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The effects of feed and protein restriction between 90 and 118 days of age on performance, bone growth and mineralization of pigs reared to 168 days of age

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ABSTRACT

Forty-eight gilts were used to investigate the effects of a 30% restriction of feed (groups F) or protein (group P) in the period from 90 to 118 days of age on performance and on bone growth and mineralization between 119 and 168 days of age, when all of the pigs were fed an adequate diet at approximately 95% of *ad libitum*, with the exception of those in one of the previously feed-restricted groups, which were offered the same diet *ad libitum* (F1). During the entire experiment, control pigs (C) were fed according to a *semi ad libitum* scale. Half of the pigs from each treatment were slaughtered at the end of periods 1 and 2, and the femur and the third and fourth metacarpal and metatarsal bones were removed and weighed. Bone mineral content (BMC) and density (BMD) were determined using a DXA scanner (NORLAND). Pigs subjected to the feed and protein restrictions in period 1 were 17% ($P<0.001$) and 7% ($P<0.001$) lighter, respectively, at 118 days of age than their control counterparts. The femur and other bones of feed-restricted pigs were also significantly lighter, and their BMC and BMD significantly lower at 118 days than those of the controls. Protein restriction had no significant effect, however, on bone weight or mineralization at 118 days of age. After 118 days of age, F1 pigs grew significantly faster than pigs on all of the other treatments and were heavier at 168 days of age than control, P-, and F-treatment pigs. At 168 days, F-treatment pigs grew faster and were of a similar weight ($P>0.05$) as controls, whereas P pigs exhibited similar growth as controls. There were no significant differences in bone weight or BMC between treatments at 168 days of age, but BMD was significantly higher in the femur and fourth metatarsal bones of F- and P-treatment pigs compared with control animals. The results indicate that young pigs subjected to short-term deficiency of protein and energy intake were able to recover and even surpass the parameters of bone/skeletal mineralization compared with adequately fed pigs.

1. Introduction

In commercial pig production, the main goal of diet formulation and feeding strategies is to maximize profits, which does not necessarily imply maximal animal performance (Chiba, 2000). Improving the efficiency of nutrient utilization

Abbreviations: ADG, average daily weight gain; BL, bone length; BM, bone mass; BMC, bone mineral content; BMD, bone mineral density; BW, body weight; DXA, dual-energy X-ray absorptiometry; ME, metabolizable energy; 3 MC, 3rd metacarpal bone; 4 MC, 4th metacarpal bone; 3 MT, 3rd metatarsal bone; 4 MT, 4th metatarsal bone.

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is important for successful pig production. Studies on the compensatory response of pigs indicate that restricted feeding decreases their growth rate, but when a diet adequate for animal requirements is used (realimentation) during the following period of growth, pigs can increase their growth and better utilize feeds (Stamataris et al., 1991; Bikker, 1994; Skiba et al., 2001). Furthermore, if pigs have the ability to achieve compensatory growth, feed costs as well as excretion of unused nutrients can be decreased by introducing a restriction phase. Compensatory growth can, therefore, have a positive impact not only on the overall efficiency of pig production, but also on the environment (Fabian et al., 2002; Reynolds and O'Doherty, 2006; Varley et al., 2011). Studies of compensatory growth and body composition in pigs have focused primarily on the impact of nutrient deposition and utilization on soft tissue growth, with less attention being paid to bone growth. Compensatory growth can follow a period of feed restriction or restriction of specific nutrients. Restriction of feed intake simultaneously reduces the intake of all nutrients, including Ca and P, which negatively affects bone mineralization and health. The effects of protein restriction on bone health and quality are inconsistent, however. Dietary proteins provide the necessary amino acids for building the bone matrix and bone growth, as they alter the secretion and also the action of the osteotropic hormone, IGF-I. Several studies have shown a deleterious effect of low protein intake on bone formation (Wang et al., 1999) and mineralization (Langlois et al., 1998; Zhang et al., 2002), as well as on bone mineral mass (Bonjour et al., 2001). Some literature data (Metz et al., 1993; Feskanisch et al., 1996) also show that high dietary levels of protein contribute to osteoporosis, loss of bone mineral mass, and increased risk of fracture. This negative effect results from increased urinary Ca excretion accompanying increased protein consumption, which leads to resorption of bone Ca (Barzel, 1995; Bushinsky et al., 2001).

It is well known that at the end of fattening, pigs tend to increase carcass fatness with a simultaneous decrease of the ability to accumulate protein. Compensation is closely connected with a rapid growth rate. Therefore, we planned restrictions and realimentation so that the expected compensatory response would occur during the final stage of fattening (119–168 days of age). Thus, we tried to prolong, in a natural way, the rapid growth of pigs until slaughter.

The objective of the current experiment was to determine the effect of short-term feed or protein deficiency (90–118 days of life) on performance, bone growth and mineralization parameters in pigs grown until the age of 168 days. The information obtained from the study can be used to modify pig nutrition strategies to improve the efficiency of pig production without deterioration of growth, bone health and mineralization.

2. Materials and methods

The experimental procedures used throughout this study were performed in accordance with national/local ethical guidelines and approved by the III Local Ethics Committee on Animal Experimentation of the Warsaw University of Life Sciences – SGGW, Poland.

2.1. Animals, diets, and experimental procedures

The experiment involved 48 gilts, which were the progeny of a Danish Landrace boar and seven Large White sows that were half-sisters. At the age of 90 days the animals were allotted to four experimental groups of 12 gilts, two or three pigs from each litter were assigned per treatment to minimize genetic variability. Two diets were used in the 90–118 day period. The control diet (A) was formulated to meet NRC requirements for pigs with a starting weight of 40 kg. The low-protein diet (P) was formulated to contain approximately 30% less protein and amino acids than the control diet (Table 1). Diets A and P were supplemented with premixes that provided vitamins and minerals in amounts consistent with NRC recommendations (1998). In both diets, the ratio of total Ca to available phosphorus was 2.95:1.

Control pigs (C) were fed at approximately 95% of *ad libitum* intake. Feed-restricted pigs (F and F1) were fed at 70% of the control animals, while the protein-restricted pigs (P) were fed at a level providing 30% lower protein and amino acid intakes, but similar levels of other nutrients as the control animals. The *semi ad libitum* intake of control pigs during each week/period of the experiment was assumed based on the *ad libitum* intake of this genotype of pigs recorded in our earlier studies (unpublished data). Due to a higher energy content in diet P, the daily allowance during a successive week of the restriction was adjusted so that they consumed the same amount of energy daily, but only 70% of the protein as C pigs.

Between days 119 and 168 of age, all of the pigs were fed diet A. For pigs C, P and F, feed intake was set at approximately 95% of *ad libitum* intake. F1 pigs were offered the same diet *ad libitum*. The design is summarized in Table 2 and the feed and nutrient intakes of pigs on the different treatments during both periods are shown in Table 3. *Semi ad libitum* feeding was used to enable better control of nutrient intake in the period of 90–118 days and to allow any compensatory responses occurring between 119–168 days to be evaluated independently of changes in feed intake. The literature on compensatory growth suggests that pigs subjected to feed restriction exhibit higher feed intake than their control counterparts when offered feed *ad libitum* (De Greef, 1992; Bikker, 1994). In contrast, protein restriction appears to have a lesser effect on feed intake during realimentation (*e.g.*, De Greef, 1992). This is why only feed-restricted pigs in the current study were fed a set amount (F) and *ad libitum* (F1) in the period of 119–168 days.

Animal age plays a crucial role in the processes of both "normal" and compensatory growth (Hogg, 1991; Lawrence and Flower, 2002). For this reason the experiment was designed to compare pigs at similar ages (not body weights), thus body weight (BW) and other investigated features were only the result of the applied feeding procedure. The pigs were housed individually in pens equipped with feeders and nipple drinkers, in a thermally neutral environment. Temperature