# Lowering dietary phosphorus results in a loss in carcass value but not decreased growth performance

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## Summary

We describe a case of minor loin damage caused by vertebral fractures sustained during the stunning process. Bone strength in these animals was apparently weakened as a result of feeding reduced concentrations of dietary phosphorus to minimize excretion of phosphorus into the environment and to decrease the cost of the diets. The fractures were estimated to cost the herd owners $4.25 and the processor $12.77 per affected pig due to lost carcass value. Dietary phosphorus concentrations in the finishing pig diets were increased; within 2 months of this intervention, the rates of minor loin damage were significantly lower. Comparisons before and after the dietary revision showed that growth performance, mortality, percentage pigs marketed, and carcass lean were not affected by the inclusion rates of dietary phosphorus we investigated in this study. This case clearly illustrates that the dietary phosphorus requirement for maximum bone strength is higher than that for maximum growth performance.

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Environmental concerns are changing the location and structure of pig production in the United States.[1] One issue of particular concern, particularly in areas densely populated with swine production units, is phosphorus excretion by swine,[2] which contributes to the accumulation of excess phosphorus in soils and leaching of phosphorus into surface waters. Excess phosphorus in surface water increases algae growth and compromises water quality.[3]

Decreasing the dietary phosphorus content consumed by the pig is a simple way to reduce excretion, as long as growth and carcass performance is not affected. Swine diets usually provide a fairly large margin of safety for dietary phosphorus;[4] however, with increased environmental concerns, many swine producers are feeding diets with lower margins of safety. Recent research with terminal pigs suggests that removing the majority of inorganic phosphorus in late finishing diets results in little or no loss in growth performance or meat quality.[5–7] A 9.7% reduction in dietary phosphorus may reduce phosphorus excretions by about 7% (i.e., about 48 g per pig)[5] during the growing-finishing period—a decrease in phosphorus excretion of approximately 480 kg (1058 lb) for every 10,000 pigs marketed. The cost of inorganic phosphorus (the third most-expensive nutrient after protein and energy in swine diets), in addition to the possible environmental costs due to excess excretion, make maintaining large margins of safety even more costly.

In this case, we investigated how phosphorus in the diets of growing pigs, formulated to maximize growth performance with a minimal margin of safety compared to NRC estimated requirements, affected growth performance and carcass value.[3]

## Case description

The herd involved in this case was stocked with pigs of PIC genotype. Pigs flowed from one of two sow farms and were commingled at weaning (16 days of age). Each group contained 1 week's production of weaned pigs. Nurseries were located on multiple sites with a maximum of four groups per site, and were flowed all-in–all-out by group, with each group housed in a single room or barn. Approximately 8 weeks after weaning, groups flowed to multiple finishing sites, each of which contained a maximum of four groups with each group housed in a single barn. All pigs were marketed to a single processor.

Corn- and soybean meal-based growing pig diets for this herd, produced in one centralized feed mill, were formulated to contain reduced dietary concentrations of available phosphorus (Figure 1). The margin of safety was decreased to minimize excess phosphorus excretion in the manure and lower feed cost per unit of gain. All diets fed to pigs < 109 kg (240 lb) bodyweight, however, still contained greater available dietary phosphorus concentrations than the inclusion estimates indicated by the NRC.[3] The concentration of phosphorus in the rations fed from 109 kg (240 lb) to market was only slightly below the NRC estimated requirement.

After these reduced-phosphorus diets had been fed for approximately 9 months, the processor notified the herd owners that the frequency of pigs with minor loin damage was greater than twice that for pigs received from other producers (1.41% versus 0.58%). Plant personnel indicated that almost all of the minor loin damage was due to vertebral fractures during the stunning process, causing blood spotting on the loin muscle, which had to be trimmed for cosmetic purposes. Fractured vertebrae have been reported as the second-largest economic loss for the processor.[8] In addition to inadequate dietary phosphorus, vertebral fractures during stunning can be caused by improper stunning.[8] However, increases in the frequency of vertebral fractures were not noted by the processor in pigs from other sources. Therefore, lowered bone strength due to the reduced intakes of dietary phosphorus was suspected.

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The available phosphorus concentration was therefore increased by 0.05% for all diets fed to pigs from 68 kg (150 lb) to market weight (Figure 1). The diets before and after the revision were balanced to provide an average Ca:P ratio of 1.1:1.

**Figure 1:** Dietary available phosphorus (%) in case herd pig diets in the "before" and "after" periods compared to NRC[3] estimated requirements, expressed as a dietary percentage.

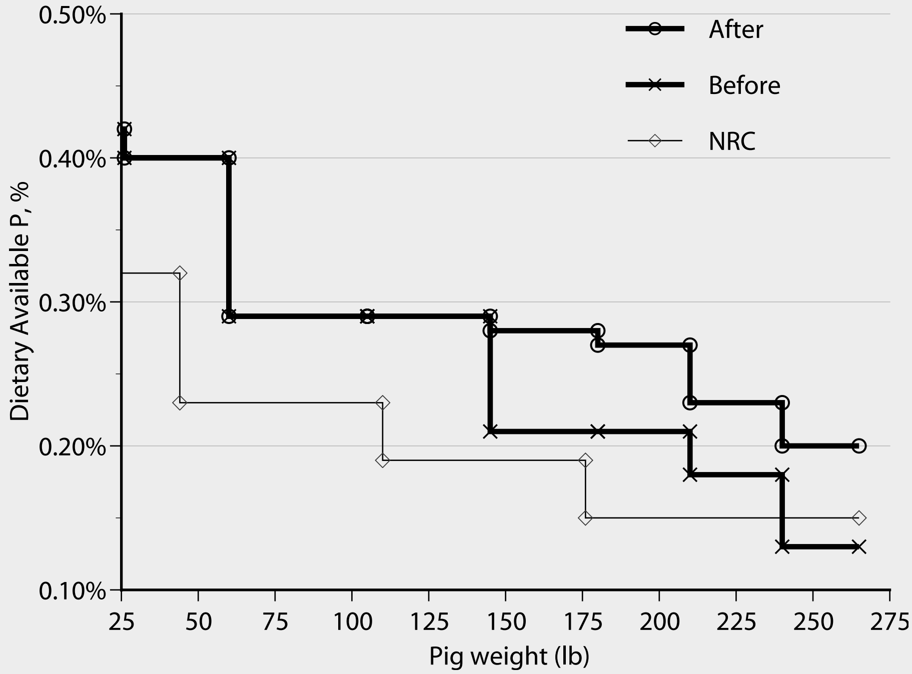


**Table 1:** Regression parameters for the two models

| Model | Slope | SE | *P* |
|---|---|---|---|
| 1 ("before" versus "transition" + "after") | -.31 | .17 | <.08 |
| 2 ("before" + "transition" versus "after") | -.74 | .16 | <.0001 |

## Data analysis

After the diet revision, data on minor loin damage were collected from the processor and examined to determine whether the increase in dietary phosphorus was sufficient. The daily rates of minor loin damage (expressed as the percentage of pigs with minor loin damage delivered to the processor per day) were compared to the daily rate for other producers that provided pigs to the processor for an 8-month period, beginning 3 months before the diets with increased phosphorus were implemented in the case herd. The frequency of minor loin damage in case herd pigs returned to values normal for that processor 2 months after the diet revision. Therefore, the data were evaluated in three time periods:

- the 3 months "before" the diet revision,
- the 2-month "transition" period from the time of revision until improvement was noted, and
- the 3 months "after" the transition period.

### Statistical analysis

The minor loin damage rates over time for the case pigs were examined using two time-series regression models. This analysis incorporated an autocorrelation error structure of lag 1 to account for correlation between consecutive points in time.[9] The first model examined the change in minor loin damage during the "before" periods versus the "transition" + "after" periods. The second model examined minor loin damage rates during the "before" + "transition" periods versus the "after" period.

The first model indicated that there was a trend ($P < .08$;Table 1) for decreases (0.31%) in minor loin damage rates when the "before" period was compared to the "transition" + "after" periods. The large day-to-day variation in frequency of minor loin damage during the "before" period began to decrease during the "transition" period (Figure 2). The second model indicated that damage rates decreased significantly (0.74%; $P < .001$) in the "after" period compared to the "before" + "transition" periods. Note that during the "after" period, the incidence of minor loin damage for the case herd was almost identical to the processor average from other suppliers.

Closeout data were examined for 17 groups in the "before" period and eight groups in the "after" period (Table 2). Data from the "transition" period were not available to include in the analysis. Because the closeouts from the "after" period had a slightly higher average beginning weight, the feed efficiency was expected to be slightly higher. Therefore, feed efficiencies (feed:gain [F:G]) were adjusted to common beginning and market weights using the procedures outlined by Dritz, et al.,[10] according to the following equation:[10]

$$\text{adjusted F:G} = \text{observed F:G} + (50 - \text{entry wt, lb}) \times .006 + (250 - \text{market wt, lb}) \times .006$$

Growth, mortality, and carcass leanness did not appear to have been affected by feeding lower dietary phosphorus concentrations during the "before" period.

After examining the closeout data and observing that the feed intake was lower than the feed intake cited by the NRC,[3] we calculated the amount of dietary available phosphorus that the pigs consumed while eating each diet (Figure 3). Before the dietary revision, pigs from 95–109 kg (210 – 240 lb) consumed 95% of the NRC estimated requirement of phosphorus, and those from 109 kg (240 lb) to market consumed 68% of the NRC estimated requirement.

## Economic analysis

Processor personnel estimated that, for this herd, trim loss (lb of pork trimmed per affected carcass) cost the owners $4.25 and the processor $12.77 per affected pig, which equated to approximately $0.06 per pig marketed for the owners and $0.18 per pig marketed for the processor (Table 3).

We calculated the net economic benefit of the dietary intervention to the owners and

**Figure 2:** Incidence of pigs with minor loin damage from the case herd compared to other suppliers for a single processor during "before," "transition," and "after" periods

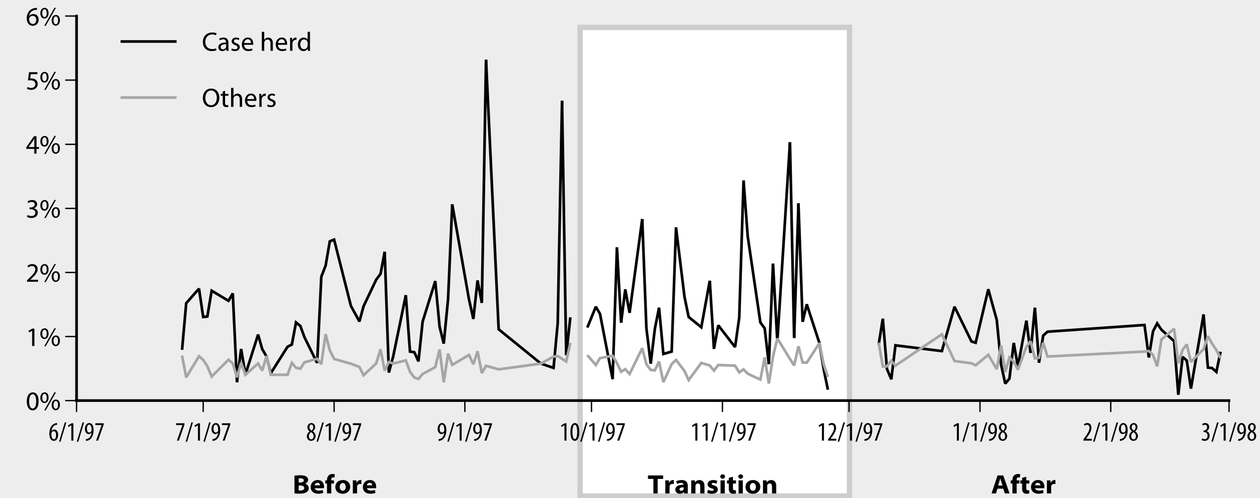


**Table 2:** Comparison of closeout growth and carcass lean of pigs in the "before" and "after" periods

| | Time period | |
|---|---|---|
| **Item** | **Before** | **After** |
| Entry weight, kg (lb) | 17.0 (37.5) | 19.5 (43.0) |
| Market weight, kg (lb) | 113.2 (249.5) | 117.3 (258.5) |
| Days on feed | 130.5 | 129.7 |
| ADG, kg (lb) | .73 (1.62) | .74 (1.64) |
| Feed:gain | 2.66 | 2.78 |
| Feed:gain adjusted* | 2.74 | 2.77 |
| Mortality | 2.9% | 4.6% |
| Lean | 54.7% | 54.6% |
| Number of groups | 17 | 11 |
| Number of pigs | 12,970 | 8354 |

* Adjusted F:G = Observed F:G + (50 – entry wt, lb) × .006 + (250 – market wt, lb) × .006.[9]

the processor based on the 0.74% reduction in minor loin damage indicated by model two, a cost to the owners ($4.25) and the processor ($12.77) per affected pig, and a $0.06 per pig marketed increase in diet cost (Table 3).

Before the dietary intervention, the net benefit to

- the owners was $0.03,
- the processor was -$0.06, and
- the pork chain was -$0.03 (Table 3).

After the intervention, the net increased income to the owners was $0.03 per pig ($4.25× 0.74%) for a net benefit of $-0.03 per pig ($0.06 increased diet cost - $0.03 increased revenue). Increasing dietary phosphorus to reduce the minor loin damage actually decreased the profit of the owners. The net benefit for the processor was $0.09 per pig ($12.77 × 0.74%) since there was no additional cost incurred. However, the pork chain value was increased by $0.03 ($0.09 reduced trim loss minus $0.06 increased diet costs). Therefore, correcting the problem resulted in a financial gain for the processor at a net cost to the owners.

## Discussion

It is unlikely that the increased frequency of loin damage observed in this herd was due solely to the reduced-phosphorus diet feed to the pigs from 109 kg to market. If it were, we would have expected to see a more rapid improvement in loin damage rates. Furthermore, we speculate that because feed intake was low in this herd, and because the pigs were a high-lean genotype, their dietary phosphorus requirement was higher than that estimated by the NRC. A number of studies reporting the effect of phosphorus in swine diets clearly demonstrate that the phosphorus requirements for maximum bone strength are higher than those for maximum growth performance.[3] Research in pigs treated with porcine somatotropin indicates that they have a greater daily dietary phosphorus requirement compared to untreated pigs, especially when it is expressed as a dietary percentage.[11,12] This occurs because lean growth rates are increased, while feed intake is lowered by the porcine somatotropin. With lowered energy consumption, pigs need a greater daily amount of phosphorus.

This case clearly illustrates that lowering dietary phosphorus concentrations can negatively influence carcass quality via loin damage and trim loss overall. Overall, increasing dietary phosphorus concentration increased the net value by $0.03 per pig. The economic loss caused by the low-phosphorus diet was greater for the processor, because the owners lost the same amount for each pound of trim, whereas the processor lost opportunity to market a portion of the carcass (loin) with the greatest economic value; thus the penalty for loin damage does not accurately reflect the severity of the economic loss for the processor. Conversely, if the owners had decided not to increase the concentrations of dietary phosphorus, they would have saved the cost of the intervention, resulting in a net profit increase of $0.03 per pig, while the processor incurred a $0.06 ([$12.74 processor loss - $4.25 penalty passed onto the owners] ×0.74%) per pig loss in value. The economic signals being sent from the processor to the herd owners in this case resulted in a net loss in value of $0.03 per pig for the owners and the packer. This illustrates how economic value can be lost in the pork chain if the true value of a defect is not signaled to previous segments in the chain.

The need to clearly signal value in the pork chain is not confined only to defects but to value-enhancing processes as well. For example, consider the economics of a nutritional modification that results in a firmer belly with higher-quality, lower-cost bacon but that has no effect on growth performance or carcass lean: under most buying programs today, carcass weight and lean are the only quality factors considered. Thus, if the producer employs the nutritional modification, s/he incurs all of the added cost of the nutritional modification and the processor enjoys all of the added economic benefit. Thus, the economic signal for the producer is clearly to forgo the use of the product and lower the total value of the pig. In this case, the owners chose to absorb the economic loss from the intervention out of consideration for other benefits (which are difficult to quantify) that derive from a long-term business relationship with the processor.

Formulating nutrient concentrations in swine diets should take more factors into account than just those necessary to maximize growth performance. Achieving the proper feeding concentration to minimize phosphorus excretion in the manure is more difficult than removing margins of safety and feeding for optimal growth performance. As this case illustrates, the phosphorus requirements suggested by the NRC are guidelines and should not be regarded as the optimums for all swine diets.

**Figure 3:** Dietary available phosphorus intake (g per day) by pigs during the "before" and "after" periods compared to NRC[3] estimated requirements

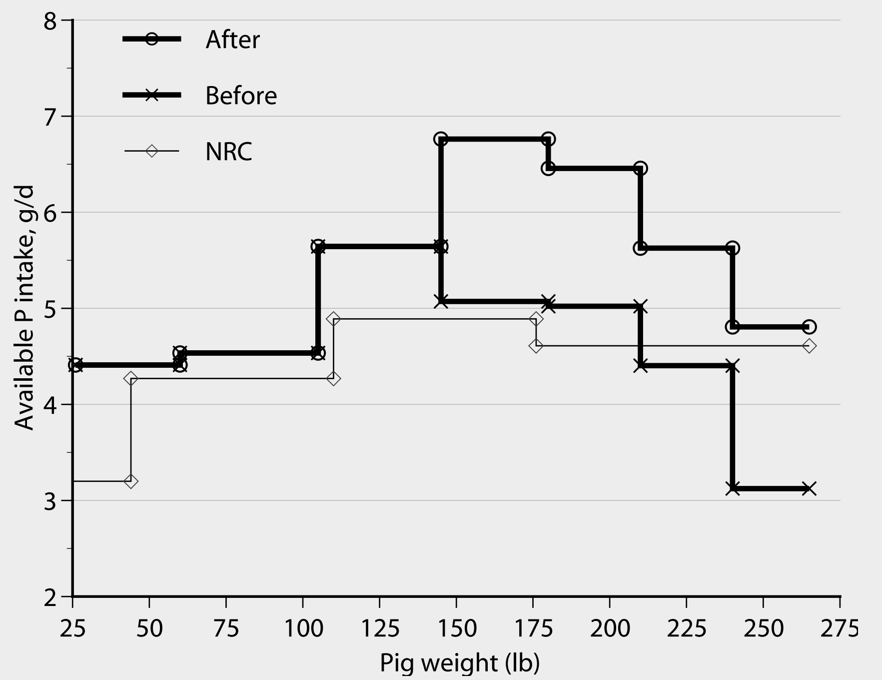


**Table 3:** Economic impact ($ per pig marketed) of an intervention increasing dietary phosphorus in the case herd

| | Producer | Processor | Pork chain |
|---|---|---|---|
| Before intervention | | | |
| reduced feed cost | .06 | — | .06 |
| increased trim loss | -.03 | -.06 | -.09 |
| net benefit = | .03 | -.06 | -.03 |
| After intervention | | | |
| increased feed cost | -.06 | — | -.06 |
| reduced trim loss | .03 | .06 | .09 |
| net benefit = | -.03 | .06 | .03 |

## Implications

- Dietary phosphorus concentrations that compromise bone strength but not growth performance can lead to problems in the processing plant due to loin damage during the stunning process.
- The dietary phosphorus requirement for optimum bone strength of the pigs observed in this case was higher than those estimated by the NRC (1998) for maximum growth performance.
- When formulating dietary phosphorus concentrations, the balance between environmental concerns and improving product quality must be weighed.

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