota resulting from *kimchi* intake. *J Nutr Food Sci* 2016;
31) Lang JM, Eisen JA, Zivkovic AM (2014) The microbes we eat: abundance and taxonomy of microbes consumed in a day's worth of meals for three diet types. *PeerJ.,* 2014
32) Dahiya DK, RenukaPuniya M,Shandilya UK, Dhewa T, Kumar N, Kumar S, Puniya AK, Shukla P (201) Gut Microbiota Modulation and Its Relationship with Obesity Using Prebiotic Fibers and Probiotics: A Review. *Front. Microbiol*, vol. 8, 563.
33) Choi IH, Noh JS, Han J, Kim H.J, Han E, Song YO (2013)*Kimchi*, a fermented vegetable, improves serum lipid profiles in healthy young adults: randomized clinical trial. *Journal of Medicinal Food*; 16 (3):223–229.
34) Corsetti A,Perpetuini G, Schirone M,Tofalo R, Suzzi G (2012)Application of starter cultures to table olive fermentation: an overview on the experimental studies. *Frontiers in Microbiology* 3:248.
35) Park KY, JK Jeong, YE Lee, JW Daily, (2014) Health benefits of *kimchi* (Korean fermented vegetables) as a probiotic food. *Journal of Medicinal Food;* 17 (1):6–20.
36) Tamang JP, Kailasapathy K(2010) Fermented foods and beverages of the world. *CRC press.*
37) Kim EK, An SY, Lee MS, Kim TH, Lee HK,HwangWS, Choe SJ, Kim TY, Han SJ, Kim HJ(2011) Fermented *kimchi* reduces body weight and improves metabolic parameters in overweight and obese patients. Nutrition Research; 31(6):436–43.
38) Mozaffarian D (2011) Changes in diet and lifestyle and long-term weight gain in women and men. *N Engl J Med*; 364:2392-2404.
39) Eussen SJPM, van Dongen MCJM, Wijckmans N, den Biggelaar L, Oude Elferink SJWH, Singh-Povel CM, Schram MT, Sep SJS, van der Kallen CJ, Koster A *et al.* (2016) Consumption of dairy foods in relation to impaired glucose metabolism and type 2 diabetes mellitus: the Maastricht Study. *Br J Nutr;*115:1453-1461.
40) An SY, Lee MS,Jeon JY, Ha ES, Kim TH, Yoon JY, Ok CO, Lee HK, Hwang WS,Choe SJ (2013) Beneficial effects of fresh and fermented *kimchi* in prediabetic individuals. *Annals of Nutrition and Metabolism;*63(1–2):111–19.
41) Alauddin M, Shirakawa H, Koseki T, Kijima N, BudijantoS, Islam J, Goto T, Komai M (2016) Fermented rice bran supplementation mitigates metabolic syndrome in stroke-prone spontaneously hypertensive rats. *BMC Complementary and Alternative Medicine;* 16(1):442
42) Kim KK, Yu D Kang, Suh H(2002) Anti-stress and anti-fatigue effect of fermented rice bran. *Phytotherapy Research*; 16(7)
43) Kong EL, BK Lee, I Ginjom, PM Nissom (2015) DNA damage inhibitory effect and phytochemicals of fermented red brown rice extract. *Asian Pacific Journal of Tropical Disease*; vol. 5 (9):732–36.
44) Baek S, Park S, Lee H(2005)Hypocholesterolemic action of fermented brown rice supplement in cholesterol-fed rats: cholesterol loweringaction of fermented brown rice. *Journal of Food Science-Chicago*;70 (8):S527
45) MeliniF, Melini V, Luziatelli F, Ficca AG, Ruzzi M (2019) Health-Promoting Components in FermentedFoods: An Up-to-Date Systematic Review. *Nutrients*;11(5).
46) Hayes M, García-Vaquero M (2016) Bioactive Compounds from Fermented Food Products. In Novel Food Fermentation Technologies; *Ojha, K., Tiwari, B., Eds.; Food Engineering Series; Springer: Cham,Switzerland,* 2016
47) Patel A, Prajapat J. B(2013) Food and health applications of exopolysaccharides produced by *lactic acid bacteria*. *Advances in Dairy Research*; 1(2):1–7.

48) Deepak V, Ramachandran S,Balahmar RM, Pandian SR K, Sivasubramaniam DS, Nellaiah H, Sundar K (2016) In vitro evaluation of anticancer properties of exopolysaccharides from *Lactobacillus acidophilus* in colon cancer cell lines. *In Vitro Cellular & Developmental Biology-Animal*;52(2):163–73.
49) Nampoothiri KM,Beena DJ, Vasanthakumari DS, IsmailB(2017) Health benefits of exopolysaccharides in fermented foods. *Boston: Academic Press*;49–62..
50) Wu MH, Pan TM, Wu YJ, Chang SJ, Chang MS, Hu CY(2010)Exopolysaccharide activities from probiotic *bifidobacterium*: Immunomodulatory effects (on J774A. 1 macrophages) and antimicrobial properties. *International Journal of Food Microbiology*; 144 (1):104–110.
51) Becerra-Tomas N, Guasch-Ferre M, Quilez J, Merino J, Ferre R, Diaz-Lopez A, Bullo M, Hernandez-Alonso P, Palau-Galindo A, Salas-Salvado J (2015) Effect of functional bread rich in potassium, gamma-aminobutyric acid and angiotensin-converting enzyme inhibitors on blood pressure, glucose metabolism and endothelial function: a double-blind randomized crossover clinical trial. *Medicine (Baltimore)* 2015
52) Yeap SK, N. Mohd Ali, H. MohdYusof, N B Alitheen, BK Beh, WY Ho, SP Koh, K Long (2012)Antihyperglycemic effects of fermented and non-fermented *mung* bean extracts on alloxan-induceddiabetic mice. *BioMed Research International* 2012.
53) Yeap SK, H. MohdYusof, NE Mohamad, BK Beh, WY Ho, NM Ali, SP Koh, K Long(2013) In vivo immunomodulation and lipid peroxidation activities contributed to chemoprevention effects of fermented mung bean against breast cancer. *Evidence-Based Complementary and Alternative Medicine* 2013.
54) Mohd Ali N, H MohdYusof, K Long, SK Yeap, WY Ho, BK Beh, SP Koh, MP Abdullah, NB Alitheen (2012) Antioxidant and hepatoprotective effect of aqueous extract of germinated and fermented mung bean on ethanol-mediated liver damage. *BioMed Research International* 2013: 693613, p.9.
55) Iraporda C, Errea A, Romanin DE, Cayet D, Pereyra E, Pignataro O, Sirard JC, Garrote GL, Abraham AG, Rumbo M (2015) Lactate and short chain fatty acids produced by microbial fermentation downregulate pro-inflammatory responses in intestinal epithelial cells and myeloid cells. *Immunobiology;* 220 (3):1161-1169.
56) KahlertS, Junnikkala S, Renner L, Hynonen U, Hartig R, Nossol C, Barta-Boszormenyi A, Da¨ nicke S, Souffrant WB, Palva A *et al*., (2016) Physiological concentration of exogenous lactate reduces antimycin a triggered oxidative stress in intestinal epithelial cell line IPEC-1 and IPEC-J2 in vitro. *PLOS ONE* 2016
57) Hiippala K, Jouhten H, Ronkainen A, Hartikainen A, Kailunanen V, Jalanka J, Satokari R (2018)The potential of gut commensals in reinforcing intestinal barrier function and alleviating inflammation.*Nutrients*; 10, 988
58) Heidari F, Abbaszadeh S,Mirak SEM (2017) Evaluation Effect of Combination Probiotics and Antibiotics in the prevention of Recurrent Urinary Tract Infection (UTI) in Women. *Biomed. Pharmacol. J.*,vol10, 691–698
59) Reid G, Beuerman D, Heinemann C, Bruce A W (2001a) Probiotic *Lactobacillus* dose required to restore and maintain a normal vaginal flora. *FEMS Immunol Med Nlicrobiol*; 32:37-41.
60) Cadieux P, Burton J, Kang CY(2002). *Lactobacillus* strains and vaginal ecology. *JAMA;* 287:1940-1941.
61) Adebolu TT, Olodun A O, Ihunweze B C (2007) Evaluation of *ogi*liquor fromdifferent grains for antibacterial activities against some common pathogens. *Afr. J. Biotech.* 6 (9): 1140-1143.
62) Rooks MG, Garrett WS (2016) Gut microbiota, metabolites and host immunity. *Nature Reviews Immunology;* 16(6), 341–352
63) Vandana UK, Barlaskar NH, Gulzar ABM, Laskar IH, Kumar D, Paul P, *et al.* (2020) Linking gut microbiota with the human diseases. *Bioinformation*;16(2):196-208
64) Iddir M, Brito A, Dingeo G, Fernandez Del Campo SS, Samouda H, La Frano MR, *et al.* (2020) Strengtheningthe Immune System and Reducing Inflammation and Oxidative Stress through Diet and Nutrition:Considerations during the COVID-19 Crisis. *Nutrients*;12(6)
65) Ashraf R, Shah N P (2014). Immune system stimulation by probiotic microorganisms.*Critical Reviews in Food Science and Nutrition*; 54(7), 938–956.
66) Opazo MC, Ortega-Rocha, EM, Coronado-Arrázola I; Bonifaz LC, Boudin H, Neunlist M,Bueno SM, Kalergis AM, Riedel CA (2018) Intestinal Microbiota Influences Non-intestinal Related Autoimmune Diseases. *Front. Microbiol*; 9, 432.
67) Stiemsma L, Nakamur RE, Nguyen JG, Michels KB (2020) Does consumption of fermented foods modify the human gut microbiota? *J. Nutr.* 150 (7): 1680-1692
68) Adiloglu A, NGonulates, MIsler, A Senol(2013)The effect of kefir consumption on human immune system: a cytokine study. *MikrobiyolojiBulteni*; 47 (2):273–81.
69) Zmora, Suez J, Elinav E (2019) You are what you eat: Diet, health and the gut microbiota. *Nature Reviews Gastroenterology &Hepatology*; 16(1), 35–56.