ALPHAGENE FEEDING AND NUTRITION GUIDE

PIGLETS AND COMMERCIAL PIGS

2021 EDITION

ALPHAGENE
OLYMEL
Collaborative production

Table of content

Introduction

The ALPHAGENE commercial pig is the result of a prolific sow selected for its growth performance and a Duroc male that stands out for its growth speed, feed efficiency and meat quality. The animals resulting from this cross are efficient, have optimal protein deposits, and remain robust through rearing, limiting losses which results in profitability throughout the nursery and growing periods. This cross meets the needs of the entire pork industry, including, producers, processors, and consumers.

The following guide provides the feeding recommendations to take full advantage of the genetic potential of ALPHAGENE commercial pigs.

1. Feeding the piglets

1.1 Feeding objectives in the nursery

The newly weaned piglet undergoes multiple stressors. These stressors include the separation from its mother and litter mates, the arrival in a new environment, and the transition from a liquid milk diet at ideal temperature to dry feed and cold water. The transition from a liquid to solid diet must be done as soon as possible to preserve the intestinal health of the piglet. The objectives of the nursery feeding program are, first, to ensure a high feed intake immediately post weaning, followed by a rapid transition to a simple grain and soybean meal diet. A high feed intake post weaning helps to maintains intestinal health, ensures rapid growth, and reduces the risk of diarrhea and mortality. Low feed intake during the first week post-weaning compromises the integrity of the intestinal wall, resulting in reduced nutrient absorption and increased risk of gastrointestinal distress. Once feed intake is well established, a rapid transition to low-complexity feeds can be applied without loss of efficiency, reducing feeding costs without affecting performance.

1.2 Factors that may influence feed intake at weaning

1.2.1 Weaning age

Increasing the age at weaning greatly facilitates the start of the piglet. The older animal has a more mature intestinal tract, which facilitates the digestion of dry feed. Older weaned piglets have better technical performance in the nursery and a lower mortality (Faccin et al., 2020).

1.2.2 Feed and water access

Feed intake is dependent on water consumption. Piglets must have easy access to clean, quality water. The water flow rate in the nursery should be between 0.5 to 0.7 L/min and the water pressure in the line should be 20 psi (Table 4). Waterers should be adjusted regularly for the size of the piglets (at shoulder height). Water quality for piglets is also important and must be free of coliforms. Lowering the pH of the water to a level of 5 to 6 is recommended for at least the first three weeks.

Offering small amounts of feed in the first few days of entry to the nursery will ensure the feed remains fresh and palatable. For this reason, it is also important to avoid excess feed at the bottom of the trough during start-up.

1.2.3 Hygiene and health

The health status of an animal greatly influences feed intake at weaning. Piglets from herds with a low health status have a lower feed intake which makes them more susceptible to intestinal disorders. The quality of washing, drying and disinfection reduces the microbial load, controlling the presence of diarrhea causing pathogenic bacteria such as E. coli and salmonella.

1.2.4 Feed complexity

The use of ingredients with highly digestible proteins and sugars or, the addition of ingredients with prior processing meant to increase digestibility can have a positive impact on feed intake at weaning. The processing of some ingredients not only increases digestibility but also allows these ingredients to exert more control over the bacterial flora within the gut improving digestive efficiency. This type of feed is particularly important for piglets less than 19 days of age or for piglets weighing less than 6.0 kg at weaning.

1.2.5 Room temperature

Controlling room temperature is essential to promoting feed intake in piglets. If room temperature is too low piglets will pileup in an effort to keep warm, rather than exploring the new environment which initiates water and dry feed intake. Rooms should be brought to the proper temperature prior to the arrival of piglets.

1.3 Feeding program adjusted for age and weaning weight

The feeding program should take into consideration the physiological maturity of the piglet (Table 1). Weaning age is the most reliable parameter to predict the digestive maturity of a piglet. The younger a piglet is weaned, the more of an impact weaning stress has on gut morphology and the longer it takes for the gut to return to its desired state (Al Masri et al., 2014; Moeser et al., 2017). Increasing weaning age reduces mortality and increases weight gain by the first week post weaning ultimately resulting in a heavier pig at nursery exit. (Main et al., 2014; Faccin et al., 2020). Older piglets are also more robust and can perform well on a simpler, more economical feeding program.

Regardless of weaning age, higher weaning weights also positively influences nursery growth performance (Main et al., 2014; Collins et al., 2017 and Huting et al., 2019)

Table 1: Feeding program based on weaning age

	Weaning age		
	< 18 days	19 – 21 days	>24 days
Weaning weights (kg)	5.5	6.3	7.5
Feed (kg/pig)			
Phase 1	1.50	1.0	-
Phase 2	5.0	5.0	5.0
Phase 3	25.5	25.3	24.7
Total feed (kg/pig)	32	31.1	29.7
Final weight (kg)	28.0	28.0	28.0
Conversion	1.42	1.44	1.45

1.4 Waterer and trough adjustments

The height of the water source should be adjusted weekly to facilitate water intake. At the beginning of the nursery period access to feed should be easy, while still avoiding accumulation of feed in the bottom of the trough. During the first week, the trough should allow for easy feed flow while, eliminating the risk of blockages due to feed moistened by piglet saliva. When transitioning past the initial diet, around the second or third week in the nursery, the troughs should be tightened to achieve approximately 50% coverage at the bottom of the trough.

Tableau 2: General nutritional specifications for piglets in nursery.

	Weaning	Transition	Pre-start
	Weight categories, kg		
Nutrients	5 – 7	7 – 12	12 - 25
Crude protein min., %	18.0	18.0	18.0
Digestible amino acids			
SID Lysine, %	1.35 – 1.45	1.25 – 1.35	1.25
Digestible Amino Acids ratio to lysine, %			
Methionine	30	28	28
Methionine + Cystine	58	58	58
Threonine	62	63	65
Tryptophan	21	19	19
Isoleucine	54	52	52
Valine	70	68	65
Leucine	100	100	100
Minerals, %			
Calcium[1]	0.75	0.82	0.77
Digestible Phosphorus[1]	0.50	0.45	0.35
Sodium	0.35	0.25	0.25

[1]Calcium and digestible phosphorus values include what is released by phytase. Refer to the matrix values of the phytase manufacturer.

Table 3: Vitamins and trace minerals specifications for piglets

		Weight categories (kg)		
Nutrients	Unit	5 – 7 kg	7 – 12 kg	12 – 30 kg
Vitamins				
Vitamin A	UI/kg	12 000	11 000	8 000
Vitamin D	UI/kg	1 500	1 500	1 500
Vitamin E	UI/kg	125	60	60
Vitamin K	mg/kg	3.0	3.0	2.0
Vitamin B12	mcg/kg	30	25	25
Thiamine	mg/kg	2.0	2.0	2.0
Riboflavine	mg/kg	6.0	6.0	5.0
Pantothenic acid	mg/kg	25.0	25.0	20.0
Niacin	mg/kg	40.0	40.0	30.0
Pyridoxine	mg/kg	7.0	7.0	3.0
Choline	mg/kg	500	500	500
Biotin	mcg/kg	200	200	150
Trace elements				
Zinc	mg/kg	125	125	125
Iron	mg/kg	110	100	100
Manganese	mg/kg	30	30	30
Copper	mg/kg	15	15	15
Selenium	mg/kg	0.3	0.3	0.3

2. Feeding growing pigs

2.1 Feeding objectives in the growing phase

Feeding growing pigs aims to maximize income over feed cost. The objective is to determine the balance between optimizing lean deposition, promoting optimal income on the slaughterhouses grading grid, and feed cost. The feed that achieves the lowest feed conversion does not necessarily offer the lowest feed cost or cost per kilogram of gain. To achieve optimal revenue on feed cost, it is essential to focus on herd health, facility hygiene and optimal growing conditions (temperature, humidity, air quality, stocking density and access to feed and water). Raising healthy pigs in a well-controlled environment allows animals to maximize nutrient digestibility and reach full genetic potential.

2.2 Feed energy levels

With adequate access to feed, growing pigs can adjust feed intake dependent on the energy density of the feed to maintain the level of growth defined by genetic potential. The ability to adjust based on the energy density must be utilized when the objective is to maximize revenue over feed cost.

Choosing the energy density of the feed should take into account the economics of the ingredient market. When an ingredient that is lower in energy than the base grain is available on the market at low cost, it may be advantageous to reduce the energy of the feed to allow for its use and thus lower the feed cost per pig produced. Similarly, to improve the feed cost per pig, an increase in energy density may be required in order take advantage of an energy-rich ingredient, even though the feed cost in dollars per ton is higher for this feed. **The level of energy used in formulation should not be a fixed parameter but, instead be subject to periodic evaluation based on changing ingredient market conditions.**

On the other hand, an increase in energy density, particularly through the addition of fat, can increase average daily gain and slaughter weight for time-limited operations. This; however, does not occur in all cases where energy density is increased. Farms where weight gain may be limited by inadequate growing conditions or limited access to feed are more likely to have increased weight gain in response to increased feed energy density.

2.3 Multiphasic feeding

The use of phase feeding is recommended during the growing period. The nutritional needs of an animal evolve with maturity, and the nutrient density will be determined according to feed intake which also evolves during the growing period. Multiphasic feeding reduces feed costs, decreases nitrogen and phosphorus release into the environment, and improves performance. For ALPHAGENE pigs during the 25 to 135 kg live weight period, a 5-phase program generally provides the best advantage. Nutritional specifications for 4 and 5 phase programs are provided in Tables 5 and 6.

2.4 Feeding segregated genders

Protein requirements of male and female pigs are different, especially above 50 kg body weight. These differences are due to the respective patterns of muscle and fat deposition. Intact males, with higher muscle deposition and lower fat accumulation, have the highest protein requirements, while castrated males have the lowest protein requirements, due to a higher fat deposit. Females are found to have intermediate protein requirements to intact and castrated males.

The interest in separate sex feeding programs comes from the differences in protein requirements. In commercial farms with castrated males and females, these differences result in higher feed intake and weight gain in the finishing period. The application of programs adapted to each sex allows for better feeding of females regarding feed efficiency and reduces the feeding cost for castrated males. The specific requirements of castrated males and females are presented in Tables 8 and 9.

Feeding in separate sexes may also be necessary if immuno-castration is used in males, thus achieving the maximum feed cost savings. However, if immuno-castration is applied in both males and females, sex separation is no longer necessary.

2.5 Shape and particle size of feed

ALPHAGENE pigs can be fed ground or pelleted feed. Pelleted feed is preferred for the first two to three weeks post weaning, considering that feed conversion can be up to 20% higher with ground feed. From 12 kg to slaughter, the difference in feed conversion is more consistent, in the range of 5.5-6%, in favor of pelleted feed, and weight gain is expected to be about 3% higher with pelleted feed (Nemecheck et al., 2015; Overholt et al., 2015).

When feed is used in the pelleted form, the grind size should be between 450 and 550 microns to minimize feed conversion and promote pellet durability. For feed in milled form, the grind size should be as fine as the feeding system allows, to achieve an optimal feed conversion. In practice, it is difficult to use a particle size below 700 microns for ground feeds.

2.6 Troughs and adjustments

Each type of trough has its advantages. The use of a dry trough results in a feed conversion that is 3.5% better than that of a wet trough, while a wet trough favors approximately 3% higher weight gain.

Dry troughs are more sensitive to the quality of pelleted feed than wet troughs. To see a feed conversion advantage with a dry trough, the percentage of fine particles in pelleted feed must be kept below 15% and the troughs must be well adjusted.

In general, a wet trough requires a more open adjustment at the beginning of rearing with a trough bottom coverage of 65-85% (Bergstrom, 2011) as to not limit intake or weight gain. In the finishing phase, the wet trough should be tightened, with a trough bottom coverage in the range of 50 to 65% as a target. The performance of animals fed with dry troughs are optimized with a trough bottom coverage of about 50%. It is important that throughout the growth phase, regardless of feed form, part of the bottom of the trough is visible. Ensuring a portion of the trough remains visible is essential, as a completely covered bottom will result in feed waste, while a completely visible bottom will result in restricted feed intake.

2.7 Nutrient access

Genetic selection has resulted in fast-growing animals that are also increasingly efficient. However, to reach their full potential, these animals must have easy, unrestricted access to nutrients, feed, and water. Proper trough and waterer adjustments complying with recommendations based on growing phase and equipment are presented in table 4. Feed shortages should be avoided and stocking density, i.e., floor space per pig should be respected in accordance to pen design and animal weight. Stocking density should therefore be, adapted according to the expected slaughter weight and exit strategies (Gonyou et al. 2006). Water must be available in quality and quantity, using physicochemical and bacteriological analyses to confirm whether treatment is required (Tables 10 and 11).

Nutrients are established according to the animal's weight and physiological needs. To facilitate management on the farm, the quantity to be distributed per phase is calculated according to the entry weight and the standard conversion of the farm. The feeding program must be adjusted according to the average entry weight of the animals, ensuring that the phase change is done at the optimal time. Visual validation of live weight at phase change is safe and recommended. This will ensure that the nutrients provided are consistent with the animals' needs. Environmental conditions also influence access to nutrients and are impacted by the weight of the pigs. Temperature, ventilation, and light levels affect feed and water consumption. Similarly, the heavier the pig, the more it can tolerate a cooler temperature (Renaudeau et al., 2011).

2.8 Influence of nutrition on meat quality

Meat quality is influenced by several factors, the most important of which are genetic selection, animal handling during the pre-slaughter period and carcass cooling techniques. Meat quality, as in texture, fat quality, marbling, color, and shelf life can also be improved by composition of feed consumed by the animals in the weeks prior to slaughter. Tight control of unsaturated fat composition in feed improves fat firmness and meat texture. For example, ingredients high in unsaturated fat such as corn distillers' grains, vegetable oils and animal-vegetable fat will have a negative impact on meat quality, while ingredients low in unsaturated fat such as wheat, barley and legumes can have a positive effect on final product quality. By working closely with the nutrition team, we can better understand the effects of diet on meat quality and how ingredients influence it.

Table 4. Space allowance for troughs and waterers.

	Nursery	Growing
Trough		
Dry trough, pigs/space	4 - 5	5 - 8
Wet trough, pigs/space		10 - 12
Width, cm/space	20 - 21	36
Waterer		
Number of pigs/water nipple	10	10 - 12
Number of pigs / bowl	20	20
Water nipple flow rate, L/min	0.5 - 1	1
Bowl flow rate, L/min	1	3
Pressure, psi	20	20 - 40

Table 5: Nutritional specification for growing pigs - 4 phases.

	Start	Growth	Finish #1	Finish #2
	Weight categories, kg			
Nutrients	25 - 40	40 - 65	65 -95	95 - 135
Crude protein min., %	17.0	15.0	13.0	12.0
Lysine Ratio SID/ME NRC[1], g/Mcal	3.30	2.96	2.49	2.22
Lysine Ratio SID/NE NRC[1], g/Mcal	4.45	3.94	3.26	2.89
Digestible Amino Acids ratio to lysine, %				
Methionine	28	28	28	28
Methionine + Cystine	58	58	58	58
Threonine	62	63	64	65
Tryptophane	19	19	19	19
Isoleucine	55	55	55	55
Valine	65	66	66	66
Leucine	100	100	100	100
Minerals, %				
Calcium[2]	0.71	0.68	0.60	0.56
Digestible Phosphorus	0.31	0.29	0.25	0.23
Sodium	0.20	0.20	0.20	0.20

[1]Energy levels may vary depending on market price of ingredients to optimize feeding costs.: NE 2425 to 2550 kcal/kg and ME 3200 to 3350 kcal/kg.

[2]Calcium and digestible phosphorus values include what is released by phytase. Refer to the matrix values of the phytase manufacturer.

Table 6: General nutritional specification for growing pigs - 5 phases.

	Start	Growth#1	Growth#2	Finish#1	Finish #2
	Weight categories, kg				
Nutrients	25 - 40	40 - 65	65-85	85 - 110	110 - 135
Crude protein min., %	17.0	15.0	14.5	13.5	12.0
Lysine Ratio SID/ME NRC[1], g/Mcal	3.30	2.96	2.56	2.30	2.20
Lysine Ratio SID/NE NRC[1], g/Mcal	4.45	3.94	3.36	3.00	2.85
Digestible Amino Acids ratio to lysine,					
Methionine	28	28	28	28	28
Methionine + Cystine	58	58	58	58	58
Threonine	62	63	64	64	65
Tryptophane	19	19	19	19	19
Isoleucine	55	55	55	55	55
Valine	65	66	66	66	66
Leucine	100	100	100	100	100
Minerals, %					
Calcium[2]	0.71	0.68	0.62	0.56	0.52
Digestible phosphorus[2]	0.31	0.29	0.26	0.23	0.21
Sodium	0.20	0.20	0.2	0.20	0.20

[1]Energy levels may vary depending on market price of ingredients to optimize feeding costs.: NE 2425 to 2550 kcal/kg and ME 3200 to 3350 kcal/kg.

[2]Calcium and digestible phosphorus values include what is released by phytase. Refer to the matrix values of the phytase manufacturer.

Table 7: Vitamins and trace minerals specifications for growing pigs.

		Weight categories, kg	
Nutrients	Unit	25 – 85 kg	85 kg - slaughter
Vitamins			
Vitamin A	UI/kg	4 000	3 200
Vitamin D	UI/kg	900	70
Vitamin E	UI/kg	40	32
Vitamin K	mg/kg	1.5	1.2
Vitamin B12	mcg/kg	20	16
Thiamine	mg/kg	1.0	0.8
Riboflavine	mg/kg	3.5	2.8
Pantothenic acid	mg/kg	15.0	12.0
Niacin	mg/kg	25.0	20.0
Pyridoxine	mg/kg	0.5	0.4
Choline	mg/kg	150	0
Biotin	mcg/kg	100	80
Oligo-elements			
Zinc	mg/kg	125	100
Iron	mg/kg	80	64
Manganese	mg/kg	30	24
Copper	mg/kg	15	12
Selenium	mg/kg	0.3	0.24

Table 8: General nutritional specifications for growing barrows -5 phases.

	Start	Growth#1	Growth#2	Finish #1	Finish #2
	Weight categories, kg				
Nutrients	25 - 40	40 - 65	65-85	85 - 110	110 - 135
Crude protein min., %	17.0	15.0	14.5	13.5	12.0
Lysine Ratio SID/ME NRC[1], g/Mcal	3.30	2.89	2.48	2.22	2.12
Lysine Ratio SID/NE NRC[1], g/Mcal	4.45	3.85	3.25	2.88	2.75
Digestible Amino Acids ratio to lysine, %					
Methionine	28	28	28	28	28
Methionine + Cystine	58	58	58	58	58
Threonine	62	63	64	64	65
Tryptophane	19	19	19	19	19
Isoleucine	55	55	55	55	55
Valine	65	66	66	66	66
Leucine	100	100	100	100	100
Minerals %					
Calcium[2]	0.71	0.68	0.62	0.56	0.52
Digestible phosphorus[2]	0.31	0.29	0.26	0.23	0.21
Sodium	0.20	0.20	0.20	0.20	0.20

[1]Energy levels may vary depending on market price of ingredients to optimize feeding costs.: NE 2425 to 2550 kcal/kg and ME 3200 to 3350 kcal/kg.
[2]Calcium and digestible phosphorus values include what is released by phytase. Refer to the matrix values of the phytase manufacturer.

Table 9: General nutritional specifications for growing females -5 phases.

	Start	Growth#1	Growth#2	Finish#1	Finish#2
	Weight categories, kg				
Nutrients	25 - 40	40 - 65	65-85	85 - 105	105 - 135
Crude protein min., %	17.0	15.0	14.5	13.5	12.0
Lysine Ratio SID/ME NRC[1], g/Mcal	3.30	3.05	2.64	2.36	2.26
Lysine Ratio SID/NE NRC[1], g/Mcal	4.45	4.05	3.46	3.07	2.94
Digestible Amino Acids ratio to lysine,					
Methionine	28	28	28	28	28
Methionine + Cystine	58	58	58	58	58
Threonine	62	63	64	64	65
Tryptophane	19	19	19	19	19
Isoleucine	55	55	55	55	55
Valine	65	66	66	66	66
Leucine	100	100	100	100	100
Minerals, %					
Calcium[2]	0.71	0.68	0.62	0.56	0.52
Digestible phosphorus[2]	0.31	0.29	0.26	0.23	0.21
Sodium	0.20	0.20	0.20	0.20	0.20

. [1]Energy levels may vary depending on market price of ingredients to optimize feeding costs.: NE 2425 to 2550 kcal/kg and ME 3200 to 3350 kcal/kg.
[2]Calcium and digestible phosphorus values include what is released by phytase. Refer to the matrix values of the phytase manufacturer.

3. Importance of water

Water is the most important nutrient consumed by pigs, so its importance is vital. It plays a role in transport and absorption of nutrients at the cellular level, in the elimination of waste products and, in the maintenance of body temperature. Water consumption by an animal is affected by its weight, age, activity, and environmental conditions. A flow rate of at least 1 liter per minute is required for pigs in the grower finisher phase. A growing pig consumes about 10% of its live weight, while sows will consume between 10 and 25 liters per day.

3.1 Water quality parameters

Table 10: Standards for key physicochemical parameters for swine drinking water. Adapted from Menegat et al. 2019.

	IDEAL STANDARDS	MAXIMUM LIMIT	COMMENTS
pH	6.4	8.5	Acidic water (pH < 5) can cause corrosion and damage to water pipes. Basic water (pH > 9) can form limescale deposits and block waterers. In addition, the pH of the water influences the dispersion of drugs used via application in the water and influences the proliferation and survival of pathogens. Basic water (pH > 7) is considered a risk factor for E. coli diarrhea and water pH should be controlled if diarrhea is a problem.
TOTAL SOLIDS, PPM	< 1 000	3 000	Includes bicarbonates, chlorides, sulfates, sodium, calcium. and magnesium. Can cause diarrhea when too high.
HARDNESS, PPM	< 60	180	This is the level of calcium and magnesium in water. It does not affect the animals, but it can lead to limescale build-up in water distribution, treatment and cooling equipment, causing clogging of waterers and filters.
ALCALINITY, PPM		1 000	
SULFATES, PPM	< 100	1 000	Sulfates are of particular concern because of their laxative effect. As a result, pigs consuming water with high levels of sulfates usually have diarrhea. Growth and reproductive performance do not appear to be adversely affected unless extreme levels of sulfates are present in drinking water.
SODIUM, PPM	< 100	200*	Excessive magnesium and sodium levels, especially if present as sulfate salts, can cause diarrhea. However, this diarrhea is mainly of osmotic and will not lead to production problem unless levels are extremely high.
MAGNESIUM, PPM		150	

	IDEAL STANDARDS	MAXIMUM LIMIT	COMMENTS
CALCIUM, PPM	< 250	1 000	High levels of calcium in the water may interfere with absorption of phosphorus in the digestive tract. Calcium and phosphorus feed levels for pigs fed high calcium water may need to be adjusted. Calcium contributes to water hardness and can cause limescale build-up in filters and waterers. which reduces volume of water supplied and. eventually. performance of the pigs.
IRON, PPM	< 0.3	0.5	Iron and manganese contamination in water causes mechanical problems in the watering system. Both minerals are present in groundwater in reduced soluble form; pumping water to the surface exposes them to air. resulting in highly insoluble oxide forms. Precipitated minerals cause all kinds of problems with waterers and other equipment.
MANGANESE, PPM	< 0.05	5	
CHLORIDE, PPM		250	
NITRITES, PPM		< 10	In water. nitrates are converted to toxic compounds. nitrites. Nitrite impairs the oxygen carrying capacity of the blood by reducing hemoglobin to methemoglobin. As a result, nitrite toxicity causes low tissue oxygenation and results in signs of cyanosis and breathing difficulties.
NITRATES + NITRITES, PPM		< 100	
POTASSIUM, PPM		300	
COPPER, PPM		2	
ZINC, PPM		25	

Table 11: Bacteriological standards for pig drinking water.

BACTERIOLOGICAL	UFC / 100 ML
TOTAL COLIFORMS	< 10
FECAL COLIFORMS	0
FECAL STREPTOCOCCI	0
ATYPICAL COLONIES	< 200

References

Al Masri S, Hünigen H, Al Aiyan A, Rieger J, Zentek J, Richardson K, and Plendl J. 2015. Influence of age at weaning and feeding regimes on the postnatal morphology of the porcine small intestine: a review of morphometric studies. J Swine Health Prod. 23:186–203.

Bergstrom, J. R., Nelssen, J. L., Tokach, M. D., Dritz, S. S., Goodband, R. D. and DeRouchey, J. M., 2012. Effects of two feeder designs and adjustment strategies on the growth performance and carcass characteristics of growing–finishing pigs. J. Anim. Sci. 90: 4555–4566.

Collins, C. L., J. R. Pluske, R. S. Morrison, T. N. McDonald, R. J. Smits, D. J. Henman, I. Stensland, and F. R. Dunshea. 2017. Post-weaning and whole-of-life performance of pigs is determined by live weight at weaning and the complexity of the diet fed after weaning. Anim. Nutr. 3:372–379.

Faccin, J. E. G., F. Laskoski, L. F. Hernig, R. Kummer, G. F. R. Lima, U. A. D. Orlando, M. A. D. Gonçalves, A. P. G. Mellagi, R. R. Ulguim, and F. P. Bortolozzo. 2020. Impact of increasing weaning age on pig performance and belly nosing prevalence in a commercial multisite production system. J. Anim. Sci. 98.

Gonyou, H.W., Brumm, M.C., Bush, E., Deen, J., Edwards, S.A., Fangman, T., McGlone, J.J., Meunier-Salaün, M., Morrison, R.B., Spoolder, H., Sundberg, P.L., Johnson, A.K., 2006. Application of broken-line analysis to assess floor space requirements of nursery and grower-finisher pigs expressed on an allometric basis. Journal of Animal Science 84, 229-235.

Huting, A.M., Wellock, I, Tuer, S., and Kyriazakis, I. 2019. Weaning age and post-weaning nursery feeding regime are important in improving the performance of lightweight pigs. J. Anim. Sci.97:4834–4844.

Menegat, M.B., Goodband, R.D., DeRouchey, J.M., M.D. Tokach, J.C. Woodworth et Dritz, S. 2019. Kansas State University Swine Nutrition Guide: Water in Swine Nutrition.

Main, R. G., S. S. Dritz, M. D. Tokach, R. D. Goodband, and J. L. Nelssen. 2004. Increasing weaning age improves pig performance in a multisite production system. J. Anim. Sci. 82:1499–1507.

Moeser, A. J., C. S. Pohl, and M. Rajput. 2017. Weaning stress and gastrointestinal barrier development: Implications for lifelong gut health in pigs. Anim. Nutri. 3:313–321.

Nemechek, J.E., Tokach, M.D., Dritz, S.S., Fruge, E.D., Hansen, E.L., Goodband, R.D., DeRouchey, J.M. and Woodworth, J.C., 2015. Effects of diet form and feeder adjustment on growth performance of nursery and finishing pigs. J. Anim. Sci. 93:4172-4180.

Overholt, 2015. Effects of pelleting growing-finishing diets with distillers dried grains with solubles (ddgs) on growth performance, carcass characteristics, and commercial bacon slicing yields of barrows and gilts. Thesis, University of Illinois.

Renaudeau, D., J.L. Gourdine, N.R. St-Pierre. A meta-analysis of the effects of high ambient temperature on growth performance of growing-finishing pigs. 2011 Journal of animal science. 89. 2220-2230.