Types and Applications of Unconventional Feed

Subjects: Agriculture, Dairy & Animal Science

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Unconventional feed, which is abundant in China, contains anti-nutritional factors and toxins; however, these can be greatly reduced with microbial fermentation, thus improving the nutrient content of the feed, enhancing animal appetites, and ultimately significantly improving the intestinal health and growth performance of animals. When oxidative stress occurs, fermented feed can effectively reduce the damage caused by stress to the gastrointestinal tract, accelerate the removal of gastrointestinal abnormalities, improve the ability to resist intestinal stress, and ensure the efficient production of animals.

unconventional feed fermented probiotics feed quality

1. Introduction

Unconventional feed refers to feed that is different in terms of the raw material source or preparation process compared to conventional feed. This kind of feed is usually obtained from diversified raw materials such as agricultural and sideline products, aquatic product by-products, and industrial by-products, which are obtained through special processing or treatment; China possesses rich resources of such materials [1][2]. However, the nutrient composition of unconventional feed is complex, and it has shortcomings such as a high content of anti-nutritional factors and poisons, poor palatability, unstable nutrient composition, and significant quality variations [3]. Therefore, the comprehensive utilization level of unconventional feed is low, resulting in a waste of resources, environmental pollution, and other problems. At present, unconventional feed processed through microbial fermentation technology, crushing, heating, hydrolysis, drying, and other methods, in order to degrade the anti-nutritional factors, toxins, crude fiber, lignin, and other substances present in it and reflect its high nutritional value [4] in terms of protein, minerals, and trace elements required for livestock supplementation, is called “special feed” or “alternative feed”. Therefore, unconventional feed is often used, in part, to replace conventional feed to reduce feed costs, improve the economic value, and achieve sustainable development in the feed industry. In recent years, the popularity of unconventional feeds has gradually increased.

2. Types and Applications of Unconventional Feed

The sources of unconventional feed are very extensive, including, but not limited to, grain and oil processing by-products, livestock and poultry processing by-products, aquatic product processing by-products, and other industrial processing by-products. Unconventional raw materials are abundant resources, but their application in

animal feeding is limited due to their high amounts of anti-nutritional factors and toxins [5][6]. Therefore, improving the quality of unconventional raw materials and elevating their utilization rate in animal feeding are important topics of current scientific feed research. Current commonly used unconventional raw materials such as wheat bran, rice bran, bean dregs, distiller's grains, sweet potatoes, straw, and other processing by-products require physical processing, chemical treatment, or microbial fermentation to decompose crude fiber and increase their feed value. Anti-nutritional factors and toxins in unconventional fermented feed can be reduced in a number of ways. During fermentation, microorganisms and enzymes that digest anti-nutritional factors such as phytic acid and cellulose are produced [7], while high-temperature treatment helps to destroy the structure of some toxins. In addition, regulating the pH and microbial metabolism during fermentation can also reduce the toxin content in feed [8]. Physical treatments such as filtration and sedimentation can also be used to reduce toxin levels [9]. By combining these methods, unconventional fermented feed can be safely provided to animals while improving their nutrient availability and health. **Table 1** shows the positive effects of the fermentation of unconventional feed on animal health, nutrition and performance, and antioxidant aspects.

Table 1. Positive effects of the fermentation of unconventional feed on animal health, nutrition and performance, and antioxidant aspects.

Unconventional Fermented Feed Feeding					
Animal	**Raw Materials**	**Probiotics**	**Regulated Items**	**Antioxidant Substance**	**References**
Boer goats	*Pennisetum giganteum*	*Bacillus coagulans* preparation	Abundance of Lactobacillus and unidentified Clostridiales ↑ Anaerovibrio and Methanobrevibacter ↓	CAT, GSH-Px activities and glutathione ↑	Qiu et al. [10]
Laying hens	Corn–soybean meal wheat bran	*Bacillus subtilis* and *Saccharomyces cerevisiae*	In relative Lactobacillus, Megasphaera, and Peptococcus abundance ↑ Campylobacter abundance ↓	Immunoglobulin A, immunoglobulin M, and immunoglobulin G ↑	Guo et al. [11]
Broilers	Corn, soybean meal, corn–gluten meal, and corn dried distillers' grains	*Lactobacillus plantarum*, *Bacillus subtilis*, and *Saccharomyces cerevisiae*	Abundance of Ruminococcaceae, Lactobacillaceae, and unclassified Clostridiales ↑ Abundance of Rikenellaceae, Lachnospiraceae, and Bacteroidaceae ↓	Acetic acid, propionic acid, butyric acid, and lactic acid ↑	Zhu et al. [12]
Laying hens	Astragalus	*Lactobacillus plantarum*	CAT, GSH-Px, superoxide dismutase	CAT ↑	Hong et al. [13]

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			and total antioxidant capacity in serum ↑		
Cobb male broilers	Corn–soybean meal	*Lactobacillus acidophilus*	Body weight, ADG, average daily feed intake, and jejunum and ileum V:C ratio at 14 d and 21 d ↑	The mRNA expression of inducible nitric oxide synthase, interleukin-8, and interleukin-1β in the jejunum ↓	Wu et al. [14]
Nursery pig	Corn–soybean meal	*Lactobacillus plantarum* and *Pediococcus acidilactici*	ADG and significantly increased fecal acetate, butyrate, and total short-chain fatty acid concentrations ↑	Short-chain fatty acid ↑	Yang et al. [15]
Berkshire pigs	Rubus coreanus	*Lactobacillus plantarum*	The mRNA expression of transcription factors and cytokines in Th1 and Treg cells ↑ The mRNA expression of T helper cell 2 and Th17 transcription factors and cytokines ↓	The mRNA expression of transcription factors and cytokines in Th1 and Treg cells ↑	Yu et al. [16]
Cyprinus carpio	Wheat, soybean meal, corn–gluten meal, chicken meal	*C. somerae XMX-1*, *S. cerevisiae GCC*−1, *L. rhamnosus GCC-3*, and *B. subtilis HGcc-1*	Health and production ↑	Liver anti-inflammatory factors transforming growth Factor-β↑	Zhang et al. [17]
Juvenile olive flounder	Garlic husks, Tuna	*Bacillus licheniformis* and *Bacillus subtilis*	Weight gain, specific growth rate, and feed efficiency ↑	Sucrose reductase↑	Fatma et al. [18]

↑ indicates an increase in substance content or enzyme activity. ↓ indicates a decrease in substance content or enzyme activity. CAT, catalase; GSH-Px, glutathione peroxidase; ADG, average daily gain; Th1, T helper cell 1; Th17, T helper cell 17.

3. The Effects and Mechanism of Fermentation on the Improvement of Unconventional Feed Quality

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Unconventional feed comes from a wide range of abundantly produced sources. The development and utilization of unconventional raw materials can not only alleviate the problem of food security, but also serve as a way to consolidate the effect of poverty alleviation. As mentioned above, unconventional raw materials have the advantages of low environmental requirements, a wide growth range, rich nutritional value, and high total output. Nowadays, through the use of microbial fermentation technology, anti-nutritional factors and other substances in unconventional raw materials can be degraded to improve the materials' nutritional value. **Figure 1** shows the expected characteristics of unconventional feed after fermentation, which can effectively reduce the amount of anti-nutritional factors and toxins and increase the flavor substances in raw feed. The antioxidant application of unconventional fermented feed in animal production is a key measure. This type of feed protects animal cells from oxidative damage by providing a rich source of antioxidants [19], such as vitamin C, vitamin E, and polyphenolic compounds that effectively inhibit the production of free radicals. In addition, the preparation of unconventional fermented feed may degrade the anti-nutritional factors and toxins in feed, reduce the load of oxidative stress in animals [20], and further reduce the incidence of oxidative damage. These antioxidants are also able to enhance the immune function of animals, making them more resistant and thus reducing the risk of disease. It is worth noting that unconventional feed has strong antioxidant activity after fermentation treatment [21], which can not only maintain the feed's nutrient integrity and extend its shelf life, but can also improve its digestion, and absorption efficiency, ultimately improving the overall health and production performance of animals. Therefore, the antioxidant application of unconventional fermented feed in animal production is of great significance for improving the sustainable development of the aquaculture industry.

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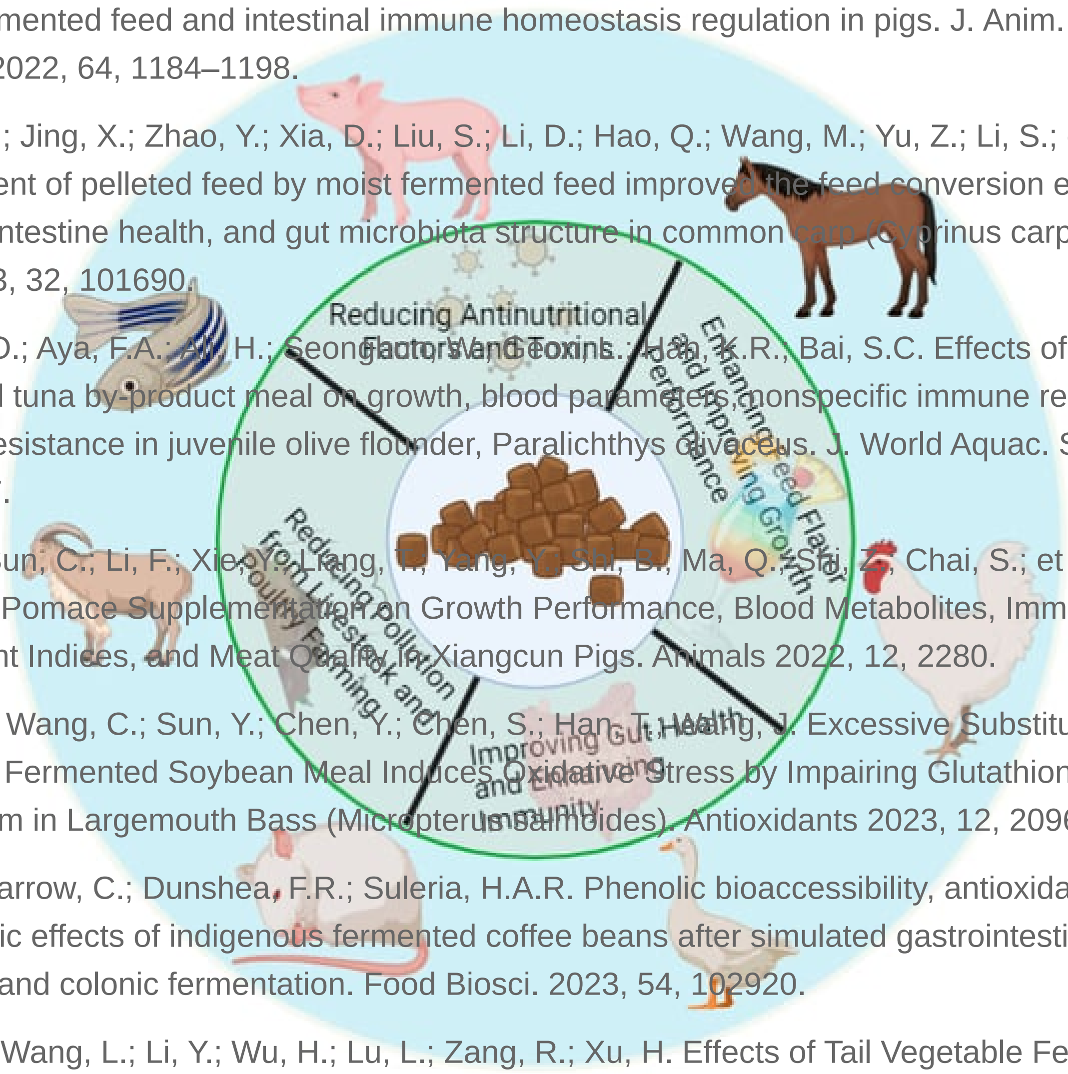

Figure 1. Expected characteristics of unconventional feed after fermentation. After fermentation, the anti-nutritional factors and toxins present in unconventional feed are greatly reduced, and the flavor substances of the feed are significantly increased. By eating fermented feed, animals can significantly improve their growth performance, improve their intestinal health, enhance their immunity, and reduce environmental pollution in the process of livestock and poultry breeding.

3.1. Reductions in Anti-Nutritional Factors and Toxins

Unconventional fermented feed uses a variety of effective measures to reduce anti-nutritional factors and toxins. Through microbial action [22], enzyme action [23], and acid base treatment, the microflora and enzymes in the fermentation process can decompose, transform, and reduce the contents of anti-nutritional factors and toxins. At the same time, proper heat treatment [24] and the screening of raw materials can further reduce the presence of these harmful substances. The process of microbial fermentation can effectively decompose anti-nutritional factors and toxins in feed [25], thereby reducing their content, and has the advantages of high treatment efficiency, no reagent residue, safe use, and less nutrient loss, so fermented feed has been widely used in actual livestock and poultry production. Fermentation improves not only the nutritional value, but also the safety of feed, making it more

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suitable for the digestion and absorption of livestock and poultry. Yeast cell walls can adsorb mycotoxins such as aflatoxin B1, reduce the absorption of mycotoxins by the digestive tract, and protect animals from the toxic effects of mycotoxins [26]. Li et al. [27] found that microbial fermented feed could further improve the growth performance and immune indexes of offspring mice.

3.2. Increases Feed Flavor and Improves Growth Performance

Fermentation produces a large number of organic acids, small peptides, amino acids, enzymes, and various metabolites that increase the natural flavor of feed, improve the palatability of feed, and promote the appetite of animals [28]. For example, lactic acid, butyric acid, acetic acid, propionic acid, and other organic acids [29] can reduce the pH value of feed and inhibit the growth of harmful microorganisms; small peptides and amino acids [30] provide nutrients that help animals grow and develop, and phytase, cellulose, and other enzymes [31] can help to decompose complex polysaccharides and proteins and improve the digestion and absorption rate of feed. Taken together, these effects promote the digestion and absorption of nutrients and improve animal growth performance [32][33]. Yeast produces alcohol and other volatile compounds with a distinctive wine aroma during fermentation. Lactic acid bacteria produce a large amount of lactic acid, which has a sour aroma during fermentation. Both different types of fermented feed can increase the appetite of animals while also having an increased nutritional value.

3.3. Improves Intestinal Health and Strengthens Immunity

Unconventional fermented feed plays an important role in improving gut health and boosting immunity. First of all, the beneficial microorganisms and metabolites produced by the fermentation process help to maintain the intestinal microecological balance, inhibit the growth of harmful bacteria, and reduce the invasion of pathogenic bacteria to the intestine, thereby improving intestinal health [34]. Secondly, the bioactive substances in fermented feed, such as organic acids, enzymes, and peptides, can promote the growth and repair of intestinal mucosal cells, enhance intestinal barrier function, and prevent the penetration of harmful substances [35]. In addition, the bioactive ingredients rich in fermented feed can also regulate the function of the immune system, promote the generation and activity of immune cells, and improve the resistance and immunity of animals [36]. Beneficial microorganisms in fermented feed can improve the structure of the intestinal microbial communities of animals [37][38], promote intestinal health, and improve the digestion and absorption of nutrients. Microbial fermented feed can stimulate the development of immune organs, improve immune function, and increase the weight of immune organs, thereby strengthening the immunity of animals [39][40][41].

3.4. Reduces Pollution from Livestock and Poultry Farming

Unconventional fermented feed plays an important role in reducing pollution from livestock and poultry farming. First of all, the use of unconventional raw materials as the main component of fermented feed can effectively use resources such as agricultural and sideline products and aquatic product by-products, reduce the demand for traditional raw feed materials, and thus reduce resource consumption and environmental pressure in the agricultural production process [11]. Secondly, the microorganisms and enzymes in the fermentation process can

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