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Commercially Available Probiotic Products for Wellbeing of Mankind, Livestock and Fishery: A Review

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ABSTRACT

In view the paucity of any consolidated attempt to review the literature on commercially available probiotic products for wellbeing and overall development of mankind, livestock and fishery, present review is conducted. The first evidence of health benefits of probiotics emerged when a report was published by Eli Metchnikoff (1908). Since then several studies have demonstrated that the probiotics have become an essential element in the prevention and treatment of certain diseases. Nowadays, wide variety of food, dairy products, beverages, livestock and fish feeds and supplements, infant formulas, dietary supplements, wellness products, pharmaceuticals, cosmetics, *etc.* containing probiotics are available in the market. Consumption of such products is associated with their authenticated efficacy in modulation of the gut microbiota leading to improvement of immune system, reduction of serum cholesterol, prevention of cancer, treatment of irritable bowel-associated diarrhoeas, antihypertensive effects as well as improvement of lactose metabolism. The regular feeding of probiotic strains, both individual and combined, may shows greater effect on absorption and utilization of feed, daily increase of body weight and total body weight of livestock. Likewise, feeding of probiotics helps fish to absorb more nutrients, improve their feed utilization efficiency, as well as to digest them better and faster compared to their regular feeds. Evidence on feeding of probiotics resulted in improved quantity and quality of milk, meat and eggs are available.

Key words: Animal feeds, Dietary supplements, Human health, Infant foods, Nutraceuticals, Probiotics, Wellness products.

The concept of probiotics has a very long history. It is associated with the consumption of fermented foods by human beings. The earliest types of probiotic foods includes dairy products fermented by lactic acid bacterial (LAB) and fungal fermentation, leavened bread fermented by yeasts and cheeses (Kopp-Hoolihan, 2001). A wide variety of probiotic products are available in market *viz.* food or dairy products, infant foods, dietary supplements, beverages, livestock feeds and fish feeds (Parvez, 2006), a swift emergence of the wave of pharmaceutical probiotic products was earlier projected (Sanders *et al.,* 2003). The probiotics are contributing in the cosmetics. Nondairy and horticulture products are also used as a delivery media for probiotics (Sreeja and Prajapati, 2016).

The probiotics can modulate the gut microflora and improve the health status of the consumers. Similarly, the administration of probiotics in the feed stuffs of livestock and fishes leads to modulate the intestinal microbiotia leading to efficient digestion and assimiliation of feeds. There is a lack of knowledge about probiotics that are used as feed additives, mainly because research is mainly focused on human nutrition. Probiotic mechanisms that modify the conversion of nutrients also need to be discussed (Simon *et al.,* 2001). Studies have demonstrated beneficial impact on reestablishment of friendly microbiota through different mechanisms such as appropriate intestinal homeostasis (Wilkins and Sequoia 2017). A consortium based approach wherein different strains from various genera of the proven probiotic organisms has been advocated (Timmerman *et al.,* 2004, Mohammed *et al.,* 2022).

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Probiotics in food/ dairy products

Food industry is constantly evolving entailing innovation phenomena that generate constant research and emerging technologies. The change of consumers' preferences, needs and acceptance is a dynamic process, hence the maintenance of food quality *via* technology-driven innovation is evident (Savino *et al.,* 2018). The cultural heritage of consumers, habits and even sustainability factors can similarly affect technology innovations applied in the food industry (Martin-Rios *et al.,* 2018). Nowadays, consumers are becoming more health conscious and concerned about the beneficial value of food, directing manufacturers to emphasize on the promotion of functional foods. A key for successful marketing and acceptance of novel foods depends not only on the concept of food quality throughout

the chain but also to added value food functionalities (Khedkar *et al.,* 2017). These organisms when administered in defined quantitative and qualitative amount will provide clinically proven health benefits apart from those delivered by fundamental nutrients in the product in question (Brown, 2018).

Food products containing probiotics can carry a single or many different bacterial strains. Specifically, in fermented food products, probiotics can be added as starter cultures while other bacterial or yeast strains co-exist. Food-based probiotic products account for a large number of formulations and can be divided in two distinct categories: Dairy products *dahi*, cheese, ice-cream, yoghurt, *etc*. and non-dairy products, *e.g.*, meats and meat products, bread or other fiber snacks, chocolates, fruit juices and fruit preparations. The vast availability of food products makes them a good and potentially effective carrier system for the delivery of probiotics. Nevertheless, their ability to deliver *via*ble cells to the human intestine may differ considerably, depending largely on the physicochemical properties of each composite food matrix (Antonia *et al.,* 2019). Consumption of probiotic bacteria through dairy food products is an ideal way to re-establish the balance of intestinal microflora. It must conform to certain requirements for a dairy food product to be considered as a valuable alternative for delivery of probiotic bacteria on one hand and for variety of probiotic cultures to use as a dietary adjunct and to exert a positive influence in the other hand (Homayouni *et al.,* 2008). It is not out of place to mention that the importance to report that probiotic bacteria should be present in a dairy food to a minimum level of 10^6 CFU/g or the daily intake should be about 10^8 CFU/g, with the aim to compensate for the possible reduction in the number of these vital microbes during the passage through the gut (Shah, 2007).

Probiotics in dietary supplements

The concept of functional foods has been evolved recently after extensive research to find out the role of nutrients on health (Gibson, 2007). It contains physiologically active components, which provide health benefits beyond basic nutrition by affecting one or more functions in the body in a targeted way (Anjuman *et al.,* 2015). A dietary supplement is an orally administered substance designed to deliver a certain dietary ingredient to complement the diet (Sharma and Devi, 2014 and Thomas and Greer, 2010). These active ingredients are usually packaged in different forms of capsules, tablets, powders (in sachets) or liquids in measured doses (Webb, 2011 and Klayraung, *et al.,* 2009). Probiotics must be able to tolerate the severe conditions of gastrointestinal tract and arrive *via*ble to the site of action (Bansal and Garg, 2008). The manufacturing process of a dietary supplement is similar to medicines; however, the severe courses of action used in medicinal products are not necessary to pursue (Amaral, 2014). A strong negative correlation between bacterial *via*bility and compression force has been observed, revealing that probiotic survival decreases *via* increasing the tablet compaction forces (Silva *et al.,* 2013). Apart from food, we can add probiotics to our diet through dietary supplements. These are not drugs, so they do not need to be approved by the food (Federal) and drug administration (FDA).

Probiotics in infant feeding

A systematic review concluded that probiotics may be beneficial in preventing eczema in infants (Zuccotti *et al.,* 2015). However, another study found probiotics to be a significant risk factor for vancomycin-resistant *Enterococcus* colonization and was suggested to mediate the acquisition and transfer of resistance genes of bacteria (Topcuoglu *et al.,* 2015). Despite this, surveys have shown that clinicians and naturopaths recommend probiotic consumption for patients with a variety of pathologies including diarrhea, ulcerative colitis and infant colic due to their low cost, over-the-counter availability and acceptable safety profile in healthy adults (Abe *et al.,* 2013 and Gasbarrini *et al.,* 2015). There is a lack of evidence that the probiotics influence the gut microbiome when given exogenously and their effect on health outcomes in infants are largely unknown (Quin *et al.,* 2018).

Reports on the colonizing capability of *Lactobacillus GG* have varied (Agarwal *et al.,* 2003). About 86% colonization rate was reported in a randomized controlled trial of *L. acidophilus*. In Columbia, the prophylactic administration of *L. acidophilus and Bif. infantis* to all neonates in an intensive care nursery with a high incidence of NEC reduced the incidence of disease compared with historical controls (Dani *et al.,* 2002).

Probiotics in pharmaceutical preparations

The use of probiotics is a new way to control and treat infections in this modern era (Sreeja and Prajapati, 2016). A wide range of probiotic products is available in the market and can be easily purchased over the counter and unlike pharmaceutical drugs, their commercial distribution is not strictly regulated. Several systems have been developed for the delivery of probiotics to the GIT such as pharmaceutical formulations and food-based products. Pharmaceutical preparations in particular are considered more effective compared to commercial food-based carrier systems although their preference mainly depends on consumers' perception (Khedkar *et al.,* 2017). Examples of pharmaceuticals for the delivery of probiotics currently include, capsules, liquids, powder beads, ampoules and tablets (Sokol *et al.,*2008). Strain selection and differentiation is considered a crucial step in both pharmaceutical and food systems. Likewise, an issue that needs evaluation is the method of preparation of the delivery matrix which may affect cell *via*bility and effective target release in the GIT (Antonia *et al.,*2019). Some of the spore-forming strains of Bacillus are marketed commercially as they survive harsh gastrointestinal conditions and bestow health benefits to the host (Khatri *et al.,* 2019). Clinical practitioners use probiotic pharma products mostly as supplements (Sreeja and Prajapati, 2016). Sarowska *et al.,* 2013, Lakra and Krishnani, 2022 sowed the exact mechanism of action of probiotics has not been explained, but a number of aspects, the way it affects the human body was found and summarized.

Probiotics in beverages

The relationship between increased number of beneficial

bacteria in gut and its biological effects are yet to be elucidated (Plaza-Diaz *et al.,* 2015). The study by Hassan *et al.* (2012) showed rice and millet grains were fermented with ABT-2 starter culture (*Str. Thermophilus, L. acidophilus* and *Bifidobacterium* BB-12) to obtain probiotic beverages, fortified with pumpkin and sesame seed milk in order to combine the high nutritive value of seeds and the health benefits of the probiotic culture. The levels of several factors, *i.e.* starter culture concentration, rice and millet level and the amount of honey, affecting the fermentation process, were established for completing a controlled fermentation for 16 h. At the end of fermentation the *via*ble cell counts reached to about 4.3x10 cfu/ml. Changes were observed in acidity and counts of probiotic bacteria as a result of fortification with pumpkin and sesame milk at 10%. The shelf-life of the rice and millet fermented beverages was estimated to be 15 days under refrigerated storage (Amal *et al.,* 2012).

There is also an increased demand for the probiotic containing vegetarian products. Furthermore, lactose intolerance and the cholesterol content are two major drawbacks related to the fermented dairy products (Heenan *et al,* 2004; Yoon *et al.,* 2006). There is a wide variety of traditional non-dairy fermented beverages produced around the world. Much of them are non-alcoholic beverages manufactured with cereals as principal raw material. The non dairy probiotic beverages may be made from a variety of raw materials, such as cereals, millets, legumes, fruits and vegetables. Studies may be classified based on the source of raw material for the production of the non dairy probiotic beverage (Vasudha and Mishra, 2013).

Probiotics in cosmetic products

The concept of "probiotics" in cosmetics is defined as living microorganisms and/or their lysates, application of which in cosmetic products in adequate amount confer a positive effect on the human skin in addition to the characteristic of the main influence of the product (Tkachenko *et al.* 2017). According to the FDA, a cosmetic is defined as "a product (excluding pure soap) intended to be applied to the human body for cleansing, beautifying, promoting attractiveness, or altering the appearance". The use of beneficial microbes for this purpose has seen the field of probiotics grow substantially (Hill *et al.*, 2014). The probiotic applications range widely in type, scope and applications including cosmetics. There are numerous studies providing evidence of the benefits of specific probiotic strains for skin health (Yu *et al.,* 2020). In addition, the mechanisms of anti-ageing suggest that some strains can help to regulate pH, reduce oxidative stress, protect from photo ageing and improve the skin barrier function (Sharma, 2016). Due to safety concerns, cosmetic products are expected to have a low content of microorganisms (below 500 cfu/g for eye-area products and 1000 cfu/g for the rest). Applications for skin care require local use (Tkachenko, *et al.,* 2017). Orally administered probiotics have demonstrated to improve the intestinal microbiome leading to a potential improvement in skin conditions such as atopic dermatitis, acne, orrosacea (Knackstedt *et al.,* 2020).

Probiotics in cattle feeds

The effect of probiotics was linked to the gastrointestinal tract and on incidence of diarrhea and other gut infections. However, the earlier research findings showed that the effects of probiotics may be more general (Fuller, 1992 and Cho *et al.,* 2011). In general, the mode of action of probiotic feed additives is mainly based on competitive exclusion, bacterial antagonism and immune modulation (Hughes and Heritage, 2002). The use of probiotics in animal feeds could be enhanced by a preliminary *in vitro* screening of the candidate organisms for its antimicrobial activity, survival in the gut, adhesion studies and antibiotic susceptibility. The analyses of phenotypic and genetic properties are also useful for industrial production (Gaggia *et al.,* 2010). Dose, timing and duration of administration of the probiotics may be a factor affecting efficacy (Sazawal *et al.,* 2006 and Rosenfeldt *et al.,* 2003). Another determinant is the age of the animals; during early life, colonization patterns are instable and the animals are susceptible to environmental pathogens. Probiotics have been proposed as a *via*ble alternative to antimicrobials to enhance animal health and productivity (Markowiakand Slizewska, 2018). Effect of probiotics on disease prevention and performance indicators and host target system microbiota are yet to be quantified and documented (Siggers *et al.,* 2007).

Probiotics in poultry feeds

Probiotics have a beneficial effect on health that stimulates the growth of friendly microorganisms and reduces/ eliminates the population of pathogens, thus improving the intestinal microbial balance and lowering the risk of gastro-intestinal diseases. Markowiak and Slizewska (2018) reported that the role of probiotics in protection against the pathogens. An accurate dosage of administration has yet to be established despite the widespread use of probiotics. Probiotics have antimutagenic, anticarcinogenic, hypocholesterolemic, antihypertensive, anti-osteoporosis and immunomodulatory effects in poultry birds. *Lactobacillus, Bifidobacterium, Leuconostoc, Enterococcus, Lactococcus, Bacillus, Saccharomyces, Aspergillus* and *Pediococcus* species are most commonly used probiotics in poultry production. The probiotics improve feed-intake, growth performance, meat quality, egg production, egg quality and have cholesterol lowering potential in poultry products. However, some studies reported no significant effect of probiotics on feed-intake, production traits, product quality and cholesterol level (Tarekegn, 2016). Probiotics are widely accepted as an alternative to in-feed antibiotics in poultry production. A probiotic containing novel strain such as *Aspergillus oryzae* is also in practice, but its effect on performance of poultry is limited (Lee *et al.,* 2006). The ban on the use of antibiotic growth promotors in many countries in order to satisfy the consumers' demands for healthy and safe meat leads to increasing researchers' interest in finding strategies to maintain chicken health and production. The use of probiotics in poultry diets has been associated with positive effects on health and

growth in birds. Changes in growth performance often affect various meat quality traits and in this context, using probiotics as dietary supplements exhibit potential as a natural way to improve poultry meat quality (Popova, 2017). The addition of probiotics to the feed improves growth performance and feed conversion in broilers and egg mass, egg weight and egg size in layers (Fig 1). This is attributed to (i) maintaining normal intestinal microflora by competitive exclusion and antagonism, (ii) altering metabolism by increasing digestive enzyme activity and decreasing bacterial enzyme activity and ammonia production, (iii) improving feed intake and digestion and (iv) neutralizing enterotoxins and stimulating the immune system (Jin *et al.,* 2019).

Probiotics in aquafeed

Aquaculture is an important food producing sector to fulfill nutritional food demand of a continuously growing population. However, disease outbreak has become a major problem in aquaculture which causes huge economic loss to aquaculture industries. The use of expensive chemotherapeutic drugs has negative impact on the aquatic environment. So there is a growing concern to find other safe, non-antibiotic based and eco-friendly alternative for the treatment of the diseases (Muziri *et al*., 2022). The use of probiotics is a promising alternative approach for the control and treatment of infectious agents and stimulation of growth, improved digestion, enhanced immune response and recuperate the water quality as well. Probiotics strengthen the fish to fight against various pathogens and improves the overall health as they show anti-bacterial, anti-fungal and anti-viral properties. The fish consuming probiotics absorb minerals and vitamins easily and in large amounts than average. Instead of using antibiotics as a treatment when the sickness is already there, it is much safer and cost-effective in all ways to use probiotics. The use of probiotics in aquaculture is a recent trend and its efficacy in aquatic environment has not been studied extensively (Chauhan and Singh, 2019). In shrimp/fish aquaculture, feed represents the most expensive production cost. The quantity and quality of diets are primary factors influencing shrimp/fish growth, health status, disease prevention, pond contamination and expenses. Utilization of probiotic bacteria has emerged as a solution with enormous applications in the aquafeed industry. The various routes of administration of probiotics and mechanism of action are shown in Fig 2 and 3. Bacillus species, principally *B. subtilis* are one of the most investigated bacteria due to:

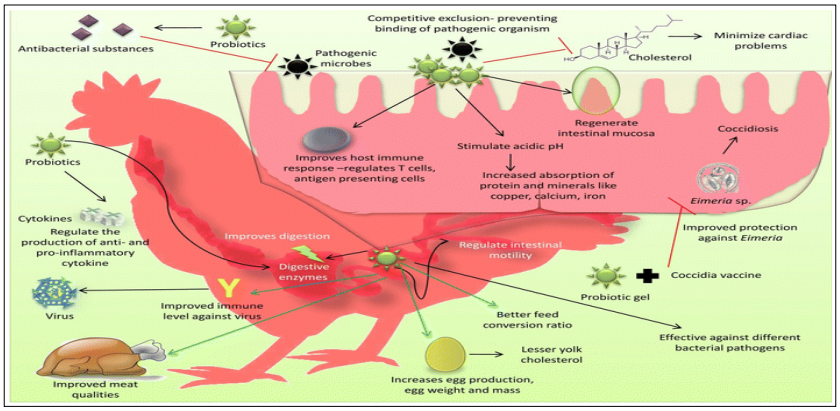

Fig 1: Modes of action and beneficial activities of probiotics in poultry.
Source: Mahmoud *et al.,* (2018).

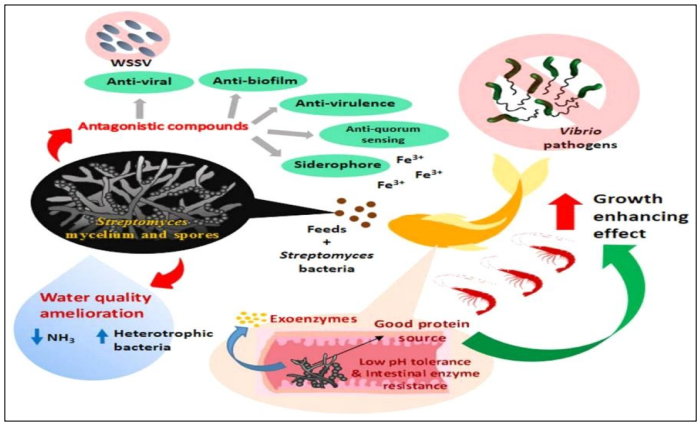

Fig 2: The mechanism of action of probiotic effects of Streptomyces bacteria and their applications in aquaculture.
Source: Tan *et al.,* (2016).

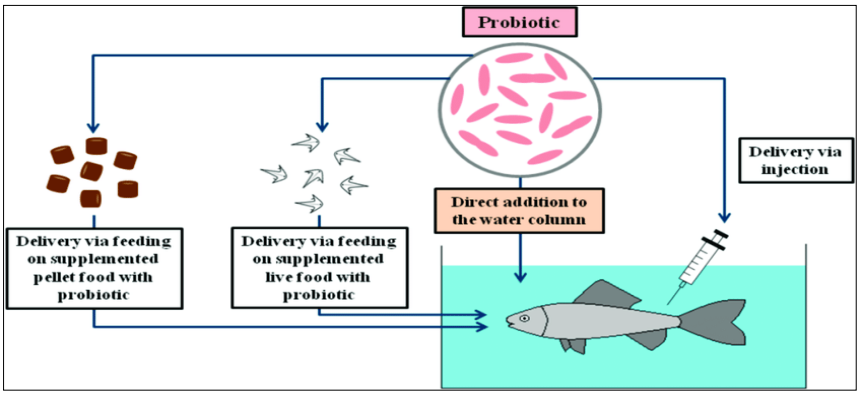

Fig 3: Different routes of probiotics administration in aquatic environment.
Source: Ladan and María (2018).

a) versatility of growth nutrients utilization, b) high level of enzymes production, c) secretion of antimicrobial compounds, d) spore producers, e) develops in aerobic and anaerobic conditions and f) *B. subtilis* is a GRAS. Functional feeds development with alternative economic nutrients and vegetable sources of proteins, carbohydrates, lipids and *Bacillus subtilis* probiotic strains, must be considered in shrimp/fish aquaculture production systems. This is an option to eliminate animal feed ingredients, improves digestion-assimilation, reduce water pollution and diseases and to increase yields and profits (Olmosand and Paniagua, 2014).

CONCLUSION

We have presented evidence substantiating that there are huge number and a verity of commercial probiotic products available in the market aimed at well-being of mankind and to flourish the production traits in livestock and fish. It is clear that probiotics are multi billion dollar industry in world wide. The pivotal use of probiotics in food and feeds is to restore the gut microbiota leading to good health and improved productivity. The daily intake of probiotics should be about 10^8 CFU/g. Data on human trials have validated the efficacy of different probiotic species, the conditions for their applications, the optimal doses and the formulation. Clinical practitioners use pharmaceuticals mostly as supplements but their functions are still not clearly illustrated. Likewise, the cosmetic industry needs to be consistent and transparent in its labeling practices and direct efforts to generating more scientific evidence before making claims to advocate probiotics as routine therapies as cosmetics. The action of probiotics in dairy/food products/beverages in livestock and fish, cosmetic products *etc.* needs to be broadly studied in more detail preferably with placebo-controlled, double blind studies.

Conflict of interest: None.

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