FEEDING PROGRAMS AND USE OF ADDITIVES IN PIGLETS

J.R. Pluske

School of Veterinary and Life Sciences, Murdoch University, Murdoch WA 6150, Australia
Email: J.Pluske@murdoch.edu.au

1.- INTRODUCTION

Nursery pigs consume only 10-15% (depending on definition/allocation of feeding stages) of total feed consumption yet they engage a significant and increasing level of interest amongst nutritionists, producers, consultants and feed additive companies. This is partly attributable to the obvious importance of transitioning pigs from the pre-weaning to the post-weaning environment, but also reflects changes that have occurred in the industry worldwide over the last two decades with regard to bans/restrictions on the use of certain types of antimicrobial agents in diets, and the concomitant growth in the use and interest in feed additives. Weaning under commercial conditions at 3 to 4 weeks of age is a challenging process, with pigs typically taking time to adapt to the sudden dietary, environmental and social insults imposed. Myriad changes occur in the gastrointestinal tract (GIT) at this time that compromise its structure and function, in turn potentially predisposing pigs to a range of enteric diseases and conditions. These processes collectively cause a ‘growth check’ and contribute to poorer production efficiency and increased mortality and (or) morbidity. A number of nutritional and (or) management interventions are typically used to amend this, with antimicrobials (including antibiotic growth promoters; AGP) generally being regarded as beneficial tools in diets and (or) water during this period. Weaning pigs in the absence, or reduction in use of, AGP has focused attention on other aspects of nutrition and (or) management to lessen the impact of the weaning transition. This paper briefly discusses feeding programs for nursery pigs and then discusses a number of nutritional tools available for the post-weaning transition, with emphasises on reduced antimicrobial use and possible dietary options.
2.- FEEDING PROGRAMS

Excellent overviews of feeding programs for nursery pigs have been described previously (e.g., Dritz et al.; https://www.asi.k-state.edu/doc/swine-info/getting-nursery-pigs-off-to-a-good-start.pdf; Pluske et al., 2005, 2006; Tokach et al., 1992, 2003), and whilst there are time-related changes to specific aspects of feeding, the overarching principles remain similar. Tokach et al. (2003) commented that the three major concepts required when formulating diets for the nursery pig are: (1) to adjust pigs to the simplest and relatively lowest cost diets as quickly as possible after weaning, (2) to recognize that the newly-weaned pig is in an extremely energy- and protein-dependent stage of growth and that maximizing feed intake is essential, and (3) diets need to be formulated with the changing digestive physiology of the weaner pig in mind, meaning that (highly digestible) ingredients complementing the pattern of digestive enzymes secreted at weaning are necessary, at least initially.

Designing diets to feed nursery pigs is similar in many respects to the approach described by Tokach et al. (2017) for feeding growing-finishing pigs, that is: (a) the most economical energy level is determined; (b) then the standardized ileal digestible (SID) lysine:energy ratio for that energy level is set; (c) then the ratio for other amino acids is set relative to SID lysine; (d) macromineral concentrations are set; and (e) levels of vitamins, trace minerals, salt, and other ingredients including feed additives are established. Nevertheless, the final formulation of nursery diets, especially those fed in the immediate post-weaning period, depends to some extent on the choice/blend of products that are included and which feed additives (if any) are used, that in turn determines the cost of the diet(s). Indeed, some of these diets are not always “least cost”, with certain ingredients, or higher levels of certain ingredients, included as they are believed to impart whole-of-life production and (or) other benefits. As an example, higher levels of lactose in diets can have benefits in terms of production and efficiency (e.g., Mahan et al., 2004; Nessmith et al., 1997; Tokach et al., 2003) and may also have prebiotic effects that beneficially modulate aspects of gastrointestinal tract (GIT) function (Daly et al., 2014), yet higher levels can add considerable cost to a diet that, depending on ingredient costs, may or may not be economical to include.

Nevertheless, many factors need to be considered when formulating nursery pig diets including weaning age and weight, ingredient selection and quality, feed type and form, feeder and waterer management and design, feed additives including antimicrobials, whether pigs are housed indoors or outdoors, and feeding management. The following discussion will focus on several of these influences.

3.- WEANING AGE

The optimum age at which to wean pigs has fluctuated over time and is often the subject of considerable discussion. In the past, the pork industry has practiced medicated (Alexander et al., 1980) and segregated (Fangman and Tubbs, 1997) early weaning, and more recently, regulations in some countries stipulate a minimum weaning age, i.e., four
weeks ([https://ec.europa.eu/food/animals/welfare/practice/farm/pigs_en](https://ec.europa.eu/food/animals/welfare/practice/farm/pigs_en)). However, and where allowable, the industry generally weans around 19-25 days of age; PIC (2015) for example, stated that the ‘right’ age for weaning is anywhere from 18 to 25 days, depending on the objectives of the production system. Age (and by corollary, pig weight) at weaning can have marked influences on subsequent GIT development, performance, body composition and survival of the young pig (e.g., Al Masri et al., 2015; Dunshea et al., 2002, 2003; Pluske et al., 1997, 2003). In a series of pioneering studies, Main and colleagues examined the impacts of different weaning ages (12 to 21.5 days) on nursery and whole-of-life performance indices. Main et al. (2004) modelled the linear rate of change of performance parameters per day increase in weaning age in the range 12 to 21.5 days, and reported that each day of difference represented an increase of 260 g in weaning weight, 930 g in weight at 42 days after weaning, 10 g in wean-to-finish average daily gain (ADG), 1.80 kg greater weight sold per weaned pig, and a decrease of 0.47% in mortality from weaning-to-finish (Table 1).

Table 1.- Modelling the linear rate of change observed as wean age increased from 12 to 21.5 days of age (Main et al., 2004)

<table>
<thead>
<tr>
<th>Item</th>
<th>Rate of linear change per day increase in wean age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Change per day</td>
</tr>
<tr>
<td>Allotment weight, kg(^a)</td>
<td>0.257</td>
</tr>
<tr>
<td>d 42 postweaning, kg</td>
<td>0.93</td>
</tr>
<tr>
<td>Off-test weight, kg(^b)</td>
<td>1.35</td>
</tr>
<tr>
<td>Wean-to-finish ADG, g(^c)</td>
<td>9.9</td>
</tr>
<tr>
<td>Wean-to-finish mortality, %(^d)</td>
<td>-0.47</td>
</tr>
<tr>
<td>Weight sold per pig weaned, kg(^e)</td>
<td>1.80</td>
</tr>
</tbody>
</table>

\(^a\)Allotment weights were taken on all pigs 3 days before weaning.

\(^b\)Off-test weight = average finishing sale weight at a fixed number of days postweaning.

\(^c\)Wean-to-finish ADG = [finisher pen weight sold - (nursery allotment weight × weaned pigs required to place finishing pen)] / (weaned pigs required to place finishing pen × days postweaning).

\(^d\)Wean-to-finish mortality = [1 - (finishing pen inventory weighed off-test/weaned pigs required to place finishing pen)] × 100.

\(^e\)Weight sold per pig weaned = off-test pen weight/weaned pigs required to place finishing pen.

More recent studies examining the physiological influences of weaning age (reviewed by Moeser et al., 2017) show the deleterious effects of a younger weaning age (less than about 19 days of age) on GIT structure and function. Age drives the maturation process but exogenous factors, especially the change of diet at weaning, are obviously important modulators. In contrast to a recommendation of an earlier weaning age, a critical evaluation of the available data by Al Masri et al. (2015) showed that weaning piglets less than 28 days of age had major adverse effects on the structure of the intestinal epithelium, especially that of the villi and crypts. The authors recommended that weaning piglets at 28 days or later should allow a safe transition from milk to solid feed, from the perspective of better developed GIT structure and function.
Nevertheless, other influences should also be considered when determining weaning age because it may also influence a pig’s predisposition to post-weaning diarrhea. McLamb et al. (2013) weaned pigs at 16, 18 or 20 days of age and administered an oral challenge of F18 ETEC (enterotoxigenic *E. coli*) at 26 days of age. Pigs were monitored after infection for 4 days for clinical signs of disease, and on day 4 post-ETEC challenge, ileal barrier function, histopathologic and inflammatory cytokine analysis were performed on ileal mucosa. McLamb et al. (2013) reported that pigs weaned at 16 days and 18 days exhibited a more rapid onset and severity of diarrhea and reductions in weight gain in response to the ETEC challenge compared with their counterparts weaned at 20 days. The ETEC challenge caused intestinal barrier injury in the ileum of early-weaned pigs, indicated by reductions in ileal transepithelial electrical resistance and elevated FD4 flux rates, but not in late-weaned pigs. Interestingly, ETEC-induced marked elevations were seen in IL-6 and IL-8, neutrophil recruitment, and mast cell activation in late-weaned pigs; these responses were attenuated in early-weaned pigs.

Weaning age, as alluded to previously, does not necessarily reflect the relative maturity (or immaturity) of the young pig, hence weaning weight (as a proxy for overall development) must also be contemplated in such a discussion. Pig weight can vary enormously at a given biological age, and this may have ramifications for subsequent performance (e.g., Dunshea et al., 2003; Pluske et al., 2003). In an Australian study, Collins et al. (2017) examined the production and financial outcomes associated with weaner diet complexity for pigs of different weight classes at weaning. These authors used 360 entire males and 360 females at weaning (27 days) and allocated them to treatments on the basis of individual weaning weight [light (L): pigs below 6.5 kg; medium (M): 6.5 to 8 kg; heavy (H): above 8.5 kg], weaner diet complexity (high complexity/cost, HC; low complexity/cost, LC), and gender (male and female). Common diets were fed to both treatment groups during the final 4 weeks of the weaner period (a period of 39 days). In the first 6 days after weaning, pigs offered the HC diets gained weight faster and used feed more efficiently than those offered the LC diets, and also tended to be heavier at the sale live weight of 123 days of age compared with pigs fed the LC diet. There were no other main effects of the feeding program on growth performance through to slaughter. However, weaning weight had a profound influence on lifetime growth performance and weight at 123 days of age, with H pigs at weaning increasing their weight advantage over the M and L pigs (101.3, 97.1, 89.6 kg respectively). The cost-benefit analyses conducted under the conditions of this farm suggested there was no cost per kg live weight gain benefit over the pigs’ lifetime by offering the HC feeding program to M or H pigs (> 6.5 kg) when weaned at 27 days of age. The HC feeding program only benefited L pigs at weaning (less than 6.5 kg) and maximized their lifetime growth performance. However, pigs fed a HC diet post-weaning tended to be heavier at the sale live weight of 123 days of age compared with pigs fed the LC diet. In a similar manner, Mahan and Lepine (1991) reported that fewer days (approximately 15) were required for heavier-weight weanling pigs to reach a final weight of 105 kg than for lighter-weight pigs, with medium-weight pigs requiring an intermediate number of days to reach 105 kg.

These results concur with numerous other authors who found that the starter feeding program influenced growth performance immediately after weaning but may not
influence lifetime performance. Whang et al. (2000) saw a reduction in performance with their low-quality starter feeding regime, but subsequent ‘catch-up’ (compensatory) growth during the grower and finisher periods such that the feeding program did not influence protein gain for the entire growth period. Skinner et al. (2014) reported that pigs fed a ‘simple’ diet after weaning had reduced body weight and ADG in the nursery period compared with pigs fed a more ‘complex’ diet, but had no effect on overall wean-to-finish growth performance. Interestingly, the inclusion of in-feed antibiotics during the nursery phase induced some compensatory growth during the grower phase, however the complexity of the diet did not have any effect on performance during the grower-finisher phase.

Therefore, a weaning age recommendation is largely system-dependent and varies according to the target(s) set against which to measure overall herd performance and profitability. However, there is now general consensus that weaning pigs younger than 15-17 days of age and lighter than ~ 4.5-5 kg will typically mean that pigs require extra care, better environments, and better nutrition after weaning, and piglets in general weighing less than ~ 3.6 kg at weaning will have a significantly reduced chance realize full-value.

4. USE OF ANTIBIOTICS, AND NUTRITIONAL AND FEED ADDITIVE INTERVENTIONS

Antibiotics were discovered over 65 years ago and were, until relatively recently, used widely in three main ways: as antibiotic growth promoters (AGP), as prophylactic or metaphylactic treatment to prevent disease, and for therapeutic purposes to treat disease. Antibiotics continue to represent an extremely important tool in the efficient and welfare conscious production of pork, and when used at low (sub-therapeutic) levels in feeds, generally improve growth rate and efficiency of feed utilization, reduce mortality and morbidity, and (or) improve reproductive performance (e.g., Cromwell, 2002). However, enteric bacteria naturally develop resistance to antibiotics at sub-therapeutic levels, and there is evidence that global levels of resistance are increasing (Aarestrup et al., 2008). Increased resistance of bacteria may impair treatment efficacy and potentially lead to therapeutic failures in pig populations. Furthermore, concerns have also been raised in recent years regarding co-selection for antibiotic resistance among bacteria exposed to biocides used as disinfectants, antiseptics and preservatives, and to heavy metals (particularly copper and zinc) used as growth promoters and therapeutic agents (e.g., Wales and Davies, 2015). Consequently, bans/restrictions on the use of AGP are now prevalent in many parts of the world.

For nursery pigs dealing with post-weaning challenges, the impacts of bans/restrictions on the use of AGP have arguably been the most profound, and have highlighted enormous interest in the use of different feed additives as alternatives or replacements to AGP in diets, and interestingly whether there may be overt disease (e.g., post-weaning diarrhea), or not. Not surprisingly, there is a plethora of papers, review articles, podcasts, magazine articles, on-line publications and so on addressing the topic of feed additives for nursery pigs. A key challenge in this entire area, however, is the
incomplete understanding of how antibiotics work to achieve their effects (Niewold, 2007); therefore and on this basis, it is questionable whether any single feed additive or feeding strategy that could replace the roles and functions of antibiotics. Table 2 describes a recent summary of the dietary options available to the pork industry to replace antibiotics (predominately AGPs) in diets and (or) water systems. Of note, there is an extensive list of feed additives, which can be defined as non-nutritive feed ingredients that are not required by swine, and hence in the absence of feed additives in a diet, no deficiency symptoms will result. Feed additives, though, may enhance production and profitability under the right circumstances.

Table 2.- Dietary ingredients and nutrients, dietary/feeding strategies and feed additives examined for improvement of pig health and performance in the absence of antimicrobials

<table>
<thead>
<tr>
<th>Functional feed ingredients and nutrients</th>
<th>Diet formulation and feeding strategies</th>
<th>Feed additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray-dried plasma</td>
<td>Low-protein diets</td>
<td>Organic acids</td>
</tr>
<tr>
<td>Alternative fiber sources</td>
<td>Limited feeding</td>
<td>Inorganic acids</td>
</tr>
<tr>
<td>Conventional egg products</td>
<td>Fermented liquid feed</td>
<td>Mannan oligosaccharides</td>
</tr>
<tr>
<td>Immune egg products</td>
<td>Minimal diet buffering capacity</td>
<td>Fructo-oligosaccharides</td>
</tr>
<tr>
<td>Milk protein products</td>
<td>Minimal antinutritional factors</td>
<td>Supra-nutritional levels of锌</td>
</tr>
<tr>
<td>Lactose</td>
<td></td>
<td>Supra-nutritional levels of copper</td>
</tr>
<tr>
<td>Polyamines</td>
<td></td>
<td>Omega-3 fatty acids</td>
</tr>
<tr>
<td>Fermented soy products</td>
<td></td>
<td>Direct-fed microbials (probiotics)</td>
</tr>
<tr>
<td>Butyric acid</td>
<td></td>
<td>Prebiotics</td>
</tr>
<tr>
<td>Gluconic acid</td>
<td></td>
<td>Yeast and yeast products</td>
</tr>
<tr>
<td>Lactic acid</td>
<td></td>
<td>Bacteriocins</td>
</tr>
<tr>
<td>Glutamine</td>
<td></td>
<td>Bacteriophages</td>
</tr>
<tr>
<td>Threonine</td>
<td></td>
<td>Antimicrobial peptides</td>
</tr>
<tr>
<td>Cysteine</td>
<td></td>
<td>Conventional and recombinant enzymes</td>
</tr>
<tr>
<td>Nucleotides</td>
<td></td>
<td>Lysozyme</td>
</tr>
<tr>
<td>Medium-chain fatty acids</td>
<td></td>
<td>Egg yolk antibodies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Essential oils</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Botanical herbs and spices</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clay minerals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rare earth elements</td>
</tr>
</tbody>
</table>

1From National Hog Farmer, 11th April 2017 (article, “Metabolite changes in the gut rule antibiotic impact”; By Michaela Trudeau, Chi Chen, Gerald Shurson, University of Minnesota Department of Animal Science; and Fernando Leite, Richard Isaacson and Pedro Urriola, University of Minnesota Department of Biomedical Veterinary Science) (originally adapted from de Lange et al., 2010; Liu, 2015).

It is pertinent here to highlight that some countries (Sweden, in particular) have been dealing without the use of AGP in diets for more than 30 years. As a result, antimicrobial use in animal production in Sweden is among the lowest in Europe and has decreased by 65% over this period (Backhans et al., 2016). Improvements in biosecurity, management, feeding and disease control have assisted in keeping use low, but
nevertheless, antibiotic use on Swedish pig farms does vary considerably between farms. Recently, to reduce therapeutic/prophylactic use of antibiotics even further, Backhans et al. (2016) reported that factors influencing antimicrobial use in Swedish farrow-to-finish pig farms were related to individual farmer characteristics such as age, gender and years of experience more than production-related factors. However, under Swedish circumstances, biosecurity level had no additional effect on antimicrobial use. Backhans et al. (2016) commented that this indicates the importance of the herd veterinarian’s communication skills to ensure correct treatment of sick animals.

Other studies, for instance in Denmark, Belgium and The Netherlands, confirm the importance of management in reducing antibiotic use (e.g., Postma et al., 2016), even when feed additives in lieu of AGP/heavy metals are used, e.g., probiotics, prebiotics, fibres etc., and other strategies such as lower protein diets may be implemented. This suggests that in some cases the use of feed additives may have little or no effect on production/’gut health’ under good management conditions. Indeed, Melliere et al. (1973) reported a diminished response to antibiotics in research facilities versus commercial facilities, and that the magnitude of the response to tylosin diminished as pigs performed better (Figure 1).

Figure 1.- The impact of the performance of control animals on the magnitude of the response to tylosin in pigs (from Melliere et al., 1973)

However, and to implement such changes in the post-weaning period especially without/reduced use of certain antimicrobials, it is necessary to find combinations of feed ingredients, either alone or in combination with feed additives acceptable for use, that are effective in ameliorating the post-weaning growth check and reducing the incidence and severity of GIT problems often encountered (Heo et al., 2012; Pluske, 2013). A greater understanding of the mechanisms whereby antibiotics (and other antimicrobials) influence animal physiology is required to develop robust, field-proven alternatives to current antimicrobials. De Lange et al. (2010) remarked that a complimentary goal in nutrition might be to formulate young pig diets with the specific task of optimizing the growth,
function and health of the GIT, for example addressing the protein/amino acid content of diets, minimal buffering capacity, minimal content of anti-nutritional factors, and supply of beneficial compounds, for example, growth factors and immunoglobulins. The optimum dietary level and type of fiber will also vary according to the nature of enteric disease challenges, ingredient supply and cost, and the production objectives. With these principles in mind, the strategic use of feed additives may be better aligned and understood.

5.- CONCLUSIONS

De Lange et al. (2010) observed that a large amount of research has already been conducted evaluating the impact of a wide range of feed ingredients and feed additives on various aspects of GIT health and development in pigs, especially after weaning, in order to improve growth performance around this time while minimizing the use of antibiotics. A better understanding of the mechanisms whereby nutrients, feed ingredients and feed additives influence animal physiology will lead to the development of robust and field-proven alternatives to in-feed antibiotics. Nevertheless, more research is required to optimize the pigs' response to these feed additives under varying conditions. A key concern with several of these additives is their effective delivery to the targeted location in the pig's GIT, therefore a combination of different approaches may provide the most effective alternative to infeed antibiotics.

6.- REFERENCES