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Meta-analysis of relationship between weaning age and daily weight gain of piglets in the farrowing and nursery phases

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Abstract

A systematic review of the literature was carried out to perform a meta-analysis to assess effects of age at weaning on the performance of piglets in the range of 14 to 42 days old. This step consisted in defining the databases and keywords to be employed in searching for papers for the meta-analysis. To that end, the databases Capes Publication Portal and Google Scholar were searched for researches published from 2001 to 2019. After the acceptance and exclusion criteria had been defined and applied, 28 papers were selected. The data were collected with Excel® software of Microsoft Office for later statistical analysis. Orthogonal polynomial contrasts were used and the linear and quadratic regression equations were fitted with hypotheses tested at the 5% significance level. The results confirmed the disadvantages of early weaning and the benefits of weaning at around 28 days old. In the farrowing phase, piglets weaned after 35 days had lower daily weight gain (DWG) (P =0.002) than those weaned at 27 days. The derivative of the regression of DWG while nursing on age revealed that a weaning age of 26.34 days yielded the maximum DWG among the ages assessed. After weaning, the maximum DWG was achieved by weaning piglets at 32.26 days. Given the performance of piglets in the farrowing and nursery phases, the results of this meta-analysis indicated the best weaning age was between 26 and 32 days.

Keywords: early weaning, performance, pigs, wellbeing
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Introduction

In industrial pig farming, one practice that results in piglets experiencing stress is related to weaning. To increase sow/year productivity, piglets are weaned increasingly early, while still physiologically immature and more susceptible to common post-weaning issues. Under natural conditions, weaning occurs gradually without sudden changes for the piglets and results in their experiencing only a low level of stress. However, natural weaning is not a viable option in commercial pig farming, since it prolongs the postpartum anoestrous interval and delays finishing animals for market. These factors have important economic implications for the farm. The technology that is currently employed in pig farming aims to reduce weaning age to increase the number of piglets each sow produces annually. Therefore, weaning has gradually been reduced from 40 to 50 days old (late weaning), to 35, 28, and 21 days (early weaning), and may even occur when the piglets are less than 21 days old (super early weaning).

One of the factors that induce stress at weaning is disruption of the social hierarchy by mixing piglets from multiple litters, in addition to separation from their mothers, and changes in nutrition and in the physical environment. Thus, weaning can activate the neuro-hormonal system, leading to increased production of steroids, which affect the immune status of the piglets and lower their resistance to infection (Kanitz *et al*., 2008. At weaning, piglets must transition from a diet that is rich in milk to one based on grain. Thus, immediately on being weaned they have limited capacity to digest and absorb proteins, carbohydrates and fat because of their lower enzyme inventory. Lactase activity decreases gradually after weaning, whereas other digestive enzymes reach near full activity at around 42 days old (Santos *et al.*, 2018). These factors can cause a reduction in intestinal villi (Pluske *et al.*, 2003), reducing digestibility of feedstuffs and leading to enteric disorders (Gomez *et al.*, 2015).

Achieving the best performance immediately after weaning depends on the age and quality of weaned piglets and the age at which weaning occurs is fundamental to enhanced development during the nursery

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phase (Kummer *et al.*, 2009). These biological factors interact with conditions of each farm (genetics, feed, facilities) to determine the best weaning age. Thus, generalities as to the ideal weaning age are difficult. The present study was conducted to assess the performance of piglets during the farrowing and nursery phases as related to the age at which weaning occurred.

Materials and Methods

A literature survey was initiated to produce a meta-analysis (Chueke & Amatucci, 2015). Databases and keywords were chosen to search for articles The scientific databases Periodic Capes and Google Scholar were searched using terms, associated or not, plural or singular, as described in Table 1. Capes Publications Portal is a virtual library that makes scientific publications from around the world freely available for teaching and research institutions in Brazil (Atallah & Puga, 2007). It currently contains 45 000 full-text journals and 130 reference bases, in addition to books, encyclopaedias, reference works, technical norms, statistics, and audio-visual content. The search was restricted to 2001 to 2019.

Table 1 Hierarchy of search terms and numbers of files returned from Capes Publications Portal and Google Scholar

Search terms	Capes Publications Portal	Google Scholar
Pig production	9.550	18.100
Pig production and weaning age	244	17.500
Pig production and weaning age and weaned piglets	85	6.000
Pig production and weaning age and weaned piglets and weight gain	43	402

Forty-three files were selected for content analysis. The acceptance and exclusion criteria were defined and applied according to methodology proposed by Munoz (2002), which recommends the use of a questionnaire related to the study objective. Two assessors answered questions to assess the applicability of each article by reading the title, abstract, and part of the results. These questions were to be answered with 'yes' or 'no'. Was the publishing date between 2001 and 2019? Were the search terms included in the title and abstract? Does the work contain different weaning ages and weights in the farrowing phase? Does the work contain different weaning ages and weights during the nursery phase? Does the work present zoo-technical performance variables? The papers that both assessors assessed affirmatively for all questions were included in the analysis, yielding 28 papers. These articles were Nielsen *et al.* (2001), Houška *et al.* (2004), Wellock *et al.* (2008), Li *et al.* (2008), Kutzer *et al.* (2009), Zonderland *et al.* (2010), Fels *et al.* (2012), Madsen & Bee (2014), Bell *et al.* (2015), Baldinger *et al.* (2016), Van Wettere *et al.* (2016), Almeida *et al.* (2017), Vanrolleghem *et al.* (2019), Montsho *et al.* (2016), Kalita *et al.* (2015), Jin *et al.* (2019), Tsourgianis *et al.* (2004), Devillers and Farmer (2009), Bohnenkamp *et al.* (2013), Vieir de Araujo *et al.* (2017), Fels *et al.* (2014), Fels *et al.* (2012), Lopez-Vergé *et al.* (2019), Main *et al.* (2002) Vila *et al.* (2016), Sulabo *et al.* (2010), Turpin *et al.* (2017), and Lawlor *et al.* (2002). They originated from the journals Livestock Production Science, Animal, Asian-Australian Journal of Animal Science, Applied Animal Behaviour Science, Livestock Science, Renewable Agriculture and Food Systems, Journal of Animal Science, The Veterinary Journal, Journal of Animal Science and Veterinary Medicine, International Journal of Scientific Research in Science and Technology, Journal of Animal Science and Technology, Behaviour, Acta Agriculturae Scandinavica, Section A - Animal Science, Applied Animal Behaviour Science, Ciência Animal Brasileira, The Journal of Agricultural Science, The Thai Journal of Veterinary Medicine, Journal of Swine Health and Production and Animal Science. Of the works selected, 75.8% were published between 2010 and 2019 and the remainder of the articles were published from 2001 to 2009. All external factors – such as nutrition, feeding, management, ambience, sanity, and genetics – were ignored, and only the data that pertained to the influence of weaning age on piglet performance were extracted.

Using Excel® software, the data regarding the impact of weaning age on piglet performance were organized for statistical analysis. The variables were tested for normality of the residuals using Shapiro-Wilk test and homogeneity of variance using Levene's test. The data exhibiting disparity were transformed and submitted to analysis of variance using RStudio Team (2020) software. The resulting means for each weaning age were submitted to quadratic and linear regression analysis.

Results and Discussion

The meta-analysis allowed for systematically assessing changes in performance of piglets weaned at different ages. For this study, 33 trials containing weaning age and weight and 14 containing initial weight and weight at weaning (WW) at different ages were used to assess total weight gain (TWG) and DWG. The number of animals in the studies ranged from 12 to 796 piglets per trial for a total of 4328 animals. Papers containing values of weight when leaving the nursery contained data from between 12 and 5728 piglets per trial for a total of 8297 animals. There were 154 averages for WW and 88 averages for DWG.

No significant difference (P >0.05) was observed for initial weight of the animals (Table 3). However, there were differences (P <0.05) for WW and DWG while nursing for piglets weaned at 18, 21, 24, 27, 35, and 42 days. Weaning weight increased linearly (P <0.01) with age at weaning and can be described by:

$$WW = 1.308 + 0.217days$$

The coefficient of variation for WW was 12.17% and the coefficient of determination for the prediction equation was 96.2%. Daily weight gain during the pre-weaning period was described by a quadratic equation (P =0.05) with coefficient of determination of 65.7%. This equation was:

$$DWG = 0.233 - 0.00268days + 0.000051days^2$$

This equation has an inflection point at 26.34 days, indicating that the minimum growth rate was achieved at that time. The coefficient of variation for DWG was 13.36%.

Table 3 Effects age at weaning on the performance of piglets in the farrowing phase

Weaning age (days)	Weight at birth, kg	Weight at weaning, kg	Daily weight gain, kg
14	1.574	4.386	0.200
18	1.580	5.228	0.202
21	1.582	6.198	0.219
24	1.574	6.555	0.207
27	1.517	7.107	0.206
35	1.532	8.041	0.185
42	1.414	11.090	0.230

The piglets weaned at 35 days old had a lower (P =0.002) DWG during the farrowing phase than those weaned at 27 days. This was interpreted to indicate reduced efficiency in piglet performance.

In the data for post-weaning performance, significant differences (P <0.05) between weaning ages were noted for WW, weight when leaving the nursery (WPN), and DWG during the nursery phase (Table 4). There was also a tendency (P =0.06) for piglets that were weaned at younger ages to be lighter when leaving the nursery.

Table 4 Effects age at weaning on the performance of piglets in the nursery phase

Weaning age (days)	Weight at weaning, kg	Age leaving nursery	Weight leaving nursery (kg)	Daily weight gain, kg
18	4.514	59.00	23.378	0.365
21	7.000	68.57	24.234	0.478
24	6.706	61.46	24.947	0.396
27	7.365	66.00	25.518	0.575
35	7.385	68.00	26.347	0.423
42	11.783	76.00	26.244	0.476

As during the preweaning phase, weaning weight was observed to be a linear function of age:

$$WW = 0.983 + 0.232\ days$$

The coefficient of determination for this equation was 81.2% and the coefficient of variation for WW was 15.4%. Thus, this dataset was slightly more variable and the equation slightly less accurate than the results from the preweaning phase. Both WPN and NWG were described by quadratic regression equations (*P* <0.01):

$$WPN = 13.567 + 0.961 days + 0.0158\ days^2$$
$$NWG = -0.0258 + 0.0322 days + 0.00499\ days^2$$

The inflection points of these equations occurred at weaning ages of 30.41 and 32.26 days. Both indicate maxima at those ages. These equations had coefficients of determination of 75.73% and 73.28%, respectively. The coefficients of variation for WPN and NWG were 11.42% and 12.46%. Thus, weaning at 30.41 days maximized the weight of pigs when they completed the nursery phase, and weaning at 32.26 days maximized their growth rate in the nursery.

During the first days of life, piglets have high nutritional requirements for growth and accumulation of muscle tissue. Nursing provides highly digestible food that is rich in fats, lactose, and casein, and piglets consume around 800 mL/day of milk (Roppa, 1998). In environments where climate, nutritional, and sanitary factors are satisfactory, piglets may gain from 200 to 240 g/day between birth and weaning (Gonzalo *et al.*, 2010). The present research found somewhat lower estimates of preweaning growth rate, between 182 and 212 g/day. Nursing sows gradually wean their litter by spending increasingly less time in the nest, and therefore reducing the milk intake of piglets (Silva *et al.*, 2014). With natural weaning, which occurs between nine and 12 weeks after farrowing, piglets continue to receive nutritional and immune support from sows as they are exposed to new dietary components (Capoulas, 2015). With abrupt weaning, this transition period does not occur and metabolic imbalances can result.

The weaning phase is important, given its correlation with the time required for an animal to reach its ideal slaughter weight (Martins *et al.*, 2018). Some European countries mandate a minimum weaning age of 35 days, whereas weaning in South America and Asia is carried out mostly between 21 and 25 days. Weaning before 21 days old may limit digestive processes because physiological development of the digestive system may be incomplete, with enzyme secretion being insufficient, which hampers digestion and nutrient absorption (Cantarelli *et al.*, 2014). Enzyme activation is greater in piglets that are more than 21 days old, which ensures better nutrient use and enhanced weight gain (Neto *et al.*, 2019). Regardless of the age at weaning, the feed provided immediately after weaning should be formulated with ingredients that meet the needs of infants, which were previously met by maternal milk, without creating gastrointestinal issues and consequently hindering their performance (Augusto *et al.*, 2011).

The intestinal maturation of piglets that are weaned when they are 21 to 28 days old is compromised by the sudden change from milk to a solid diet, which leads to a decrease in feed intake and hindered performance (Cantarelli *et al.*, 2014). Dunshea *et al.* (2003) observed that piglets weaned after 20 days old take approximately four days to return to their weights at weaning, whereas those weaned before 17 days take about a week to recover. Similarly, Lima *et al.* (2011) found that when piglets are separated from their mothers at 21 days old, they exhibited reduced growth, particularly in the first week after weaning. Among piglets that were weaned at seven, 14, and 28 days, those weaned at seven days spent less than 1% of their time at the feed trough during the first two days after weaning in contrast with 3% and 5% for those weaned at 14 and 28 days (Johnson *et al.*, 2012). Because growth is related to feed consumption, these differences can result in uneven batches of nursery piglets when they are weaned on the same day. Furthermore, Main *et al.* (2002) observed that when piglets were weaned at 12, 15, 18, 21, and 22 days old and then separated, weight increased linearly and variation in WW decreased, thus reducing batch unevenness as weaning age increased.

Gonzalo *et al.* (2010) reported that weaning, piglets before they are 21 days old, causes alteration in social and physiological behaviours of piglets. Behaviour of piglets weaned early is characterized by increased vocalization, restlessness, and aggressive behaviour (Orgeur *et al.*, 2001; Weary & Fraser, 1997). Souza and Zanela (2008) reported that weaning age affected piglet intelligence by interfering with psychological memory, and that the earlier piglets are weaned, the higher their rates of aggressiveness and agonistic behaviour. Thus, sudden early weaning, with a concomitant change in environment, affects their social behaviour and psychological wellbeing, leading to stress, fights, and hierarchy issues with the batch, and results in suboptimal performance. Among practices causing stress, Sommavilla (2011) reported that change in physical environment is the least studied stressor in pig farming, despite being highly relevant because it influences several aspects of production and is usually related to social disruption, which is intensified by early weaning.

Piglets lack active physiological immunity up until 21 days old (Torres *et al.*, 2016). Therefore, piglets weaned at 21 days may exhibit immune deficiency after weaning until they are actively protected, whereas those weaned at 28 days will be protected passively and actively after weaning.

When assessing the production cost of piglets weaned at different ages, Main *et al.* (2004) concluded the most profitable age for weaning was 21 days. Lima *et al.* (2010) observed increases of 2.4% and 24% in cost per kg for animals weaned at 24 and 28 days, compared with those weaned at 21 days. Lima *et al.* (2010) inferred that 21 days was thus the most appropriate weaning age under the conditions of the study. However, the cost per kg of weaned piglets must not be considered alone, since weaning age influences future performance significantly. Piglets that are weaned later have better post-weaning performance indices (Smith *et al.*, 2007).

In the present study, it was found that weaning from 28 days onwards led to lower DWG in the farrowing phase, which might compromise economic viability. Such results suggest that piglets weaned at 28 days are physiologically ready to switch from milk to a nursery diet and are able to use starch and other complex carbohydrates as their main sources of energy (Chamone *et al.*, 2010). The results confirmed the disadvantages of early weaning and the benefits of conventional weaning around 28 days. These studies reported better performance for weaning in this age range, enabling new approaches for trials that compare weaning ages and their impact on weight when leaving the nursery, growth, and finishing.

Conclusion

The optimal age for weaning piglets appears to be between 26 and 32 days, based on the meta-analysis of results from the literature.

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Authors' Contributions

JKV (Orcid: http://orcid.org/0000-0001-8547-4149) planned the experimental project, data collection, writing, statistical analysis and interpretation. JPM assisted in data collection and writing. FRC supervised the experiment and assisted in writing. RTRP worked on statistical analysis and helped in interpreting results. RGG helped in revising and formatting the manuscript.

Conflict of Interest Declaration

No author has a conflict of interest relative to this work.

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