

Effectiveness of feed restriction to improve feed efficiency in finishing pigs

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ABSTRACT

Objective: To review the effects of feed restriction in finishing pigs on production efficiency and meat quality.

Design/methodology/approach: A bibliographic review of feeding management in pigs fed *ad libitum*, restricted, and their combination was carried out.

Results: Feed restriction decreases the growth rate, but if the restriction is moderate, better feed efficiency can be obtained. Feed restriction followed by feed *ad libitum* results in compensatory growth, which equals or improves continuous free access feeding.

Study limitations/implications: Implementing feed restriction can be useful to improve feed efficiency and in periods that it is necessary to slow down growth.

Findings/conclusions: Moderate feed restriction (−10%) of finishing pigs improves feed efficiency. Feed restriction of less than 20% for 30 days, followed by *ad libitum* feed, promotes compensatory growth and improves feed efficiency.

Keywords: feeding strategy, feed efficiency, compensatory growth, finishing pigs.

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INTRODUCTION

There are different feeding plans (*ad libitum*, restricted or a combination of both) that are implemented with the aim of increasing or decreasing the growth rate, age and live weight (LW) at slaughter, or manipulating meat quality (Carco *et al.*, 2018 a,b; Schiavon *et al.*, 2018; Pouillet *et al.*, 2019).

Under free access feeding conditions, pigs are encouraged to maximize feed consumption, which can decrease the digestibility of nutrients (Njoku *et al.*, 2015a) and the feed efficiency (Dalla Bona *et al.*, 2016; Njoku *et al.*, 2018; Schiavon *et al.*, 2018).

Feed restriction (FR) consists in offering the animals a regulated amount of feed, normally lower than what the pigs are capable of ingesting voluntarily (Brustolini *et al.*, 2019). Depending on the percentage of FR, it is possible to improve the feed efficiency and the meat quality, since severe FR can drastically affect the growth rate and the fat content in the meat (Njoku *et al.*, 2013; Kim *et al.*, 2014; Dalla Bona *et al.*, 2016; Carco *et al.*, 2018ab).

FR followed by a period of free access feeding leads to the compensatory growth mechanism, with which greater weight gain and better feed efficiency are observed during this refeeding period, making it possible to attain optimal weights at the time of slaughter, with high feed efficiency (Lovatto *et al.*, 2006; McEwen *et al.*, 2009; Pouillet *et al.*, 2019), without a negative effect on meat quality (Wiecek *et al.*, 2011; Pugliese *et al.*, 2013). The purpose of this review is to summarize studies that show the effectiveness in the implementation of FR in finishing pigs on the productive efficiency and meat quality.

Feed restriction (FR) in fattening pigs

One of the main challenges to make pig production systems more efficient is to define the strategic feeding plan according to the objective of production (Njoku *et al.*, 2015a). FR can be a useful strategy to improve meat quality and, at the same time, to improve feed efficiency by reducing the waste of feed and improving the digestibility of the nutrients consumed, accompanied by a reduction in the needs for maintenance and higher energetic efficiency for the synthesis of protein and fat (Lebret *et al.*, 2001; Njoku *et al.*, 2015a; Pouillet *et al.*, 2019).

Feed restriction and productive behavior

Pigs with FR present better weight gain than pigs fed with free access; however, the feed efficiency (FE) in pigs subjected to FR is not affected or improved (Kim *et al.*, 2014; Dalla Bona *et al.*, 2016; Carco *et al.*, 2018a; Brustolini *et al.*, 2019). The implementation of a FR regime of 7% in finishing Talent line Topigs pigs reduced weight gain (3.2-3.5%) and feed consumption (7.4%), although the FE increased (2-4%) (Dalla Bona *et al.*, 2016; Schiavon *et al.*, 2018). Njoku *et al.* (2018) observed that 10% FR did not affect the LW at slaughter. More encouraging data show that a FR of 15% increased the FE in 8%, although it reduced the weight gain (Kim *et al.*, 2014).

The amount of feed offered, the frequency and the feeding rate (consumption of feed per visit/duration of the visit) in pigs can restrict or decrease the feed consumed, using these as variants of the FR regime, modifying the consumption behavior to compensate the restriction and increasing the feeding speed or the time devoted to feeding (Carco *et al.*, 2018a). Feed restriction (*ad libitum* vs. 2.5 and 2.75 kg) in pigs (22-114 kg of LW) reduced the feed consumption between 15 and 22%, which resulted in lower weight gain, without a negative effect in feed conversion (Quiniou *et al.*, 2012).

On the other hand, the pigs responded to FR by increasing their feeding rate (Carco *et al.*, 2018a; Schiavon *et al.*, 2018). Manipulating the feeding rate through FR affects feed consumption, and consequently the growth, although it has low influence in feed conversion (Njoku *et al.*, 2013; Colpoys *et al.*, 2016; Carco *et al.*, 2018b). The pigs with a higher feeding rate (7% FR) had better LW (16%) and weight gain (27%) than the pigs without restriction (feeding *ad libitum*) (Carco *et al.*, 2018b). In a similar study, Njoku *et al.* (2013) found that the final LW, weight gain and FE improved when feed was offered more times (1-3 times) with FR (1.5, 2.0 and 2.5 kg), observing higher weight gain and FE with 2 or 2.5 kg of feed divided into three servings.

As is suggested in the aforementioned, FR can be an effective feeding strategy; however, there must be care not to make it too severe, since there could be some irreversible negative effects in the productive behavior. Njoku *et al.* (2013; 2015b) observed that pigs fed with 2.0 and 2.5 kg/d obtained similar weight gains and feed conversion, although with negative effects for animals fed with 1.5 kg. Lebret *et al.* (2001) observed that the reduction of 25% in the feed offered to pigs decreases weight gain in 25%, which represented that the LW for market would be reached 30 days later than the animals fed at free access; no effect was found in the FE. This information agrees with what was found by Boddicker *et al.* (2011) who indicate differences in the FE of growing pigs between the *ad libitum* feeding regime and FR of 25%, although FR of 45% decreased the feed efficiency.

Feed restriction, characteristics of the carcass and meat quality

FR in pigs increases feed efficiency, although the negative response that there may be in weight gain must be considered, as well as the characteristics of the carcass, and the quality and chemical composition of the pig meat (Njoku *et al.*, 2015 a,b; Dalla Bona *et al.*, 2016; Njoku *et al.*, 2018).

Nevertheless, some studies report that FR does not affect meat quality (Dalla Bona *et al.*, 2016; Njoku *et al.*, 2015b; 2018), although it can lead to changes in the growth of internal organs (Njoku *et al.*, 2015b; 2018). In addition, FR (7%) can negatively influence the percentage of fat, lean meat, and protein synthesis (Colpoys *et al.*, 2016), and the characteristics of the carcass (Njoku *et al.*, 2015b; 2018; Dalla Bona *et al.*, 2016; Schiavon *et al.*, 2018; Brustolini *et al.*, 2019). However, Carco *et al.* (2018b) observed that FR of 7% in pigs causes greater accumulation of protein (22%) and lipids, higher carcass weight (16%), weight of lean cuts (14%), and weight of fatty cuts (21%). Another aspect of FR in pigs is that the carcass weight has a low coefficient of variation, important in production chains given the economic value of this aspect (Gallo *et al.*, 2015; Schiavon *et al.*, 2018).

The feeding program in pigs affects the lipid body composition. FR reduced the dorsal fat content (Quiniou *et al.*, 2012) and intramuscular lipids (Lebret *et al.*, 2001; Minelli *et al.*, 2019), while it increased the concentration of polyunsaturated fatty acids (Wiecek *et al.*, 2011; Dalla Bona *et al.* 2016; Minelli *et al.*, 2019) and omega-3 (Wiecek *et al.*, 2011; Minelli *et al.*, 2019) in the meat fat.

Feed restriction and refeeding period

The pigs show an accelerated growth rate or compensatory growth when they are provided feed at free access after a period of FR; in addition, the weight gain accumulated in both feeding regimes can be higher or the same as with continuous *ad libitum* feeding, reaching optimal weights at sacrifice and a good FE (Kristensen *et al.*, 2004; McEwen *et al.*, 2009). It has been found that FR followed by compensatory growth does not affect the meat quality (Pugliese *et al.*, 2013). Compensatory growth could be a feasible strategy when the cost of raw materials and the price for market of the pigs are disadvantageous for the producer.

The compensatory growth in pigs depend on the age, the level of restriction, and the duration of the FR period, from the moment when FR begins, and the duration of the refeeding period (Therkildsen *et al.*, 2002; Lovatto *et al.*, 2006; Pouillet *et al.*, 2019). Therkildsen *et al.* (2002) studied the effects of the duration of the refeeding period after FR in pigs, which were 70 days away from slaughter. The pigs received feeding *ad libitum* or 60% of the *ad libitum* level for 28, 43, 52 and 60 days, followed by feeding *ad libitum* (42, 27, 18 and 10 days, respectively) during the rest of the fattening period and until sacrifice. FR resulted in a lower weight in comparison to the pigs fed *ad libitum*; however, the pigs showed compensatory growth in the subsequent period of feeding *ad libitum*. The pigs refed *ad libitum* for a minimum of 27 days before slaughter had similar carcass weight and muscular mass than the pigs of the control treatment, and the meat quality was not affected. McEwen *et al.* (2009) indicated that limited feeding (70-85%) in pigs followed by feeding *ad libitum* improved feed conversion, reduced feed consumption (7.5%), and increased weight gain, presenting similar days to sale compared to pigs fed *ad libitum*. A better FE was also confirmed by the studies carried out by Daza *et al.* (2007). These results show an increase in feed efficiency and suggest an economic benefit by limiting feeding and applying the effect of compensatory growth.

For their part, Pouillet *et al.* (2019) studied the effect of FR of short duration and severe (restriction of 50% during 6 days) and refeeding (14 d) on the production and metabolism of pigs. FR reduced the growth rate and the FE which was quickly compensated with refeeding. In a similar design but with shorter refeeding (7 days), Lovatto *et al.* (2006) did not observe compensatory growth. In the case of severe FR in pigs, the reduction in weight gain is expected to be proportionally higher than the reduction in feed consumption, due to greater relative importance of the necessary nutrients for maintenance (Lovatto *et al.*, 2006; Pouillet *et al.*, 2019).

A period of FR that is too long must be managed carefully. A study by Serrano *et al.* (2009) assessed pigs in the finishing stage that had previously been feed restricted (72-82%) for 100 days and refed for 54 days before sacrifice; they found increased feed consumption (9%) and weight gain (20%), and improved feed conversion (13%) in comparison to pigs fed *ad libitum* during the stage of refeeding. Although at the end of the trial the pigs fed *ad libitum* weighed 9.7 kg more than the restricted pigs, the feed efficiency and the meat quality were not affected with any feeding regime.

FR followed by a period of feeding at free access allows directing the high supply of energy when the pig is adult, due to the limited growth and biological rhythm in the previous phase, which could alter the fat deposition and the meat characteristics. McEwen *et al.* (2009) indicated that FR (70-85%) of pigs during the growth phase followed by feeding *ad libitum* reduced intramuscular fat, compared to pigs fed *ad libitum*. Kristensen *et al.* (2004) observed that the compensatory growth improved meat tenderness when pigs are subjected to a restriction regime of 31% during 52 or 62 days and a refeeding period of 60 to 70 days. However, other studies (Daza *et al.*, 2007; Lebret *et al.*, 2008; Serrano *et al.*, 2009; Wiecek *et al.*, 2011) in different refeeding periods (21-63 days) did not find a positive effect in the meat quality or the fat content.

Effect of feed restriction on metabolism

The compensatory growth due to FR implies a greater replacement of muscular proteins, increasing the activity of proteases (calpains) after the pigs are returned to feeding *ad libitum*; this activity can continue until the post mortem period, which presents the potential of increasing meat tenderness (Kristensen *et al.*, 2004; Therkildsen *et al.*, 2002); however, Therkildsen *et al.* (2002) observed that a greater activity of calpains and collagen (rechange and resynthesis) did not improve meat tenderness.

Feeding *ad libitum* tends to promote the synthesis of body fat that is inefficient in terms of feed conversion (Njoku *et al.*, 2013). Kim *et al.* (2014) inform that FR of 15% in the diet of growing pigs altered the expression of the fat tissue of key enzymes that regulate acetyl-CoA carboxylase, the fatty acid synthase, hormone-sensitive lipase, and the lipoprotein lipase during the finishing period; this suggests a decrease in the capacity of de novo synthesis of fatty acids and an increase in lipolytic activity. The effect of FR decreases the availability of energy for de novo synthesis, primarily of saturated fatty acids, which leads to greater unsaturation of the lipids, in addition to an increase in polyunsaturated fatty acids (Daza *et al.*, 2007).

The change in growth rate and FE during FR of pigs suggests changes in the metabolism and use of nutrients, which shows modifications in the levels of metabolites and hormones. FR reduced blood urea (Lovatto *et al.*, 2006; Schiavon *et al.*, 2018; Pouillet *et al.*, 2019), which is associated to lower feed consumption and better balance of the N ingested; a reduction in the cholesterol level is also reported (Pouillet *et al.*, 2019).

In terms of the effect of FR on the hormonal level, leptin was reduced and ghrelin increased (Barretero *et al.*, 2010; Pouillet *et al.*, 2019); it increased the growth hormone and decreased insulin and glucose (Barretero *et al.*, 2010). The concentration of IGF-1 was reduced in pigs with FR, although they returned to normal levels during the period of feeding *ad libitum* (Therkildsen *et al.*, 2004; Chaosap *et al.*, 2011). The liberation of growth hormone by the pituitary gland stimulates the production of IGF-1, stimulating bone and muscular growth (Schiaffino *et al.*, 2013).

Lower weight gain during FR can be due to a lower availability of nutrients for growth and to a higher proportion of the energy being used for maintenance (Lovatto *et al.*, 2006). However, a higher FE during FR could reduce the metabolic rate related with a lower weight of the entrails during compensatory growth (Koong *et al.*, 1983; Hornick *et al.*, 2000), and a more efficient use of nutrients (Lovatto *et al.*, 2006; Pouillet *et al.*, 2019).

Factors that affect the response to feed restriction

Feed consumption in pigs is influenced by the genotype (including the sex, the breed), the health status, the diet's characteristics, environmental factors and possible interactions (Schiavon *et al.*, 2018). The degree of response during compensatory growth after FR could be due to differences in the genotype of pigs, since feed restriction is especially appropriate for pigs of unimproved genotypes with low FE (Kristensen *et al.*, 2004), since the level of FE between genotypes is associated to the difference in fat and protein deposition (Pouillet *et al.*, 2019). Also, the percentages of FR should be applied in function of the sex, so that

they are higher as the growth rhythm is higher, since there are marked differences between males and females (McEwen *et al.*, 2009; Serrano *et al.*, 2009).

The thermal environment has an important effect on feed consumption, growth rate and FE (Cervantes *et al.*, 2016). Feeding *ad libitum* can predispose the animals to obesity, thermal stress, high incidence of limping, high morbidity and mortality due to skeletal disorders, and heart failure (Njoku *et al.*, 2018). The FR protocol in pigs reduces the body temperature (around -0.4 °C) and respiratory frequency; this taking into account that when there is an overconsumption of energy, it is channeled to the increase in body temperature (Njoku *et al.*, 2013; Cervantes *et al.*, 2016; Pouillet *et al.*, 2019). Therefore, the reduction in metabolic heat production leads to a better FE and reduction of caloric stress (Lovatto *et al.*, 2006).

CONCLUSIONS

Applying feed restriction of less than 10% can be viable in finishing pigs since it improves feed efficiency without affecting the characteristics of the carcass and the meat. The implementation for a period of 30 days with a restriction lower than 20%, followed by feeding *ad libitum*, is a useful strategy to promote compensatory growth and to improve feed efficiency.

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