Improving Feed and Nutrient Utilization by Feed Processing

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Importance

Global meat production is expected to rise by 12% from 2023 to 2032 with pork production growing from 117 to 129 million metric tons per year (OECD and FAO). Most of the environmental footprint in pork production comes from the feed system, which includes crop cultivation, feed manufacturing, and transportation. Improving pig health, management, and feed efficiency can help meet the growing demand for pork while reducing the environmental impact (Andretta et al., 2021). During feed manufacturing, various processes can have a significant impact on feed efficiency.

Grinding and Particle Size

Grinding reduces particle size and increases surface area for enzymatic digestion leading to improved dry matter digestibility and feed efficiency (Han et al., 2001). For example, reducing ground corn particle size from 865 to 339 µm improved apparent ileal digestibility of gross energy by 11% and starch by 7%, though protein and P digestibility were unaffected (Rojas and Stein, 2015). On average, a 100 µm reduction in particle size results in approximately 1% improvement in feed efficiency due to enhanced digestibility (Menegat et al., 2019).

The extent of feed efficiency improvement depends on production phase and diet form. In finishing pigs fed meal diets, benefits of particle size reduction appear linear down to 300 µm (De Jong et al., 2012). However, for pelleted diets in nursery and finishing pigs, the optimal particle size is 500-600 µm, (De Jong et al., 2013; Kippert et al., 2021). Excessively fine grinding in meal-based nursery diets can reduce average daily feed intake, offsetting potential gains in feed efficiency (Gebhardt et al., 2018).

Summary

- Optimal particle size (~400-600 µm) improves nutrient digestibility and feed efficiency
- Reducing corn from 865 → 339 µm increased energy digestibility by 11% (Rojas and Stein, 2015)
- Excessive reduction (< 400 µm) increases risk of gastric ulcers
- Roller mills provide more uniform particle size than hammer mills

Pelleting

Pelleting compresses feed into dense particles using heat, moisture, and pressure. It improves handling, reduces feed wastage, and enhances nutrient utilization through starch gelatinization and increases digestibility.

Pelleting converts mash feed into dense pellets, improving feed efficiency and average daily gain (ADG) through reduced feed wastage and enhanced nutrient digestibility (Farahat, 2015; Menegat et al., 2019; Lancheros et al., 2020). Feed efficiency can improve by up to 8%, with much of the benefit attributed to less wastage (Van Kempen and Van Heugten, 2000). Responses vary by production stage, with greater improvements observed in nursery pigs (9.8%) compared to finishing pigs (5.8%) (Lancheros et al., 2020).

Pelleting enhances gross energy digestibility via starch gelatinization during processing, with average gains of 3.2% across various grains, and slightly greater benefits in high-fiber cereals such as barley compared with wheat or corn

(Danel, 2017). Protein digestibility also improves due to protein denaturation and inactivation of enzyme inhibitors, increasing enzyme access (Dunmire and Paulk, 2021).

Pellet quality is critical in determining the magnitude of response. High-quality pellets reduce fines and wastage, whereas a 10% increase in fines can reduce feed efficiency by 1% (Vukmirović et al., 2017; Menegat et al., 2019). For example, if a diet with 20% fines yields a 6% improvement in feed efficiency, raising fines to 50% would reduce the benefit to 3%. Feeder type also influences outcomes, with pigs fed pelleted diets showing efficiency gains when using dry or wet/dry feeders, but not with liquid feeding systems (O'Meara et al., 2020). Overall, pelleting consistently improves performance, though the degree of benefit depends on pellet quality, grain type, and feeding system.

Summary

- Improves ADG and feed efficiency by up to 8%, mainly by reducing wastage; nursery pigs benefit more (9.8%) than finishing pigs (5.8%) (Van Kempen and Van Heugten, 2000; Lancheros et al., 2020)
- Heat and steam gelatinize starch and denature proteins, increasing energy (+3.2% ATTD) and protein digestibility (Danel, 2017; Dunmire and Paulk, 2021)
- A 10% rise in fines lowers feed efficiency by ~1%; high-quality pellets minimize wastage and maximize benefits (Vukmirović et al., 2017; Menegat et al., 2019)

Extrusion

Extrusion subjects feed to high temperature, moisture, and shear pressure, modifying starch and protein structure. It is less common than pelleting but has unique advantages for improving digestibility. Extrusion is a thermo-mechanical process where moistened, starch- or protein-rich ingredients are plasticized and cooked using heat, pressure, moisture, and mechanical shear (Miladinovic and Zimonja, 2010). Similar to pelleting, extrusion improves nutrient digestibility and feed efficiency in pigs by enhancing the availability of starch, energy, and amino acids. Research shows extrusion increases digestibility of gross energy and starch in corn, wheat, and DDGS, as well as amino acid digestibility in corn, soybean meal, and field peas (Lancheros et al., 2020). Across studies, extrusion has been associated with an 11% improvement in feed efficiency for growing pigs, with a smaller but positive numerical improvement of 4.4% reported in nursery pigs [multiple sources as cited by Lancheros et al. (2020)]. Thus, extrusion represents an effective feed processing method to enhance nutrient utilization and overall pig performance.

Summary

- Uses heat, moisture, pressure, and shear to cook starch- and protein-rich ingredients, improving nutrient availability
- Enhances gross energy and starch digestibility in corn, wheat, and DDGS, and AA digestibility in corn, soybean meal, and field peas
- Improves feed efficiency by 11% in growing pugs and a 4.4% numerical gain in nursery pigs

Enzyme & Chemical Treatments

Enzymes and chemical treatments enhance nutrient availability by breaking down anti-nutritional factors or releasing bound nutrients. Common approaches include phytase, carbohydrases, proteases, and alkali or heat treatments. Fermentation and chemical treatments of feed ingredients have shown potential to improve nutrient utilization and pig performance. A meta-analysis by Xu et al. (2020) found that fermented feed ingredients increased feed efficiency by 4.5% in nursery and growing pigs. Similarly, replacing soybean meal with enzyme-treated or fermented soybean meal improved protein, energy digestibility and overall feed efficiency (Ma et al., 2019; Muniyappan et al., 2023). Chemical treatments with sodium hydroxide, ammonia, calcium oxide, or calcium hydroxide can also enhance feed value (Rojas and Stein, 2017). However, while effective in ruminants, research on their benefits in non-ruminants is limited.

Summary

- Fermentation improves feed efficiency by 4.5% in nursery and growing pigs
- Chemical treatments improve nutrient value in feeds, though evidence in non-ruminants is limited

Combined Treatments

Feed processing methods such as pelleting, extrusion, and fine grinding improve nutrient digestibility and feed efficiency, but their combined impacts are not always additive. For example, Rojas et al. (2016) reported that while pelleting and extrusion each increase starch digestibility compared to meal diets, their combination provides little additional benefit since starch digestibility approaches 100% with either method alone. However, combining fine particle size with heat processing can increase the risk of gastric ulcers, which reduces efficiency and raises mortality. This risk is further compounded by out-of-feed events from poor management or reduced feed intake during disease challenges. Genetic predisposition may also influence susceptibility to gastric ulcers, highlighting the importance of balancing feed processing improvements with animal health concerns (Gottardo et al., 2017).

Energy Cost of Feed Processing

While processing methods enhance nutrient utilization and reduce nutrient excretion, they also require additional energy inputs. Feed processing consumes roughly 40-60 kWh/ton of feed, with pelleting and milling accounting for the highest proportions at 40% and 26%, respectively (Redecker and Thoben, 2012). Finely grinding diets further increases electrical energy consumption and lowers feed mill throughput (Vukmirović et al., 2017; Gebhardt et al., 2018). An optimal balance must be struck between improving feed efficiency and the environmental and economic costs associated with energy-intensive feed processing.

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