**Power of lactic acid bacteria: Their current application in agriculture**

Essodolom TAALE1\*, Amakoé ADJANKE1, Koffi Kibalou PALANGA1, Tiatou SOUHO1 and Atti TCHABI1

1 : Laboratoire des Sciences Agronomiques et Biologiques Appliquées (LaSABA), BP 404, Campus Nord, Route Nationale N°1, Université de Kara, Kara, Togo.

\*Auteur correspondant : Email : [e.taale@univkara.net](mailto:e.taale@univkara.net); etaale1981@gmail.com; Tel : (+228) 93 18 28 86 / 98 04 69 64

# Introduction

From ancient times to the present day, humans and animals have always coexisted with microbes. A microbe (from Greek μικρός, mikrós, "small" and βίος, bíos, "life") or microorganism or microorganism (from Greek μικρός, mikrós, "small" and from ὀργανισμός, organismós, "organism") is a living organism which, individually invisible to the naked eye, can only be observed with the aid of a microscope. It belongs to the group of unicellular organisms (<https://fr.wikipedia.org/wiki/Micro-organisme>). The word microbe was introduced by French surgeon Charles-Emmanuel Sédillot in 1878. The domestication of these microbes has enabled humans to produce a variety of foods (fermented and non-fermented) with diverse and attractive properties, more digestible and thus contributing to achieving food safety but also helping to maintain consumer health. Among these microbes is the group of lactic acid bacteria.

According to Holzapfel and Wood (2014), the LAB belong to the Gram-positive bacterial phylum *Firmicutes* with ‘low’ (≤55 mol%) G+C in the DNA. Murindangabo et al. (2023) described LAB group in this terms: ubiquitous, Gram-positive, probiotic, and facultative aerophilic microorganisms. They are commonly found in wide range of environments including food-rich environments, decaying plants, milk products, human gut, vaginal flora, and on the skin of various living organisms. These multifaceted bacteria have multiple roles including promoting food safety; promoting plant growth; improving soil, animal, and human health. For Fitzpatrick and O'Keeffe (2001) they are known as fastidious microorganisms because their culture required a complex nutrient due to their inability to synthesize B-vitamins and amino acids.

LAB play a multifaceted role in the food (due to the action of their produced metabolites which inhibit the growth of pathogenic and spoilage microorganisms (Kröckel, 2013); agricultural, and medicine sectors and has GRAS (Generally Recognized as Safe) status by the Food and Drug Administration (Bintsis, 2018). The ability of LAB to produce polyamines, NO, or other signal molecules may contribute to plant growth stimulation or stress alleviation (Lamont et al., 2017). In agricultural sector, PGPM can improve the ability of plants to withstand stressful environments by protecting plants from abiotic stresses or by altering the stress response of the plant, thus improving the survival of the entire phytomicrobiome (Lamont et al., 2017) . Microbe-associated molecular patterns (MAMPs) are known to change plant response to biotic stresses (Henry et al., 2012) and abiotic stresses and it is likely that MAMPs produced by LAB are responsible for increases resilience of plants treated with LAB. None of these MAMP elicitors for LAB have yet been identified, but the identification of MAMP elicitor compounds could lead to a better understanding of the plant-microbe relationship, as well as enable to purification of active MAMP compounds for use as bioelicitors (Lamont et al., 2017).

Apart from their proven role in protecting and preserving foodstuffs against pathogenic and spoilage microorganisms, several studies have shown that lactic acid bacteria can be highly beneficial to plant growth (Mundt and Hammer, 1968; Higa and Kinjo, 1991; Vessey, 2003; Tsavkelova *et al.*, 2006; Henry *et al.*, 2012; Gaggìa *et al.*, 2013; Kang *et al.*, 2015; Murindangabo *et al.*, 2023). This study is a review of the literature on the potential application of lactic acid bacteria and their metabolites in agriculture, notably in plant growth, in protecting plants against bio-aggressors and in controlling the accessibility of minerals in the rhizosphere.

# **Methodology**

Data were collected by consulting online available published scientific articles and thesis on potential application of Lactic Acid Bacteria (LAB) and their metabolites in agriculture. So, we searched the electronic bibliographic database of the scopus, Elseviers, Googlscholar, Hinari and Agora using the ‘All databases’ selection. We used a combination of search terms including “lactic acid bacteria” AND “plant growth”, “Lactic Acid bacteria” AND “Agriculture”, “Lactic Acid Bacteria” AND “food protection”, “Lactic Acid Bacteria” AND “soil fertilization”, “Lactic Acid Bacteria” AND “Soil protection”, etc… Collected data were, cleaned, sorted in ordfer to extract and quantify the relevant and valuable information to help an in-depth understanding of current roles played by LAB in agriculture (soil, plant and food). Due to the limited research on this topic, we also identified important review articles and checked the references listed within each and the citations of these as previously described by Murindangabo et al. (2023).

# **Results and discussion**

# **Presentation of LAB genus**

Pfeiler and Klaenhammer (2007), da Silva Sabo et al. (2014), Sadiq et al. (2019a) and Ogunbanwo et al. (2020) described lactic Acid Bacteria (LAB) as Gram-positive, catalase-negative, facultative anaerobic, non-sporulating, non-motile and acid-tolerant bacteria with shapes like a sphere (coccus) or rods, in single cells or couples, tetrads and short to long chains. They belong to the order *Lactobacillales* and include the following genera: *Aerococcus*, *Alloiococcus*, *Carnobacterium*, *Enterococcus*, *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Oenococcus*, *Pediococcus*, *Streptococcus*, *Tetragenococcus*, *Vagococcus* and Weissella, which are all low-G+C content organisms (31–49%). Some specific optimal conditions of growth are pH4 and temperature of 30°C for the mesophilic and 44°C for the thermophilic LAB (Taale et al., 2013; da Silva Sabo et al., 2014).

# **Specificity of LAB groups**

The LAB are a diverse group of organisms with a diverse metabolic capacity. This diversity makes them very adaptable to a range of conditions and is largely responsible for their success in acid food fermentations. LAB can be divided into three groups based on fermentation characteristics: (i) obligately homofermentative (produce essentially lactic acid), (ii) facultatively heterofermentative, and (iii) obligately heterofermentative. The two latter are able to accumulate also a variety of fermentation end-products, including lactic, acetic, and formic acids, ethanol and carbon dioxide (Klaenhammer et al., 2005; Claesson et al., 2007; Pot, 2008). As lactic acid is the major end product of carbohydrates catabolism, the term ‘lactic acid bacteria’ was given to bacteria belonging to this group(Giraffa, 2014; König and Fröhlich, 2017). Indeed, their antimicrobial action in food preservation is due to the metabolites they produce including organic acids, bacteriocins, enzymes, alcohols, and other low molecular- weight substances(Moradi et al., 2020).

## **Production of organic acids**

Lactic acid, acetic acid, phenyllactic (PLA), hydroxyphenyllactic (OH-PLA), formic, propionic, butyric, coumaric, benzoic, salicylic, vanillic, and indole-3-lactic (ILA) acids are organics acids produced by strains belonging to lactic acid bacteria group. The major organics acids produced are lactic and acetic acid (Guimarães et al., 2018).

According to VickRoy (1985) and Tian et al. (2021) lactic acid (LA) is an important fine chemical intermediate and has broad applications in food, medicine, cosmetics, pharmaceutical, leather, textile industries and degradable material industries. LA plays a major role as a chemical feedstock capable of being converted to various chemicals such as acrylic acid, propylene glycol, acetaldehyde, and 2,3-pentanedione because of the presence in his structure hydroxyl (–OH) and carboxyl (–COOH) groups (Varadarajan and Miller, 1999). Nowadays, LA can be produce either by chemical synthetic or by microbial fermentation but biological method (microbial fermentation) has the advantage that an optically pure lactic acid can be obtained by choosing a strain of lactic acid bacteria. Also this method is respectful to nature as now the goal of humanity is to reduced chemical synthetic products. To achieve this goal it’s important using raw material (substances and LAB strains) for LA production may have several characteristics such as low cost, low levels of contaminants, rapid fermentation rate, high lactic acid yields, little or no by-product formation, and year round availability (Ryu et al., 2003). In order to propose a solution, Oh et al. (2005) produced lactic acid production from agricultural and renewable resources (such as barley, corn, and wheat) using *Enterococcus faecalis* RKY1. They also demonstrate that this is a way to use cheap raw substrates without additional nutrients.

## **Proteases**

In addition to organic acids, LABs can also produce enzymes for various applications, which are discharged into the intra- and/or extracellular environment. LAB proteases are low-molecular-weight proteins produced as preproenzymes in bacterial cells (Linares-Morales et al., 2020; Worsztynowicz et al., 2020; Ji et al., 2021). Exopeptidases (leave the peptide bond proximal to the carboxy or amino termini of the substrate) and endopeptidases (cleave the peptide bonds away from the termini of the substrate) are two types of proteases produced by LAB strains (Ramachandran et al., 2016; Mamo and Assefa, 2018; Gurumallesh et al., 2019). According to Mahajan et al. (2023), proteases are a very important class of enzymes, which are used in industrial processes because of their diversified catalytic potential which allows their extensive use in different industries (meat, dairy, brewing, food additives, feed and bakery, etc…).

## **Lipases**

**Lipases are atypical hydrolases.**Due to their kinetic and substrate specificities, triacylglycerol acyl-hydrolases or lipases are atypical enzymes. In function of their microenvironment, lipases are able to act as hydrolases in aqueous solution or as biocatalysts in organic synthesis. As hydrolases, they are responsible of the triglycerids catabolism into fatty acids and glycerol. In many organisms, this reaction plays a major role in the fat and lipid metabolism. In addition, lipases are also able to hydrolyse phospholipids and cholesterol esters. In organic solvent, lipases could catalyse reactions such as esterifications, acidolysis or alcoolysis with enantio-, regio- and chimioselectivity. Lipases form a mixed class of enzyme due to their animal, vegetal or microbial origins. All those properties led to the development of many applications in the food and chemical industries but also in the medical and therapeutic field(Fickers et al., 2008).

As biocatalysts of industrial significance, therapeutic applications, and flavouring agents in the food industry, lipases from LAB (intracellular or extracellular ) are of great importance because of their ability to perform unique fatty acid transformation reactions such as hydration, dehydration, isomerization, and saturation has several industrial applications(Messaoudi et al., 2010). *Lactobacillus acidophilus, Latilactobacillus Sake, Lactiplantibacillus Plantarum, Lacticaseibacillus casei* are some strains of LAB producing lipases.

**Application of lipases produced by LAB strains:**

* **Agriculture and breeding waste management:** Effluents from abattoirs, leather industries, poultry waste, etc., can be treated usinglipase as an eco-friendly method. The wastewater from the poultry industry typicallycontains a high concentration of oil and fat (Lambrechts and Pretorius, 2000) and apply lipases are the best solution to propose; solution which lead to reduce synthetic chemicals use. Also this biological processes take care of preventing unpleasant odors from solid materialaccumulation as well as sedimentation (help to fight biofilms formations). These LAB lipases can hydrolyze and dissolve the fat material present inthe agriculture and breeding waste and hence can reduce the usage of chemical solvents that are known to affectmicrobial diversity and affect world climate and farmers and concummers health.
* **LAB lipase as biology sensors:** according to Younis and Stewart (1998) due to the high diversity of lipases of LAB, they offer a range of molecules with different specificities that can be selectively employed for sensing purposes why their application in clinical diagnostics wherein the release of glycerol is being monitored.
* **Esterases:** LAB have been shown to have esterase activity in whole cells or culture supernatants, indicating that the ester profile of the beverage may be changed as a result of the growth of these cells in grape juice or wine. LAB esterases have been studied mostly in the dairy sector, where they have a role in the taste and defect characteristics of cheeses. Several studies showed that LAB esterases produced by *Streptococcus* (Maicas et al., 1999), *Leuconostoc*, Lactococcus (Stevens and Ough, 1993), and *Enterococcus*, have the capacity to both manufacture and hydrolyze compounds (Katz et al., 2002)..

## Enhance food acceptance by consummers by producing exopolysaccharides

Caggianiello et al. (2016) and Zannini et al. (2016) demonstrated that EPSs produced by LAB can modify the rheological properties, texture, and mouthfeel of food products. Also they could be used in the food industry as viscosifiers, stabilizers, emulsifiers, or other emulsifier gelling agents. Furthermore the availability of LAB starter cultures that produce EPSs in situ during fermentation could be a suitable alternative for products where adding polysaccharides requires specification as food additives.

Immunostimulatory and antitumor effects or reduction of blood cholesterol are some benefits attributed to microbial exopolysaccharides (Vinderola et al., 2006; Caggianiello et al., 2016).

For example in burkina Faso, the use of dextran (EPSs) from LAB for the production of composite pieces of bread from local cereals (millet and sorghum)(Tapsoba et al., 2023) had been initiated. This work is being carried out by researchers in the Food Technology Department of the Research Institute of Applied Sciences of the National Center for Scientific and Technological Research (DTA/IRSAT/CNRST).

# **Ecology niches of lactic acid bacteria**

Lactic acid bacteria a ubiquitous bacteria found in decomposing plant material, vegetables, fruits, dairy products, fermented food, fermented beverages, silages, juices, sewage, the gastrointestinal tracts and cavities of humans and animals (Sathe et al., 2007; Trias Mansilla et al., 2008; Djadouni and Kihal, 2012; Liu et al., 2014). LAB also are LAB are halotolerant and survive in low water intensity and high salinity in dry environments as described by Fhoula et al. (2013) from his work he had isolated and characterized 119 LAB strains from the rhizosphere of olive trees and desert truffles.

Table 1 : LAB diversity in ecosystem

|  |  |  |
| --- | --- | --- |
| **Ecosystem** | **Distinct ecology niches** | **LAB Strains** |
| Agroecosystem | * Phyllosphere * Endosphere * Rhizosphere | *Lactobacillus, Lactococcus, Enterococcus, Leuconostoc* and *Weissella*  *Lactobacillus* |
| Decomposing site | * Plant materials (vegetative propagules, sweet corn, cotton, wheat seeds) * Dairy products * Organics fertilizers * Sevage |
| Fermentation media | * Dairy products * Vegetables * Fruits (strawberry fruit, pepper, cucumber,) * meat, vegetable and cereal plant environments (maize, sorghum, millet) * Beverage * Silage/feed |
| Gut | * Livestock * Pets * Birds * Fish * Bees |
| Cavity of human and animals | * Oral cavity * Vaginal cavity * Intestine |

Source: (Chen et al., 2005; Klaenhammer et al., 2005; Sawadogo‐Lingani et al., 2008; Dalie et al., 2010; de Melo Pereira et al., 2012; Rzhevskaya et al., 2013; Shrestha et al., 2014; Baffoni et al., 2015; Minervini et al., 2015; Tapsoba et al., 2017; Bangar et al., 2021; Raman et al., 2022)

# **Their use in farming and soil fertility**

According to Raman et al. (2022) nowadays, LAB are considered as promising candidates for sustainable agriculture (table1)because they may promote seed germination, increase soil fertility, aeration, and solubility, alleviate various abiotic stress, neutralize toxic gasses, plant growth, stimulate shoot, and root growth. They can also promote biodegradation, accelerate the soil organic content, and produce organic acid and bacteriocin metabolites; which show an antagonistic effect against phytopathogens, inhibit fungal and bacterial populations in the rhizosphere and phyllosphere. All these properties confer to LAB in the development of sustainable agriculture is due to the existing interaction between plants and microbes (LAB). Therefore, microbial-based agricultural practices and advancements could promote plant health by improving microbes’ decomposition (decomposing macromolecular substances in organic material, degrading indigestible polysaccharides, and transforming undesirable flavor substances especially during composting) process improving nutrient acquisition, and protecting the plant from biotic and abiotic stress (Avis et al., 2008; Lamont et al., 2017; Wang et al., 2021).

Tableau 1 : Action of LAB on sustainable agriculture

|  |  |  |
| --- | --- | --- |
|  | **Benefit action of LAB** | **References** |
| **Rhizosphere/soil** | * interaction between plants and beneficial microorganisms like LAB, fungi, * 20–40% of the carbohydrates and organic acids are release and attract the LAB and colonize the root systems’ surface favouring their proliferation * Limits: * LAB diversity in soils depends on carbon richness, which is abundant in the fruit tree rhizosphere * not being a dominant bacterial group in most soils * microbial communities in the rhizosphere are largely shaped by plant species and age, as well as environmental factors such as temperature and moisture. | (Ekundayo, 2014; Shrestha et al., 2014; Canarini et al., 2019; Raman et al., 2022) |
| **Microorganisms colonizing rhizosphere or soil** | Rhizobium sp., Bacillus sp., and Pseudomonas sp., mycorrhizal fungi, LAB  **Limit:** LAB have been reported to be most numerous in carbon-rich soil environments, such as those under fruit trees or animal agriculture | (Yanagida et al., 2005, 2006; Reyes-Escogido et al., 2010) |

The potential LAB applications in a sustainable agriculture is represented in figure1.

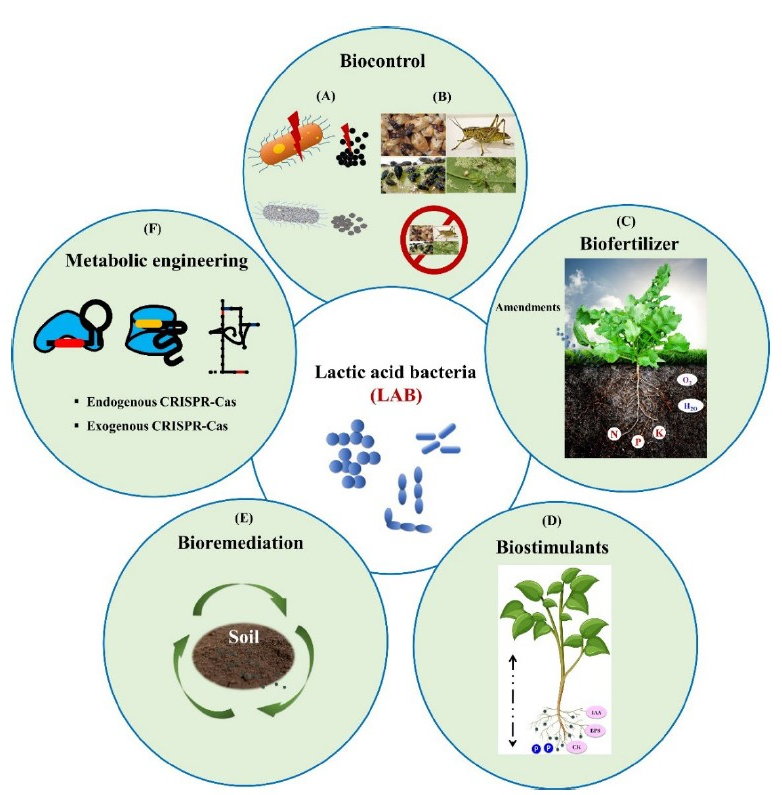


Figure 1 Lactic acid bacteria (LAB) agricultural application. (**A**). Anti-bacterial and anti-fungal activity; (**B**) biopesticides and insecticides; (**C**) biofertilizer increases soil fertility, aeration and retention of moisture content, elevates the mineral uptake and organic decomposition, acetifies the soil and reduces pest diseases. (**D**) IAA, cytokinin, and siderophore secretion increases the root and shoot length and solubilizes the phosphate in the soil. (E) Heavy metal removal, detoxification of fungal mycotoxins, acidification by LA and organic acid, increases organic decomposition, and increases the organic content in the soil, biodegradation. (F) CRISPR-Cas systems and derived molecular machines, endogenous or exogenous engineering to enhanced functional attributes (Raman et al., 2022).

## **LAB as biofertilizer**

Wang et al. (2019) defined biofertilizers as substances containing a variety of microbes to protect the plant and enhance the plant’s nutrients. In other hand, microbial-based biofertilizers increase crop yield and accelerate the mineral update of the plant root. Further, they enhance the organic matter catabolism. LAB are one of the major microbial groups responsible :

* for decomposing a variety of organic materials during compost (Partanen et al., 2010), animal and plant waste to assimilate organic matter such as lignin and cellulose materials (Hidalgo et al., 2022). Indeed, LAB-based fermented compost materials increase soil fertility, soil structure, aeration, neutralize alkalinity, and promote moisture retention and increase organics acid production. That is why Raman and his team (Raman et al., 2022) suggest to use LAB-based composting materials because they are well suitable for alkaline soils and could promote phosphorous and iron precipitates, such as Calcium, phosphates and iron oxides. Those conditions led to a significant availability of manganese, iron, nitrogen, phosphorus, and potassium in soils which also lead to increased root and shoot lengths (Murindangabo et al., 2023).
* for silage formation (MacDonald et al., 1991), and methogenic anaerobic digestion systems (Li et al., 2011);
* for Crop yield and enhancing organic matter degradation when LAB and bacillus-based biofertilizers were used (Blais, 2013).

Wang et al. (2008) explain that biofertilizer role (figure2) attributed to LAB strains could due to their natural ability to interact with plants which could be an attractive strategy to exploit their fermenting metabolism for developing a eco-friendly and functional biofertilizer. For Lamont et al. (2017) understand the symbiotic relationship between plants and LAB could be exploited to improve agricultural plant production.

## **Symbiotic Relations between Plants and LABs**

Nature is fascinating in many ways. While opposites clash and repel each other, there are also elements that live in harmony, so closely related that they become interdependent in order to survive. In such cases, we generally speak of symbiosis, a complex phenomenon that can be beneficial for all concerned, or parasitic for some. Symbiosis means living together. A symbiotic relationship describes a close, long-term relationship between different species. Nature is full of symbiotic relationships of all kinds, such as the bee and the flower, the clownfish and the anemone, or the human intestine and the prokaryotic intestinal bacteria that live there. The organisms involved in a symbiotic relationship are called symbionts. From this description, we can already deduce that there are several types of symbiotic relationships. There are three (<https://dailygeekshow.com/relation-symbiotique/>):

* The first is called mutualism. In this type of symbiosis, the relationship is beneficial for both symbionts. In other words, it's a win-win association between the two organisms involved. The perfect example of mutualism is that of bees and flowers. Flowers provide food for bees by collecting nectar, and flowers reproduce thanks to bees carrying pollen from flower to flower. It should be noted that there are still various types of mutualistic symbiosis, depending on the purpose and type of dependency between the symbionts. Other example is that Lactic acid bacteria and plants live in symbiosis, means that they live together and provide mutual benefit to each other. Also, plants in nature interact with a diversity of beneficial, pathogenic, and benign microorganisms. As described by (Vessey, 2003), rhizobia, Bacillus, Pseudomonas and mycorrhizal fungi are common symbiotic rhizosphere microorganisms. The functional roles of other groups of potential Plant Growth-Promoting Microorganisms (PGPMs), including lactic acid bacteria (LAB), have been explored (Lamont et al., 2017). PGPMs can promote plant growth by improving nutrient acquisition, acting as biocontrol agents (BCAs), improving the ability of the host plant to withstand biotic and abiotic stress, or by producing compounds that directly stimulate plant growth through multiple mechanisms simultaneously (Avis et al., 2008). According to Lamont et al. (2017) if the plant-LAB relationship provides an advantage to the plant, this relationship can be promoted or manipulated to improve agricultural production. Because for them plants interact with diverse communities of beneficial, benign, and pathogenic microorganisms in the environment and must be able to distinguish between members of these communities to optimize growth;
* Commensalism: Commensal relationships are those in which one species derives all the benefits from its relationship with the other, while the other receives no benefit or detriment from the symbiosis. These benefits may include locomotion, shelter, food or protection from the host species. An example of commensalism is the relationship between orchids and the trees they grow on. While orchids depend on the host tree for sunlight, the plant is not a source of harm to the tree. Orchids are small, easy-to-support plants with their own photosynthesis process. This means the plant doesn't extract any nutrients from the tree, apart from the water that runs off the outer bark;
* Parasitism: While we tend to think of symbiosis as a harmonious, peaceful relationship, this is not always the case. In cases of parasitism, one of the organisms benefits from the symbiotic relationship to the detriment of the other. Lice are a perfect example of parasitism. They live on the scalp, where they suck blood and cause itching in the host. Moreover, there are generally two types of host in parasitism: the definitive host and the intermediate host. A definitive host provides a home for an adult parasite, while an intermediate host unknowingly provides a home for a juvenile parasite.

## **LAB as biostimulant**

Tsavkelova et al. (2006) demonstrated that some PGPMs produce hormones (figure2) that can stimulate plant growth. Thus, *Lactobacillus acidophilus* has been reported to produce cytokinens (Lynch, 1985), and some strains of Lactobacillus have been shown to produce indole-3-acetic acid (IAA)(Mohite, 2013; Shrestha et al., 2014; Giassi et al., 2016) while others do not (Kang et al., 2015). As biostimulants, LAB can directly promote plant growth or seed germination, as well as alleviating various abiotic stresses (Lamont et al., 2017). (Higa and Kinjo, 1991); Higa (2001); (Somers et al., 2007; Paulsen et al., 2009) precise that since 1930s, *Lactobacillus*, was used as an indispensable component of sustainable agriculture, to control pests, condition soils, and stimulate plant growth.

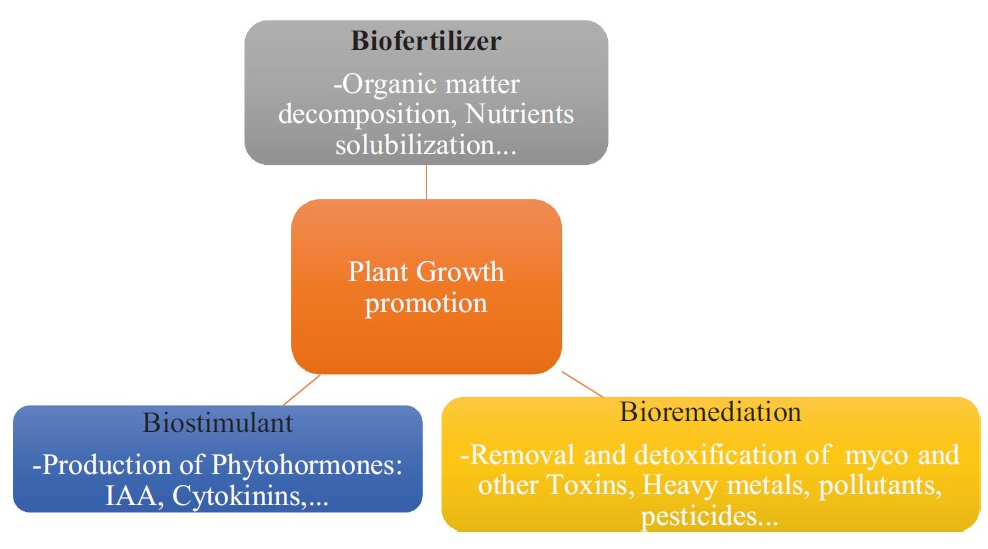


Figure 2 The role played by lactic acid bacteria in the enhancement of plant growth (Murindangabo et al., 2023).

# **Actions of LAB and their metabolites on crop aggressors/ agents of food spoilage**

Their ability to produce organic acids, phenolic compounds, antimicrobial (fungal, bacterial) metabolites, flavor substances, and bacteriocins (figure 3) (Taale et al., 2013; Taale et al., 2016a; Taale et al., 2016b; Taale et al., 2020) has put LAB among the best food preservatives (Delves-Broughton et al., 1996; Dalie et al., 2010). Indeed, they are used in wineries and breweries (for starting the malolactic fermentation), bakeries, and other plant and animal-based foods and drinks factories and play big roles in the production of cheese, bread, yogurt, silage, and others as reported by (Nguyen et al., 2015). The protected food includes post-packaging heat treatments, control of water activity, vacuum packaging, or the addition of preservatives to control in fermented dairy products (Garnier et al., 2017; Snyder and Worobo, 2018). Fermented food are most where LAB has served as an effective biocontrol agent; where they control a wide variety of fungal and bacterial phytopathogens (Lamont et al., 2017) growth helping to minimize food spoilage (Muhialdin et al., 2013); that is why they are generally recognized as safe (GRAS).

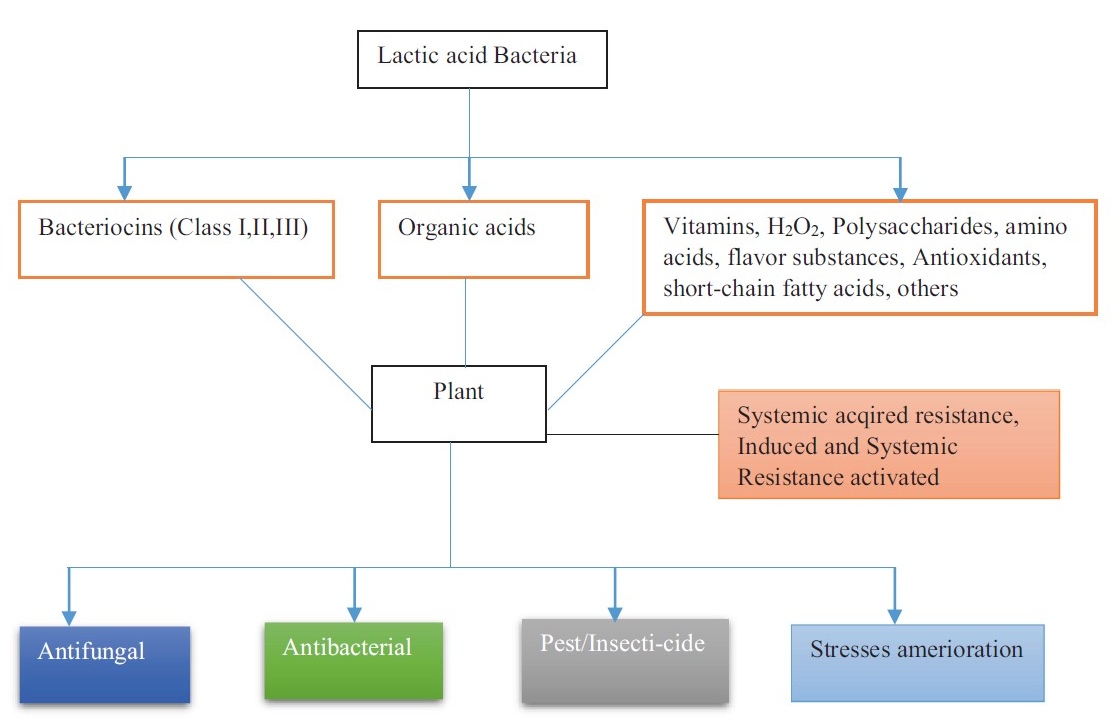


Figure 3 The role of lactic acid bacteria in biocontrol and stress amelioration(Murindangabo et al., 2023)

According to Sadiq et al. (2019b) about 50% of fruits and vegetables in tropical regions are lost every year due to fungal spoilage. The Food and Agricultural Organization (FAO), estimates that mycotoxin contamination of food crops globally is 25% and could be up to 60–80% (Eskola et al., 2020). Maize, groundnuts, and tree nuts are the most common foods at risk of contamination with aflatoxins commonly produced by *Aspergillus, Penicillium, Fusarium*, and *Alternaria* genera, affecting cereal grains (Wagacha and Muthomi, 2008). Among them, F. oxysporum is a soil-borne pathogenic fungi that is a significant causative agent in damage to horticultural crops. *Fusarium* wilt is a common disease in the Solanaceae family. *Fusarium* species decrease crop yield and cause considerable losses in banana production.

Fungal contamination of foods may lead to the accumulation of mycotoxins, secondary metabolites of some fungal species. Mycotoxins are a public health concern due to their high prevalence, teratogenic, carcinogenic, mutagenic, and immune suppression effects as reported by (Dalié et al., 2010; Abrunhosa et al., 2016; Ji et al., 2016). The consumption of food contaminated by microbes has been associated with different foodborne diseases, and form an integral part of food safety concerns (Gonelimali et al., 2018). Some examples of successful application of LAB to control food spoilage (figure 3 and 4) and extend his self-life are listed below:

* **Dairy products:** Fungal contamination of dairy foods can occur at different stages, from dairy farms to dairy processing units and at consumers’ homes as reported by Garnier et al. (2017). Dairy products are very susceptible to fungal spoilage, which causes economic losses and is a public health concern due to the possible production of mycotoxins (Fernandez et al., 2017). Lactobacillus plantarum, Lactobacillus rhamnosus and Lactobacillus casei have been successful used to fungal spoilage in dairy products. (Fernandez et al., 2017; Xu et al., 2021).
* **Bakery:** The most widespread species of fungi that contaminate bakery products belong to the genera *Aspergillus, Penicillium, Eurotium*, *Monilia, Mucor, Endomyces, Cladosporium, Fusarium and Rhizopus* (Lavermicocca et al., 2000; Lavermicocca et al., 2003; Guynot et al., 2005); where they responsible for off-flavours, the production of mycotoxins and allergenic compounds.
* **Silage:** Lactic Acid Bacteria (LAB) have applications in many industrial areas and play an important role in the preservation process of moist forages for animal feeding (silage). The basic principle silage is to store the surplus forage keeping its stability and nutritional value until it is required to feed the animals. This process takes place in anaerobic conditions, where the *Enterococcus faecalis, E. lactis, E. faecium, Lactocillus plantarum, Lb. acidophilus, Lb. brevis, Lb. buchneri, Lb. casei, Lb. citrovorum, Lb. curvatus, Lb. dextranicum, Lb. fermentum, Lb. mesenteroides, Lb. viridescens, Pediococcus acidilactici, Ped. cerevisae, Ped. pentosaceus* inhibits the proliferation of spoilage microorganisms, which are less tolerant to acidic conditions(Santos et al., 2013). *Lactobacillus buchneri* isolated from corn silages showed antifungal activity against F. graminearum (Paradhipta et al., 2021).
* **Fresh fruits and vegetables** naturally contain microorganisms that will eventually spoil them, however, some of these microorganisms are key players in the fermentation process of the fruits and vegetables. L*actobacillus, Leuconostoc, Weissella, Tetragenococcus* and *Pediococcus* species (Gbashi et al., 2023). They are responsible for the characteristic by-products of fermented vegetables which include carbon dioxide (CO2), ethanol (ethyl alcohol), and lactic and acetic acids from the natural vegetable sugars often contribute to inhibiting other harmful and undesirable microorganisms that could cause spoilage or undesirable characteristics in the final product. At the same time, the produced CO2 helps in maintaining the low-oxygen conditions that fermenting bacteria need while also stabilizing the color and flavor of the vegetables (Gbashi et al., 2023). LAB isolated from fresh fruits and vegetables were used as biocontrol agents against the phytopathogenic and spoilage bacteria and fungi Xanthomonas campestris, Erwinia carotovora, Penicillium expansum, Monilinia laxa, and Botrytis cinerea (Trias et al., 2008).

Figure 4 illustrate the potential role of LAB and its metabolites in the food production and food security.



Figure 4 Food applications of LAB against fungal contamination

Source: (Bangar et al., 2021)

For (Trias Mansilla et al., 2008), (Roselló et al., 2013) and (Konappa et al., 2016) there are three known mechanisms by which LAB acts as a biocontrol agent:

1. through the production of antimicrobial compounds,
2. reactive oxygen species ;
3. and bacteriocins (nisin, reutericyclin, sakacin, lacticin, pediocin); by excluding pathogens by pre-emptively colonizing plant tissues vulnerable to infection, and by altering the plant immune response.

**Conclusion**

In the fight against global warming and, above all, to reduce the use of chemically-synthesized products in agriculture and agricultural products during storage and processing, it is essential for less advanced countries such as those in Africa to seek innovative solutions that protect the environment and consumer health by using bacteria naturally present in nature and in food matrices. Among these bacteria are the lactic acid bacteria that colonize most of our traditional products/foods such as mawè, agbélima, etc. in Togo. The symbiotic action of these bacteria with plants and their roots and soil microorganisms is an alternative path to be explored in order to reduce the use of chemical fertilizers in a sustainable agriculture. To achieve this, less advanced countries such as Togo need to invest in application research, by promoting the use of products by local populations and by equipping laboratories whose analyses will reassure consumers, but also enable isolated strains to be used for other useful purposes.

1. **References**
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