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

Daniel Joe Dailin, Nor Hasmaliana Abdul Manas, Nur Izyan wan Azelee, Shanmugaparakasham Selvamani, Hesham A. El-Enshasy

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 welfare 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 (Zorriezrahra 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 (Martin 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).

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, CO₂ 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 (Elayed 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 lactococcus strain such as Lactococcus lactis ssp. cremoris MRS47 (Vieira et al., 2017), Lactococcus lactis ssp. Lactis 44Lac (Haghshenas et al., 2014) and Lactococcus lactis 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 thermophilae (Mallina et al., 2018),

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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., 2018). 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 produced 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.](image)

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-Sariñana 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 scurvy 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
downregulate 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 practicability 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
typically 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 Dhevendran (2010) had reported that
microbial production of indoleacetic acid, which is a growth-
promoting hormone, was responsible for better growth of
Xiphophorus helleri. 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 Rhodoturula 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.

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


