Specialty Ingredients in Nursery Diets

Highly-digestible, nutrient-dense, specialty feed ingredients in nursery diets are often used to improve feed intake and performance of newly weaned nursery pigs. The most common feed ingredients with specific application in nursery diets are discussed in this fact sheet.

Protein sources

Dietary protein sources can be derived from plant or animal sources. Plant protein sources are typically less expensive than animal protein sources, but may contain various anti-nutritional factors. Animal protein sources are typically palatable and contain highly digestible amino acids, but variability in composition is often greater than plant sources. The interest in the use of plant-based protein sources is growing because of biosecurity concerns related to feeding animal-based protein sources.

Plant protein sources

Plant protein sources provide most of the protein in swine diets and soybean meal is the leading protein source. However, soybean meal might not be suitable to be fed as sole protein in the early post-weaning period.

Pigs have a transitory hypersensitivity reaction to soybean meal induced by allergenic proteins, namely glycinin and β-conglycinin, and indigestible carbohydrates of soybeans. Pigs experience a transitory period of poor nutrient absorption and low growth performance following the first exposure to a diet with high amounts of soybean meal (Li et al., 1990). The effects are transitory and pigs develop tolerance after 7 to 10 days (Engle, 1994). To alleviate the effects during this period, pigs are gradually acclimated to diets with increasing amounts of soybean meal after weaning.

The initial post-weaning diets should contain low amounts of soybean meal and then gradually increase soybean meal in the following nursery diets. The early exposure to soybean meal reduces the potential for delayed-type hypersensitivity reaction and adjusts the pig to diets containing soybean meal as the primary protein source. Furthermore, soybean meal can be further processed to remove the allergenic compounds and improve the utilization of soy proteins by weanling pigs (Jones et al., 2010).

♦ Fermented or enzyme-treated soybean meal

Further-processed soybean meal by microbial fermentation or enzymatic treatment is done to reduce the allergenic proteins and indigestible carbohydrates of soybeans (Stein et al., 2016). Microbial fermentation is usually accomplished by the inclusion of microbes to soybean meal, such as *Aspergillus oryzae*, *Bifidobacterium lactis*, *Lactobacillus subtilis*, among others. Enzymatic treatment is commonly performed by inclusion of proprietary enzymes and yeast to soybean meal (Stein et al., 2016).

Fermented or enzyme-treated soybean meal have greater concentration of crude protein than soybean meal, approximately 50 to 55% (Cervantes-Pahm and Stein, 2010; Jones et al., 2010). However, the standardized ileal digestibility of most amino acids and particularly lysine is lower in fermented or enzyme-treated soybean meal compared to conventional soybean meal (Cervantes-Pahm and Stein, 2010). The reduction in digestibility of amino acids is due to heat during the drying process to produce fermented or enzyme-treated soybean meal.

The inclusion of fermented or enzyme-treated soybean meal by up to approximately 10% in nursery diets in place of other high-quality protein sources does not adversely affect nursery performance (Jones et al., 2010; Kim et al., 2010; Yuan et al., 2017). However, greater inclusion rate of the enzyme-treated soybean meal can reduce feed intake of nursery pigs (Jones et al., 2018b). In general, specialty soy protein products provide an opportunity to reduce soybean meal content in diets for weanling pigs.

♦ Soy protein concentrate and isolate

Soy protein concentrate and isolate are high protein products derived from dehulled, de-oiled soybeans (or soy flakes). Soy protein concentrate contains at least 65% crude protein and soy protein isolate is the most concentrated soy protein source, with at least 85% crude protein (NRC, 2012).

During processing of soy protein concentrate and isolate, the allergenic proteins and indigestible carbohydrates of soybeans are mostly removed (Stein et al., 2016). However, the antinutritional factor trypsin inhibitor might be present in greater quantities compared to soybean meal because processing does not necessarily involve heat-treatment (Cervantes-Pahm and Stein, 2010).

The inclusion of soy protein concentrate at approximately 14% in nursery diets improves growth performance compare to soybean meal. However, greater inclusion rates may affect palatability and reduce feed intake (Lenehan et al., 2007). The cost of soy protein isolate is usually prohibitive to use in nursery diets.

Animal protein sources

Animal protein sources have been commonly used to minimize soybean meal inclusion in initial nursery diets and encourage feed intake in weanling pigs. Animal protein sources are typically palatable and contain highly digestible amino acids. However, animal protein sources are more expensive and variability in composition is often greater than plant protein sources.

Biosecurity concerns arise from the potential disease transmission via animal-sourced ingredients, particularly porcine-based. Animal protein sources typically undergo a thermal processing that eliminates most pathogens, but post-processing recontamination can be a concern. In addition, some pork marketing programs may limit the use of animal protein sources in swine diets.

♦ Spray-dried blood products

Spray-dried blood products are by-products obtained from swine and bovine slaughter plants. Spray-dried blood cells and spray-dried plasma are produced by separating the blood fractions, whereas spray-dried blood meal contains both blood cells and plasma (Almeida et al., 2013).

Spray-dried blood products are often used in diets for weanling to enhance feed intake and growth rate in the early post-weaning. Spray-dried blood products are able to stimulate feed intake either as spray-dried plasma or as spray-dried blood meal (DeRouchey et al., 2002). Most of the benefits of spray-dried plasma are in the early post-weaning period, with typical inclusion rates up to 6% spray-dried plasma in initial nursery diets (van Dijk et al., 2001; Remus et al., 2013). Spray-dried porcine plasma may provide slightly more benefit than spray-dried bovine plasma (van Dijk et al., 2001), but concerns with biosecurity are greater (Aubry et al., 2017).

Spray-dried blood products contain high concentration of crude protein (75 to 90%) and lysine (7 to 8%) (NRC, 2012). Standardized ileal digestibility of lysine and most amino acids is high, above 95 to 95% (Almeida et al., 2013). However, lysine availability is reduced with use of excessive heating during processing of spray-dried blood products.

The use of spray-dried blood products requires attention to a favorable balance of branched-chain amino acids due to the high concentration of leucine but low concentration of isoleucine and valine, particularly in spray-dried blood cells or blood meal (Kerr et al., 2004; Goodband et al., 2014). Also, the concentration of methionine is low in all spray-dried blood products. The inclusion of other protein sources or supplementation of diets with feed-grade amino acids is important to adjust the amino acid profile in diets with spray-dried blood products (Remus et al., 2013).

Spray-dried blood products may vary substantially in composition and quality according to source and processing methods. The application of heat is critical to eliminate pathogens (Narayanappa et al., 2015), but post-processing recontamination can be a concern. In order to minimize the risk of disease transmission via feed ingredients, it is advisable to only use non-porcine-derived blood products.

♦ Meat and bone meal

Meat and bone meal is a by-product from various tissues obtained from harvesting plants. Meat and bone meal contains high concentrations of crude protein (50 to 55%), lysine (2.5%), and most amino acids except for tryptophan (NRC, 2012). Standardized ileal digestibility of lysine and most amino acids is low, approximately 65 to 80% (Kong et al., 2014). Moreover, lysine availability is further reduced with use of excessive heating during processing of meat and blood meal.

Meat and bone meal is an excellent source of calcium and phosphorus, providing the minerals in high concentration and with a high phosphorus bioavailability (Traylor et al., 2005).

Meat and bone meal quality and composition may vary substantially according to the raw materials characteristics. The thermal processing of meat and bone meal is critical to eliminate pathogens, but post-processing recontamination can be a concern. In order to minimize the risk of disease transmission via feed ingredients, it is advisable to only use non-porcine-derived meat and bone meal.

♦ Poultry meal

Poultry meal is a by-product from viscera and various tissues obtained from poultry harvest. Poultry meal contains high concentration of crude protein (60 to 65%), lysine (4%), and most amino acids except for tryptophan (NRC, 2012). The digestibility of amino acids can be affected by the ash content of poultry meal. The ash content is directly related to the level of bone included in poultry meal and is a measure associated with low digestibility and inferior quality (Keegan et al., 2004). Moreover, lysine availability is further reduced with use of excessive heating during processing of poultry meal.

Poultry meal quality and composition may vary substantially according to the raw materials characteristics. The thermal processing of poultry meal is critical to eliminate pathogens, but post-processing recontamination can be a concern

♦ Fish meal

Fish meal is a product obtained by processing whole fish or fish waste. Fish meal typically contains high concentration of crude protein (60 to 65%) and lysine (4.5%), favorable amino acid profile, and omega-3 fatty acids (NRC, 2012). Standardized ileal digestibility of lysine and most amino acids is high, approximately 85% (Cervantes-Pahm and Stein, 2010).

The inclusion of fish meal in nursery diets enhances palatability and usually increases feed intake with a typical inclusion of approximately 3 to 6% fish meal (Jones et al., 2018a).

Fish meal quality can vary considerably depending on the species of fish, raw fish freshness, and processing method (Kim and Easter, 2001; Jones et al., 2018a). Fish solubles, also known as stickwater concentrate, is a by-product rich in B vitamins and minerals derived from fish meal processing. The amount of fish solubles is variable in fish meal, generally found at 8 to 15%, but it is not associated with fish meal quality or nursery pig performance (Jones et al., 2018a).

Currently, there is no single laboratory test that provides a general estimate of fish meal quality. Analysis of mineral content and fat can be used as an indicative of fish meal feeding value. Fish meal with high mineral content (> 20%) and lower fat level (< 7.5%) is generally from fish offal and contains lower feeding value compared to fish meal from whole fish. Freshness of raw fish can be estimated by analysis of total volatile nitrogen. Values below 0.15% total volatile nitrogen generally indicate fish meal freshness. Bacterial analysis is important to assess quality of fish meal, as *Salmonella* can be transmitted via fish meal (Morris et al., 1970).

♦ Porcine intestinal mucosa products

Porcine intestinal mucosa products are by-products of the pharmaceutical industry obtained from processing of porcine intestinal mucosa to extract the anticoagulant heparin. Commercially available products are generally referred to as enzymatically-hydrolyzed intestinal mucosa, dried porcine solubles, or peptones. The concentration of crude protein is high (50 to 60%) and amino acid profile is favorable (Myers et al., 2014). Standardized ileal digestibility of lysine and most amino acids is high, above 80 to 85% (Sulabo et al., 2013).

Porcine intestinal mucosa products provide small peptides that are easily digestible by nursery pigs. Porcine intestinal mucosa products can be added at approximately 6% in nursery diets (Myers et al., 2014).

Variation in composition of porcine intestinal mucosa products is due to different plant proteins used as carriers during drying and processing of intestinal mucosa (Jones et al., 2010; Myers et al., 2014). The thermal processing of porcine intestinal mucosa products is critical to eliminate pathogens, but post-processing recontamination can be a concern.

♦ Spray-dried egg

Spray-dried egg is a by-product from the egg industry produced only from eggs without shell that do not meet the quality standards for human consumption. Spray-dried egg contains high concentration of crude protein (50%), lysine (3.5%), and favorable amino acid profile (NRC, 2012).

Spray-dried egg provides bioactive compounds, such as antimicrobial proteins (lysozyme) and antibodies (IgY). The composition of spray-dried egg is thought to provide benefits to improve health (Song et al., 2012). Moreover, hens can be immunized against pathogens, such as enterotoxigenic *Escherichia coli*, and the hyperimmunized eggs serve as a pathogen-specific antibody source (Da Rosa et al., 2014).

♦ Whey protein concentrate

Whey protein concentrate is produced by having an additional process of ultrafiltration of liquid whey before the drying process (Grinstead et al., 2000). The ultrafiltration process concentrates the whey protein and removes most of the lactose. Whey protein concentrate contains 75 to 80% crude protein and low lactose concentration, generally around 5% (NRC, 2012). Whey protein concentrate is an edible-grade product in high demand by the food industry, limiting its availability for use in nursery diets.

Yeast protein source

♦ Dried fermentation biomass

Dried fermentation biomass consists of residual material from the feed-grade amino acid production. Feed-grade amino acids are derived from amino acid-producing bacteria in a process that requires a carbon source (sugars) and a nitrogen source (yeast extract) for bacterial fermentation. The fermentation biomass left after extraction of crystalline amino acids is used to produce dried fermentation biomass.

Dried fermentation biomass contains high concentration of crude protein (around 80%), lysine, and essential amino acids (Sulabo et al., 2013; Almeida et al., 2014). Standardized ileal digestibility of lysine and most amino acids is high, above 90% (Sulabo et al., 2013; Almeida et al., 2014).

Dried fermentation biomass can be added at approximately 15 to 20% in nursery diets (Sulabo et al., 2013; Almeida et al., 2014). However, high levels can have a negative impact on feed intake, which could be related to the amount of amino acid-producing bacteria within the dried fermentation biomass. The amino acid-producing bacteria are not harmful to pigs, but a structural component of Gram-negative bacteria (lipopolysaccharide) may have endotoxin activity (Wallace et al., 2016), which affects feed intake.

Feed-grade amino acids

Feed-grade amino acids have been used to reduce specialty protein sources in nursery diets. The replacement of intact protein sources by feed-grade amino acids increases as feed-grade amino acids become available and economically justifiable. Currently, feed-grade lysine, methionine, threonine, tryptophan, and valine are all economical to include in nursery diets in the United States.

The use of feed-grade amino acids is key to meeting the amino acid requirements of nursery pigs, with accompanying reduction in dietary crude protein and savings in diet cost. However, it is important to ensure a sufficient supply of nitrogen for synthesis of non-essential amino acids when formulating diets with high levels of feed-grade amino acids.

Carbohydrate sources

Starch carbohydrates are an excellent energy source for pigs. However, in the early period after weaning, carbohydrate sources must be highly digestible to serve as a readily available source of energy for weanling pigs, particularly to counteract the low feed intake after weaning.

Lactose

Lactose is the carbohydrate component derived from milk and provides an easily digestible source of energy for pigs. The addition of lactose in nursery diets improves growth rate of weanling pigs, particularly in the early period after weaning (Tokach et al., 1995; Grinstead et al., 2000). There is a benefit of providing 5 to 30% dietary lactose during the entire nursery period (Mahan et al., 2004; Cromwell et al., 2008), but it is recommended to direct the use of lactose to initial nursery diets and for a short period of time because the magnitude of response dramatically decreases, and lactose products are expensive. Typically, initial nursery diets contain around 18% lactose (Mahan et al., 2004).

Common lactose sources are crystalline lactose (100% lactose), whey permeate (80% lactose), and dried whey (72% lactose). Whey products also provide a source of protein to the diet. When replacing one lactose source by another in the diet, care must be taken to evaluate both lactose and amino acids levels. The key is to know the lactose concentration and replace on an equal lactose basis, and then replace the amino acids with an appropriate high-quality protein source.

Whey products are derived from milk curdling during production of milk products like cheese and yoghurt (Grinstead et al., 2000). Whey products used in nursery diets are preferentially derived from cheese production ('sweet whey') rather than yoghurt production ('acid whey'). The use of edible-grade whey are also preferred over feed-grade whey products (Nessmith et al., 1997).

Quality of whey products is affected by excessive heat during processing, which reduces lactose and amino acid contents and results in whey with a brownish color.

Over-heating also reduces digestibility of lactose and amino acids, which leads to scouring in pigs. Spray-drying is the preferred method to prevent over-heating because of the fast evaporation at lower temperatures compared to roller drying (Grinstead et al., 2000). The levels of minerals also vary during processing and above 11% mineral content leads to scouring in pigs (Nessmith et al., 1997). Indicators of high-quality whey products include white or yellowish color, absence of black specs, and mineral content below 8.5% (Nessmith et al., 1997).

From a feed milling standpoint, the addition of lactose products in the diet influences feed processing. For pelleted diets, high levels of lactose can increase friction during the pelleting process. In this case, the addition of fat in nursery diets with high levels of lactose is often used to enhance lubrication of the pellet die and prevent heat damage. For meal diets, high levels of lactose can increase bridging and reduce flowability in bins and feeders.

Sucrose

Sucrose is a simple carbohydrate extracted from sugar cane or sugar beet. Sucrose provides an easily digestible source of energy for pigs from glucose and fructose. Young pigs have limited ability to utilize sucrose, but sucrase activity rapidly increases after weaning.

Sucrose can be considered as a replacement for lactose in nursery diets, particularly in diets with no animal-based products. The addition of 5 to 10% sucrose in initial nursery diets improves growth performance of weanling pigs as effectively as lactose (Mavromichalis et al., 2001). Products based on sucrose and other simple sugars can also partially replace lactose without an impact on growth performance (Naranjo et al., 2010; Guo et al., 2015).

Dextrose

Dextrose is a form of glucose typically extracted from corn that provides an easily digestible source of energy for pigs. Similar to sucrose, the use of dextrose or products based on dextrose and other simple sugars can partially replace lactose in initial nursery diets without an impact on growth performance (Turlington et al., 1989; Mahan and Newton, 1993; Bergstrom et al., 2007).

Fat sources

Weanling pigs have limited ability to digest and utilize fat to improve growth performance (Tokach et al., 1995). The ability to utilize fat improves with age, particularly for animal fats compared with vegetable oils.

In the early post-weaning period, weanling pigs seem to require a more digestible fat source rich in unsaturated and short-chain fatty acids for efficient energy utilization (Gu and Li, 2003). Vegetable oils like soybean oil and coconut oil are high quality sources of energy for weanling pigs (Weng, 2016), but cost often limits the use in nursery diets. Animal fat sources of good quality like choice white grease or beef tallow are usually more cost-effective to use in nursery diets.

The addition of 3 to 4% fat is mainly used to improve the pelleting process of initial nursery diets with high levels of lactose. As fat utilization for growth performance gradually improves with age, 1 to 3% fat can be added to nursery diets depending on economics.

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