Meta-analysis of the effects of endoparasites on pig performance

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\textbf{ABSTRACT}

A meta-analysis was carried out in order to study the effects of endoparasites on the performance of growing pigs. Criteria that should be considered for the publication selection were: (1) the health challenge caused by parasites; (2) pig in growing phase; (3) presentation of the nutritional composition of the diets and (4) animal performance. Meta-analysis followed three sequential analysis: graphical, correlation and variance–covariance. The group that were infected with parasites had an average daily feed intake 5\% lower than that the control group (2044 vs. 2147 g d\(^{-1}\); \(P < 0.001\)), their average daily weight gain was also 31\% lower (665 vs. 987 g d\(^{-1}\); \(P < 0.001\)) and their feed conversion ratio was 17\% superior than that of the control group (3.07 vs. 2.62; \(P < 0.001\)). The variance decomposition demonstrated that 59\% of the reduction in weight gain was explained by the reduction in their feed intake, as well as a 6\% reduction being due to parasites.

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1. Introduction

Swine endoparasitism is heterogeneous in regard to the species involved and also with regard to the pathogenicity of the parasites (Roepstorff et al., 1998; Stewart and Hale, 1988). The effects of endoparasites depend on the parasite load and the individual resistance of the host, which can be influenced by environmental and nutritional factors. Endoparasitism can occur with or without the presence of clinical symptoms. In the first case, it can be lethal, especially in the initial growth phase. The absence of clinical symptoms is important for production, because if it goes unnoticed, it can cause economical loss due to the reduction in the pig performance (Pedersen et al., 2002; Thomsen et al., 2006). Endoparasitism does not manifest itself as a relevant problem in current pig farming. This is due to new technology, and above all, those technologies related to the interruption of the parasitic cycles, such as confinement facilities when used with specific prophylactic techniques. However, not all preventive techniques can be practiced in outdoor free range or in deep litter systems.

Parasites act as a stressor stimulus to animal metabolism, altering the nutritional demands of the host (Pedersen and Saeed, 2001). However, little is known about the implications of the interaction of endoparasitism with nutritional components and animal performance. Furthermore, the studies presented controversial results and the different approaches applied hindered to a global analysis of the variables involved. Meta-analysis is an alternative for this problem; a tool capable of creating new results through a re-analysis of the data available in literature. Through this method, different experimental variables can be integrated and systemic responses to the experimental diversity can be established. In view of this, the aim of the study was to analyze the effects of

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parasitism on the performance parameters of pigs through meta-analysis.

2. Materials and methods

Articles were selected for creating a database. Criteria to the selection of papers to be included in the database were: (1) the health challenge caused by parasites; (2) pig in growing phase; (3) presentation of nutritional composition of the diet; and (4) animal performance. The database was created from information obtained in various articles; with respect to the materials and methods used and the results obtained. It was compiled from 18 articles (Table 1) published between 1971 and 2009, indexed in periodicals (Journal of Animal Science, Parasitology and Veterinary Parasitology). The database totalled 1279 animals (barrows and females) distributed over 256 treatments.

The analyzed variables were related to experimental characteristics (experimental period, age and body weight), nutritional composition of the diets and performance. The methodology for the definition of dependent and independent variables, as well as for the data codification, followed the recommendations described in the literature (Lovatto et al., 2007; Sauvant et al., 2008). The codification for general, Inter and Intra effects, were initially introduced by attributing sequential numbers for adjustment of the experimental variability. For the general codification, a number was attributed for each publication inserted in the database. A sequential number was also given to each Inter codification, and located with the general codification, (i.e.: general codification = 2, Inter codification = 2 * 01 = 201), in such a way so as to give a specific code for each treatment within the database. The same codification was used for Intra codification, however, attributed only to groups with repeated measurements (such as body weight and age). Lastly, the treatments were coded for the parasitized and control groups.

The analysis was performed in three sequential stages: (1) graphic, to analyze the biological coherence of the data and observe the existence of distribution patterns; (2) correlation, to identify the related variables; and (3) variance–covariance, to compare the groups and obtain the prediction equations. The covariates used for variance–covariance analysis were the factors with the highest correlation coefficients (Lovatto et al., 2007; Sauvant et al., 2008). Regression equations were obtained through variance–covariance analysis using the GLM procedure. The variables included in the model were the general and Intra codification, and the covariates were daily feed intake, average body weight, average age, and/or crude protein intake. Variance decomposition was performed in order to observe the intensity of the effects that interfere with the analyzed variables. For this decomposition, the daily weight gain was the response and in the model was used codification for the general effect and for challenge (control animal or challenged animals), and the covariates were daily feed intake and average body weight. All the analyzes were performed using the Minitab 15 (2007) software.

3. Results

The parasitized group presented a reduction of 5% (P<0.001) in average daily feed intake, a reduction of 31% (P<0.001) in average daily weight gain, and an increase of 17% (P<0.001) in average feed conversion ratio (Table 2).

![Table 1](data:image/png;base64,iVBORw0KGgoAAAANSUhEUgAAAIUAAABpCAYAAAB8ZfJAAAAGXRFWHRTb2Z0d2FyZQBBZG9iZSBJbWFnZVJlYWR5ccllPAAAAySURBVHja3MzFv7h7mBBgQEAfKopjgAAAAASUVORK5CYII=

Table 1

<table>
<thead>
<tr>
<th>Reference</th>
<th>Included in analysis</th>
<th>Number of animals</th>
<th>Infection type</th>
<th>Parasite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arends et al. (1990)</td>
<td>–</td>
<td>490</td>
<td>Natural</td>
<td>Sarcoptes scabiei</td>
</tr>
<tr>
<td>Davies (1995)</td>
<td>–</td>
<td>176</td>
<td>Induced</td>
<td>S. scabiei</td>
</tr>
<tr>
<td>Hale and Stewart (1979)</td>
<td>+</td>
<td>48</td>
<td>Induced</td>
<td>Trichuris suis</td>
</tr>
<tr>
<td>Hale et al. (1981)</td>
<td>+</td>
<td>96</td>
<td>Induced</td>
<td>Oesophagostomum spp</td>
</tr>
<tr>
<td>Hale and Marti (1983)</td>
<td>+</td>
<td>40</td>
<td>Induced</td>
<td>Stephanurus dentatus</td>
</tr>
<tr>
<td>Hale and Marti (1984)</td>
<td>+</td>
<td>64</td>
<td>Induced</td>
<td>Strongyloides ransomi</td>
</tr>
<tr>
<td>Hale et al. (1985)</td>
<td>+</td>
<td>32</td>
<td>Induced</td>
<td>Ascaris suum</td>
</tr>
<tr>
<td>Pedersen and Saeed (2001)</td>
<td>+</td>
<td>40</td>
<td>Induced</td>
<td>Trichuris suis</td>
</tr>
<tr>
<td>Pedersen et al. (2002)</td>
<td>+</td>
<td>51</td>
<td>Induced</td>
<td>T. suis + A. suum</td>
</tr>
<tr>
<td>Petkevicius et al. (2007)</td>
<td>+</td>
<td>28</td>
<td>Induced</td>
<td>T. suis</td>
</tr>
<tr>
<td>Southern et al. (1989)</td>
<td>+</td>
<td>96</td>
<td>Induced</td>
<td>A. suum</td>
</tr>
<tr>
<td>Stewart et al. (1972)</td>
<td>+</td>
<td>48</td>
<td>Induced</td>
<td>S. ransomi + A. suum + Oesophagostomum spp</td>
</tr>
<tr>
<td>Thomsen et al. (2006)</td>
<td>+</td>
<td>32</td>
<td>Induced</td>
<td>T. suis</td>
</tr>
<tr>
<td>Urban et al. (1989)</td>
<td>+</td>
<td>108</td>
<td>Natural/induced</td>
<td>A. suum</td>
</tr>
<tr>
<td>Van Krimpen et al. (2010)</td>
<td>+</td>
<td>32</td>
<td>Induced</td>
<td>A. suum</td>
</tr>
<tr>
<td>Zimmerman et al. (1971)</td>
<td>+</td>
<td>296</td>
<td>Natural</td>
<td>A. suum</td>
</tr>
<tr>
<td>Zimmerman et al. (1973)</td>
<td>+</td>
<td>96</td>
<td>Natural</td>
<td>A. suum</td>
</tr>
<tr>
<td>Zimmerman et al. (1971)</td>
<td>+</td>
<td>172</td>
<td>Natural</td>
<td>A. suum</td>
</tr>
</tbody>
</table>

All animals were kept in indoor system.
The variance decomposition demonstrated that 59% of the variance of weight gain, is due to reduction in feed intake. In addition, parasitism was responsible for a further 6% of reduction in weight gain. The effect of parasitism is responsible for a 2.4% in the variation (P < 0.001) on the final weight.

The equations obtained from variance–covariance analysis for the performance indexes of both parasitized and control groups are presented in Table 3. Based on the equation to predict the weight gain in parasitized pigs, the increase in crude protein intake favored the weight gain. For each increment of 1 g in protein intake, an increase of 1.1 g in the daily weight gain of the parasitized group is expected. The crude protein intake presented a high correlation (0.83; P < 0.001) to weight gain in parasitized pigs.

Parasitism interfered in the pig weight gain (Figs. 1 and 2). Parasitized pigs need 131 days to reach their termination phase considering 72 kg, while the non-challenged animals need only 126 days, representing an increase of 4% on the duration of the growth phase.

Even though the equations obtained by this study are empirical, the inclusion of age or body weight as covari-ables has turned them into dynamic ones, allowing their application in mathematical models. These results are important, because the lack of dynamic information results in various mathematical models becoming deficient for not simulating the animal growth, considering the effects of sanitary challenges, like parasitism.

4. Discussion

The adaptation of the host due to endoparasites can be compared to situations such as, alterations in quantity and quality of their feed, as well as physiological disorders (Hoste, 2001). Therefore, the analysis on the effects caused by endoparasites on the performance of pigs was conducted without taking into consideration the species involved. This is because the impact on the performance, due to endoparasite, is more related to how the host adapts to the severity or the type of immune response. The leukocytes represent less than 0.5% of the animal live weight and total levels of antibodies contribute to less than 0.1%. Therefore, even if the immune response is severe, the increase in the leukocyte and antibody levels do not cause a big nutrient demand, that would normally be used for body deposition (Klasing et al., 1987).

In this context, two main aspects in the parasite-host relation may be considered. The first one considers

![Fig. 1. Daily feed intake in the control and parasitized pig groups.](image)

![Fig. 2. Daily weight gain adjusted for daily feed intake for control and parasitized groups.](image)
the influence of the parasites on the host metabolism. Observing the effects of feed intake and parasitism on weight gain through variance decomposition, it is evident that feed intake is the main factor involved in performance variations. Therefore, feed intake reduction is the main response characteristic of the host to the parasite (Kyriazakis et al., 1998). Variance decomposition indicates that the presence of the endoparasites in the host also reduces weight gain. The parasite causes lesions like cellular dedifferentiation in the intestinal mucosa membranes or microvillus atrophy in the host, reducing the weight gain (Hoste, 2001). Therefore, though the parasitized group has a reduction of only 5% in feed intake, it demonstrated a downfall of 31% in weight gain. This difference indicates that, although anorexia explains a good part of the weight gain reduction in the challenged animals, other mechanisms probably related to parasitism affected this variable.

The second feature of the parasite-host relation involves the effect of nutrition on the host and his ability to resist to illness caused by the parasites. This interaction was analyzed through the feed intake and weight gain graphs (Figs. 1 and 2). At the beginning of the growth period, feed intake is higher in the parasitized group. This suggests that the pig organism demands more nutrients for resisting and adapting to this challenge. As the challenged animal grows, the relationship between weight gain in both groups is constant; however, the reduction in feed intake is higher. One of the adaptive responses of the parasitized organism is the increase in the intestinal absorption levels and the size of the areas free of endoparasites, counteracting the productive losses and consequently countering absorption of the parasitized areas (Hoste, 2001). Thus, it is possible to assume that at the onset of parasitism, the host looses productive potential due to the challenge of not being able to adapt to the endoparasites. As the pig grows, it adapts physiologically and also develops its immune system to modulate any damages, balancing out the weight gain (Kyriazakis et al., 1998). The increase in the absorption levels, apart from being a mechanism for balancing out any losses, could lead to levels of weight gain higher than the control group, suggesting a compensatory gain.

The worst performance of the parasitized group could be related to immunologic stress. The activated macrophages release pro-inflammatory cytokines that act directly on the peripheral somatic tissues, inducing a series of metabolic responses and causing immunological stress. In the central nervous system, the cytokines alter the neuroendocrine system, reducing the growth hormone secretion (Johnson, 1997). Thus the animals that were immunologically challenged, present a lower growth rate, even without presenting any clinical indications (Klasing et al., 1987; Spurlock, 1997). This highlights once again, the results obtained by variance decomposition. Therefore, exposure to immunogenic or inflammatory agents results in specific alterations in the hormonal and metabolic environment, reducing growth, raising feed conversion ratio and increasing nutritional requirements of the parasitized animals (Klasing et al., 1987).

The weight gain equation of the parasitized group demonstrates that when the average age was used as a covariable (WG = 0.2522 + 0.0047 × AA), a coefficient of determination of 0.66 was obtained; however, when the crude protein intake was included (WG = 0.0463 + 0.003 × AA + 0.0011 × CPI), the coefficient of determination increased to 0.90. This highlights the importance of protein in the adaptive response of the host. When the body weight of the animals was used as a covariable for the weight gain equations, the inclusion of crude protein intake did not increase considerably the coefficient of determination, showing that the body weight adjusted better as an explanatory variable in relation to average age.

For this last equation, for each increase of 1 g in crude protein intake is expected to result in an increment of 1.1 g in the daily weight gain of the parasitized group. Low protein and energy levels in diets hinder the adaptive response to the parasite (Pedersen et al., 2002). In part, the importance of the protein in the adaptive response of the host can be explained by the large demand for amino acids, needed for the growth and adaptation of the gastrointestinal tissues. When an animal is infected with parasites, endogenous losses of protein occur in the gastrointestinal tract that arises from the sequestration of plasma, as well as epithelium and mucoprotein loss. These results in a transfer of amino acids from the productive processes, like muscle deposition and bone formation, to the plastic protein synthesis, gastrointestinal repair and mucus replacement (Coop and Holmes, 1996). This deviation of nutrients can increase feed conversion ratio and reduce the protein gain. A way to circumvent the situation would be an adjusting diet, by increasing the amount of specific amino acids. An example of such amino acids is threonine that improves nutrient absorption and is essential to the epithelium renewal (Stoll et al., 1998).

In this context, parasitized animals ingest fewer nutrients than what is necessary for the maximum expression of their genetic potential for protein deposition. Depending on the parasitosis, pigs can demonstrate behavioral alterations, increasing their energy need, causing an even bigger increase in the basal metabolism and, consequently, in the energy requirement (observe Table 2). This leads to a reduction in the protein deposit synthesis and increases the protein degradation rates (Pedersen and Saeed, 2001; Pedersen et al., 2002; Thomsen et al., 2006).

During current pig farming, health and productive management had an important role in control and mitigation of performance losses caused by endoparasites. However, the alternative production systems still coexist with this problem, which tends to worsen if measures are not taken to control the resistance to anti-parasite medications. An alternative, observed through this study, would be to increase the nutrient input through diets enriched in essential amino acids supporting the adaptation of the host and consequent modulation of the parasitic population. New studies regarding the influence of supplementation of specific amino acids assist in the understanding of the mechanisms that interfere in the parasite-host relation.

5. Conclusions

The simple presence of endoparasites induces an reduction in body weight. Parasitism reduces the rate
of weight gain. Increases in the level of crude protein in the diet, favored the weight gain of challenged animals.

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References

Minitab, 2007. (Minitab Inc.).