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Environmental ethics in animal farming: Agricultural probiotics

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Abstract
Importance of probiotics in animal farming has mostly been discussed in terms of the impact on animals' general health and productivity. The impact is mainly due to intestinal microbial balance, antimicrobial and anti-inflammatory agents, and vitamins produced by probiotics, competing with pathogens for nutrient and the adhesion of epithelial receptors, and enhancement of intestinal nutrient absorption. However, in this article, we have focused on the environmental benefits of probiotics use in agriculture, which is actually another side of this valuable coin; probiotic. Some of these environmental benefits are the indirect advantages which are achieved through the usage of probiotics as a replacement for antibiotics and other chemical growth promoters in animal farming. However, the direct environmental benefits are not well-discussed in the literature. These are mainly by changing the microbial diversity not only in animal body, but in the farm environment and providing natural sources of beneficial microbes for other hosts, and improving the quality of animal products. It is highlighted here that worthiness of direct environmental benefits gain from probiotics in agriculture is not less than the indirect ones, if it is not more. It is concluded that strategy of using probiotics in animal farming improves the environment directly and indirectly and therefore encouraging/assisting animal farmers to practice this environmental-friendly system should be seriously considered especially by the policymakers.

1. Introduction

Probiotics have several definitions in the literature, but all those definitions are in agreement that probiotics are live microorganisms, which are able to provide benefits to their hosts. The term "probiotic" was given to these microbes a few decades ago while many of these beneficial strains were used unwittingly in fermenting foods, especially milk, thousands years ago (Fuller 1991). The type of benefit depends on the strain of probiotic and targeted body part, i.e., gastrointestinal tract (GIT)(Liévin-Le Moal and Servin 2014) and/or non-intestinal organs such as oral and nasopharyngeal (Burton et al. 2011), skin (Krutmann 2009), and vagina (Martín et al. 2012). Although most of the performed probiotic studies are focused on the effects of the beneficial microbes on human health, however,the use of probiotics for animals' well-being is getting good attention from researchers. Animal growth and, therefore, increasing in carcass weight, increasing milk and egg production, enhancing the quality of animal products (e.g. increasing the amount of protein and decreasing the cholesterol content), and immune system stimulation are the main targets of using agricultural probiotics; also known as direct-fed microbial. These probiotics used in animal farming are administered through different methods such as in the feed, in the water and by oral gavage, and they are mostly from the genera *Lactobacillus*, *Enterococcus*, *Bacillus* and *Saccharomyces* (Gaggìa et al. 2010).

Incredible studies of several research groups, including Selman Waksman team (Waksman and Schatz 1943), for discovering antimicrobial compounds in early 1940s and scientific evidence of positive effects of these antibiotics on animal growth (Groschke and Evans 1950; Whitehill et al. 1950) in late 1940s and early 1950s provided the scientific grounds that antibiotics were legally approved as animal feed additives by the US Food and Drug Administration (UFDA) in 1951. However, those days, not many people might imagine that the application of antibiotics as growth promoters in animal farming were going to be criticized in only a few decades due to the dramatic growth in number of incidences of antibiotic resistance human infections. Although the overuse of antibiotics in medical treatment of human has been named as one of the most important factors in this issue (Andersson and Levin 1999; Davies and Davies 2010) but application of antibiotics in agriculture is also a key reason (Khachatourians 1998; Gilchrist et al. 2007; Hume 2011). Hence, restriction of the use of antibiotics in animal feed as growth promoters (*e.g.*, completely banned by European Union in 2006) and searching for alternatives to antibiotics have become the main strategies recommended by experts. Based on the efficiency of probiotics demonstrated in agriculture, they were reported as potential alternative for antibiotics (Tomasik and Tomasik 2003; Apata 2009).

Comparison of antibiotic and probiotic supplements in animal feed confirmed that the selected strains of probiotics can be considered natural substitute for antibiotics (Yeo and Kim 1997; Onifade et al. 1999). This replacement of antibiotic growth regulators with probiotics, which means the absence of antibiotic in farms unless in case of serious pathogenic infections, has significant positive impact on environment. These are, in fact, the indirect beneficial impacts of agricultural probiotics on environment as comparative alternatives to antibiotics. However, direct-fed microbial havedirect beneficial effects on environment, which are not well-considered. In this article, our focus lies on both direct and indirect impacts of using agricultural probiotics on environment and human health.

2. Direct Environmental Impacts of Agricultural Probiotics

It has been demonstrated in the literature that probiotics affect the composition of gastrointestinal microbiota through different mechanisms such as reducing the pH, competing for nutrients and perhaps production of antimicrobial compounds such as bacteriocin (Krehbiel et al. 2003; Walsh et al. 2008; Marubashi et al. 2013). Microbial diversity and abundance after application of probiotics in animal husbandry have mostly been studied by considering the animal’s microbiota especially GIT, and it has been demonstrated that direct-fed microbial significantly affect the microbial diversity in animals (Davis et al. 2007). Meanwhile, the evaluation of the effects of agricultural probiotics on outside environment of animal body was mainly limited to faecal samples. Some of the agricultural probiotics’ impacts on diversity and abundance of microbial community of GIT and/or faeces of animals fed diets supplemented with direct-fed microbial, are shown in table 1.

Table 1. *Exemplary studies demonstrating efficacy of agricultural probiotics use in animal farming.*

Probiotic strain(s)	Effect on the monitored microbe(s)	Examined sample	Animal	Reference
Propionibacterium P15 and *Enterococcus faecium* EF212	Reduce *Streptococcus bovis*	Rumen	Cattle	(Ghorbani et al. 2002)
L. acidophilus NPC 747	Reduce *Escherichia coli* O157:H7	Feces	Cattle	(Brashears et al. 2003)
Heat-resistant spore-forming *Bacillus* spp.	Reduce *Salmonella* sp. and *Clostridium perfringes*	GIT	Turkey and Broiler	(Tellez et al. 2012)
L. acidophilus and *St.faecium*	Reduce *E. coli* O157:H7	Feces	Lamb	(Lema et al. 2001)
L. acidophilus and *L. sporogenes*	Gram negative bacteria	Gut	Giant freshwater prawn	(Venkat et al. 2004)
Bacillus sp. S11	Reduce *Vibrio* spp.	Gut	Black tiger shrimp	(Rengpipat et al. 1998)
Bacillus sp. S11	Increase *Bacillus* spp. Including *Bacillus* S11	Gut	Black tiger shrimp	(Rengpipat et al. 1998)
Lactobacillus, Bifidobacterium, Enterococcus, and *Pediococcus*	Increase *Lactobacillus* and *Bifidobacterium*	Caecum	Broiler	(Mountzouris et al. 2007)
L. acidophilus 27SC	Increase Lactobacilli	Feces	Dairy calf	(Abu-Tarboush et al. 1996)
Lactobacilli	No significant effect on Lactobacilli and Streptococci	Small intestine	Broiler	(Jin et al. 1998)

Many of these probiotic strains are anaerobic and, therefore, they may not grow in the presence of atmospheric oxygen out of the host GIT. However, their presence in environment provides the natural microbial resources of these beneficial strains to be transferred into other animals and colonise the GIT (Figure 1a). This is very critical for new-born animals that will not only obtain GIT microbes from their mothers, but also from surrounding environment (Mackie et al. 1999). Animal wastes (manure and other types of waste) have been reported as one of the main sources of pathogenic microorganisms (Gerba and Smith 2005). It has been also shown that movement of pathogens in animal wastes causes environmental pollution (Mawdsley et al. 1995). Reduction in shedding of pathogenic microbes in animal feces and farm environment obtained by application of direct-fed microbial may reduce the risk of pathogen transmission and, therefore, diseases because livestock-environment interaction is known as the main factor moderating the health of food producing animals (Dowd et al. 2008).In addition to the positive effect of probiotics on microbial diversity and competing with pathogens' probiotics are able to reduce the risk of infectious disease significantly by boosting immune systems of livestock (*e.g.*,diarrhea)(Sissons 1989).Reduction of disease susceptibility has been recommended as one of the steps to avoid disease transmission in animal farms (Pell 1997) and, therefore, a healthier environment, and it is achievable by application of probiotics in animal farming.

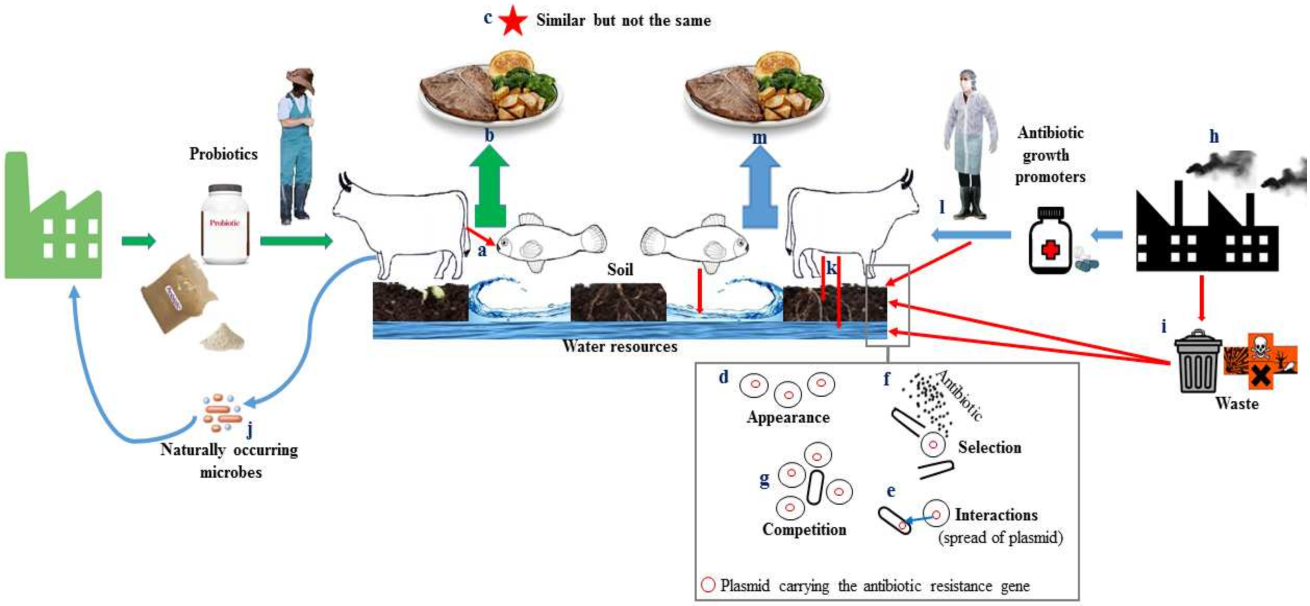

Figure 1. *Schematic comparison between agricultural probiotics as growth promoters and antibiotics as growth promoting agents in animal farming with focus on health and environmental impacts from farm to fork (supply chain system). a: probiotic strain transferring from food-producing animals to other animals; b: enhancing the quality of products using probiotics; c: labelling system for providing information for consumers; d: appearance of drug-resistant microbes; e: horizontal gene transformation and spread of plasmid contains antibiotic-resistance gene; f: selective pressure by entering antibiotic into environment; g: the appeared antibiotic-resistant microbes compete with other microorganisms present in the environment, especially for nutrient; h: environmental pollution caused by drug manufacturing; i: environmental pollution caused by disposal and recycling in the process of drug production; j: naturally occurring microbes are the source of agricultural probiotics; k: entrance of antibiotics from animals to environment (e.g. via urine, feces and carcass); l: antibiotic in animal feed is a health hazard for farmers and vets; m: antibiotic residues in animal products.*

Improvement of animal welfare using direct-fed microbial also enhances the quality of products (Figure 1b). This quality enhancement is achieved by reducing carcass microbial contamination (Apata 2009), improving the product contents such as reducing cholesterol level in egg (Mahdavi et al. 2005) or in meat (Lubbadeh et al. 1999) or enhancing the mount of protein in milk (Yu et al. 1997), and transferring the actual probiotic strains into products (*e.g.*, from mammary gland into milk)(Espeche et al. 2009). Based on the strong relationship between food diet and human health, improvement in quality of animal products can potentially reduce the concern over health issues related to animal products consumption (Gaggìa et al. 2010).

It is also the right of consumer to be aware of the presence of animal products that was used to enhance quality.Either beneficial microbes (natural components of the environment)or chemical growth promoters (synthetic additives) wereused on farm to produce an animal based product. Labeling has a critical impact on consumer's decision to purchase a productand it has also been recommended to supplysuch information about animal welfare on the product label(Kehlbacher et al. 2012). To our knowledge, no labeling system is developed to label animal products produced in farms applying direct-fed microbial. Hence, we suggest that improvement is needed in labeling for this type of animal products (Figure 1c).

3. Indirect Environmental Impacts of Agricultural Probiotics as a Substitute to Antibiotics

Various problems related to the application of antibiotics in animal husbandry, particularly using themas feed additives for the purpose of growth promoting, have been well-documented (Anomaly 2009; Duckenfield 2013). Identification ofeffective probiotic strain for each particular food producing animal would greatly help in reducing the application of antibiotics as growth promoters in animal farming. In this part, we are highlighting some of the environmental and health benefits of removing antibiotic growth promoting agents from animal farming practices, as indirect environmental benefits of applying probiotic alternatives, by pointing the disadvantages of antibiotic growth promoters in agriculture.

Usage of antibiotics is known as the key reason of appearance/evolution, selection, and distribution of drug-resistant microbes (Witte 1998). Witte (1998) compared the amount of antibiotic used for human medical therapy with its usage in animal husbandry in some different countries to highlight the concern of extreme usage of antibiotics in animal feed and increasing the risk of antibiotic-resistance pathogen appearance (Figure 1d). Detection of antibiotic-resistant pathogens in body (*e.g.*, gut flora of pigs) and feces/urine (*e.g.*,fecal enterococci in poultry) of animals fed with antimicrobial feed additives andalso in environment (*e.g.*, shrimp farming freshwater environment) have been extensively reported(Tschäpe 1994; van den Bogaard et al. 2002;Carvalho et al. 2013). The microbial biodiversity can be affected by the presence of new antibiotic-resistant microbes which compete and interact with the environmental microbes. Among these interactions, transferring the antibiotic resistance gene through horizontal gene transformation to other microbes (Figure 1e), especially to pathogens have been frequently reported (Tschäpe 1994). However, the effects of antibiotics used in livestock farming on microbial diversity do not limit to these points. Entry of antimicrobial agents used in animal farming into environment (via animal feed, feces and urine) can eliminate the growth of microbes which are not resistance to those particular antibiotics and at the same time provide a better environment for the growth of resistant strains (selective pressure is showed in Figure 1f). Some of these antibiotic susceptible microbes are beneficial microbes living in GIT and some of them are outside animal body promoting the growth of plants such as nitrogen-fixing and phosphate-solubilizing bacteria. In addition to the selective pressure, the beneficial microbes need to compete with the newly appeared antibiotic-resistance strains, especially for nutrients (Figure 1g).

Although transferring the antibiotic resistance gene(s) from the new antibiotic-resistant strains to human pathogens has been mentioned as the most serious human health risk of application of antibiotic growth promoters (Apata 2009), production and application of antibiotics have also some other negative impact on environment and human health. Environmental pollution resulted by drug manufacturing (Figure 1h), and disposal and/or recycling (Figure 1i) has been well-discussed (Daughton 2003). While, agricultural probiotics are naturally occurring beneficial microorganisms that are originally isolated from organisms/environmental samples (Figure 1j) and therefore their re-entry into environment is not considered an environmental hazard. Presence of used antibiotics in animal farming in fecal and urine samples of animals have been confirmed (Ingerslev et al. 2001), which is another pathway for entrance of these compounds to environment (Figure 1k). For example, certain antibiotics used in agriculture such as sulfadimidine and tylosin were detected in environment by Christian et al. (2003).

Farmer’s situation has also been pointed as one of the important human health aspects, which needs to be concerned in animal farming (Röcklinsberg 2014). Entrance of antibiotic to the environment during the application of them in farm can be considered one of the direct hazards to vets’/farmers’ health (Hamscher et al. 2003) which is highlighted in Figure 1l. However, it is not the only human health hazard and presence of unchanged antibiotic residues in animal carcass (*e.g.*, chicken meat) (Tajick and Shohreh 2006), animal products (*e.g.*, milk) (Sischo 1996) and egg (Wang et al. 2005) extends the human health risk to all consumers (Figure 1m). It is exactly the same pathway of transferring the antibiotic-resistance strains from animals to human and the food supply chain.

4. Conclusions and Recommendations

Direct-fed microbial can be chosen based on their beneficial activities among naturally occurring microorganisms and re-entry to the nature toenhance immune system and productivity of farm animals as well as influence the environmentpositively. One of the main impacts is the influence of probiotics on microbial abundance by increasing the population of beneficial microbes and reducing the shedding of pathogenic microorganisms not only in animal GIT, but also from outside environment. Application of probiotics in animal farming also enhances the chance of probiotic colonization in other hosts’ GIT (*e.g.*, birds around farms). This reduction of pathogen shedding and increase in the diversity as well as abundance of beneficial microbes is likely to reduce the risk of pathogen transmission. Consumers of animal products are also able to obtain products with boosted quality; low microbial contamination plus improved nutrition. However, improvement in labeling for these products is needed. Next to these direct benefits of agricultural probiotics, removal of antibiotic growth promoters in animal farming by substituting with probiotics has several environmental advantages. Reducing the risk of acquiring antibiotic-resistant microbes, absence of antibiotic residual in animal products and providing a safer environment for farmers and vets are some of these advantages.

Various scientific studies, carried out in different livestock farms and laboratories, have confirmed that there is a strong link between application of antibiotic growth promoters and environmental pollution, and therefore, health risks. It is also demonstrated how environment benefits from application of probiotics in animal farming. Now, this question should be discussed why application of chemical growth promoting agents, especially antibiotics, is still practiced in many farms and direct-fed microbialare not getting a real place in animal husbandry yet. We believe that this situation has arisen because of various factors and only one particular party cannot be blamed. The following recommendations are proposed here for dealing with this challenge: a) providing sufficient information for animal farmers about the significant advantages of using agricultural probiotics; b) conducting studies to find potential probiotic strain(s) for each particular host species/breed; c) assisting agricultural probiotics producers with research and development; and d) helping animal farmers to find the suitable probiotics alternatives for antibiotics and technologiesfor probiotics application in sustainable manner on farms. However, implementation of these recommendations needs collaboration and coordination between policymakers, governors, researchers, educational institutes, probiotic manufacturers, and animal farmers.

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