Postbiotics: Unlocking Microbiome Health Benefits in Pet Food

Humans have consumed fermented foods (and drink) for millennia. Christ turned water into wine, a fermented drink. Cultures around the world have consumed various fermented foods such as German sauerkraut, Korean kimchi, Russian kefir, Japanese miso, Norwegian rakfisk, Indian pitha, and so forth. Almost all human cultures have in common the culturing of dairy products (e.g., cheese, yogurt, cottage cheese, etc.) that provide healthy nutrition to people around the world.

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Fermented foods for human use appear to be popular due to their stability, being a good source of nutrients, safety, and palatability (Rezak *et al.*, 2018). Fermented foods are associated not only with addressing human gastrointestinal disease, but also type II diabetes and cardiovascular disease. In a survey of fermented foods, Rezak *et al.* (2018) found live bacteria levels ranging from 10^5 to 10^9 cfu per gram in these foods. Consumer awareness of fermented food benefits is growing, as a 2018 trends survey of restaurant menu items indicated a 149% increase in fermented food offerings (Resendes, 2019).

Novel and unusual pet food products have been marketed based on ingredients obtained through fermentation. In the USA, Wild Earth pet food products were originally founded on the inclusion of a fungi-based protein source (dried aspergillus oryzae fermentation product). This protein source is referred to as a "clean" protein source due to it being produced by fungi. Further, Wild Earth food products also contain yeast and are touted as "clean protein" due to not being produced from animals, with "90% fewer resources required than meat-based" foods. While this food makes a strong "sustainability" message, there are myriad probiotic-related health benefits that make fermented foods appealing for consumption.

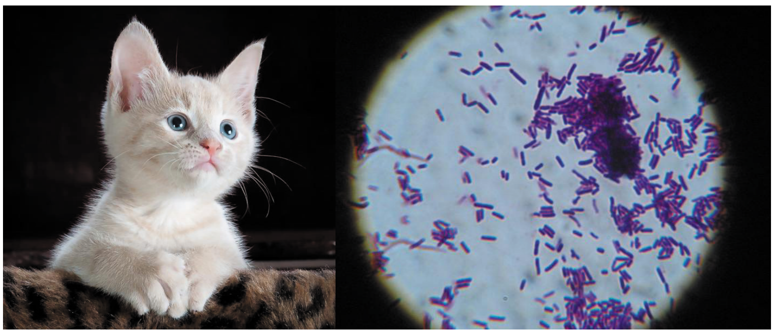
Probiotics are generally considered to be live organisms which are typically taken as a dietary supplement or added to food. Benefits of consuming probiotics involve decreased gut pathogens, improved immune function, reduced levels of pro-carcinogens available in the intestine, suppressed tumour formation, normalised stool formation, and so forth (Dicks and Botes, 2010).

With all the interest in fermented foods and common use of probiotics by humans and associated health benefits, why haven't more mainstream brands pet food leveraged the benefits of fermentation or probiotics in their products? The simple answer is that the main product forms, extruded and retorted (canned), are not conducive to keeping probiotics alive. These forms create harsh processing conditions and (or) packaging environments which normally don't maintain live cultures. (An exception to this is spore-forming bacteria that can survive extrusion. However, the fact remains that the commonly used product forms, extrusion and retort, greatly limit which live organisms can be added to pet foods.)

While live organisms are the "machines" or "mini-manufacturing plants" inside one's intestines to produce many of the benefits of fermentation, they are not the only way that fermentation benefits can be conferred upon the pet. To understand how we can achieve probiotic benefits without the need for ongoing gut-level fermentation, we need to take a step back and understand how probiotics are positively influencing the gut environment.

Microorganisms' Innate Defences

While we often focus on the impact of pathogens, such as Salmonella, on our health or our pet's health, microorganisms of all types (including beneficial ones) are constantly under threat. As a result, microorganisms have natural defences such as the ability to secrete anti-microbial compounds to make themselves more competitive in their environment. For example, a lactic acid bacteria, *Lactococcus lactis*, actively secretes hydrogen peroxide (Ito *et al.*, 2003). As such, it has been known for many years to be effective against food-borne pathogens. More broadly, several antimicrobial compounds are produced by bacteria to aid their survival in a harsh environment. A class of compounds called lantibiotics is an example of this (Mantravadi *et al.*, 2019). Mantravadi *et al.* (2019) noted almost twenty unique compounds considered lantibiotics. These researchers also noted that since lantibiotics have several modes of action, there is no known antibiotic resistance to them, creating excitement over the power of naturally sourced anti-pathogenic compounds. Further, other classes of antimicrobial compounds exist, indicating the power of post-fermentative derived mixtures (fermentates) to play an important role in shifting gut

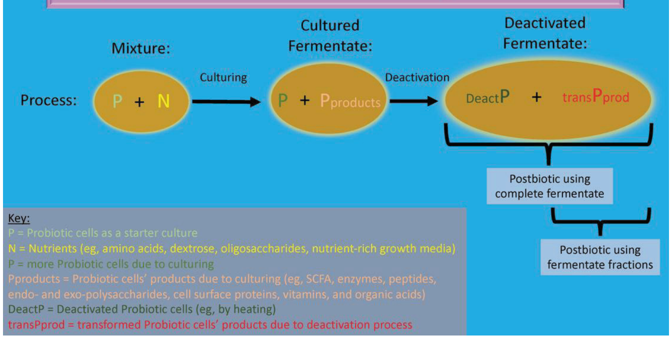


Attribution: "IMG_1814" by shok is licensed under CC BY-NC-ND 2.0 microflora populations. The net result of this is that these fermentates do not necessarily need to contain live probiotic bacteria to effect gut-based changes to the host. Hence the term, postbiotics.

Postbiotics Defined

The term postbiotic is relatively new. As such, its definition is still evolving. With that said, postbiotics are defined as "any factor resulting from the metabolic activity of a probiotic or any released molecule capable of conferring beneficial effects to the host in a direct or indirect way" (Tsilingiri *et al.*, 2013 as described by Malashree *et al.*, 2019). More simply stated, postbiotics are the compounds produced during the growth of probiotics, including the probiotics themselves (see Figure 1). As discussed previously, many of these compounds are antimicrobial/anti-pathogenic. To clarify, postbiotics do not need to contain live microorganisms to be effective. And some postbiotics are specifically created by disrupting the live probiotic organisms so their cellular contents are available to enhance the efficacy of the postbiotic material.

Figure 1. Process of Obtaining Postbiotics



Examples of Postbiotic

Postbiotics' efficacy lies in the compounds produced and, in addition, in the contents of the probiotic microbes' cells. As such, postbiotics do not need to, and often don't, contain live microorganisms. To begin with, postbiotics are not necessarily new to the pet food industry (Table 1). However, current postbiotics in use are under-recognised for their role in animal health. Current postbiotics include by-products of the brewing industry (i.e., brewer's yeasts), isolated fractions of yeast (e.g., mannanoligosaccharides, B-glucans), and organic acids. Additional postbiotic options include a variety of fermentates, tyndallised (i.e., heat-killed) probiotics, lysates of bacteria, and isolated fractions obtained from a fermentation process. While examples of additional postbiotic options in current pet applications do exist, there is much more potential to utilise them as well as expand the use of existing current applications of postbiotics.

Why Postbiotics are Important in Pet Foods

The current primary pet food product forms commercially sold today are: 1) dry, extruded and 2) retort (canned). These products are typically stored at ambient conditions with shelf-life length up to about 18 months. Neither of these forms normally offer a conducive environment to assure probiotics (live cells) stability during: 1) distribution shipping conditions and 2) shelf-life of the product. In contrast, postbiotics have the potential to play an important role in improving pet health due to their ability to be stable in these product forms.

An emerging and growing trend for alternative pet food forms exists with lightly processed pet foods. Due to their high moisture and the type of packaging used, many of these lightly processed pet foods are kept under refrigerated conditions (rather than ambient conditions). These products typically have a shorter shelf-life than extruded or retorted products (about six months). Postbiotics not only offer potential health benefits in these foods, but they also may offer ways to uniquely stabilise and thus extend shelf-life in these products.

Evidence for Postbiotics' Efficacy

From a health perspective, postbiotics have been shown to be effective anti-obesity agents. *Lactobacillus reuteri* was isolated from dog's saliva and heat-treated to kill the bacteria. The heat-killed *L. reuteri* was then administered to mice that resulted in less age-associated weight gain compared to control mice (Varian *et al.*, 2016). More broadly, Reynes *et al.* (2019) reviewed several postbiotic compounds including short-chain fatty acids (SCFA) and reported their ability to increase thermogenesis and insulin sensitivity, thus explaining other benefits of postbiotic compounds on conditions related to obesity. These findings agree with dogs fed fermentable fibres (sources of SCFA) and their ability to improve insulin sensitivity through increasing GLP-1, a potent insulin secretagogue (Massimino *et al.*, 1998).

A particular strain of probiotic which has considerable data behind it is *Bifidobacterium longum* 35624. Schiavi *et al.* (2018) recently reported that the exopolysaccharide obtained from *B. longum* 35624 was able to decrease the allergic responses in lung and airway tissues. Patten and Laws (2015) reviewed a number of studies involving the exopolysaccharide (EPS) from a variety of Lactobacilli strains. Authors concluded that Lactobacilli EPS had benefits related to immunomodulation, antioxidant properties, and heavy metal binding.

Preserving food products is essential to assure proper shelf-life before consumption. Seidler *et al.* (2019) discuss numerous compounds excreted by lactic acid bacteria (LAB) including phenyllactic acid, propionic acid, salicylic acid, diacetyl, fatty acids, cyclic dipeptides, etc. which could influence product stability. Authors cite at least four different mechanisms at work that can inactivate spoilage organisms and (or) pathogens: 1) cell wall instability/permeability, 2) proton gradient interference, 3) oxidative stress, and 4) enzyme inhibition. These compounds and mechanisms are found sometimes in all LAB or select LAB such as *L. plantarum, L. reuteri, Propionibacterium freudenreichii, L. spicheri, L. buchneri, L. diolivorans, L. amylovorus, L. rhamnosus, L. brevis, L. acidophilus*, etc. A literature review done by da Costa *et al.* (2019) described bacteriocins produced by LAB and how they apply to use in meat products. Authors found that Lactococcus, Enterococcus, Pediococcus, and Lactobacillus were the most

Compound	Current Usage	Current Level of Usage
Brewer's yeast	Protein source, general health	Broad – found in many global pet food companies' products
Mannanoligosaccharides	Gut health	Limited – found in specialised products globally
B-glucans	Gut health, immune, other health conditions	Limited – found in specialised products globally
Organic acids (e.g., acetic, butyric, lactic)	Food stability, anti-pathogen risk in food	Somewhat – found in a large pet food company's products
Tyndallised probiotic strains	Gut health, diarrhoea, dermatitis, other health conditions	Rare – found in limited product lines in regional areas
Isolates of lysates and excreted compounds	Obesity, skin, to be discovered	Non-existent likely due to being relatively new and regulatory challenges

Table 1. Postbiotic Examples and Usage in Pets

prevalent LAB studied, with examples of them producing bacteriocins including nisin, enterocin, pediocin, pentocin, and sakacin.

The applications of postbiotics to enhancing health are clear, as conditions such as obesity and skin health (e.g., dermatitis) are obvious maladies in pets. The role of postbiotics in improving shelf-life is especially important in lightly processed, extruded, semi-moist treats, and virtually all non-retorted food and treat products. The potential role of postbiotics in stabilising meats is also a great opportunity given the high susceptibility of meat to degradation as well as contamination from pathogens such as Salmonella.

Sustainability

Postbiotics as ingredients for pet foods are generally quite sustainable, whether sourced as a by-product of the brewing industry or newly created in a fermentation vessel. The ability of these organisms to be scaled and replenished is nearly limitless.

Conclusions

Given their: 1) role in promoting health, 2) product compatibility, and 3) sustainability, one must ask the question, what stands in the way of broader adoption of postbiotics in the pet food industry? And further, what will be the impetus to more widespread adoption of these health-promoting ingredients?

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