What We Know About Feeding Liquid By-Products to Pigs

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Introduction

Liquid feeding systems have been extensively used for many years to utilize liquid by-products in swine production feeding systems in Western Europe. However, use of this technology has been limited in North America and other regions around the world until recently. The increasing popularity of using liquid feeding systems in North America is being driven by extremely high prices of conventional dry feeds, a tremendous increase in availability and low cost of liquid by-products from biofuels production, and numerous growth performance, health, and animal well-being advantages that liquid feeding systems provide compared to dry feeding systems. In fact, approximately 20% of growing finishing pigs in Ontario, Canada are fed using liquid feeding systems (SLFA, 2007).

Liquid feeding systems involve computer controlled feed production and frequent feeding of liquid diets that can be successfully used in all phases of swine production. Typically, liquid diets contain 20 to 30% dry matter. In some liquid feeding systems, partial fermentation of ingredients or diets is allowed to occur, resulting in production of organic acids and proliferation of beneficial bacteria, such as Lactobacilus acidophilus (de Lange et al., 2006). One of the most important aspects of using liquid feeding successfully is to ensure that the proper ratio of water:dry matter content and frequency of feeding is achieved for the specific production phases where it is used.

Benefits of Liquid Feeding vs. Dry Feeding

There are many advantages of using liquid feeding systems compared to dry feeding in swine production. These include improved nutrient utilization, flexibility and control of feeding programs, utilization of inexpensive liquid by-products, reduced environmental impact, and improved animal performance (Jensen and Mikkelsen, 1998; Russell et al., 1996; Canibe and Jensen, 2003; Brooks et al., 2001; Lawlor et al., 2002). Liquid feeding may also enhance gut health, reduce the need for feed medications, and improve animal well-being (Brooks et al., 2001; Canibe and Jensen, 2003).

Feeding liquid diets containing fermented ingredients have resulted in improved growth performance, and reduced mortality and morbidity in nursery and growing-finishing pigs (Geary et al., 1996;1999; Canibe and Jensen, 2003; Scholten et al., 1999). These benefits appear to be due to enhanced nutrient availability, and reduced growth and shedding of pathogenic bacteria such as Yersinia, Salmonella, and E. coli due to low pH (Geary et al., 1996;1999; Scholten et al., 1999; van Winsen et al., 2001; Demeckova et al., 2001). Furthermore, pepsin activity is increased due to lower pH resulting in improved protein digestion (Scholten et al., 1999). The presence of lactic acid bacteria and organic acids (lactic acid and butyric acid) in fermented liquid feeds may also have positive effects on digestive and immune functions (Simon et al., 2003; Mroz, 2003).

Challenges of Using Liquid Feeding

Consistency of by-product supply

It is essential to have formal agreements with by-product suppliers to obtain a consistent quantity and quality of by-products being used. This is important because dry feed premixes and supplements are custom formulated for the specific by-products being used in liquid feeds and because switching between some by-products may reduce growth performance due to the need for the pigs digestive system to adapt to the changing nutrient composition when switching between by-products.

High water content of by-products

Many by-products have high moisture (70-90%), low dry matter content. As a result, it is difficult to economically justify transporting liquid by-products long distances due to the high cost per kg dry matter. Furthermore, the amount of water provided to pigs using liquid feeding is higher than used in conventional dry feeding systems. As a result, manure volume can be increased along with increased humidity and moisture levels in swine facilities.

Variability in nutrient content

Nutrient content of by-products can vary substantially from batch to batch and among sources (Braun and de Lange, 2004). Frequent sampling and nutrient analysis allows for making more precise diet formulation adjustments to avoid feeding excessive or limited amounts of nutrients in liquid feeding systems. Ideally, certificates of quality and nutrient profiles should be obtained from suppliers that guarantee that the by-products are free of contaminants and meet regulatory requirements (Braun and de Lange, 2004).

High salt content of some by-products

Liquid whey and bakery waste can contain significant amounts of salt. Sweet whey is the by-product remaining after the production of soft cheeses whereas, acid whey is produced from the longer duration of pressing for hard cheeses and has a lower pH. Since salt is added to cheese before pressing, the liquid whey remaining can contain as much as 10% salt on a dry matter basis. As a result, pigs should be provided ad libitum access to water in addition to the water contained in liquid feed to avoid salt toxicity. High salt content and low pH of liquid whey can accelerate deterioration of concrete floors and steel feeders and equipment in swine facilties. Similarly, the salt content of some bakery by-products may require reduction or elimination of supplemental salt in the diet formulation and may limit the amount of the by-product used.

Loss of synthetic amino acids during storage of liquid feeds

Research conducted in Denmark showed that about 17% of added synthetic lysine was lost after 24 hours of storage of fermented liquid feed (Pedersen et al., 2002). This loss is likely due to preferential utilization of free amino acids by microbes found in fermented feeds (de Lange et al., 2006). Niven et al. (2006) showed that these losses are primarily due to the presence of coliform bacteria present in liquid feed and that when large amounts of lactobacillus bacteria are present, very little lysine is lost. Therefore, to minimize loss of synthetic amino acids, they should be added to liquid feeds after stable fermentation is achieved, when liquid feed contains more than 75 mMol lactic acid, or when the pH is less than 4.5 (Braun and de Lange, 2004).

Homogeneity of mixed feed

Braun and de Lange (2004) showed that there were substantial differences in mineral content of feed samples collected at the second or second last valve in the feed line in some commercial farms they surveyed. They noted that unmixing of feed is less of a concern using modern liquid feeding equipment as well as when using higher viscosity liquid by-products such as condensed distillers solubles and corn steep water (by-products of the ethanol industry) to keep mineral particles in suspension longer.

Common By-Products Used in Liquid Feeding Systems

There are a number of liquid by-products produced in the food and biofuels industries that are well suited and economical for use in swine liquid feeding systems. However, some of the challenges of using liquid by-products involve variability in nutrient content, consistency of supply, and close proximity of by-product production to swine farms in order to minimize transportation cost. Braun and de Lange (2004) described and summarized some of the common by-products used in liquid feeding systems. These include those from milk processing (sweet whey, acid whey, butter milk), bakery waste (bread, cookies, crackers, and miscellaneous confectionaries), candy (sugar syrup), brewer's wet yeast (by-product of beer manufacturing), and liquid by-products from ethanol production (corn condensed distiller's solubles and corn steep water).

Liquid whey is highly palatable. Acid whey contains about 15% protein which is highly digestible if it has not been treated with excessive heat. It is also an excellent, highly digestible energy source for young pigs because it contains approximately 60% lactose. However, due to the rapidly declining ability of the pig to effectively digest lactose as it ages, digestive upset can occur in older pigs when it is abruptly included in liquid feed or fed at high dietary levels. The high salt content can result in salt toxicity if additional access to fresh water is not provided.

Buttermilk contains about 30-35% protein and 5-6% fat on a dry matter basis. It is an excellent by-product to use in liquid feeding systems because of its high protein and energy value.

Bakery waste can vary substantially in nutrient content depending on the type of food by-products in the mixture. Bread is high in energy but may require special handling equipment to remove wrappers. Bread meal should be limited to no more than 30% of dry matter intake for pigs. Cookies and crackers can contain high amounts of fat and sugars making them excellent energy sources. Depending on the type of bakery product, salt content can be relatively high and should be taken into account when formulating the liquid feed supplements.

A slurry of brewer's wet yeast contains about 11-16% dry matter and contains active yeast which may cause further fermentation and frothing during storage. Organic acids should be added to the slurry to reduce the pH and kill the yeast before shipping to the pig farm. Brewer's wet yeast is an excellent source of high quality, highly digestible protein and contains enzymes and co-factors which benefit pig health and performance. It is generally added at a rate of 2-5% in swine diets but can be used to replace up to 80% of the protein if it is economical. Good growth performance can be achieved when feeding wet brewer's yeast but the response appears to vary depending on stage of production where it is fed. Feeding it to lactating sows may cause diarrhea in nursing pigs.

Sugar syrup generally has a dry matter content of approximately 65% and is high in energy but essentially devoid of protein, vitamins, and minerals. High sugar content can cause digestive upsets in pigs and therefore, it should be limited to no more than 5% of the diet.

Liquid By-Products from the Ethanol Industry

The production of biofuels, particularly ethanol, is rapidly increasing around the world in response to the need to become less dependent on petroleum and improve the natural environment. In the U.S., most of the ethanol is produced by dry-grind ethanol plants using a process shown in Figure 1. By-products from dry-grind ethanol plants include wet and dried distiller's grains, wet and dried distiller's grains with solubles, modified "wet cake" (a 50% moisture blend of distiller's grains and solubles), and condensed distiller's solubles. Approximately 30% of the distiller's grains with solubles are marketed as a wet by-product for use in dairy operations and beef cattle feedlots located near ethanol plants. The remaining 70% of distiller's grains with solubles is dried (DDGS) and marketed domestically and internationally for use in dairy, beef, swine and poultry feeds. Alternatively, wet milling is also used to produce ethanol and this process involves separating components of the corn kernel prior to fermentation as shown in Figure 2. The resulting by-products from wet-milling are corn gluten meal, corn gluten feed, corn germ meal, and condensed fermented extractive. Corn steep water is a liquid by-product that is another attractive ingredient to use in liquid feeding systems for swine.

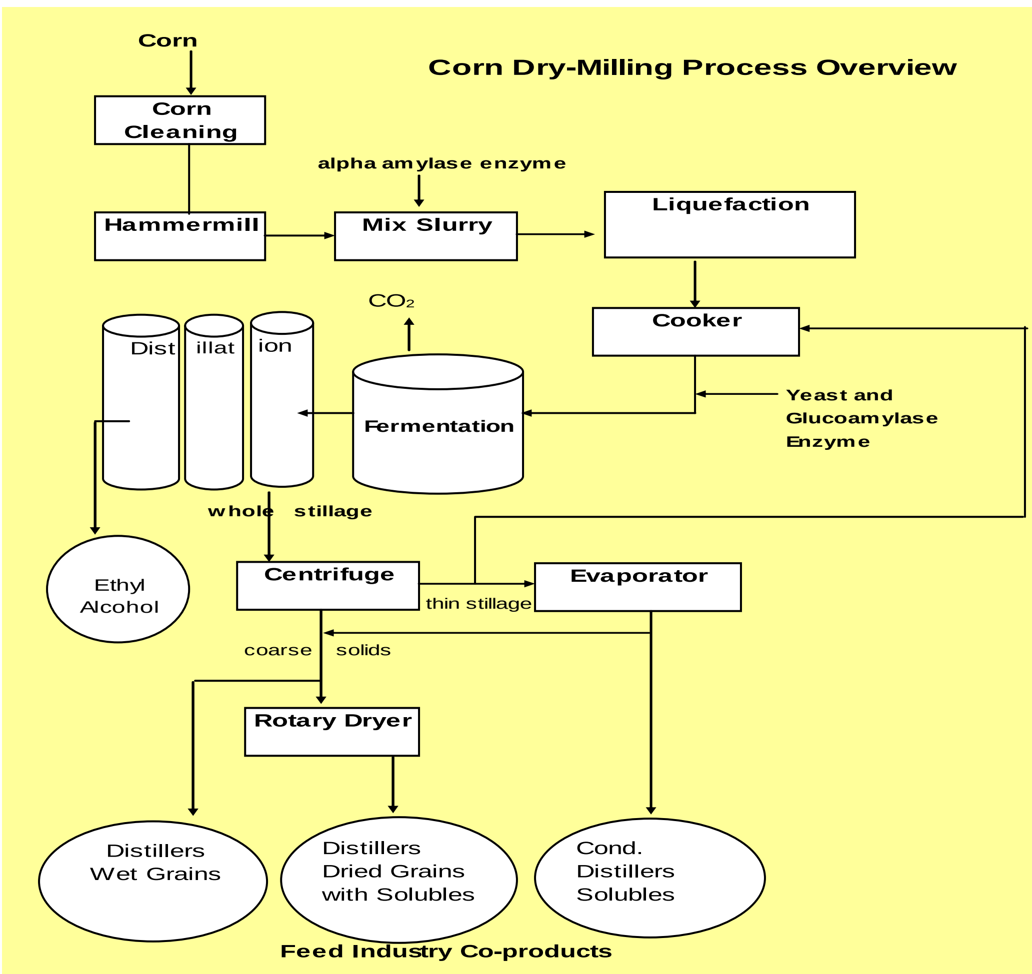

Figure 1. The dry-grind process of producing ethanol and distiller's by-products.

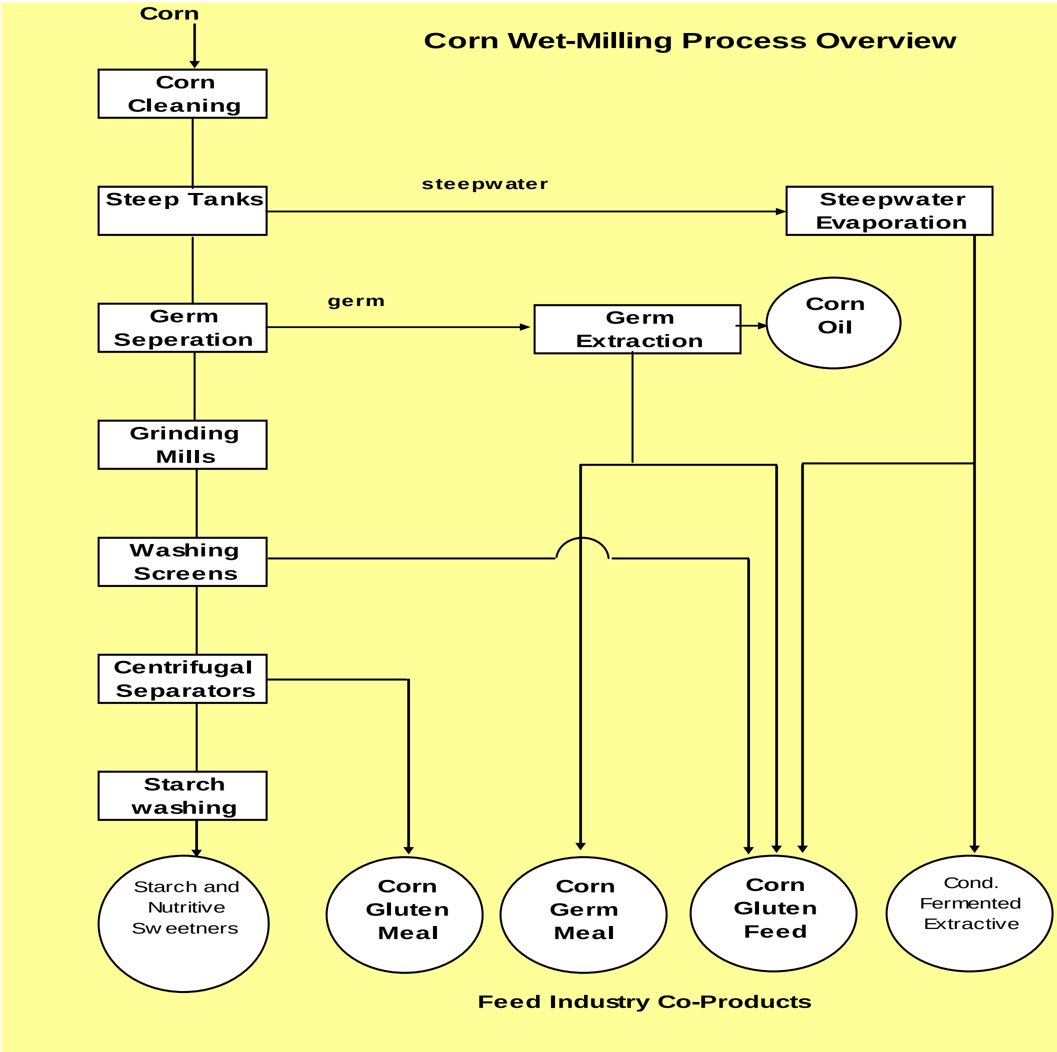

Figure 2. The wet-milling process of producing ethanol and corn by-products.

Ethanol plants prefer to market wet by-products due to rising fuel costs and challenges associated with drying the condensed solubles. On the other hand, U.S. pork producers are searching for ways to reduce feed costs due to record high feed ingredient prices. As a result, U.S. pork producers are beginning to use liquid feeding systems to utilize relatively low cost liquid by-products from the ethanol industry.

The two wet corn by-products from the ethanol industry that have been evaluated for use in swine liquid feeding systems are condensed distillers solubles (CDS) and steep water (de Lange et al., 2006). Braun and de Lange (2004) analyzed the nutrient composition of CDS from samples collected from commercial pig farms using liquid feeding systems in 2003 and these results are shown in Table 1. Storing CDS for at least one day on the farm and allowing uncontrolled fermentation resulted in an increase in acetic, propionic, and lactic acid which likely contributed to a slightly lower pH. As shown in Table 2, corn steep water is substantially higher in crude protein, ash, phosphorus, and lactic acid than CDS. However, approximately 80% of the phosphorus in corn steep water is bound as phytate and is unusable by the pig unless phytase enzyme is added in improve digestibility. Furthermore, corn steep water is substantially lower in energy than CDS due to the low fat content.

Table 1. Nutritional composition (overall mean, std. deviation, and range) of fresh and stored corn condensed distiller's solubles (CDS) samples collected on commercial pig farms in Ontario Canada (100 % dry matter basis).

Nutrient	Fresh CDS		Stored CDS	
No. samples	5		5	
Dry matter, %	30.5 ± 0.58	(29.7-31.1)	27.2 ± 3.58	(22.5-31.2)
Crude protein, %	22.3 ± 1.28	(20.8-24.1)	25.2 ± 1.63	(23.5-27.8)
Crude fat, %	18.9 ± 1.36	(17.4-20.9)	22.4 ± 1.23	(20.7-23.7)
Ash, %	8.4 ± 0.59	(7.8-9.1)	10.0 ± 1.09	(9.0-11.8)
Ca, %	0.04 ± 0.01	(0.02-0.06)	0.06 ± 0.01	(0.04-0.07)
P, %	1.43 ± 0.12	(1.25-1.58)	1.64 ± 0.15	(1.47-1.85)
Na, %	0.21 ± 0.04	(0.15-0.27)	0.21 ± 0.03	(0.18-0.25)
pH	3.7 ± 0.2	(3.5-3.9)	3.5 ± 0.1	(3.4-3.6)
Acetic acid, %	0.11 ± 0.02	(0.08-0.13)	1.66 ± 1.67	(0.32-4.53)
Propionic acid, %	0.63 ± 0.10	(0.50-0.76)	0.88 ± 0.27	(0.69-1.33)
Butyric acid, %	0.01 ± 0	(0.01-0.01)	0.01± 0.01	(0.01-0.01)
Lactic acid, %[1]	9.8		15.4	
Total non-starch polysaccharides, %	6.1 ± 0.2	(5.9-6.3)	5.5 ± 1.2	(3.5-6.7)
Starch, %	9.9 ± 2.0	(7.7-12.2)	6.8 ± 1.1	(5.1-7.9)
Total sugars, %	3.5 ± 0.3	(3.2-4.0)	1.2 ± 1.2	(0-2.7)

[1]Lactic acid was determined from pooled samples.
Source: Braun and de Lange (2004)

Table 2. Nutritional composition of corn steep water (100 % dry matter basis).

Nutrient	Corn Steep Water
No. samples	3
Dry matter, %	45
Crude protein, %	50
Crude fat, %	0.5
Ash, %	18.0
K, %	5.0
P, %	3.3 (~ 80% bound in phytate)
Mg, %	1.5
pH	4.3
Lysine, %	2.0
Lactic acid, %[1]	20.0

[1]Lactic acid was determined from pooled samples.
Source: Niven et al. (2006)

One of the challenges of adding condensed distiller's solubles to liquid feeds is overcoming the apparent negative effects on palatability (de Lange et al., 2006). However, when the initial pH was standardized to 6 and *Lactobacillus acidophilus* and *Bacillus subtilus* were used as inoculants, pH declined, and lactic acid and other volatile fatty acids were produced resulting in a more palatable feed (de Lange et al., 2006). Squire et al. (2005) fed diets containing 0, 7.5, 15.0, and 22.5% CDS to growing pigs and showed that feed palatability was reduced when more than 15% CDS was included in the diet. Feeding the non-fermented CDS diet resulted in reduced growth rate, feed intake, and feed conversion compared to pigs fed the corn-soybean meal control diet, while growth performance of pigs fed the fermented CDS diet was not different from pigs fed the control diet (Table 3). Energy and protein digestibility were reduced when feeding the fermented CDS diet compared to pigs fed the non-fermented CDS and the control diet. However, fat digestibility of the non-fermented and fermented CDS diets was greater than when pigs were fed the control diet. In this study, only pigs on the control and non-fermented CDS diets were fed to slaughter weight. Feeding the non-fermented CDS diet resulted in similar carcass dressing percentage, backfat depth, loin depth, carcass lean yield compared to pigs fed the control diet indicating that acceptable carcass quality can be achieved when feeding liquid non-fermented CDS diets to growing-finishing pigs. It is important to note that loin pH was higher from pigs fed the CDS diet compared to pigs fed the control diet which likely resulted in a trend toward reduced loin drip loss. Reduced drip loss is a significant benefit to meat processors.

Table 3. Growth performance, nutrient digestibility, and carcass quality of pigs fed liquid diets containing corn and soybean meal with either non-fermented or fermented corn condensed distillers solubles at 15% of dry matter.

	Control	**Non-fermented CDS**	**Fermented CDS**
No. of pens	6	6	6
Initial body weight, kg	23.5	23.3	23.4
Final body weight, kg	50.1[a]	47.5[b]	48.6[ab]
Avg. daily gain, g/d	952[a]	858[b]	898[ab]
Avg. daily feed intake, kg/d[1]	1.62[a]	1.49[b]	1.61[a]
Feed:gain[1]	1.70	1.73	1.80
Energy digestibility, %	81.6[ab]	82.5[a]	79.9[b]
Protein digestibility, %	72.5[a]	73.2[a]	69.3[b]
Fat digestibility, %	80.9[b]	85.4[a]	85.4[a]
Final body weight, kg	106.5	107.0	
Carcass dressing, %	82.1	82.6	
Backfat depth, mm	16.6	17.1	
Loin depth, mm	54.3	53.7	
Carcass lean yield, kg	61.1	60.9	
Loin pH	5.74[b]	5.80[a]	
Loin drip loss, %	9.63	8.83	

[1]Dry matter basis

[a,b] Means within rows with different superscripts differ ($P < 0.05$).

Source: de Lange et al. (2006)

Niven et al. (2006) reported results from a preliminary study that showed that growth rate and feed conversion were numerically improved when pigs were fed liquid diets containing 5% corn steep water (SW) but adding 10% SW numerically reduced pig performance. In a larger subsequent study, de Lange et al. (2006) showed that average daily gain, average daily feed intake, and feed:gain were not significantly affected when pigs were fed liquid diets containing 0, 7.5, or 15% phytase treated SW, but adding 22.5% SW resulted in reduced performance (Table 4). No significant effects were observed for dietary inclusion level of SW for carcass weight, loin depth, backfat depth, and lean yield.

Table 4. Growth performance and carcass characteristics of pigs feds liquid diets containing increasing levels of phytase treated corn steep water (SW).

	0% SW	**7.5% SW**	**15% SW**	**22.5% SW**
No. of pens	4	4	4	4
Initial body wt., kg	69.1	68.8	68.8	69.3
Final body wt., kg	108.3	104.6	107.7	103.1
Avg. daily gain, g/d	1191^{a}	1080^{a}	1063^{a}	899^{b}
Avg. daily feed intake, kg/d	2.76^{a}	2.49^{ab}	2.58^{ab}	2.29^{b}
Feed:gain	2.33^{a}	2.30^{a}	2.42^{ab}	2.55^{b}
Carcass wt., kg	86.3	82.7	83.4	80.5
Loin depth, mm	58.2	58.9	56.4	58.3
Backfat depth, mm	18.1	18.7	18.0	17.1
Lean yield, %	60.3	60.3	60.5	60.1

^{a,b} Means within rows with different superscripts differ ($P < 0.05$).
Source: de Lange et al. (2006)

In summary, feeding diets containing 15% fermented corn condensed distillers solubles results in comparable growth performance to when typical liquid corn-soybean meal diets are fed, but feeding diets containing 15% non-fermented corn distillers solubles results in reduced performance due to reduced palatability. However, feeding liquid diets containing 15% non-fermented condensed distillers solubles results in similar carcass composition compared to pigs fed liquid corn-soybean meal diets. Similarly, feeding liquid corn-soybean meal diets containing up to 15% corn steep water treated with phytase results in acceptable growth performance and carcass compostion comparable to feeding a typical liquid corn-soybean meal diets. Corn condensed distillers solubles and steep water can successfully be used in liquid feeding systems for growing-finishing pigs to achieve satisfactory growth performance and carcass quality at a substantial feed cost savings.

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