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Sprouts as probiotic carriers: A new trend to improve consumer nutrition

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A R T I C L E I N F O

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A B S T R A C T

Over the past few decades, efforts to eradicate hunger in the world have led to the generation of sustainable development goals to reduce poverty and inequality. It is estimated that the current coronavirus pandemic could add between 83 and 132 million to the total number of undernourished people in the world by 2021. Food insecurity is a contributing factor to the increase in malnutrition, overweight and obesity due to the quality of diets to which people have access. It is therefore necessary to develop functional foods that meet the needs of the population, such as the incorporation of sprouts in their formulation to enhance nutritional quality. Germination of grains and seeds can be used as a low-cost bioprocessing technique that provides higher nutritional value and better bioavailability of nutrients. Consequently, the manuscript describes relevant information about the germination process in different seeds, the changes caused in their nutritional value and the use of techniques within the imbibition phase to modify the metabolic profiles within the sprouts such as inoculation with lactic acid bacteria and yeasts, to generate a functional symbiotic food.

1. Introduction

Germination is a bioprocessing technique used by the food industry to enhance nutrients in seeds and grains such as cereals, oilseeds, legumes and vegetable seeds, and is considered an economical and affordable tool (Samec et al., 2018; Zhang et al., 2021). The best nutrient utilization comes from the breakdown of macronutrients to smaller molecules, such as amino acids, simple sugars and other nutritional compounds (Liu et al., 2017). Sprouts also stand out for the decrease of anti-nutritional components present in grains and seeds, making these foods more digestible and with better sensory attributes (Ohanenye et al., 2020), in addition to being a rich source of phenolic compounds, vitamins and minerals (Hassan Mekky et al., 2020). In recent years, the consumption of sprouts has increased, as they are considered as a functional food that improves the health status of the consumer. Therefore, research has focused on studying the effects of sprouting on nutritional composition, phytochemical profile and biological activities that can be promoted (Galieni et al., 2020).Within the germination process it has been detailed that, in each of its phases, there are factors that influence the content of nutrients and bioactive compounds. Soaking is the stage known as imbibition. In the literature there are reports that the time, humidity, the presence of light and the substance in which the seed is soaked determine the efficiency and quality of the growth stage (Vötterl et al., 2019).

Probiotics are microorganisms, which when administered in adequate amounts, will confer a health benefit to the host. There are many applications that can be given to them for the treatment of diseases from autoimmune disorders, inflammation to different types of cancers (Markowiak & Śliżewska, 2017). They are currently sought to be incorporated in alternative food matrices and not only in capsule form. This trend is related to the population's interest in improving their eating habits (Świeca et al., 2018). According to the literature, soaking seeds and grains with a solution containing probiotic microorganisms improves their organoleptic, nutritional and functional properties at the time of germination, generating a functional food based on sprouts, which guarantees the growth and survival of probiotics and excellent microbiological quality. This strategy would allow access to a food of excellent nutritional quality and with beneficial effects on consumer health (Świeca et al., 2019).

On the other hand, food insecurity is a problem that affects a large

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number of people worldwide. The inequality that affects the population in Mexico has generated an increase in the prevalence of malnutrition, obesity, overweight and micronutrient deficiencies. Current estimates indicate that close to 690 million people suffer from hunger. Therefore, a number of targets have been developed to decrease the total number of people affected by food insecurity by generating safe, nutritious, sufficient and affordable food (FAO, et al., 2020). The food industry has focused on developing functional foods that provide a health benefit to the consumer, such as the use of sprouts in their formulation.

The objective of this work is to study the effect of germination on the nutritional content, phytochemical profile and biological activities, for its incorporation in a functional food.

2. Sprouts

Germination is a simple, economical and effective technique to enhance the nutritional content in seeds and grains of cereals, oilseeds, legumes and vegetable seeds used in the food industry, highlighting that it is an economical tool within everyone's reach (Baranzelli et al., 2018). During germination, widespread activation of seed metabolism occurs, giving rise to metabolic transformations (Yang, et al., 2021), causing a series of enzymes involved in obtaining energy, metabolism of functional compounds and construction of protective structures to be activated. These enzymes act by hydrolyzing starch, proteins and lipids present in the seed into simple sugars, fatty acids and free amino acids, in addition to causing an increase in bioactive components such as antioxidants and flavonoids (Chen et al., 2016). Likewise, anti-nutritional components present in the seeds are decreased, thus improving its digestibility (Cornejo, Novillo, Vil lacres, & Rosell, 2019).

The germination process varies according to the seed or grain used (Sofi et al., 2020). Germination begins with the disinfection technique, in which the seeds are decontaminated to eliminate the presence of pathogenic microorganisms. The most commonly used products during this step are chlorine, sodium hypochlorite and acid compounds. However, the use of chemicals is currently avoided because of the effect they can have on consumer health (Phua et al., 2014; Zhang et al., 2020). Therefore, other alternatives have been sought, such as the use of lactic acid bacteria and yeasts during soaking used as a pretreatment in the imbibition phase, modifying its phytochemical and nutritional profile upon germination (Świeca et al., 2018, 2019; Swieca et al., 2019). Soaking is considered one of the steps with the greatest importance at the time of germination. The factors that determine the time, temperature and seed weight (g)/water volume (mL) ratio of the soaking process will depend on the dimensions such as coat thickness and absorption capacity of seeds and grains (Zhou et al., 2017).

2.1. Germination cycle

Germination consists of three stages (Fig. 1). Phase or stage I is characterized by a rapid absorption of water by the seed, which leads to swelling and change of shape (Bewley, 2001), causing the seed membrane to be affected by rehydration, changing the amount of metabolites and cellular solutes in the seed. At this stage, a series of physiological processes begin, such as protein synthesis, DNA repair and respiratory activities, increasing oxygen consumption and carbon dioxide release, as well as mitochondrial repair, which plays an important role in increasing the production of adenosine triphosphate (ATP), necessary for the germination process. This stage is known as imbibition. There are several studies in which at this stage the seed is put in contact with different solutions to limit bacterial growth and evaluate its effect at the metabolic level.

Phase II of germination occurs at the time when the rate of seed water uptake stabilizes (Bewley, 1997; Weitbrecht et al., 2011). At this stage, several events occur such as continuous DNA repair, mitochondrial and protein synthesis. At the same time, embryo expansion and attenuation of seed coatings begins (Bewley, 1997). There are a number

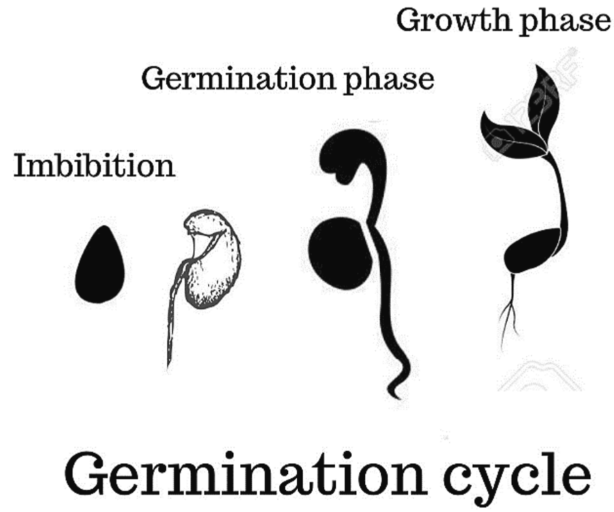

Fig. 1. Stages of the germination cycle.

of factors to consider for this phase such as light, temperature, humidity, irrigation and time. Germination is normally carried out in dark conditions, with a temperature of 20–30 °C. Seeds and grains should be watered daily to maintain adequate moisture for optimal growth, plus it is recommended to change the water frequently to eliminate metabolites and limit the growth of pathogenic microorganisms (Gan et al., 2017). The moment when the prominence of the radicle can be observed emerging through the seed coat is when the end of phase II and the beginning of phase III is marked. Phase III is distinguished by the displacement of storage reserves, triggering increased water uptake and seedling growth; it is also referred to as the growth phase (Tuan et al., 2019).

2.2. Factors influencing germination

Controlled germination is influenced by external factors such as temperature, humidity, illumination, oxygen and duration of germination (Nelson et al., 2013). As a response to mitigate the stress to which they are exposed, plants have developed physiological and chemical modifications which originate an increase in the production of metabolites as a form of protection (Ding & Feng, 2019). Moisture contained in sprouted grains and seeds affects the quality and storability of sprouts in the short and long term. The moisture content of sprouts is 35–60 % (Dziki & Gawlik-Dziki, 2019). Subjecting sprouts to a drying process is most convenient, to inhibit microbial growth. It is also advisable to store sprouts at low temperatures, to avoid undesirable reactions. The recommended temperature is below 18 °C, mainly because sprouted grains and seeds breathe during storage producing heat. Controlling the humidity present in the sprouts ensures a lower presence of pathogenic microorganisms (Agha et al., 2017).

Sprouts have been implicated in foodborne diseases (Keshri et al., 2019). Other factors that influence the contamination of sprouts are seeds that have high microbial loads, which will later affect the sprout. Also the high volume of water used during sprouting, temperature, germination medium, soaking water, are conditions that contribute to microbial contamination (Miyahira & Antunes, 2021). The most frequently reported pathogenic microorganisms in sprouts are *Salmonella*, *E. coli* and *L. monocytogenes* (Baker et al., 2019). To prevent contamination of sprouts, chemicals such as chlorine, calcium hypochlorite, sodium hypochlorite, and acetic acid are used. However, these chemicals have adverse effects on human health and quality attributes (Liang et al., 2019). Hypochlorous acid is a chemical that is widely used for the purpose of decontaminating horticultural products. However, this substance produces carcinogens that affect human health status. It has been described in the literature that by using other regulating substances, sprouts are considered safe for consumption (Zhang et al., 2020). An alternative technique to the use of chemicals to control the growth of pathogens during the sprouting process is lactic acid bacteria as competitive inhibitors. In different studies it has been identified that a group of lactic acid bacteria replaced the natural microflora of the sprouts. In addition to being described their capacity to produce bacteriocins (Mridula & Sharma, 2015; Miyahira, & Antunes, 2021).

3. Influence of the germination process on nutrients

3.1. Bioactive compounds

Sprouts are a source of active compounds. The germination process leads to changes in the nutritional components of sprouted seeds and grains (Kim et al., 2020). Special interest has been shown on antioxidants and polyphenols generated in sprouts for their biological activities (Erba et al., 2018). Recent studies mention that the sprouting technique significantly increases the content of several vitamins such as vitamin C and B complex (Gan et al., 2016). There is also an increase in mineral content compared to non-germinated seeds and grains. The authors justify that the elevation of minerals may be due to the breakdown of phytates that act as chelators, by the action of the enzyme phytase. Some of the minerals that have been reported in sprouts are zinc, calcium, magnesium, potassium and iron (Mir et al., 2021).

Germination affects the content of total polyphenols in sprouts. Most studies mention that soluble phenolic compounds can gradually accumulate in sprouted seeds and grains. The increase in soluble phenols is attributed to de novo synthesis and transformation (Gan et al., 2017). The main precursor for phenol synthesis is glucose, so the high concentration of glucose in sprouts can be related to the increase in polyphenols (Chen et al., 2018). Conversely, the concentration of bound phenolic compounds depends on the rate of release and conjugation at different stages of germination. For example, in the early stages proteins and carbohydrates are hydrolyzed to free amino acids and simple sugars, with bound phenolic compounds being released from the cell wall. However, in the later stage of germination, these compounds are found forming part of the new cell walls (Gan et al., 2017).

Other bioactive compounds found in sprouts are γ-aminobutyric acid (GABA), melatonin and inositol. GABA is an inhibitory neurotransmitter, which regulates blood pressure, heart rate, pain and anxiety (Mody, Dekoninck, Otis, & Sol, 1994). In addition to demonstrating antidiabetic activity, being an insulin secretagogue in the pancreas (Donkor et al., 2012). Melatonin is a hormone involved in the regulation of the circadian cycle. Studies refer that germination increases its content in seeds and grains (Gamble et al., 2014; Aguilera et al., 2014). D-chiro-inositol (DCI) is a coenzyme involved in the insulin signaling pathway and glucose transport, being considered as a mediator of insulin secretion with anti-diabetic effect. Sprouted seeds and grains show increased DCI content (Adams et al., 2014; Gan et al., 2016).

3.2. Nutritional composition

Grains and seeds contain energy reserves made up of carbohydrate, protein and fat molecules for later utilization in the germination process. These molecules are hydrolyzed by enzymatic action to smaller compounds such as simple sugars, free amino acids and fatty acids, for utilization by the seed (Yang et al., 2021). Starch is a polysaccharide present in grains, composed of amylose and amylopectin units (Zhou et al., 2017). It is noted for the functional and nutritional properties it imparts to foods (Vanier et al., 2017). In the germination process, starch undergoes changes in its structure, depending on the crop variety and treatment conditions (Wang et al., 2019). Some studies have reported that the total starch content is decreased, after germination (You et al., 2016), in addition to finding an increase in starch granule surface pores, with a higher proportion of short, branched chains in amylopectin, affecting the viscosity of the sprout (Pinkaew, Wang & Naiviku, 2017). On the other hand, proteins from sprouted grains and seeds become more available for utilization. Stored proteins are hydrolyzed to provide amino acids and energy needed for germination (Ohanenye et al., 2020). In the case of fatty acids, an increase in the first days of germination in monounsaturated fatty acids, especially oleic acid, has been reported. The concentration of fatty acids depends on conditions such as seed and grain type, germination time and light exposure (Dhakal et al., 2014).

3.3. Digestibility

There are a few processing techniques related to improving the quality and nutritional bioavailability of grains and seeds to reduce the anti-nutritional compounds present. Among the most used techniques are soaking, boiling with water, sterilization with autoclaves, fermentation, steam blanching, dehulling and alkaline or acid solutions (Esenwah & Ikenebomeh, 2008; Slupski, 2011). Soaking and fermentation are processes that occur in tandem, upon starch reduction, inducing the synthesis of enzymes that act on phytates and some flavonoid compounds (Handa et al., 2017). Phytates act as antinutritional factors due to the interactions they present when binding with different minerals such as Ca^{2+}, Mg^{2+}, Zn^{2+}, Fe^{2+}, Fe^{3+}, Cu^{2+} and Mn^{2+}. This is due to the formation of non-soluble compounds which hinders the absorption and bioavailability of minerals in food (EL-Suhaibani, Ahmed & Osman, 2020). They can also form complexes together with proteins and thus change their enzymatic activity and solubility. Humans are not able to digest phytic acid, so soaking and germination reduce phytic acid and increase the solubility of minerals in food (Marolt & Kolar, 2020).

4. Sprouts of different seeds and grains

4.1. Legumes

Plants of the family Fabaceae (legumes) are the third largest family of flowering plants. They can be cultivated in different regions of the world and their uses include the manufacture of medicines and food, among others (Farag et al., 2020). Legumes are considered as an excellent source of nutrients such as starch, protein, minerals, and phenolic compounds (Swieca et al., 2019). Legumes contain antinutritional factors such as inhibitors of some protease enzymes, amylases, hemaggluteins, in addition to antivitamin factors, flatulence factors, metal binders, toxic amino acids, among others (Enwere, 1998). It is usually processed before consumption, either by canning, frying or cooking. However, germination is also used as a bioprocessing technique, since it improves nutrient digestibility and mineral bioaccessibility. According to several authors, germination of legumes improves nutritional content, protein content and reduces antinutritional composition (Owuamanam et al., 2014).

4.2. Oilseeds

Oilseeds contain about 15 % fat, in addition to protein. The contribution of proteins and bioactive peptides with antioxidant and antihypertensive properties place oilseeds as a functional food (Kotecka-Majchrzak et al., 2020). They are also noted for their contribution of unsaturated essential fatty acids and bioactive compounds such as phytosterols, tocopherols and phenolic compounds (Mamone et al., 2019). Some oilseeds possess antinutritional factors that limit nutrient utilization. The main antinutritional factors are trypsin inhibitors, glucosinolates, and cyanogenic glycosides (Woyengo, Beltranena & Zijlstra, 2017).

4.3. Vegetables

Vegetable sprouts are an excellent source of bioactive compounds that benefit consumer health. Sprouts can have a concentration of 2 to

10 times more photochemical compounds than adult plants. Glucosinolates are bioactive compounds found in cruciferous plants such as radish and broccoli. These compounds are hydrolyzed into bioactive products such as isothiocyanates and indoles by the action of the enzyme myrosinase in conjunction with chewing and the function of the intestinal flora. The above compounds are known for their excellent antioxidant, anti-inflammatory and anticarcinogenic activates (Baenas et al., 2017). Another of the most consumed vegetables in the world is beet, known for its beneficial effects. Studies have mainly focused on the content of betalains present in this vegetable, which are pigments with the presence of nitrogen. Betalains play an important role in the process of oxidative stress, inhibiting the proliferation of tumor cells. The component that makes betalains stand out from other active compounds is nitrate, which is converted to nitric oxide by bacteria in the organism. In several studies it has been reported that increased nitric oxide improves performance in athletes and resistance to fatigue. Nitrate has also been found to influence blood pressure reduction by preventing hypertension (Takács-Hájos and Vargas-Rubóczki, 2022). Current research seeks to evaluate the content of bioactive compounds in beet sprouts.

4.4. Cereals

Cereal-based foods are considered one of the first sources of calories in the human diet. Whole grains are rich in photochemicals, antioxidants and sterols giving them functionality. The cereal germination technique has been recognized as a method to improve the nutritional quality of whole grains, due to the changes it causes in nutritional and physicochemical properties. Moreover, it has been found in the literature that grain germination leads to the development of changes in the structure of the microbiota by increasing the process of utilization of carbon and nitrogen sources by probiotic microorganisms (Barret et al., 2015; Landry, Sela and McLandsborough, 2018; Perri et al., 2020).

5. Probiotics

The term probiotic was first introduced by Lilly and Stillwell in 1965, defining it as a factor of microbiological origin that stimulates the growth of other organisms (Villanueva et al., 2015). Probiotics are defined by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization as living organisms, which when administered to a host in adequate amounts, confer health benefits. It has been suggested that probiotics provide a large number of health benefits, positively affecting the intestinal microbiota by regulating the amount of microorganisms, and thus stimulating the immune and non-immune mechanisms of the mucosa (Valdovinos et al., 2017).

5.1. Mechanism of action of probiotics

There are different mechanisms of interaction of probiotics with immune system cells. In the case of lactic acid bacteria, it has been observed that they can be captured by the M cells of the intestinal epithelium, which allow the uptake and transport of antigens from the intestinal lumen to the submucosa, and facilitate the stimulation of the lymphoid tissue (Novak et al., 2007). They also cause changes in the gastrointestinal environment, such as the induction of an acid pH below 4, by the production of short-chain fatty acids (SCFA), such as acetates, butyrates, etc. (Agudelo et al., 2016). In addition, they possess the ability to adhere to enterocytes and colonocytes, affecting the composition of the intestinal ecosystem, by increasing the non-dependent barrier effect of the immune system, and as a result of the production of bacteriocins, they compete with various pathogens, hindering the passage of pathogenic bacteria to the lymph nodes and blood (Gusils et al., 2002; Tormo, 2006; Alavi et al., 2012).

The microorganisms of the microbiota act by stimulating mucin production; inhibiting pathogens, causing a decrease in intestinal permeability, activating macrophages and increasing phagocytic capacity (Sánchez Salguero & Santos Argumedo, 2018). In addition to causing an increase in the production of Immunoglobulins A, M and G, and other regulatory elements (Jirillo et al., 2018). On the other hand, their immunomodulatory effect is due to the fact that there is a large surface area of lymphoid tissues within the intestinal mucosa, and lactic acid bacteria can be taken up by the M cells present in the epithelium, facilitating the stimulation of lymphoid tissue, influencing T cell responses. The effects of probiotics depend largely on the interaction they have with dendritic cells, and the type of probiotic strain, with cases of inhibition or stimulation of IL-10 and IL-12 cytokine production being observed, favored a tolerance or humoral immune response, respectively (Jirillo et al., 2018).

5.2. Probiotics in food

Recently, the interest in the use of probiotics in foods has increased, due to the various beneficial effects that have been attributed to them (De Morais, 2016). The minimum amount in which a probiotic must be present in a food, to be considered functional is 10^6 CFU/g, and thus the consumer can obtain all the benefits previously mentioned (Guimarães et al., 2019).

In the food industry, probiotics are mainly found in fermented and non-fermented dairy products, such as fruits, vegetables and dried meat. They can also be micro- encapsulated to be added in non-fermented foods, so that they can withstand the conditions that the food matrix provides, and maintain their viability when passing through the digestive tract, and its secretions such as gastric acids and bile juice (Espitia et al., 2016). In addition to the fact that the technological processes that are used, can also be detrimental to these microorganisms, due to the decrease in water activity, damaging the structure of the probiotic microorganism (Romanov et al., 2018). Microencapsulation is mainly intended for protection against factors such as pH, oxygen, light, among others, decreasing the reactivity of probiotics to the environment to avoid their degradation, likewise disguising unpleasant tastes and odors (Nguyen et al., 2018). Among the most commonly used methods for encapsulation, spray drying, electrospraying, extrusion, emulsion and coacervation are mentioned (De Prisco & Mauriello, 2018).

Likewise, probiotics have been incorporated in coatings and packaging for their antimicrobial properties to extend shelf life and maintain food stability, this is known as active packaging, which is an alternative to avoid the use of antibiotics, replacing them with probiotics, also releasing active compounds to preserve the food, acting as a barrier against oxygen, and reducing the rates of moisture and gas transfer. Edible coatings added with probiotics have been used in products such as bread, cookies and fruits (Soukoulis et al., 2015).

5.3. Effects of probiotics on diseases

There are different reports on the beneficial effects of probiotics in various pathological conditions. It is known that the microbiota is different in obese and lean people, a probiotic supplementation can help to modulate the intestinal microbiome, depending on the species and strain used. The use of probiotics as adjuvant therapy has been shown to reduce body mass index and waist circumference in the management of obesity and its comorbidities (Calderón & Acosta, 2019). The mechanisms that explain these benefits are attributed to the reduction of the inflammatory and oxidative profile (Jung et al., 2018) and to the metabolites secreted by probiotic microorganisms, mainly SCFAs product of the fermentation of non-digestible compounds (Byrne et al., 2015). Another effect of probiotics is on irritable bowel syndrome (IBS), where it has been observed that some specific strains, can alleviate symptoms such as abdominal pain, bloating or abdominal distension, constipation and bowel habits in this type of patients (Hungin et al., 2018).

In food allergies and intolerances, beneficial effects of probiotics on the patient have also been documented, such is the case of people with allergies where IgA is increased by the consumption of probiotics, improving allergy symptoms (Sánchez Salguero & Santos Argumedo, 2018), while in patients with intolerances dysbiosis occurs, probiotics help regulate the number of microorganisms in the microbiota (Sharma & Bhagatwala, 2019). As for IBD, the use of multi-strain has shown, a remission of UC, however, a probiotic intake in CD has not been shown to have satisfactory results in disease remission (Floch et al., 2015; Guslandi, 2015).

6. Sprouts as a functional food

The International Food Information Center (IFIC) of the European Union defines functional foods as "those products to which a specific compound is intentionally and in a controlled manner added to increase their health properties" (Biesalski et al., 2011). The ingredients responsible for this effect may be naturally present in the food or have been added during processing (prebiotics, probiotics, antioxidants, polyunsaturated fatty acids, phytosterols, phytoestrogens, polyphenols, carotenes, lycopenes, among others) (Yamada et al., 2008).

The use of probiotics and prebiotics as functional foods is of great interest because of their great potential to modulate the intestinal biome (Reyes Esparza and Rodríguez Fragoso, 2011), mainly in diseases related to inflammatory processes, since a functional imbalance alters the mutualistic relationship between the host and its microorganisms causing intestinal dysbiosis, (Aranda et al., 2019) which is described as a process of imbalance between the amount and type of normal microorganisms present in the microbiota, which can result in pathological and clinical conditions, in the medium and long term (Icaza-Chávez, 2013).

In recent years, the consumption of functional foods has been promoted, leading to an increase in the demand for them, due to their health benefits (Pringsulaka et al., 2015). Therefore, the food industry takes into account aspects to develop functional foods such as the food to be developed must be frequently consumed and contains natural ingredients, higher concentrations of the active ingredients than those found in nature or ingredients added during the formulation process. Also has both nutritional value and positive health effects (Calvo et al., 2012). There is very little information about the development of functional foods based on sprouts, this matrix being uncommon as carriers of probiotics. Table 1 shows some examples of legumes and cereals inoculated with probiotics and their main characteristics.

Table 1
Main properties of sprouts inoculated with probiotics.

Legume and cereal sprouts	Main Property	Reference
Soy bean	Fresh and stored soybean sprouts are a source of isoflavones with multidirectional antioxidant activity. The addition of probiotic bacteria improved the antioxidant capacity and showed stability after storage. Probiotic carriers.	Świeca et al., 2019; Świeca, Baraniak, & Gawlik-Dziki, 2013
Mung bean	Increase in the digestibility of sprouts inoculated with probiotics. Probiotic carriers.	Świeca et al., 2018; Swieca et al., 2019; Świeca & Gawlik-Dziki, 2015
Adsuki bean	Probiotic carriers. Functional food.	
Cowpea	Including green bean sprout powder in the formulation of a juice provides an amount of 120 mg of polyphenol catechin equivalents to the diet.	Simsek et al., 2014
Lentil	The germination and inoculation process with probiotics reduces *Staphylococcaceae species (S. hominis, M. caseolyticus* and *Staphylococcus* sp. species). In another study it is mentioned that integrating lentil sprout flour into a juice provides half the daily requirement of vitamin C. Within the formulation of a cookie with lentil sprout flour, a statistically significant increase in protein values was observed. Probiotic carriers.	Sáez, Saavedra, Hebert, & Zárate, 2018; Simsek et al., 2014; Polat, Capar, Inanir, Ekici, & Yalcin, 2020; Sáez et al., 2018
Chickpea	Considerable increases in *E. casseliflavus* and *Lc. Lactis* in chickpea flour from sprouted grains.	Perri et al., 2020
Wheat	Increase in probiotic microorganisms in wheat sprout sourdough without probiotics	De Angelis, Minervini, Siragusa, Rizzello & Gobbetti, 2019
Barley	fermentation of sourdoughs, the masses are characterized by the presence of *L. fermentum*	Harth, Van Kerrebroeck & De Vuyst, 2016

6.1. Sprouts as a vehicle for probiotics

Probiotics are usually consumed in the form of food supplements in capsule form. On the other hand, it is known that probiotics can influence the microbiological and organoleptic quality of food, so these are incorporated fermented vegetables and beverages, meats and dairy (Świeca et al., 2018). The current needs of the population are based on improving their health, so new food matrices have been implemented as a vehicle for probiotics for this purpose. Sprouts inoculated with probiotics are considered as a new symbiotic functional food, which ensures the development of probiotic as the contribution of prebiotics by the sprouts. Sprouts are a source of resistant starch, dietary fiber and oligosaccharides that exhibit prebiotic activity (Gawlik-Dziki et al., 2021). During the imbibition stage the probiotic microoganisms are absorbed by the seeds, having a greater access to the nutrients necessary for their development (Fig. 2). Factors such as germination temperature, inoculation method and seed type directly influence the efficiency of production of probiotic-rich sprouts (Świeca et al., 2018). Studies by Świeca (Swieca et al., 2019), proved that sprouts are an excellent source of probiotics and can be used for functional food formulation. In addition to boosting the phenolic content of sprouts, improving the digestibility of nutrients and increasing the microbiological quality of sprouts by replacing the natural microbiome with lactic acid bacteria (Złotek et al., 2019). In general, germination and fermentation in conjunction with probiotics are an excellent tool to improve the nutritional and sensory properties of grains and seeds (Wu and Xu, 2019). By using these techniques, improvements can be obtained in the organoleptic characteristics of foods such as nutritional enrichment, reducing antinutrients, improving shelf life, in addition to offering improvements in the functional properties of the food (Ebert et al., 2017). The viability for sprouts to carry probiotics is based on the susceptibility shown by the food matrix such as starch and proteins contained in grains and seeds. The increase in this susceptibility is due to the sequence of enzymatic metabolism that begins in the first stage of germination to split macronutrients into smaller nutrients that are easier to use for the plant and the microorganism acting symbiotically (Świeca & Gawlik-Dziki, 2015). In a study carried out by Raimondi et al., in 2017, in addition to a reduction in the percentage of total carbohydrates, a reduction of 29 % and 20 % in protein content was observed in lentil and bean sprouts respectively, justifying this effect by the growth of the probiotic (Raimondi et al., 2017). In the literature it has been documented that probiotics effectively use different polysaccharides such as starch and some oligosaccharides as their energy source. Compared to sprouts without probiotics, sprouts that carry probiotics are rich in total proteins, amino acids, free peptides and resistant starch; which provides extra functional activity in the consumption of sprouts with probiotics (Gawlik-Dziki et al., 2021). An increase in total free sugars and a decrease in starch has also been observed in cereal sprouts inoculated with probiotic yeasts; These findings are of vital importance to continue the development of

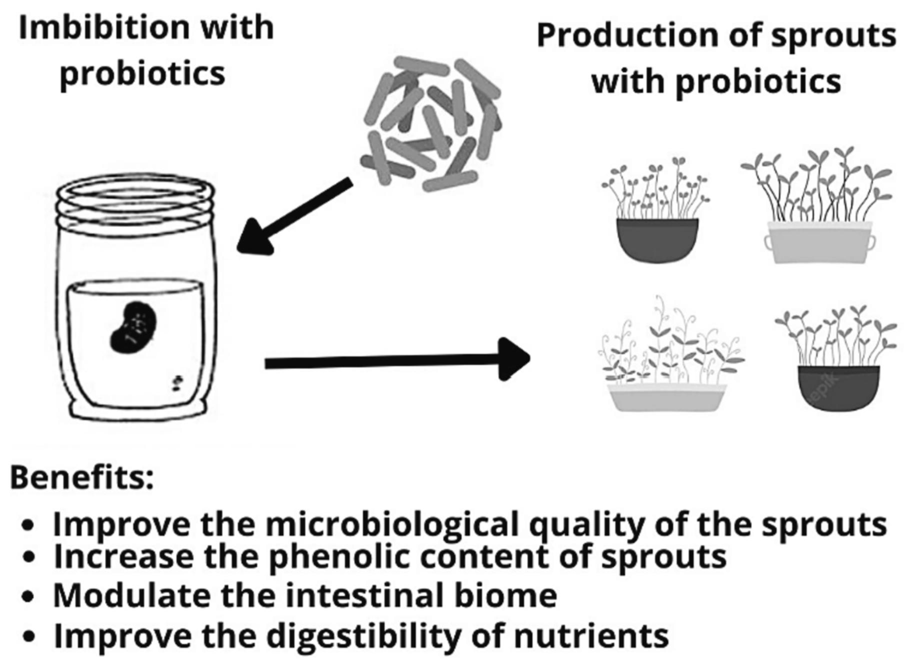

Fig. 2. General scheme of the imbibition process of seeds with probiotics during germination.

research on sprouts with probiotics based on the current needs of the population. The current trend forces the food industry to look for new functional food matrices that offer improved nutritional quality (Molska et al., 2022).

6.1.1. Sprouts as ingredients in functional foods

In a study carried out by Le et al. (Le et al., 2021), different varieties of quinoa sprouts were studied, which provided important information about the high functional values they provide, such as the wide range of phytochemicals providing antioxidant activity. On the other hand, an investigation carried out on buckwheat sprouts inoculated with probiotic yeasts was characterized by an increase in the amount of total proteins, amino acids and peptides, mostly methionine (essential amino acid). Current evidence determines that modifying the composition of different cereal grains inoculated with probiotic yeasts provides a higher content of free sugars and a decrease in total starch (Sytar, Biel, Smetanska, & Brestic, 2018). Indicating that the integration of sprouts as active ingredients in other foods is an excellent tool to increase nutritional value, provide a beneficial effect on consumer health and improve food quality. There are different proposals in the food market where sprouts are integrated into the formulation of different foods. Bakery products and juices are some of the foods where they are incorporated in greater proportion. In 2023, (Bermejo & Munné-Bosch, 2023) mixed fresh and dried chia sprouts into a yogurt formulation, demonstrating an improvement in the content of vitamin C and beta-carotene. Considering this mixture, a potential ingredient for the food industry and managing to innovate by creating functional foods by adding them (Eker & Karakaya, 2020). Referring to the baking industry, wheat sprouts are the main ingredient for making bread and tortillas, due to their cost and availability, in addition to integrating other sprouted grains to improve nutritional content. By integrating sprouted wheat into different formulations, it could increase the consumption of whole grains in general, in addition to offering an increase in the daily intake of fiber (Liu et al., 2017). Another way to integrate sprouts is in presentations such as bars, pastas and other snacks. Different studies determined that vegetable juices with sprouts can be considered as a food for people with chronic diseases such as cardiovascular pathologies, type II diabetes and obesity, since they confer beneficial health effects such as angiotensin-converting enzyme and alpha amylase enzyme inhibitory activity (Simsek, Kancabas & Karakaya, 2018). In addition to excellent antioxidant and hemagglutinating activity. Mridula & Sharma in 2015, developed a probiotic non-dairy beverage based on sprouts presenting organoleptic properties pleasant to the consumer and acting as a vehicle of microorganisms beneficial to their gut microbiota. Sprouted flours from different seeds and grains have been reported to have anti-inflammatory and antioxidant activity, however, the technological properties within incorporation into other products need to be further investigated (Baranzelli et al., 2018; Tuan et al., 2019).

7. Conclusions

Currently, the prevalence of diseases linked to poor dietary habits and food insecurity has led to the search for the development of functional foods that can help prevent the onset of these pathologies. A number of alternative food matrices have been studied as carriers of probiotics, however few matrices support the conditions of the digestive tract. Sprouts can be classified as a functional food, since when inoculated with probiotic microorganisms during the imbibition stage, it has been determined that they are effective carriers of probiotics and ensure their survival in harmful conditions of the digestive tract. In addition to providing an increase in bioactive substances and a better utilization of nutrients when consumed.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Stephany Nefertari Chavez Garcia reports financial support was provided by National Council on Science and Technology (CONAHCYT).

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