

Use of feed technology to improve energy and nutrient utilization of diets for growing pigs

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Summary

All diets fed to pigs are processed before feeding and processing often impacts digestibility of energy and nutrients. As an example, particle size reduction, pelleting, and extrusion will result in improved digestibility of energy, and therefore, increased net energy of diets. Usage of carbohydrate degrading enzymes, and possibly also microbial phytase, may also aid in increasing digestibility of energy. Pelleting and extrusion also results in increased amino acid digestibility, and recent evidence indicates that increased conditioning time as well as increased pellet die thickness will improve amino acid digestibility. Microbial phytase or direct fed microbials may also result in small improvements in digestibility of amino acids. The digestibility of phosphorus can effectively be improved by inclusion of microbial phytase in the diets, but particle size reduction, pelleting, or extrusion do not appear to impact phosphorus digestibility. However, inclusion of certain metabolites of vitamin D may increase digestibility of phosphorus above what is achieved by using microbial phytase.

Introduction

Energy, amino acids, and phosphorus are the most expensive components of diets for pigs and any improvement in the absorption and utilization of these nutrients, therefore, will result in improved economy of feeding pigs. Whereas the impact of using different feed ingredients in diets for pigs is well documented there is much less information about the impact of feed technology on utilization of energy, amino acids, and phosphorus. There are, however, a number of technologies that may be used to aid in greater energy and nutrient digestibility. The objective of the current contribution is to briefly review some of the technologies that are available to capture greater values of ingredients included in diets for pigs. Because this abstract was written in response to an invitation to the author to give a presentation about feed technologies at the 3rd Animal Feed Technology Course that took place in Utrecht, the Netherlands, June 2026, the majority of the references used are from the authors own laboratory.

Energy

Energy usage is a function of digestion, absorption, and metabolism of fat, protein, starch, and fiber. Increased digestibility of fat, protein, and starch, and increased fermentability of energy will, therefore, result in increased availability of metabolizable energy to the animal. Technologies to increase energy digestibility or fermentation include particle size reduction, pelleting, extrusion, and usage of feed additives including enzymes. Clear improvements in the digestibility of energy in cereal grains and diets have been demonstrated multiple times by reducing the particle size of cereal grains (Lancheros et al., 2020). It is possible that reduction of particle size using roller milling is a more efficient process to increase energy digestibility compared with hammer milling (Acosta et al., 2020), but more research to determine the impact of milling type on energy digestibility is needed. The reason for the improved energy digestibility that has been observed as the particle size is reduced primarily is an improvement in starch digestibility in grains milled to a reduced particle size (Rojas and Stein, 2015; Ibagón et al., 2024a; 2024b; Lee et al., 2025a). It therefore appears that although pigs generally are efficient in digesting starch, improvements are possible with the use of technologies that make starch granules more accessible to the starch digesting enzymes. Starch digestibility may also be improved by pelleting or extrusion, which has resulted in increased energy digestibility (Stein and Bohlke, 2007; Rodríguez et al., 2020; Lee et al., 2025a). It is also possible that reduced particle size will result in increased fermentation of dietary fiber, and therefore improved total tract digestibility of fiber, which also contributes to an improvement in energy digestibility (Song et al., 2025). Combined, the improvements in nutrient and energy digestibility that have been demonstrated by reducing particle size of cereal grains or by pelleting or extrusion of diets have resulted in increased gain to feed ratio of weanling or growing pigs (Paulk et al., 2015; Rojas and Stein, 2016; Lancheros et al., 2020). Pigs fed diets with reduced particle size also have increased dressing percentage and therefore produce more saleable meat, which is due to a reduced weight of the intestinal tract (Paulk et al., 2015; Rojas et al., 2016a). As expected, the combined effects of reducing diet particle size have resulted in increased net energy of diets containing grains ground to a reduced particle size (Ibagón et al., 2024a; Lee et al., 2024; Song et al., 2024).

Energy digestibility may also be improved by inclusion of carbohydrate digesting enzymes in diets for pigs. Specifically, inclusion of xylanase or xylanase-beta glucanase combinations may aid in increasing the

fermentation of dietary fiber (Casas and Stein, 2016; Oliveira et al., 2022; Acosta et al., 2025; Song et al., 2025) although there are also many reports from experiments where no effects of fiber digesting enzymes were observed. The use of microbial phytase may also increase energy digestibility although increases may be modest (Arredondo et al., 2019). Nevertheless, the increased fiber and energy digestibility that are obtained if enzymes are added to diets results in improved growth performance of pigs (Acosta et al., 2025). There is currently also an interest in the use of microbial amylases in diets for pigs, and it is possible that microbial amylase also is efficient in improving energy digestibility, but currently, there is a lack of published reports where positive responses to microbial amylases have been demonstrated. However, because any increase in starch digestibility will result in increased energy digestibility, it is possible that this technology will be used in the future.

Another technology that potentially can be used to increase energy digestibility is addition of emulsifiers to diets, which may increase small intestinal digestibility of dietary lipids. There are, however, limited data to document the effectiveness of emulsifiers in diets for pigs, and it is not clear how much fat needs to be included in diets to obtain a positive response (Lee et al., 2025b). It is also not clear if emulsifiers work better in diets with saturated fatty acids than with unsaturated fatty acids, and future research needs to address these questions.

Amino acids

In contrast to starch digestibility, the standardized ileal digestibility (SID) of amino acids is usually unaffected by particle size (Rojas and Stein, 2015; Ibagón et al., 2024a; 2024b; Song et al., 2025) indicating that pigs are very efficient in digesting protein even when grains are coarsely ground. It is, however, possible to increase SID of amino acids by pelleting diets (Stein and Bohlke, 2007; Rojas et al., 2016b; Dunmire et al., 2024; Lee et al., 2025a; Lopez et al., 2025; 2026). It is likely that the reason for the increased SID of amino acids in pelleted diets is that the heat generated during pelleting results in protein unfolding and therefore easier access for the digestive enzymes. Recently, it was demonstrated that a pellet die thickness of 10 millimeter results in greater SID of amino acids than if the pellet die thickness is 6 or 8 millimeter, although all three pellet die thicknesses resulted in SID of amino acids that was greater than in mash diets (Lopez et al., 2026). Greater pellet die thickness will result in increased friction heat, which supports the hypothesis that it is the heat generated during pelleting that is the reason for the increased SID of amino acids. Likewise, a conditioning time of 180 seconds results in greater SID of amino acids than a conditioning time of 30 or 60 seconds (Lopez et al., 2025), which may also be a result of increased exposure to heat.

Amino acid digestibility may also be increased by extrusion of diets (Stein and Bohlke, 2007; Rojas et al., 2016b), which further indicates that heat treatment may increase SID of amino acids. Extrusion appears to be slightly more effective in improving SID of amino acids compared with pelleting, but in terms of amino acid digestibility, there appears to be no advantage of pelleting extruded diets (Rojas et al., 2016b).

It is also possible to increase SID of amino acids by using some of the newer microbial phytases (Espinosa et al., 2022; Lagos et al., 2022; 2023). Smaller, but significant, improvements in the SID of some, but not all, amino acids may also be obtained if direct fed microbials are included in diets for growing pigs (Blavi et al., 2019) indicating that a beneficial change in the intestinal microbiota may improve small intestinal protein hydrolysis and/or absorption of amino acids. Recently, there has been interest in adding proteases to diets to improve amino acid digestibility, but documented positive responses on SID of amino acids are scarce. It is, however, possible that future developments in biotechnology will result in improved proteases that can be used to improve the SID of amino acids in diets for pigs.

Phosphorus

Reduction of particle size usually does not improve the digestibility of phosphorus (Liu et al. 2012; Rojas and Stein, 2015; Ibagón et al., 2024c), and there are no indications that pelleting or extrusion impacts the digestibility of phosphorus. However, phosphorus digestibility is effectively improved by addition of microbial phytase to diets as has been demonstrated in multiple experiments (Poulsen et al., 2010; Arredondo et al., 2019; Lagos et al., 2022; 2023; Espinosa et al., 2022; 2024). There is also recent evidence that inclusion of the Vitamin D metabolite 25-OH-D₃ will result in increased digestibility of phosphorus in diets for growing pigs and reproducing sows (Lee et al., 2022; Jaramillo et al., 2025) and it is possible that other vitamin D metabolites also are effective in improving phosphorus digestibility. However, there is a need for more research to determine how different sources of vitamin D and different vitamin D metabolites may impact the digestibility of phosphorus in diets for growing pigs and sows.

Conclusions

A number of technologies may be employed to improve the nutritional value of diets fed to pigs. Because most ingredients need to be ground before inclusion in diets for pigs, an important consideration is to determine the particle size that is used to grind the ingredients. In general, the smaller the particle size that is used, the greater the digestibility of energy. Energy digestibility is also improved by pelleting or extrusion and usage of carbohydrases or microbial phytase may also aid in increasing energy digestibility. Amino acid digestibility can be improved by pelleting and extrusion and possibly also by microbial phytase, whereas particle size reduction, generally does not improve amino acid digestibility. Use of microbial phytase and specific vitamin D metabolites will also result in increased digestibility of phosphorus, whereas pelleting, particle size reduction, or extrusion do not appear to be effective in increasing digestibility of phosphorus.

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