



Importance Of *Bacillus Coagulans* as A Probiotic in Food Industry

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<https://doi.org/10.5281/zenodo.7487092>

Abstract

As these days, because of growing purchasers request, the interest in probiotic foods is increasing and it is attracted widespread attention and their applications in medical services and animal husbandry has been promising. Among numerous probiotics, in recent years *Bacillus coagulans* has become a key player in the field of probiotics. So, this article is all about the highlights of *Bacillus coagulans* as a probiotic and overview of proposed health benefits, remembering its applications in food industries.

Introduction

Probiotics are defined as living bacteria that, when administered in adequate amounts, confer a health benefit on the host (FAO/WHO, 2001) and that have been used for centuries (Behnsen *et al.*, 2013). Probiotics can be formulated into many alternative styles of products, including foods, tablets and nutritional dietary supplements. Examples of probiotic products in market include: probiotic lassi, icecreams, dahi, yogurt etc. Probiotic foods are available in grocery stores & supermarkets, while probiotic supplements are available in pharmacies and healthfood shops. There are two basic forms of probiotic microorganisms employed in foods: the vegetative form and the spore form (Özüsağlam, 2010). Species of *Lactobacillus* and *Bifidobacterium* are most ordinarily used as probiotics, but the yeast *Saccharomyces cerevisiae* and some *E. coli* and *Bacillus* species are also used as probiotics. The term “probiotics” was first introduced in 1965 by Lilly and Stillwell.

Introduction Of *Bacillus Coagulans*

The survival rates of *Lactobacillus* strains are highly affected by the production process, storage and transportation of food. However, these microorganisms cannot endure heat treatment, for which the



cold spot temperature is approximately 75 °C (Ruiz *et al.*, 2011; Baka *et al.*, 2015). They are very sensitive to heat, so for these probiotic foods, heat treatment is not appropriate. Nevertheless, it has been expressed that this limitation could be overwhelmed by the usage of spore-forming probiotic microorganisms like some non-pathogenic *Bacillus* species (*Bacillus coagulans*), which are not as well-known as LAB and yeasts, are being utilized as probiotics (Hyronimus *et al.*, 2000). Due to their spore forming abilities, they are recognized as an ideal choice in development of utilitarian nourishments by securing their protection in high-temperature applications (Fares *et al.*, 2015; Pilevar & Hosseini, 2017).

The organism was first isolated and described as *Bacillus coagulans* in 1915 by B.W. Hammer at the Iowa Agricultural Experiment Station as a cause of an outbreak of coagulation in evaporated milk packed by an Iowa condensary. Separately isolated in 1935 and described as *Lactobacillus sporogenes* in the fifth edition of Bergey's Manual, it exhibits characteristics typical of both genera *Lactobacillus* and *Bacillus*. However, in the seventh edition of Bergey's, it was finally transferred to the genus *Bacillus*.

Bacillus coagulans is a gram-positive, facultative anaerobic, nonpathogenic, spore-forming, lactic acid-producing bacteria (Özüsglam, 2010). It is resistant to heat; the optimum growth temperature for *B. coagulans* is 35 to 50°C and the optimum growth pH is 5.5 to 6.5 (Karri *et al.*, 2016). Its spores are terminal, while spores of other species are central or subterminal. It has the characteristic of microorganisms utilized as probiotics (Kristjansson, 1991). It also produce various enzymes like thermostable α -amylase, lipases, xylanases etc (De Clerck *et al.*, 2004). For this reason, *B. coagulans* is significant from an industrial point of view. It has been reported as safe by the US Food and Drug Administration (US FDA) and the European Union Food Safety Authority (EFSA) and is included in the Generally Recognized As Safe (GRAS) and Qualified Presumption of Safety (QPS) list (EFSA, 2013).

Special features

They are an ideal choice for the improvement of cereal primarily based products due to the fact that they can maintain their viability in heat-treated cycles such as baking and boiling as well as the spores gain a stable state during the food stockpiling (Fares *et al.*, 2015). Bacteriocin produced from *B. coagulans* had an inhibitory effect against *E. coli* (NCTC-10418), *Pseudomonas aeruginosa* (NCIB-9016), *Klebsiella pneumoniae* (NCIB-9111), *Bacillus subtilis* (NCTC-6346), *Staphylococcus aureus* (*S. aureus*) (NCTC7447) and *Candida albicans* (CBS-562) (Abada, 2008) and also had an antifungal effect on *Botrytis cinerea*, *Fusarium pallidoroseum* and *Fusarium moniliforme* (De Senna and Lathrop, 2017)



As an anionic antibacterial substance, the bacteriocin produced by *Bacillus coagulans* is a broad-spectrum antibacterial agent in opposition to Gram-positive bacteria, which are embroiled in transmission of food-borne disease (Abdhul *et al.*, 2015; Fu *et al.*, 2018). The mechanism of action of bacteriocin pertains to their capacity to penetrate outside of pathogenic microorganisms, inflicting amino acids and inorganic salts spill from the cells, thereby restraining growth. (Riazi *et al.*, 2009; Riazi *et al.*, 2012).

Bacillus coagulans can help establish an anaerobic intestinal environment, by devouring free oxygen in the intestine and stomach and reduces redox reactions creating an unfavourable environment for various pathogens thereby promoting the growth of some probiotics (anaerobic microorganisms) such as *Lactobacillus* and *Bifidobacterium*. (Kodali & Sen, 2008).

Bacillus coagulans can help establish acidic intestinal environment by utilizing various carbon sources to secrete lactic acid and acetic acid in anaerobic conditions at temperatures under 50°C and lactic acid is the most vital and significant antimicrobial substance secreted by *B. coagulans* in human gut (Glaser & Venus, 2018; Jiang *et al.*, 2016).

Inoculation of *Bacillus subtilis* var. natto ATCC 15245 and *Bacillus coagulans* ATCC 31284 spores in sausages and they found that by formulation, chopping and surfactant, viability and growth of *Bacillus coagulans* spores were influenced. By applying different household-type cooking methods (boiling, microwave cooking and deep frying) and cold storage to sausages, they reported that *B. coagulans* spores count was adequate to characterize the sausages as probiotic (Jafari *et al.*, 2017).

Bacillus coagulans GBI-30, 6086 was used in pasta and various cooking process (5-7 min) were applied. After the manufacturing techniques, *B. coagulans* count was 9 log cfu/100g and they reported that this concentration of probiotic microbes was sufficient to show a useful impact for consumers with excessive dietary cost and sensorial properties (Fares *et al.*, 2015). Nutty delight museli is the product containing *B.coagulans* SNZ 1969 and India is the manufacturer of this product (<https://www.probiotaevent.com/wp-content/uploads/2017/02/Emma-Schofield-Probiota-2017.pdf>). Likewise, commercial probiotic formulations containing *Bacillus coagulans* are like Staimune (*B. coagulans* GBI-30, 6086, Ganeden USA), Sporlac R (*B. coagulans* GBI-30, Sanzyme Japan) etc.

Health Benefits in Animals

Nowadays, *B. coagulans* ATCC (Hung *et al.*, 2012) and commercial strains like *B. coagulans* MTCC 5856 (Majeed *et al.*, 2016) have been used in animal feeds. *Bacillus coagulans* could diminish the loose bowels rate and improve the growth performance of piglets (Zhang *et al.*, 2018). It also helps in



improving the balance of intestinal microbiota in broiler chickens by improving the feed conversion ratio and additionally has growth-promoting effect (Hung *et al.*, 2012). It has likewise been used in aquaculture and reported that it significantly improves the final weight, daily weight gain and relative weight gain of the shrimp (Wang & Gu, 2010).

Health Benefits in Human Beings

In co-activity with gut microbiota, *Bacillus coagulans* has been appeared to build gut supplement assimilation and accessibility to help absorption (Maathuis *et al.*, 2010). As *Bacillus coagulans* has an ability to produce variety of enzymes, it is equipped for improving the successful use of devoured nourishments. For example, *Bacillus coagulans* RCS3 can secrete β -galactosidase during growth, which can degrade lactose, found in milk, into glucose and galactose, improving the digestibility of milk and effectively alleviating lactose intolerance (Batra *et al.*, 2011).

Bacillus coagulans helps in maintaining immune homeostasis. Daily intake will result in increase in their colonization in gut resulting in increased number of beneficial microbial population & decreased number of pathogenic strains and causes pathogen exclusion. By cytokine expression & dendritic cell migration, moreover, it could proliferate different immune cell for production of anti-inflammatory cytokines to maintain immune homeostasis.

Bacillus coagulans can help in promoting healthy bowel movements by likewise invigorating intestinal peristalsis, reduce the production of harmful substances such as amines and improve the intestinal metabolic environment and evading aggregation of poisons in the body (Nyangale *et al.*, 2014). A study on the impacts of *B. coagulans* lilac-01 on intestinal movements in human patients demonstrated that the administration of *B. coagulans* could adequately alleviate constipation, enhance the sensation of fecal retention and improve the intestinal environment compared with the control group (Kimiko *et al.*, 2015). *B. coagulans* SANK 70258 has also been additionally shown to improve bowel movement frequency, improve stool shape and color, reduce intestinal ammonia, diminish sputum, p-cresol and improve fecal scent (Ara *et al.*, 2002). Moreover, *Bacilluscoagulans* PTA 6086 administration essentially help in decreasing inflammation by improving the health of the cells of the gut lining, thereby improving nutrient absorption through ideal advancement of the absorptive area of the villi (Kimmel *et al.*, 2010).

Bacillus coagulans also helps in alleviating Major depressive disorder (MDD). This is because there is communication between the gut and the brain (microbiota- gut-brain axis). So, when an abnormal microbiota associated with a disrupted gut barrier, there is an activation of the mucosal immune system



leads to release of inflammatory mediators and other neuroactive molecules into systemic circulation from where they reach brain and result in some of the mental symptoms like incorporating a distraction with mortality, sentiments of blame, low state of mind, diminished personal satisfaction and upset rest or craving (Moschopoulos *et al.*, 2018). This may result in carbohydrate malabsorption and could be associated with mental depression. Alternately central stimuli, stress can disrupt mucosal immunity, gut microbiota, gut barrier function and lead to gut dysfunction. LactoSpore[®] with GRAS status which contains spores of *B. Coagulans* MTCC 5856 strain helps in alleviating MDD (Majeed *et al.*, 2016).

Bacillus coagulans also has the anti-oxidant property. When the intestinal microbiota becomes abnormal, harmful microorganisms proliferate excessively and eventually cause significant oxidative stress (Jones *et al.*, 2017) by producing high- level free radicals that will ultimately exert cytotoxic effects on the membrane phospholipids of the intestinal epithelial cells (Chauhan *et al.*, 2014). *Bacillus coagulans* could alleviate the oxidative stress via increasing the activities of myeloperoxidase (MPO) and anti-superoxide anion free radical (AFASER), decreasing the content of malondialdehyde (MDA), regulating the transcriptional regulation levels of antioxidant enzymes and Nrf 2-Keap1 signaling molecules.

➤ **Prevents Muscle Damage During Exercise**

Extreme exercise for subsequent periods can cause deferred beginning muscle soreness, muscle torment and firmness, diminished apparent recovery increased muscle damage and decreased execution 24-48 hours after the workout ends. That can the thin lining of the small intestines causing proteins to leak into the bloodstream and this will trigger inflammation, oxidative stress and even autoimmune reactions.

GanedenBC³⁰ may assist to prevent this by closing the “tight intersections” the spaces between cells in the small intestines so that these proteins can’t escape. *Bacillus coagulans* GBI-30, 6086 decreases inflammation and encourages ideal development of the absorptive area of the villi by enhancing the health of the cells of the gut lining and thus improves nutrient absorption (Kimmel *et al.*, 2010). It also produces digestive enzymes like alkaline proteases leads to digest proteins and results in increased protein absorption as compared to endogenous human proteases alone. That outcomes in quicker recuperation of strength after muscle damaging exercise (Buckley *et al.*, 2010).

➤ **In Treating Gastrointestinal Disease Like Irritable Bowel Syndrome (Ibs) & Inflammatory Bowel Disease (Ibd)**

Both are common functional gastrointestinal (GI) disorder, there are changes in the gut flora-



have lower amount of *Lactobacillus* and *Bifidobacterium* in their guts and higher levels of harmful *Streptococcus*, *E. coli* and *Clostridium* and it is characterized by abdominal pain or discomfort, diarrhea, constipation, abdominal bloating and flatulence (King *et al.*, 2003). Will increase in inflammation, increasing sensitivity to gas in the intestine, reducing immune function and changing digestive motility.

Bacillus coagulans MTCC 5856 produces the short chain fatty acids and bactericidal proteins that results in decreased luminal pH and will bind to pathogenic bacteria and causes suppression of the growth (O'Mahony *et al.*, 2005). Will result in improvement of the barrier function of the epithelium and alteration of the immune activity of the host (Collins *et al.*, 2002).

➤ **Treat Colitis**

Clostridium difficile associated disease (CDAD) occurs due to certain types of bacteria that predominate in the colon (e.g., members of Firmicutes and Proteobacteria) and is associated with diarrhea and colitis. BC³⁰ probiotic treatment will help in reducing actual numbers of *C. Difficile* in colon and also helps in preventing re-occurrences of *C. Difficile* infection following withdrawal of Vancomycin (Fitzpatrick *et al.*, 2012).

➤ **Helps In Cadmium and Mercury Poisoning**

Cadmium (Cd) and mercury (Hg) are hefty metals that have become a significant worry for general wellbeing as they have toxic effects on the gut ecosystem. Adequate metal exposure will bring about the immediate death of beneficial microorganisms due to interruption of fundamental functions and more continuous changes in population sizes (Ghorbani *et al.*, 2002).

Bhakta *et al.* 2012 demonstrated two probiotic bacteria (*Bacillus coagulans* and *Lactobacillus plantarum*) and prebiotic (inulin) were applied as synbiotic diets and they reported that they considerably affected fecal microbiota. This synbiotic diet assume a part in protection against cadmium and mercury inhibitory effect as probiotics have the biggest function in binding metals, forestalling their entrance to the body and thus securing the host.

➤ **To Control Hypercholesterolemia**

Cardiovascular diseases are one of the significant reasons of deaths in adult. Abhari *et al.* 2015 conducted a study, he used *Bacillus coagulans* capsules (each containing 360 million spores) administered per day, in hyperlipidemic patients reported to reduce cholesterol.

The deconjugation of bile acids by probiotic bacteria causes assimilation of cholesterol in the growing cells, produces bile salt hydrolase enzyme and the incorporate in the cellular membrane to inhibit



the formation of cholesterol micelles resulting in reduction in serum cholesterol by reducing cholesterol solubility and thus excreted in faeces.

➤ Gut Functions Improvement in Elderly Population

With the increasing age (> 65 years old), with reduced fiber intake, reduction of riboflavin in the diet (Khan *et al.*, 2012), the number of *Bifidobacteria* and *Firmicutes* decreases in the gut, while the number of Proteobacteria and several opportunistic pathogens increases and can lead to disturbances in the intestinal flora and ultimately that will cause increase in oxidative stress with age (Finkel *et al.*, 2000), reduced gut motility later in life etc.

Nyangale *et al.* 2014 conducted a study and administered *Bacillus coagulans* PTA-6086 with prebiotics in elders reported to increase populations of beneficial bacteria *Faecalibacteria prausnitzii*. This bacteria is found to elicit some beneficial effects, improve immune and gut function and this synbiotic diet may represent another course for improving gut health of older men and women.

➤ Treating Rheumatoid Arthritis (Ra)

RA is a disease that develops when there is an imbalance in the cytokine network, either from excess production of pro-inflammatory cytokines or from inadequate natural anti-inflammatory mechanisms (Arend, 2001) leads to articular pain and eventually cartilage degradation and this development of arthritis is directly related to gastrointestinal microbiota, the mucosal and systemic immune responses.

Hyronimus *et al.* 1998 found that *Bacillus coagulans* gets activated in the intestines and releases anti-inflammatory molecules, bacteriocins and lactic acid compete for sites of mucosal adherence, works to dislodge and causes elimination of antagonizing microbes to modulate the gut microflora and the immune response.

Baharav *et al.* 2004 conducted a study, reported that Ganeden BC³⁰ helps in alleviating RA symptoms by downregulating proinflammatory cytokines (eg, IFN- γ , IL-12, TNF- α) without altering regulatory cytokines (eg, IL-10, TGF- β) causes anti-inflammatory effects.

➤ Prevent Bacterial Vaginosis (Bv)

BV is the most common vaginal disease worldwide and is characterized by decrease of native *Lactobacilli*, increase in colonizing foreign microbes- that produces sialidase and causes an elevated pH and leads to symptoms like white discharge, fishy odor, burning micturation, itching, soreness and redness at vulva (Hapsari *et al.*, 2006). Reid *et al.* 2003 used *Bacillus coagulans*-Unique IS2 when orally



consumed after the excretion from the rectum they ascend to vaginal tract as these strains have altering the ability of the pathogens to transfer to this niche. Intestinal passage of these probiotic strains also prompted an advantageous effect on the vaginal microflora. Anukam *et al.* 2006 directly administered these probiotic strains alongwith standard antibiotic treatment in vagina resulted in maintenance of a lowpH as it produces antimicrobial substances like acids and hydrogen peroxide.

➤ **Cancer Prevention**

Azimirad *et al.* 2017 investigated immunomodulatory effect of *Bacillus* probiotic spores on the production of lipopolysaccharide (LPS)-induced interleukin 8 (IL-8) in HT-29 intestinal epithelial cells. They studied colonization of purified spores *Bacillus subtilis* (natto) and *Bacillus coagulans* and their anti- inflammatory effects. They reported that they have ability to both increase and decrease the production of anti-inflammatory cytokines which play an important role in prevention of carcinogenesis.

Conclusion

Probiotics offer a moderately innocuous route of improving customer wellbeing, generally from the perspective of reducing the dangers of gastrointestinal-mediated disorders and so they are a very successful sector of the functional foods industry. As *Bacillus coagulans* is attracting interest as it resists strong gastric acid, high temperatures and antibiotics as compared to other LAB and its spore forming property is primary attributes that makes the probiotic of choice in clinic applications(to treat, prevent, control any conditions).

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