Review On Probiotic Potential In Human Health, Aquaculture And Animal Feed

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Abstract: Probiotics, a term that means "promoting life" where living microbes function to regulate the microbiota of a host body compartment. Hence, it conferring health-promoting activities to the host. Current research has provided strong evidence that probiotics microorganisms are beneficial for human health, aquaculture and animal. The use of probiotics is increasing dramatically due to a better understanding of their beneficial effects. Consumption of probiotics increases with overall potential welfares such as antibacterial, antiviral and antifungal activity, immunomodulatory abilities to enhance the health and welfare of humans, aquaculture and animal. This review emphasized on revising the existing data for the potential beneficial effect of probiotics on human, aquatic and animal for different species of probiotics. This review could contribute towards future studied to further puzzle out the mechanisms of probiotics action. Hence, the selection criteria for potential probiotics will be well defined in the future.

Index Terms: Probiotics, microbial, human health, aquaculture, animal

1. INTRODUCTION

The term probiotic arises from Latin 'pro' and 'bios' from Greek which bring the meaning 'for life' which referring to beneficial microorganisms (Zorriehzahra et al., 2016). Probiotics defined as living microbes that intended to exert beneficial health benefits by accumulating sufficient numbers of beneficial microbes to colonize in the host body compartment (Shida and Nanno, 2008). International Scientific Association for Probiotics and Prebiotics (ISAPP) and other scientific publications clarified the denotation of probiotics (Fijan, 2014). Probiotics have been defined as living microbes which when administrated with a sustainable amount to confer well-being on the host by the Joint Food and Agriculture Organisation/ World Health Organization. In recent decades, scientists have provided strong evidence that probiotic microorganisms are helpful in preventing and treating various detrimental diseases. The usage of probiotics is increasing dramatically due to a better understanding of their beneficial effects given by specific strain. Based on the Thomson Reuter Web of Science database, probiotic yielded 8356 publications in the last 5 years (2014-2018) and about 1018 publications within half of the year 2018. Increasing awareness among the community for not using antibiotics for the treatment of diseases due to its negative side effects such as immune repression encourages them to search for a healthier and safer alternative for treatment.There are around 100-1000 microbial species colonized in human guts to promote well-being by modulating host internal environment (Kerry et al., 2018). Ingesting probiotics is associated with the overall benefit of modulation of host immunity and the promotion of host defense (Martín et al., 2013). The usage of probiotics has been shown to enhance enzymatic digestion, feed value antimicrobial activity on pathogenic microorganisms, mutagenic and cancer-preventive, thus, elevated immune response (Pandiyan et al., 2013). Most of the probiotic effects facilitated via immune regulation particularly by controlling the balance of cytokines of pro-inflammatory and anti-inflammatory (Both et al., 2011).

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2 PROBIOTIC MICROORGANISM

Throughout the screening process, microbes can be identified as beneficial or harmful microorganisms. Hence, novel candidate probiotics with immunomodulatory properties can be determined (Gareau, Sherman and Walker, 2010). The physiological characteristics like clear beneficial effect and non-pathogenic to the host, survivability viable bacteria cell throughout the long-term storage and last but not least, survive when administrated to the gastrointestinal tract. Then, it only considered those microorganisms as probiotics (Marteau, 2006).The most common probiotic used in our daily life is Lactic acid bacteria and Bifidobacteria. Certain yeasts used as probiotic as well such as Saccharomyces boulardii (Didari et al., 2014). Species of the genera of lactic acid and bifidobacteria are generally-recognized-as-safe (GRAS) status (Ranadheera et al., 2017). Some of the essential probiotic genera are Lactobacillus, Lactococcus, Enterococcus, Streptococcus, Bacillus, Bifidobacterium and Saccharomyces.

Certain gram positive facultative anaerobic or microaerophilic rod-shaped bacteria are categorized in genus Lactobacillus (Fijan, 2014). Lactobacillus usually categorized into the homofermentative group and heterofermentative group. The homofermentative group consists of Streptococcus, Pediococcus, Lactococcus, Enterococcus, whereas heterofermentative group consists of Leuconostoc, Weissella. Lactobacilli have the capability to utilize the Embden-Meyerhof-Parnas (glycolytic) pathway to produce lactic acid. In addition, it can generate ethanol, lactate, CO_2 or even exploit the phosphoketolase pathway using acetate from glucose (Both et al., 2011). Newly discovered probiotic strains Lactobacillus delbrueckii sp bulgaricus WICC-B-02 found from breast milk confer beneficial health effect (Elsayed et al., 2014). Lactic acid bacteria were applied frequently on a large scale as starter cultures to produce fermented beverages in the food industry (Klare et al., 2007). The previous study reported the probiotic potential of several lactoccus strain such as Lactococcus lactis ssp. cremoris MRS47 (Vieira et al., 2017), Lactococcus lactis ssp. Lactis 44Lac (Haghshenas et al., 2014) and Lactococcus lactic WH-C1 (Wang et al., 2015). Streptococcus and Enterococcus are reported on having probiotic effects such as Streptococcus salivarius K12 (Doyle et al., 2017), Streptococcus thermophiles (Mallina et al., 2018),

Enterococcus faecium (Holzapfel et al., 2018) and Enterococcus faecalis (Mishra and Ghosh, 2018).Gram positive spore-forming aerobic or facultative aerobic categorized in genus Bacillus with great potential probiotic properties such as Bacillus subtilis (Wang et al., 2018), Bacillus licheniformis (Gobi et al., 2018), Bacillus aerius (Meidong et al., 2018), Bacillus coagulans (Yu et al., 2018) and Bacillus toyonensis (Roos et al., 2018). Several gram positive non-motile anaerobic bacteria categorized in genus which can be consider as vital probiotics microorganism such as Bifidobacterium longum (Pereira-Caro et al., 2018), Bifidobacterium infantis (Kumar et al., 2018), Bifidobacterium adolescentis (Florindo et al., 2018) and Bifidobacterium breve (Athalye-Jape et al., 2017). In addition, Saccharomyces cerevisiae (Sabbatini et al., 2018) and Saccharomyces boulardii categorized in genus Saccharomyces (El Enshasy and Elsayed, 2017). Another type of yeast species such as Cryptococcus sp. (El-Baz et al., 2017) and Kluyveromyces sp. (Hun et al., 2013).

3 PROBIOTIC IN HUMAN HEALTH

Human-microbiome superorganism formed by a distinctive reservoir of a diverse group of microbes. Recently, probiotic received gigantic attention in human life. Probiotic, not only is good bacteria but also intended to contribute to preventing various diseases and improving human well-being. Cognizance of this, the extensive probiotic research has been carried out on probiotic materials which provide a great deal of variety of biological activities including anti-pathogenicity, angiogenic activities, anti-obesity effect, anti-diabetic effect, anti-inflammatory effect, cancer and allergic preventive, are briefly discussed below and also depicted in Figure 1. Probiotics fermented in dairy fermentations have been proven with the great ability to produce bioactive molecules and throughout the process, it will produce enzymes that adding the extra value to the final products. Probiotics act as microbial biofactory as it synthesizes various bioactive compounds such as bioactive peptide, bacteriocins, enzymes, vitamins, gamma-aminobutyric acid, enzymes, conjugated linoleic acid, and exopolysaccharides. This means that the probiotic concept is not restricted as the bacteria must survive and colonize in the gut and valuable metabolite being yield in the body. The biofunctionality idea explains that these bioactive compounds produced from probiotics also benefit human health (Linares et al., 2017).

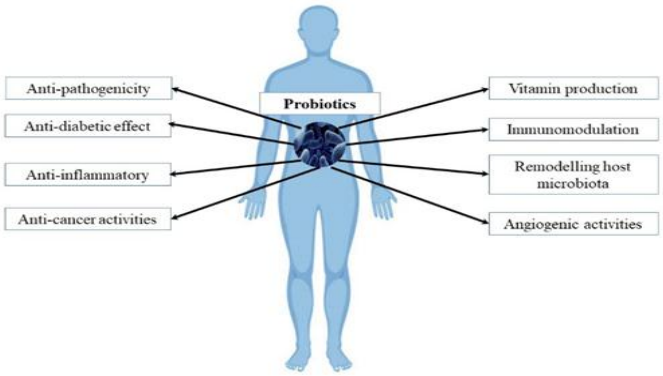

Figure 1. *Applications of probiotics for benefits of human healthiness.*

Thirteen types of essential vitamins obtained from food in our daily life as the human body unable to synthesize these proteins. Deficiencies of vitamins in human diet are still very common around the world, mainly because of the unbalanced diet and unable to afford proper food (Linares et al., 2017). Various species of Lactobacillus are proven with the capability to generate various vitamins which including vitamin cobalamin (B12) and folic acid (B9) in the dairy products. Gu et al. (2015) have reported Lactobacillus reuteri strains have the ability to produce vitamin B12 even is from different origins. Epidemiological evidence suggesting that diet lacking vitamin B2 with the administration of probiotic L. reuteri able to enhance pathologies in B12-deficient mice model. These clearly show probiotics have great potential in treating B12 deficiency (Gu et al., 2015). Utilization of lactic acid bacteria in the milk fermentation able to generate bioactive peptide as the proteolytic enzyme system from the bacteria able to produce enzyme to cleave the protein to bioactive peptide fragment. These peptides possessing biological characteristics, such as antihypertensive, antimicrobial, antithrombotic, antioxidative and immunomodulatory (Linares et al., 2017). In addition, probiotics produce exopolysaccharides (EPS) which play a pivotal role in modulating host microbiota and immune systems. The previous researcher reported that probiotic species such as Lactobacillus kefiranofaciens are able to produce beneficial polysaccharides and applied in the food and pharmaceutical industries (Dailin et al., 2016). Works done by El Sayed et al. (2017) have proven that EPS produced by L. kefiranofaciens exerted anti-cancer properties. Wang et al. (2015) also reported EPS is being produced significantly in kefir using Lactobacillus plantarum YW11.Supplementation with probiotics has great potential against various enteric pathogens as it can compete for the adhesion sites with pathogenic microbiota with their unique features and then colonized in the gut. Hence, the specific genes related to the intestinal tract is being triggered to detach pathogens or activate the host's immune response (Kerry et al., 2018). Probiotics are well known as it confers a health benefit to the host. One of the most valuable properties of probiotic is anti-pathogenic microbial activities against pathogenic bacteria. Probiotic bacteria found to be effective against Salmonella enterica which have the ability to cause enteric fever and diarrhea. In worldwide, Salmonella is the most common bacteria that cause food borne disease (Tejero-Sariñena et al., 2013). Interestingly, short-chain fatty acids (SCFAs) produce by probiotic able to prohibit pathogen growth. In addition, the expression of several bacterial enzymes can degrade harmful compounds in the gut when SCFAs help to sustain suitable pH conditions in colonic lumen (Kareem et al., 2014).The population of probiotics in the human gut is proven to prevent various gastrointestinal diseases. Inflammatory bowel diseases (IBD) is a term to describe Crohn's disease (CD) and ulcerative colitis (UC) which are among the most detrimental inflammation of the lower gut. Previous research stated that the equilibrium of the microbiota in the gut plays a pivotal role in the negative regulation of inflammatory bowel disease (IBD). It is understood that the administration of probiotics could be a potential approach to suppress the disorder (Spiller, 2016). A recent study suggests that the interacting between probiotic population and the host's immune system have positive impact on maintaining tissue homeostasis in healthy individuals (Bene et al., 2017). In a recent study, oral administration of L. reuteri - a human-origin probiotic strain had proven with the capability to prolong lifespan and successfully re-modulated the

microbial population in the gut of scurfy mice with microbial dysbiosis (He et al., 2017). It is a major breakthrough where consumption of probiotics had proven scientifically with the ability to manipulate and restore the microbial diversity in the human gastrointestinal environment. Besides the gut, it is well-known that there is an association between probiotics and human urogenital microbial flora. According to Behzadi et al. (2019), urinary tract infections are the world's second most common infectious diseases that affect the lower and/or upper parts of urinary tract caused by gram negative bacteria, gram positive bacteria and yeasts. Today sophisticated medicines are not intended to cure the medical condition in old times as these pathogenic bacteria mutated go through the time and eventually becoming resistance to existing medicines. The human vagina inhabited by approximately 50 different species. One of the common bacteria is Lactobacillus species that are the main contributor for regulating the vaginal micro-environment. Therefore, the focus here should be on developing or discovering new supplements consisting of beneficial microorganisms which able to act against opportunistic pathogens (Kerry et al., 2018). Based on a recent survey by the International Diabetes Federation (IDF) of Southeast Asia, worldwide diabetic patients reaching more than 425 million people and this number are most likely elevated to 629 million by 2045 if no any precautions are taken before it turns to the worst (Diabetes Atlas, 2017). To date, there are no solutions to cure diabetes completely. Larsen et al. (2010) suggested that this disorder could be neutralized by using probiotics to enhance the population of natural microbiota significantly. Recent works have proven that obesity in human was associated with an increased population of bacteroidetes over time and simultaneously with the depleting population of Firmicutes in the gut (Le Barz et al., 2015). Therefore, the administration of probiotics found to be helpful in reducing the overweight and obese problem (Kobyliak et al., 2016). Probiotic strains have properties on preventing a number of adipocyte tissue increase that contribute to obesity.Probiotics have also been receiving plenty of attention because it might be a potential anti-carcinogenic agent. Cancer has been a deleterious disease all the time. Now, researchers realized probiotics also take a crucial part in cancer therapy. Therefore, in vivo study and clinical trial study will be the main focus to verify the potential of anticancer of probiotics (Kerry et al., 2018). In addition, In vitro studies also reported certain probiotics to have the ability to prevent allergic disorders and significantly alleviated the corresponding allergic symptoms (Nazir et al., 2018).Angiogenesis is speeding up for the wound healing process through delineated cellular responses to regenerate damaged tissues in humans (Folkman, 2006). Probiotics reported with the ability to down-regulate the pro-inflammatory cascades and alter the inflammatory cytokine profiles. However, it is a strain-specific regulation that also reduces visceral hypersensitivity, enhances epithelial barrier function and responds against spinal afferent traffic as well as stress. Besides, probiotics also well-known many crucial and functional attributes including complete basic nutritional and clinical supplementation requirements for humans. Therefore, more efforts must be focused on evaluating novel probiotic strains and how they have applied practicality in conferring health benefits to human health.

4 PROBIOTICS IN AQUACULTURE

The aquaculture sector has been growing tremendously to cater to the increasing seafood demand from consumers. The increased demand has urged a fast production of aquaculture. With the rapidly developed aquaculture but poor sanitary management, many disease outbreaks occurred within the industry causing severe annual economic losses (Bondad-Reantaso et al., 2005). Extensively using antibiotics in the aquaculture disease control has raised up another problem which is the emergence of the antibiotic resistance bacteria populations causing lots of infected diseases incurable (Huang et al., 2015). The residual antibiotics found in the aquacultures also pose a potential health risk to humans upon consumption of those cultured animals (Chen et al., 2015). The application of probiotics in aquaculture had proven that it is not only effective to fight against pathogens but also improve the growth and health of aquatic livestock. This summarized in Table 1.Streptomyces sp. is one of the bacteria species that potentially used as a probiotic for aquaculture (Tan et al., 2016). Das et al. (2010) reported that the supplementation of Streptomyces sp. in the feed improved the growth performance of various shrimps and fishes species. Streptomyces sp. produced various hydrolytic enzymes like amylase and protease to improve the digestion of feed in the aquatic livestock digestive tract. In addition, work done by Dharmaraj and Dhevendaran (2010) had reported that microbial production of indoleacetic acid, which is a growth-promoting hormone, was responsible for better growth of Xiphophorus hellerifed. Bacillus sp. is a well-known genus of probiotic that is commercially used for humans. Probiotic effects on aquaculture were evident as the application of B. subtilis, B. licheniformis and B. pumilus in water and feed has promoted expression of salinity stress resistance and immune responses of cobia larvae (Rachycentron canadum) (Garrido Pereira et al., 2014). B. subtilis applied in sea cucumber farming as probiotics (Liu et al., 2012; Zhao et al., 2012).Other potential microorganisms that showed probiotic effects were reported such as Rhodotorula benthica D30 that accelerated the growth rate of sea cucumber (Apostichopus japonicus) as well as enhancing its digestion, immunity and disease resistance when supplemented with the feed (Wang et al., 2015). Intestinal microorganisms isolated from grass carp (Ctenopharyngodon idellus) which are Shewanella xiamenensis A-1, S. xiamenensis A-2, and Aeromonas veronii A-7, exhibited probiotic effects such as resistance toward A. hydrophila infection as well as enhancing the immune system of the fish when supplemented in the feed (Wu et al., 2015).

Table 1. Potential probiotics for aquaculture.

Probiotic species	Livestock	Reference
Streptomyces sp.	Shrimp, Penaeus monodon	(Das, Ward and Burke, 2010)
Streptomyces fradiae	Post-larval shrimp, Penaeus monodon	(Aftabuddin et al., 2013)
Streptomyces sp.	Ornamental fish, Xiphophorus helleri	(Dharmaraj and Dhevendaran, 2010)
Bacillus spp.	Cobia larvae, Rachycentron canadum	(Garrido Pereira et al., 2014)
Rhodotorula benthica D30	Sea cucumber, Apostichopus japonicus	(Wang et al., 2015)
Bacillus subtilis	Sea cucumber, Apostichopus japonicus	(Liu et al., 2012; Zhao et al., 2012)
Shewanella xiamenensis A-1, S. xiamenensis A-2, and Aeromonas veronii A-7	Grass carp, Ctenopharyngodon idellus	(Wu et al., 2015)

5 PROBIOTICS IN ANIMAL FEED

Lactic acid bacteria are the very common probiotics used in livestock production. These bacteria have proven to impose various effects on the animal. For example, Lactobacillus pentosus isolated and identified from broiler excreta has shown probiotic effects to poultry in modulating the immune responses and improving animal health (García-Hernández et al., 2016). Awad et al. (2010) stated that the supplementation of lactic acid bacteria in the animal diet improved the intestinal structure and digestion efficiency. In fact, the bacteria could modulate microbial population as well as cellular metabolic processes in the animal organs to increase the growth of internal organ tissue (Croom et al., 2007). Lactobacillus salivarus strain C65 isolated from the broiler intestinal tract also showed probiotic characteristics (Rondón et al., 2008).Bacillus has been less characterized than lactic acid bacteria as probiotics (Ji et al., 2013). Bacillus has an advantage as probiotic as it forms spore, hence could withstand extreme pH and temperature in the animal gut (Cutting, 2011). Several Bacillus has been isolated and characterized as potential probiotics. The fermented soybean (Churpi) origin Bacillus subtilis AMS6 had proven to exhibit probiotic attributes. It was used as an excellent candidate as an animal feed additive to improve the digestion of fiber and gut health of the animal (Manhar et al., 2016). Probiotics also showed greater inhibition effect against S. typhimurium infection, which is the key factor for morbidity and mortality of calf. B. subtilis isolated from naturally fermented congee also reported showed probiotic properties (Wang et al., 2010). Among other reported potential probiotic includes Bifidobacterium (Wang et al., 2015), yeast (García-Hernández et al., 2012), Wickerhamomyces anomalus (Torres et al., 2014), Lactococcus lactis (Bhanwar et al., 2013), Escherichia coli Nissle 1917 was designed to prevent gut infection caused by Pseudomonas aeruginosa in animals (Hwang et al., 2017). Development of such engineered microorganism is potential to use as therapeutic against specific pathogen infection in animal gut, hence is a great alternative to antibiotics that are known to cause the rising of antibiotic-resistant bacteria and health problems on human.

6 CONCLUSION

The results reported so far with the usage of probiotics for the human, aquatic and animal is promising as these probiotics exert various effects in improving the host's health, regulating immune response and improving the growth of the host. The ability of these microorganisms to fight and build resistance against pathogen infection shows the potential of probiotics to replace antibiotics, which uncontrolled usage has caused the emergence of superbugs that have resistance against the wide-range of antibiotics. However, the success of probiotic supplementations depends on many factors like the strains, concentrations, and management used. Therefore, it is crucial to understand the mode of probiotic action for selection for a suitable and potential probiotic strain. In the future, priority must be given to studies related to probiotics resistance to antibiotics as well as the potentials of transmitting genetic elements to other microorganisms.

ACKNOWLEDGMENT

The authors would like to extend their sincere appreciation to MOHE and Universiti Teknologi Malaysia FOR HICOE GRANT NO R.J130000.7851.4J386.

REFERENCES

[1] Aftabuddin S, Kashem MA, Kader MA, Sikder MNA, Hakim MA. (2013) Use of Streptomyces fradiae and Bacillus megaterium as probiotics in the experimental culture of tiger shrimp Penaeus monodon (Crustacea, Penaeidae). AACL Bioflux 6: 253-267.

[2] Athalye- Jape G, Rao S, Simmer K, Patole S. (2018) Bifidobacterium breve M- 16V as a probiotic for preterm infants: A Strain- Specific Systematic Review. Journal of Parenteral and Enteral Nutrition, 42: 677-688.

[3] Awad WA, Ghareeb K, Böhm J. (2010) Effect of addition of a probiotic micro- organism to broiler diet on intestinal mucosal architecture and electrophysiological parameters. Journal of Animal Physiology and Animal Nutrition, 94: 486-494.

[4] Behzadi P, Behzadi E, Pawlak-Adamska EA. (2019) Urinary tract infections (UTIs) or genital tract infections (GTIs)? It's the diagnostics that count. GMS Hygiene and Infection Control, 14.

[5] Bene K, Varga Z, Petrov VO, Boyko N, Rajnavolgyi E. (2017) Gut microbiota species can provoke both inflammatory and tolerogenic immune responses in human dendritic cells mediated by retinoic acid receptor alpha ligation. Frontier in Immunology, 8: 427.

[6] Bhanwar S, Singh A, Ganguli A. (2014) Probiotic characterization of potential hydrolases producing Lactococcus lactis subsp. lactis isolated from pickled yam. International Journal of Food Sciences and Nutrition, 65: 53-61.

[7] Bondad-Reantaso MG, Subasinghe RP, Arthur JR, Ogawa K, Chinabut S, Adlard R, Tan Z, Shariff M. (2005) Disease and health management in Asian aquaculture. Veterinary Parasitology, 132: 249-272.

[8] Both E, György É, Ábrahám B, Lányi S. (2011) Beneficial effects of probiotic microorganisms. A review. Acta University Sapie Aliment, 4: 44-58.

[9] Chen H, Liu S, Xu XR, Liu SS, Zhou GJ, Sun KF, Zhao JL, Ying GG. (2015) Antibiotics in typical marine aquaculture farms surrounding Hailing Island, South China: occurrence, bioaccumulation and human dietary exposure. Marine Pollution Bulletin, 90: 181-187.

[10] Chichlowski M, Croom J, McBride BW, Havenstein GB, Koci MD. (2007) Metabolic and physiological impact of probiotics or direct-fed-microbials on poultry: a brief review of current knowledge. International Jounal of Poultry Science, 6: 694-704.

[11] Cutting SM. (2011) Bacillus probiotics. Food Microbiology, 28: 214-220.

[12] Dailin DJ, Elsayed EA, Othman NZ, Malek R, Phin HS, Aziz R, Wadaan M, El Enshasy HA, (2016) Bioprocess development for kefiran production by Lactobacillus kefiranofaciens in semi industrial scale bioreactor. Saudi Journal of Biological Sciences, 23: 495-502.

[13] Das S, Ward LR, Burke C. (2010) Screening of marine Streptomyces spp. for potential use as probiotics in aquaculture. Aquaculture, 305: 32-41.

[14] Dharmaraj S, Dhevendaran K. (2010) Evaluation of Streptomyces as a probiotic feed for the growth of ornamental fish Xiphophorus helleri. Food Technology and Biotechnology, 48: 497-504.

[15] Diabetes atlas. (2017) International Diabetes Federation, IDF Diabetes Atlas, Chausséede la Hulpe 166, 1170 Watermael-Boitsfort, Belgium.

[16] Didari T, Solki S, Mozaffari S, Nikfar S, Abdollahi M. (2014) A systematic review of the safety of probiotics. Expert Opinion On Drug Safety, 13: 227-239.

[17] Doyle H, Pierse N, Tiatia R, Williamson D, Baker M, and Crane J. (2018) Effect of oral probiotic Streptococcus salivarius K12 on

Group A Streptococcus pharyngitis: A Pragmatic Trial in Schools. The Pediatric Infectious Disease Journal, 37: 619-623.

[18] El Baz AF, El-Enshasy HA, Shetaia YM, Mahrous, H, Othman, NZ, Yousef AE. (2018) Semi-industrial scale production of a new yeast with probiotic traits, Cryptococcus sp. YMHS, isolated from the red sea. Probiotics and Antimicrobial Proteins, 10: 77-88.

[19] El Enshasy HA, Elsayed, EA. (2017) Kinetics of cell growth and invertase production by the biotherapeutic yeast, Saccharomyces boulardii. Journal of Scientific and Industrial Research, 76: 477-484.

[20] Elsayed EA, Farooq M, Dailin D, El-Enshasy HA, Othman NZ, Malek R, Daniel E, Wadaan M. (2017) In vitro and in vivo biological screening of kefiran polysaccharide produced by Lactobacillus kefiranofaciens. Biomedical Research, 28.

[21] Elsayed EA, Othman NZ, Malek R, Tang T, El Enshasy H. (2014) Improvement of cell mass production of Lactobacillus delbrueckii sp. bulgaricus WICC-B-02: A newly isolated probiotic strain from mother's milk. Journal of Applied Pharmaceutical Science Vol, 4: 008-014.

[22] Fijan S. (2014) Microorganisms with claimed probiotic properties: an overview of recent literature. International Journal of Environmental Research and Public Health, 11: 4745-4767.

[23] Flkman J. (2006) Angiogenesis, Annual Review of Medicine, 57: 1-18.

[24] Florindo RN, Souza VP, Manzine LR, Camilo CM, Marana SR, Polikarpov I, Nascimento A S. (2018) Structural and biochemical characterization of a GH3 β-glucosidase from the probiotic bacteria Bifidobacterium adolescentis. Biochimie, 148: 107-115.

[25] García-Hernández Y, Rodríguez Z, Brandão LR, Rosa CA, Nicoli JR, Elías A, PérezSánchez T, Boucourt R, Halaihel N. (2012) Identification and in vitro screening of avian yeast for use as probiotic. Research in Veterinary Science, 9: 798–802.

[26] Gareau, MG, Sherman PM, Walker WA. (2010) Probiotics and the gut microbiota in intestinal health and disease. Nature Reviews Gastroenterology and Hepartology, 7: 503-514.

[27] Garrido-Pereira MADR, Schwarz M, Delbos B, Rodrigues R, Romano L, Sampaio L. (2014) Probiotic effects on cobia Rachycentron canadum larvae reared in a recirculating aquaculture system. Submission article platform-Latin American Journal of Aquatic Research, 42.

[28] Gobi N, Vaseeharan B, Chen JC, Rekha R, Vijayakumar S, Anjugam M, Iswarya A. (2018) Dietary supplementation of probiotic Bacillus licheniformis Dahb1 improves growth performance, mucus and serum immune parameters, antioxidant enzyme activity as well as resistance against Aeromonas hydrophila in tilapia Oreochromis mossambicus. Fish and Shellfish Immunology, 74: 501-508.

[29] Gu Q, Zhang C, Song D, Li P, and Zhu X. (2015) Enhancing vitamin B12 content in soy-yogurt by Lactobacillus reuteri. International Journal of Food Microbiology, 206: 56–59.

[30] Haghshenas, B., N. Abdullah, Y. Nami, D. Radiah, R. Rosli, and A. Yari Khosroushahi. (2014). Different effects of two newly- isolated probiotic Lactobacillus plantarum 15HN and Lactobacillus lactis subsp. lactis 44Lac strains from traditional dairy products on cancer cell lines. Anaerobe 30: 51- 59.

[31] He, B., Hoang, T.K., Wang, T., Ferris, M., Taylor, C.M., Tian, X., Luo, M., Tran, D.Q., Zhou, J., Tatevian, N. and Luo, F., 2017. Resetting microbiota by Lactobacillus reuteri inhibits T reg deficiency–induced autoimmunity via adenosine A2A receptors. Journal of Experimental Medicine, 214: 107-123.

[32] Holzapfel W, Arini A, Aeschbacher M, Coppolecchia R, Pot B. (2018) Enterococcus faecium SF68 as a model for efficacy and safety evaluation of pharmaceutical probiotics. Beneficial Microbes, 9: 375-388.

[33] Huang Y, Zhang L, Tiu L, Wang HH. (2015) Characterization of antibiotic resistance in commensal bacteria from an aquaculture ecosystem. Frontier Microbiology, 6: 914.

[34] Hun CH, Mohd Sueb MS, Abd Malek R, Othman Z, Elsayed EA, Ramili S, El Marzugi NA, Sarmidi MR, Aziz R, El Enshasy HA. (2013) Bioprocess development for high cell mass production of the probiotic Yeast-Kluyveromyces lactis. IOSR Journal of Pharmacy and Biological Sciences, 8: 49-59.

[35] Hwang IY, Koh E, Wong A, March JC, Bentley WE, Lee YS, Chang MW. (2017) Engineered probiotic Escherichia coli can eliminate and prevent Pseudomonas aeruginosa gut infection in animal models. Nature Communications, 8: 15028.

[36] Ji J, Hu SL, Cui ZW, Li WF. (2013) Probiotic Bacillus amyloliquefaciens mediate M1 macrophage polarization in mouse bone marrow-derived macrophages. Archives of Microbiology, 195: 349-356.

[37] Kareem KY, Ling FH, Chwen LT, Foong OH, Asmara SA. (2014) Inhibitory activity of postbiotic produced by strains of Lactobacillus plantarum using reconstituted media supplemented with inulin, Gut Pathog, 6: 1-7.

[38] Kerry RG, Patra JK, Gouda S, Park Y, Shin HS, Das G. (2018) Benefaction of probiotics for human health: A review. Journal of Food and Drug Analysis, 26: 927-939.

[39] Klare I, Konstabel C, Werner G, Huys G, Vankerckhoven V, Kahlmeter G, Hildebrandt B, Müller-Bertling S, Witte W, Goossens H. (2007) Antimicrobial susceptibilities of Lactobacillus, Pediococcus and Lactococcus human isolates and cultures intended for probiotic or nutritional use. Journal of Antimicrobial Chemotherapy, 59: 900-912.

[40] Kobyliak N, Conte C, Cammarota G, Haley AP, Styriak I, Gaspar L, Fusek J, Rodrigo L, Kruzliak P. (2016) Probiotics in prevention and treatment of obesity: a critical view. Nutrition & Metabolism, 13: 14.

[41] Kumar K, Saadi M, Ramsey FV, Schey R, Parkman HP. (2018) Effect of Bifidobacterium infantis 35624 (Align) on the lactulose breath test for small intestinal bacterial overgrowth. Digestive Diseases and Sciences, 63: 989-995.

[42] Larsen N, Vogensen FK, van-den-Berg FW, Nielsen DS, Andreasen AS, Pedersen BK, Al-Soud WA, Sorensen SJ, Hansen LH, Jakobsen M. (2010) Gut microbiota in human adults with type 2 diabetes differs from non-diabetic adults, PLOS One, 5: 1-10.

[43] Le Barz M, Anhê FF, Varin TV, Desjardins Y, Levy E, Roy D, Urdaci MC Marette A. (2015) Probiotics as complementary treatment for metabolic disorders. Diabetes and Metabolism Journal, 39: 291-303.

[44] Linares DM, Gomez C, Renes E, Fresno JM, Tornadijo ME, Ross RP, and Stanton C. (2017) Lactic acid bacteria and bifidobacteria with potential to design natural biofunctional health-promoting dairy foods. Frontier in Microbiology, 8: 846.

[45] Liu ZM, Ma YX, Yang ZP, Li M, Liu J, Bao PY. (2012) Immune responses and disease resistance of the juvenile sea cucumber Apostichopus japonicus induced by Metschnikowia sp. C14. Aquaculture, 368: 10-18.

[46] Mallina R, Craik J, Briffa N, Ahluwalia V, Clarke J, Cobb AG. (2018) Probiotic containing Lactobacillus casei, Lactobacillus bulgaricus, and Streptococcus thermophiles (ACTIMEL) for the prevention of Clostridium difficile associated diarrhoea in the elderly with proximal femur fractures. Journal of Infection and Public Health, 11: 85-88.

[47] Manhar AK, Bashir Y, Saikia D, Nath D, Gupta K, Konwar BK, Kumar R, Nima D, Mandal M. (2016) Cellulolytic potential of probiotic Bacillus Subtilis AMS6 isolated from traditional fermented soybean (Churpi): An in-vitro study with regards to application as an animal feed additive. Microbiological Research, 186: 62-70.
[48] Marteau P. (2006) Living drugs for gastrointestinal diseases: the case for probiotics. Digestive Diseases, 24: 137-147.
[49] Martín R, Miquel S, Ulmer J, Kechaou N, Langella P, Bermúdez-Humarán LG. (2013) Role of commensal and probiotic bacteria in human health: a focus on inflammatory bowel disease. Microbial Cell Factories, 12: 71.
[50] Meidong R, Khotchanalekha K, Doolgindachbaporn S, Nagasawa T, Nakao M, Sakai K, Tongpim S. (2018) Evaluation of probiotic Bacillus aerius B81e isolated from healthy hybrid catfish on growth, disease resistance and innate immunity of Pla-mong Pangasius bocourti. Fish & Shellfish Immunology, 73: 1-10.
[51] Mishra AK, Ghosh AR. (2018) Characterization of functional, safety, and probiotic properties of Enterococcus faecalis AG5 isolated from Wistar Rat, demonstrating adherence to HCT 116 cells and gastrointestinal survivability. Probiotics and Antimicrobial Proteins, 10: 435-445.
[52] Nazir Y, Hussain SA, Abdul Hamid A, Song Y. (2018) Probiotics and their potential preventive and therapeutic role for cancer, high serum cholesterol, and allergic and HIV diseases. BioMed Research International.
[53] Pandiyan P, Balaraman D, Thirunavukkarasu R, George EGJ, Subaramaniyan K, Manikkam S, Sadayappan B. (2013) Probiotics in aquaculture. Drug Invention Today, 5: 55-59.
[54] Pereira-Caro G, Fernández-Quirós B, Ludwig IA, Pradas I, Crozier A, Moreno-Rojas J M. (2018) Catabolism of citrus flavanones by the probiotics Bifidobacterium longum and Lactobacillus rhamnosus. European Journal of Nutrition, 57: 231-242.
[55] Ranadheera CS, Vidanarachchi JK, Rocha RS, Cruz AG, and Ajlouni S. (2017) Probiotic delivery through fermentation: Dairy vs. Non-Dairy Beverages. Fermentation, 3: 67.
[56] Rondón AJ, Samaniego LM, Bocourt R, Rodríguez S, Milián G, Ranilla MJ, Laurencio M, Pérez M. (2008) Isolation, identification and partial characterization of the probiotic properties of Lactobacillus sp. strains obtained from the gastrointestinal tract of broilers. Ciencia Tecnologia Alimentaria, 6: 53-63.
[57] Roos TB, de Moraes CM, Sturbelle RT, Dummer LA, Fischer G, Leite FPL. (2018) Probiotics Bacillus toyonensis and Saccharomyces boulardii improve the vaccine immune response to Bovine herpesvirus type 5 in sheep. Research in Veterinary Science, 117: 260-265.
[58] Sabbatini S, Monari C, Ballet N, Mosci P, Decherf AC, Pélerin F, Perito S, Scarpelli P, Vecchiarelli A. (2018) Saccharomyces cerevisiae–based probiotic as novel anti-microbial agent for therapy of bacterial vaginosis. Virulence, 9: 954-966.
[59] Shida K, Nanno M. (2008) Probiotics and immunology: separating the wheat from the chaff. Trends in Immunology, 29: 565-573.
[60] Spiller R. (2016) Irritable bowel syndrome: new insights into symptom mechanisms and advances in treatment. F1000Research, 5: 1-11.
[61] Tan LTH, Chan KG, Lee LH, Goh BH. (2016) Streptomyces bacteria as potential probiotics in aquaculture. Frontiers in Microbiology, 7: 79.
[62] Tejero-Sarinena S, Barlow J, Costabile A, Gibson GR, Rowland I. (2013) Antipathogenic activity of probiotics against Salmonella Typhimurium and Clostridium difficile in anaerobic batch culture systems: is it due to synergies in probiotic mixtures or the specificity of single strains. Anaerobe, 24: 60-65.
[63] Vieira CP, Cabral CC, da Costa Lima BR, Paschoalin VMF, Leandro KC, Conte-Junior CA. (2017) Lactococcus lactis ssp. cremoris MRS47, a potential probiotic strain isolated from kefir grains, increases cis-9, trans-11-CLA and PUFA contents in fermented milk. Journal of Functional Foods, 31: 172-178.
[64] Wang J, Tang H, Zhang C, Zhao Y, Derrien M, Rocher E, Johan ET, van-Hylckama Vlieg, Strissel K, Zhao L, Obin M, Shen J. (2015) Modulation of gut microbiota during probiotic-mediated attenuation of metabolic syndrome in high fat diet-fed mice. The ISME Journal, 9: 1.
[65] Wang J, Xing Z, Tang W, Zheng Y, Wang Y. (2015) Isolation, identification, and potential probiotic characterization of one Lactococcus from kefir grain. Food Science and Biotechnology, 24: 1775-1780.
[66] Wang JH, Zhao LQ, Liu JF, Wang H, Xiao S. (2015) Effect of potential probiotic Rhodotorula benthica D30 on the growth performance, digestive enzyme activity and immunity in juvenile sea cucumber Apostichopus japonicus. Fish and Shellfish Immunology, 43: 330-336.
[67] Wang WC, Yan FF, Hu JY, Amen OA, Cheng HW. (2018) Supplementation of Bacillus subtilis-based probiotic reduces heat stress-related behaviours and inflammatory response in broiler chickens. Journal of Animal Science, 96: 1654-1666.
[68] Wang Y, Zhang H, Zhang L, Liu W, Zhang Y, Zhang X, Sun T. (2010) In vitro assessment of probiotic properties of Bacillus isolated from naturally fermented congee from Inner Mongolia of China. World Journal of Microbiology and Biotechnology, 26: 1369–1377.
[69] Yu Y, Wang C, Wang A, Yang W, Lv F, Liu F, Liu B, and Sun C. (2018) Effects of various feeding patterns of Bacillus coagulans on growth performance, antioxidant response and Nrf2-Keap1 signaling pathway in juvenile gibel carp (Carassius auratus gibelio). Fish and Shellfish Immunology, 73: 75-83.
[70] Zhao Y, Zhang W, Xu W, Mai K, Zhang Y, Liufu Z. (2012) Effects of potential probiotic Bacillus subtilis T13 on growth, immunity and disease resistance against Vibrio splendidus infection in juvenile sea cucumber Apostichopus japonicus. Fish and Shellfish Immunology, 32: 750-755.
[71] Zorriehzahra MJ, Delshad ST, Adel M, Tiwari R, Karthik K, Dhama K, Lazado CC. (2016) Probiotics as beneficial microbes in aquaculture: an update on their multiple modes of action: a review. Veterinary Quarterly, 36: 228-241.