LAB-Fermented Foods

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Lactic acid bacteria (LAB) are involved in producing a considerable number of fermented products consumed worldwide. Many of those LAB fermented foods are recognized as beneficial for human health due to probiotic LAB or their metabolites produced during food fermentation or after food digestion. LAB are responsible for a great diversification in the flavor and texture of fermented foods. They can also release an array of health-modulating compounds and signal molecules in the matrix during fermentation. These food-derived bacteria and their metabolites can interact with the intestinal microbiome and with the host itself like members of an orchestra playing a health symphony for the intestine and the organisms in general

lactic acid bacteria fermented foods health benefits

1. Health Effects of Foods Fermented by LAB

In the past years, the consumption of probiotics was strongly recommended, and the involvement of positive microorganisms in the formulation of foods with a health claim was widespread. Nowadays, due to a more profound knowledge of the probiotics' health effects and the mechanism behind them, it is possible to broaden the range of microorganisms involved in the formulation of functional foods. In some cases, LAB that are part of the spontaneous microbial population of one food, drive the beneficial effects to the host without being recognized (yet) as probiotics [1][2][3][4]. Positive effects connected to fermented foods have been empirically known for centuries. In many cultures, fermented foods are heritage foods and an integral part of local traditions, probably because fermentation was the only way to preserve foods [4]. Nowadays, regular consumption of fermented foods, especially lactic-fermented ones, has been reported to improve the immune system, reducing the probability of developing morbidities [2] due to a constant communication between bacteria and host immune system. This communication changes the microbial composition of the intestine, maintaining under control pathogenic microflora and meanwhile supporting beneficial microbes populations [5].

Among fermented foods, dairy products have been mainly associated with beneficial effects. This is partly due to the significant number of proteins available in the substrate for cellular duplication. During fermentation, because of acidification and microbial enzymes activity, proteins are denatured and lose their original conformation, releasing sequences of small peptides studied for their potential health-related effects. One of the most studied and regarded groups of bioactive peptides is represented by Angiontensin-1-Converting Enzyme (ACE) inhibitors. These bioactive peptides have been studied for their anti-hypertensive effect, and several guidelines suggest consuming fermented dairy products as a non-pharmacological way of controlling hypertension. Scientific evidence reported two main peptides as carriers of hypotensive effect: VPP (valine, proline, proline) and IPP (isoleucine, proline,

proline) [4][6][7]. ACE inhibition occurs when ACE I is sequestered by the C-terminal sequence of ACE-inhibitors. In this way, ACE cannot convert angiotensin I in angiotensin II, a potent vasoconstrictor. Synthesis of angiotensin II leads also to degradation of bradykinin, a vasodilator; soaring blood vessels' constriction; and dramatically increasing blood pressure [6][7].

Furthermore, LABs can produce exopolysaccharides (EPS), long sugars polymers formed by repeated units of mono- or oligosaccharides, that are gaining a lot of attention from the scientific community, due to their technological role [8], but also for their promising health benefits [9]. EPS can be divided in two macro-categories depending on the sugars presents in the main chain: (i) Heteropolysaccharides (HePSs) are polymers of different monosaccharides; (ii) Homopolysaccharides (HoPSs) are polymers of one sugar, repeated many times. In the latter case, HoPSs can be divided into glucans or fructans depending on the sugar composing the polymer chain, glucose, and fructose, respectively. Production of HoPS takes place outside microbial cells, mediated by membrane enzymes that hydrolyse and reassemble the sugars in a new EPS chain. By contrast, HePSs synthesis is more complex, and the chain contains more than one sugar moiety, normally being glucose, galactose, and rhamnose. Still, in different LAB's EPS it is possible to find different sugars or other functional groups like acetyl and phosphate groups [10]. Normally, HePSs are associated with the modulation of host function, e.g., antioxidant effect or immune modulation, while HoPSs are associated with prebiotic properties, indicating how the conformation of these branched sugars and the monomeric composition influence the impact on the host [10][11]. The prebiotic effect exerted by LAB's EPS is the subject of particular interest, because of the production of SCFA, gasses, and organic acids involved in the inhibition of noxious bacteria and the improvement of host's metabolism [10]. EPS produced by LABs proved to be more effective in increasing the amount of Bifidobacteriaceae in the intestinal lumen with respect to inulin, the most used bifidogenic oligosaccharides. At the same time, an antagonist effect towards *Bacteroides* and Clostridia was shown. Gut microbiota is strongly affected by the presence of EPS in the intestinal lumen, especially by HoPSs, that result to be the most suitable substrates for fermentation, while HePSs are normally not fermentable, but their ability to modulate the immune system make them of capital importance in maintaining a general health status [11].

In fact, EPS are supposed to have antioxidant and immunomodulatory effects, as well as the ability to reduce cholesterol in the bloodstream and its absorption; anticancer and anti-diabetic effects are just some of the positive features that may be exerted. Furthermore, they also have a role in fighting the presence of harmful bacteria in the intestine, since they can disrupt biofilms, removing the protection of pathogenic microorganisms and exposing them to stresses and attacks. Different studies were carried out to explore these proposed effects for EPS. Still, it has to be considered that many of these experiments were carried out in vitro or with animal models, missing the confirmation from clinical trials on humans [11]. Some studies on animals pointed out the anti-cholesterolemic effect of EPS. This effect is based on increasing the high-density lipoprotein (HDL) ratio: total cholesterol with reduction of lipidic deposits in the bloodstream, especially in the aorta. In other experiments, it was observed that bile acids were scavenged by EPS, reducing in this way the amount of cholesterol present in the blood. This can be due also to the utilization of blood cholesterol to synthesize new bile acids, which are subsequently employed in digestion processes. Results are of course promising, even if the mechanism through which EPS lowers cholesterol content in the blood is still not precisely known [11].

Health effects of food fermented by LAB (**Figure 1**) are known and have been studied for a long time. Despite this, we do not yet know all the mechanisms of action and the secondary effects of LAB and their derived compounds. For many years, literature have focused on health effects of bacteria isolated and recognized as probiotics, but more recent studies shed light on the beneficial effects of bacteria involved in food fermentation that are not considered probiotics due to the non-complete compliance to probiotics guidelines. As an example, LAB proved to be useful in homeostasis both directly in the gut and indirectly utilizing pathways' modifications that lead to an improvement of host health status [12][13].

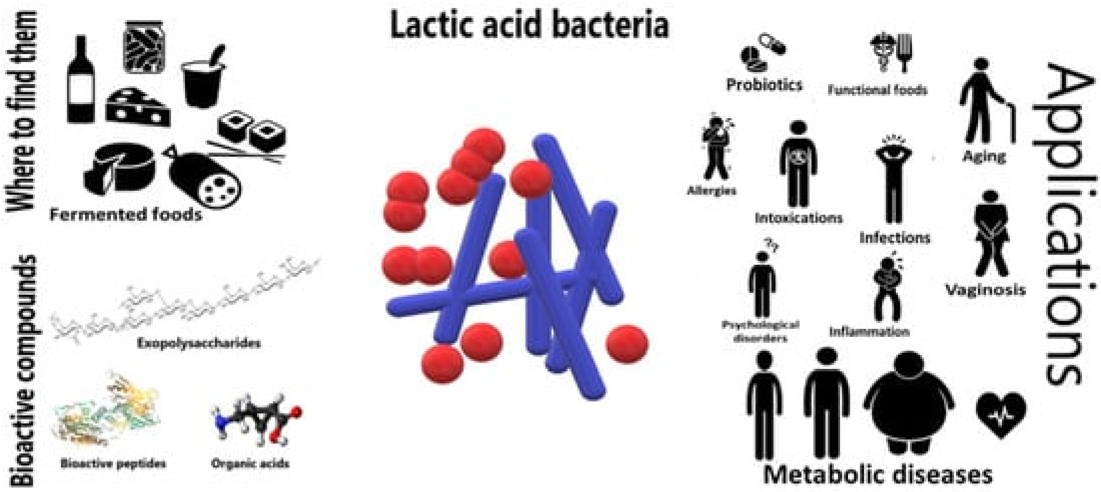

Figure 1. Scheme of LAB bioactive compounds and health-related effects, adapted with permission from [14] Copyright © 2018 George, Daniel, Thomas, Singer, Guilbaud, Tessier, Revol-Junelles, Borges and Foligné.

2. Health-Related Effects of Different LAB Fermented Foods

2.1. Fermented Dairy Products

Milk is probably one of the first fermented food staples by mankind. Historically, the first fermentations happened accidentally due to unpasteurized milk's tendency to spontaneously ferment due to the high level of nutrients and microbes [15][16]. From a biochemical point of view, fermentation is a complex combination of events. After lactose metabolism, different compounds are generated, such as: acids, ethanol, and carbon dioxide. The production of acids leads to a decrease of the pH, limiting the growth of negative microflora. Aroma compounds are also produced, increasing palatability and acceptance of foods and nutritional compounds like vitamins, minerals, bioactive molecules, and EPS [17]. Nowadays, after millennia of traditions and evolution of dairy art, fermented milk products represent about 20% of the total revenue generated by the fermented-foods markets all over the world. Production of fermented milks arose after 1950 when the demand for yoghurts and other similar products increased sensibly, attracting the attention of companies and consequently moving the production from a small-scale, in artisanal farms, to a mass production led by big multinationals [17]. Milks from different animals have become raw material for dairy fermentations. In fact, it is possible to find yoghurts, cheeses, and sour milks produced with cow milk, goat, sheep and horse milk as just examples in global markets. Even though dairy fermentations originally started from wild LAB present in milk, nowadays companies cannot rely anymore on spontaneous microflora, because of technological properties and possible health issues related to raw materials. For this reason, almost all industrially-fermented dairy products are produced with selected starters, or with back-slopping technique [17][18][19].

2.2. Vegetable Fermented Products

Vegetables are mainly fermented by LAB both spontaneously and by means of inoculum and back-slopping [20][21]. Among these lacto-fermented vegetables are fermented cabbage (kimchi and sauerkrauts), fermented leaf (gundruk) and pickles (cucumber, chillies, capers and others). Many of the positive features related to fermented vegetables are derived from the effects of acids and fermentation, which, as a consequence of fermentation, change their form to become more bioavailable, thus increasing their effect and elimination of anti-nutritional compounds [22]. In this review, we focus on the two main products derived from cabbage fermentation, representing a widely consumed staple in western and eastern areas of the world: sauerkrauts and kimchi. Fermentation of vegetables has as primary effect of increasing the shelf-life of food. Moreover, it allows to ameliorate the intake of nutrients like fiber, vitamins, and minerals. This effect is particularly useful since it permits the introduction of these micronutrients in periods when vegetables are unavailable.

3. Conclusions

The aim of this review was to highlight the ability of LAB involved in food's fermentation to exert beneficial effects on human health. Regular ingestion of foods fermented by LAB in the diet can be a great help, due to the introduction of bioactive compounds that are released during fermentation and become available during digestion. It is well established that the ingestion of LAB-fermented foods can modulate the gut microbiome in its functionality and response to stress and attacks, both due to the presence of health-related LAB species and their metabolites produced during fermentation. LAB's ability to produce bioactive peptides, vitamins, organic acids, bacteriocins, signalling molecules (NO), and antimicrobial compounds (H_2O_2) plays a fundamental role in promoting and maintaining a health status in consumers of LAB-fermented products. Despite the need of a higher amount of in vivo studies on a wider population and considering also the possible interaction among different fermented foods contemporaneously introduced, the pieces of evidence reported in the literature so far suggest that higher ingestion of LAB-fermented foods in the diet, daily, could contribute to a healthy lifestyle and in the maintenance of organisms functions and health.

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