Online Journal of Animal and Feed Research
Volume 4, Issue 5: 113-120 (2014)
ISSN 2228-7701

EFFECT OF WEANING AGE AND SEX ON BONE DEVELOPMENT OF PIGS RAISED UNDER INTENSIVE SYSTEM AND SLAUGHTERED AT 70 KG BODY WEIGHT

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ORIGINAL ARTICLE
Received 23 Feb. 2014
Accepted 20 Mar. 2014

ABSTRACT: The aim of the study was to determine the effects of weaning age and sex on bone development of pigs raised under intensive system and slaughtered at 70 kg body weight. A total of 24 piglets were randomly assigned to 3 weaning ages: treatment 1 (21 days of age), treatment 2 (28 days of age) and treatment 3 (35 days of age). Feed and water were given *ad libitum* up to slaughter weight of 70 kg. Data were analysed as completely randomized design (CRD) using the General Linear Model (GLM) procedure of statistical analysis system, version 9.3. Weaning age did not have significant ($P > 0.05$) effect on bone length and width of pigs. However, pigs weaned at 35 days of age tended to have longer femur (17.4 ± 0.17 cm), tibia (16.0 ± 0.19 cm) and humerus (15.6 ± 0.17 cm) than those weaned at 21 and 28 days of age. A 28 days weaning age resulted in significantly heavier femur (239.0 ± 6.19 g *vs.* 216.8 ± 6.19 g), tibia (145.8 ± 4.02 g *vs.* 132.0 ± 4.02 g) and humerus (211.7 ± 4.91 g *vs.* 195.9 ± 4.91 g) compared to 21 day weaning age. Tibia ash percentage was significantly higher (52.3 ± 0.65 % in pigs weaned at 35 days of age compared to those weaned at 28 (47.6 ± 0.65 %) and 21 days (46.8 ± 0.65 %). Pigs weaned at 35 days had significantly higher tibia Ca content (38.4 ± 0.36 %) compared to those weaned at 28 (37.2 ± 0.36 %) and 21 days (36.9 ± 0.36%). Phosphorus content of the tibia bone was significantly affected by weaning age while Mg content was not affected. Males had significantly heavier femurs (226.4 ± 3.89 g) than females (207.2 ± 3.89 g) pigs weaned at 21 days while tibia and humerus fresh weight of pigs weaned at 21 days was not affected by sex. Sex did not affect tibia mineral content at 21, 28 and 35 days weaning ages. Piglets can be weaned at 21 or 35 days of age without negatively affecting bone development. Twenty one days weaning age is recommended as pigs weaned at this age reach slaughter weight earlier than other weaning ages.
Keywords: Bone Length, Bone Mineral Content, Bone Weight, Sex, Weaning Age.

INTRODUCTION

In conventional pig farming, weaning involves separation of piglets from the sow and littermates, often mixing piglets with unknown peers and the loss of milk which is the main source of nutrition, thus exposing young piglets to several stressors (Hotzel et al., 2010). Pigs are weaned at around 30 days of age and then raised to market weight, often in the same buildings which can serve as breeding areas for pathogens leading to reinfection of the whole population of pigs in the farm (Whiting and Pasma, 2008). In the past decade, segregated- and medicated-early-weaning practices have been used by swine producers to optimize the health of their piglets to increase feed efficiency and growth performance which improve economic efficiency (Johnson et al., 2012). Biological changes in metabolism, immune system, and intestinal functions occur during and immediately after weaning that may have both short and long-term effects on pig growth and health, regardless of age of pig at weaning (Campbell et al., 2013).

Some of the benefits of early weaning age (≤21 days) include increased facility utilisation, increased numbers of litters per sow per year and a reduction in the spread of diseases (Worobec, 1997). However, early weaning is stressful because the piglet must quickly adapt to dramatic changes in its social and physical environment. These combined stressors have a significant impact on post weaning pig health and welfare through reductions in feed intake and performance, development of behavioural vices, and increased susceptibility to disease (Moeser et al., 2007; Colson, 2006). However, special diets and management schemes have been developed to overcome nutritional problems associated with early weaning. On the other hand, late weaning reduces stress, increases post-weaning feed intake but does not improve intestinal functionality; hence it is economically not sustainable (van der Meulen et al., 2010). Most of the differences between early-weaned and late-weaned pigs are evident soon after weaning but they disappear before slaughter (Hohenshell et al., 2000).

There is still much debate about what age piglets should be weaned (Shipka, 2011; King, 2013) as both early weaning and late weaning have advantages and disadvantages. Therefore, it is important to identify age at weaning suitable for Botswana conditions that would promote growth, performance, welfare of animals and economic

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Scienceline/Journal homepages: http://www.science-line.com/index/; http://www.ojafr.ir

viability of piggeries. Therefore, this study was carried out to determine the effect of weaning age and sex on bone development of pigs raised under intensive system and slaughtered at 70 kg body weight.

MATERIAL AND METHODS

The experiment was carried out at Chemae Farm, near Matebeleng village in Kgatleng District from May to November 2013. The site is situated on 24° 32′ 54.12′′ S 26° 1′ 3.55′′ E, at an altitude of 980 m above sea level. The area had average daily temperature of 15 °C in winter (May to July) and 29 °C in summer (August to November).

Animal management

Forty eight piglets [(Landrace x Large white) x Topigs (Tempo x Topigs 40) x Topigs] cross were randomly assigned to 3 treatments. There were 4 replicates in each treatment and each replicate had 4 pigs (2 males and 2 females). Treatment 1 was for piglets weaned at 21 days, treatment 2 at 28 days and treatment 3 at 35 days. Twenty-eight day weaning period served as a control. Teeth and tail cutting were carried out when piglets were 1 day old while iron injection and castration were done at 3 days of age. Iron injection was administered intramuscularly on the neck. Castration was performed surgically using sharp and disinfected blades.

Pigs were not vaccinated against any disease but were treated for internal parasites using piperazine (active ingredient: piperazine adipate 100%) at 1.2 g/10 kg body weight. Triatix pour on (active ingredient: amitraz 2% m/v) was used to control external parasites. Cosumix Plus (active ingredients: sulphachlorpyridazine sodium and trimethoprim) and sulfazine 33 1/3 % (active ingredient: sulphadimidine) were used to treat pigs for diarrhoea. The pigs were raised in 12 pens each measuring 2.2 m x 2.2 m in a naturally ventilated house with concrete floor and corrugated iron roofing. Wheat straw was used as bedding material and was replaced every fortnight. During cold days, heating was provided to the piglets using coal.

Diets

The pigs in all treatments were fed commercial diets that complied with Botswana Bureau of Standards pig feeds specification (BOS 190:2006). From 10 to 35 days of age, piglets were offered creep feed, weaner diet from 35 to 70 days of age and thereafter grower diet up to slaughter weight of 70 kg. Feed and water were provided *ad libitum* throughout the study period. The analysed nutritive composition of the diets expressed in g/kg is shown in Table 1.

Table 1. Nutrient composition of diets offered to pigs raised under intensive system

Nutrient (g/kg)	Creep diet	Weaner diet	Grower diet
Crude protein	185.1 ± 0.34	156.7 ± 7.15	148.5 ± 0.84
Moisture	85.2 ± 0.53	72.9 ± 0.58	76.8 ± 0.18
Crude fibre	14.9 ± 0.006	22.4 ± 1.33	64.0 ± 9.66
Crude fat	10.9 ± 0.27	17.4 ± 0.37	19.1 ± 0.35
Calcium	7.3 ± 0.07	5.5 ± 0.04	4.5 ± 0.03
Phosphorus	4.5 ± 0.06	3.3 ± 0.08	4.5 ± 0.05

Ante mortem treatment

At 70 kg body weight, pigs were transported early in the morning (i.e., 0700 hr.) in an open vehicle with rails to a local abattoir in Gaborone for slaughter. Upon arrival at the abattoir, the pigs were held in lairage for 12 hr. with free access to water until slaughter the following morning. The animals were slaughtered humanely by electrical stunning (240 V, 0.5 A, 5s), exsanguinated, scalded, dehaired and eviscerated (Serrano et al., 2009). After slaughter, the carcasses were hanged so that blood drains away. *Ante mortem* and *post-mortem* inspections were carried out by meat inspectors in accordance with Livestock and Meat Industries Act of 2007. After inspection, the carcasses were chilled at 7 °C for 24 hr.

Data collection

After 24 hr. in the chiller, the carcasses were dissected into two halves: left and right. The right half was deboned manually using knives so that bone measurements could be carried out. After deboning, all the bones were frozen at -20°C until analysis. Tibia, femurs and humeri were removed and measured for bone length, wide bone shaft width (Kanakov et al., 2004). Bone lengths and bone shaft widths were measured using digital calliper with accuracy of 0.001 mm (Chiripasi et al., 2013). Fresh weights of bones were measured immediately after deboning of the carcasses while dry weights were measured after drying the bones at 110 °C for 24 hr. (Alexander et al., 2010).

Tibia bone ash %, Ca %, P % and Mg % was determined after drying the bones. Bone marrow was physically removed from each bone using steel teaspoon. After drying, ash % was determined by ashing bones in a muffle furnace at 550 °C for 24 hr. Calcium, P and Mg were determined by dissolving 1 g of ash into 10 ml 3M hydrochloric acid and boiled for 10 minutes in a 100 ml beaker and allowed to cool for 30 minutes (AOAC, 1996). Thereafter, 1 ml of the sample was put into 200 ml volumetric flask and topped to the mark using distilled water.

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Calcium and Mg were determined using flame atomic absorption spectrophotometer (make: Varian Australia PTY Ltd, model: 220 FS) while P was determined using ultra violet spectrophotometer (make: Shimadzu, model: UV – 1800).

Statistical analysis

Data were analysed as completely randomized design (CRD) using the General Linear Model (GLM) procedure of Statistical Analysis System, version 9.3 (SAS Institute, 2010). The reported least squares means were separated using least significant difference (t test). The significance level considered for all the statistical tests was P < 0.05. The following statistical model was used for the analysis:

$Y_{ijk} = \mu + W_i + S_j + (WS)_{ij} + \beta(AGE_{ijk} - AGE) + \varepsilon_{ijk}$

where Y_{ijk} = response variable (bone development: bone length, width, fresh weight, dry weight, ash %, Ca %, P %, Mg %)

μ = general mean,

W_i = effect of weaning age at level i (21 days, 28 days, 35 days),

S_j = effect of sex at level j (male, female),

$(WS)_{ij}$ = effect of interaction WS at level ij,

β = linear regression coefficient of AGE_{ijk} on age at slaughter,

AGE = mean age of animals at slaughter,

AGE_{ijk} = age of individual animals at slaughter,

E_{ijk} = random error.

RESULTS AND DISCUSSION

Bone length

Weaning age did not have significant effect on bone length of pigs slaughtered at 70 kg body weight (Table 2). Pigs weaned at 35 days tended to have longer femur (17.4 vs.17.1 cm), tibia (16.0 vs.15.8 cm) and humerus (15.6 vs.15.2 cm) than those weaned at 28 days. Pigs weaned at 21 days of age had 17.0, 15.9 and 15.3 cm for femur, tibia and humerus lengths, respectively. The current results are consistent with Richmond and Berg (1972) who reported 15.52 cm, 17.10 cm, 16.25 cm for humerus, femur and tibia lengths, respectively for pigs weaned at 21 days and slaughtered at 68 kg. Chaudhary and Price (1987) reported femur and humerus length of 16.9 and 16.0 cm, respectively for pigs weaned at 21 days and slaughtered at 179.5 days of age. Furthermore, Liu et al. (1999) reported shorter humerus (13.04±0.58 cm), femur (14.11±0.64 cm) and tibia (12.95±0.63 cm) for pigs slaughtered at 84 days of age. According to Mao et al. (2008), studies in mice and chickens have shown that the limb bone lengths are strongly controlled by genes. Therefore, environmental factors like weaning age are unlikely to have significant effect on bone length.

As expected, pigs weaned at 35 days had numerically longer bones compared to 21 and 28 day weaning ages. Hohenshell et al. (2000) observed an improvement in average daily gain of early-weaned pigs compared with late-weaned pigs. It was suggested by Do (2012) that increasing weaning age up to 32 days can be an effective production strategy to improve growth rate which is consistent with current results.

Bone width

Weaning age did not have significant effect on bone width (Table 2). Femur width remained the same (23.0 mm) in all the weaning ages. Carter and Cromwell (1998) reported femur width of 26.90 mm which is greater than 23.0 mm found in the current study. In this study, pigs were slaughtered at 70 kg while in the study by Carter and Cromwell (1998) they were slaughtered at 114 kg body weight. Tibia and humerus were numerically wider for pigs weaned at 21 days than those weaned at 28 days. Compared to 28 day weaning age, 35 day weaning age had numerically narrower tibia (20.8 mm) and wider humerus (26.2 mm). These slight variations in bone widths could be due to differences in genetics and level of bone mineralization.

Bone weight

Fresh weight: Bone fresh weight was significantly (P<0.05) influenced by weaning age (Table 2). At 21 days weaning age resulted in lighter femur (216.8 g), tibia (132.0 g) and humerus (195.9 g) compared to 28 day weaning age. The current results are consistent with Richmond et al. (1972) who recorded weights of 207.7 g, 227.74 g and 160.48 g for humerus, femur and tibia, respectively of pigs weaned at 21 days and slaughtered at 68 kg. Similarly, Chaudhary and Price (1987) reported femur and humerus fresh weights of 243.0 and 226.0 g, respectively for pigs weaned at 21 days and slaughtered at 179.5 days of age. Narayanan et al. (2008) stated that pigs weaned at 21 days require more days to reach market weight, and hence recommended 28 day weaning age. In the current study, there was significant difference in tibia fresh weight for pigs weaned at 28 and 35 days. The tibia fresh weight of pigs weaned at 28 days was 145.8 g while it was 132.9 g for pigs weaned at 35 days. However, there was no significant difference in bone fresh weight for pigs weaned at 21 and 35 days although 35 day weaning age tended to have higher numerical values (Table 2). These findings disagree with Danko and Bilkei (2004) who found that early weaned pigs were heavier at slaughter than late weaned ones. Variations in bone weight could be attributable to bone tissue deposition and resorption that continuously occur in the body of a living animal (Hanagriff, 2012).

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Table 2. Means and standard errors of lengths, widths, weights and mineral content of bones of pigs raised under intensive system, weaned at different ages and slaughtered at 70 kg body weight

Variable	21 days	28 days	35 days	SEM	LSD	P value
Bone length (cm)						
Femur	17.0[a]	17.1[a]	17.4[a]	0.17	0.50	0.36
Tibia	15.9[a]	15.8[a]	16.0[a]	0.19	0.56	0.71
Humerus	15.3[a]	15.2[a]	15.6[a]	0.17	0.52	0.51
Bone width (mm)						
Femur	23.0[a]	23.0[a]	23.0[a]	0.41	1.22	0.96
Tibia	21.3[a]	21.1[a]	20.8[a]	0.46	1.37	0.23
Humerus	25.9[a]	25.5[a]	26.2[a]	0.34	1.00	0.10
Bone fresh weight (g)						
Femur	216.8[a]	239.0[b]	223.8[ab]	6.19	18.40	0.04
Tibia	132.0[a]	145.8[b]	132.9[a]	4.02	11.93	0.04
Humerus	195.9[a]	211.7[b]	204.2[ab]	4.91	14.60	0.01
Bone dry weight (g)						
Femur	122.9[a]	142.4[b]	128.7[a]	4.47	13.29	0.02
Tibia	76.9[a]	89.0[b]	80.4[a]	2.63	7.80	0.01
Humerus	115.2[a]	127.6[b]	118.6[ab]	3.26	9.68	0.04
Slaughter age (days)	130.8[a]	134.6[ab]	137.0[b]	1.59	4.72	0.04

SEM = Standard error of means. LSD = Least Significant Difference; [a,b] Means within the same row having different letters differ significantly; P < 0.05

Dry weight

Bone dry weight was significantly higher in pigs weaned at 28 day of age compared to other weaning ages. Pigs weaned at 28 days tended to have heavier dry humerus (127.6 g) than those weaned at 35 days (118.6 g). No significant difference in bone dry weights from pigs weaned 21 and 35 days weaning ages was observed although 35 day weaning age tended to have heavier bones (Table 2). The heavier bones from pigs weaned at 35 days could be due to the fact that pigs were on sow's milk longer than other weaning ages. Petrovič et al. (2009) stated that the characteristic feature of the suckling period of piglets is an extremely rapid development of bones enabled by unique milk nutrition with a high fat content provided by the dam.

Slaughter age

Weaning age had significant (P<0.05) influence on slaughter age (Table 2). In this study, pigs weaned at 35 days of age took a longer time (137 days) to reach market weight (70 kg) compared to those weaned at 21 days of age (130.8 days). However, there was no significant difference in slaughter age between 28 day weaning age and other weaning ages. These results agree with Danko and Bilkei (2004) who found that days to slaughter do not differ between the early or late weaned pigs.

Bone mineral content

Tibia ash was significantly higher at 35 days weaning age (52.3%) compared to 21 days (46.8%) and 28 days (47.6%) weaning ages (Table 3). However, weaning age did not have significant influence on ash content of pigs weaned at 21 and 28 days. The ash content of 47.6% in the present study is lower than the ash contents of 53.5 to 61.1% reported by Crenshaw et al. (1981) in pigs weaned at 28 days. It is also lower than 57.6% reported by Kornegay et al. (1973). The ash content of tibia in the current study is higher than 37.4% for pigs weaned at 17 days of age reported by Jolliff and Mahan (2012). The variation in the ash contents could be due to the young age (56 days) at which the pigs were slaughtered in the study by Jolliff and Mahan (2012) compared to the slaughter age of 130.8 days in the current study. Previous study by Field (2000) found that bone ash content increases with age.

There was significant difference in Ca content between 35 day weaning age and other weaning ages (Table 3). However, the Ca content of tibia bone was not significantly (P>0.05) different between 21 and 28 day weaning ages. Pigs weaned at 35 days had the highest Ca content (38.4%) and those weaned at 21 days the lowest Ca content (36.9%). There was no significant difference in P content between 28 and 35 day weaning ages although 28 weaning age tended to have higher P content (18.3%) compared to 35 days (17.4%). Phosphorus content was significantly less (16.9%) for pigs weaned at 21 days compared to those weaned at 28 days (18.3%). The current results are consistent with Field (2000) who reported Ca and P contents of bones of mammals of 37% and 17%, respectively. Varley et al. (2010) reported lower P (8.59%) and Ca (18.19%) contents in metacarpal bones. According to Saraiva et al. (2011), bone resorption occurs in order to maintain P and Ca ratio resulting in a decrease of bone mineral content. In the current study, weaning age did not have significant (P > 0.05) effect on Mg content of tibia bone although pigs weaned at 21 days tended to have higher content of Mg (0.54%) (Table 3).

Influence of sex on bone development

Bone length: Sex had no significant (P>0.05) effect on bone length of pigs weaned at 21, 28 and 35 days (Tables 4 to 6). The current results are consistent with Tatara et al. (2012) who found no significant difference between sexes in the length of femur of pigs. In the current study, females had longer tibia (16.0 cm) than males (15.7 cm). Similarly, Richmond and Berg (1972) found no significant difference in length of humerus in male and female pigs. On the contrary, Richmond and Berg (1972) reported significantly longer femur and tibia in males than

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female pigs weaned at 21 days and slaughtered at 68 kg. Essien and Fetuga (1988) also found significant difference in the lengths of femur, tibia and humerus between male and female pigs.

Table 3. Means and standard errors of mineral composition of tibia bone of pigs raised under intensive system, weaned at different ages and slaughtered at 70 kg body weight

Variable	21 days	28 days	35 days	SEM	LSD	P value
Ash %	46.8^{a}	47.6^{a}	52.3^{b}	0.65	1.92	< 0.0001
Ca%	36.9^{a}	37.2^{a}	38.4^{b}	0.36	1.06	0.03
P%	16.9^{a}	18.3^{b}	17.4^{ab}	0.45	1.35	0.01
Mg%	0.54^{a}	0.48^{a}	0.44^{a}	0.08	0.21	0.29

SEM = standard error of the means; LSD = Least Significant Difference; ^{a,b} Means within the same row having different letters differ significantly; $P < 0.05$

Table 4. Means and standard errors of lengths, widths, weights and mineral content of bones of pigs weaned at 21 days of age, raised under intensive system and slaughtered at 70 kg body weight

Variable	Male	Female	SEM	LSD	P value
Bone length (cm)					
Femur	17.0^{a}	17.0^{a}	0.18	0.67	0.88
Tibia	15.7^{a}	16.0^{a}	0.25	0.90	0.46
Humerus	15.3^{a}	15.3^{a}	0.28	1.01	0.97
Bone width (mm)					
Femur	23.0^{a}	23.1^{a}	0.50	1.80	0.93
Tibia	21.6^{a}	20.9^{a}	0.59	2.15	0.42
Humerus	26.0^{a}	25.7^{a}	0.36	1.32	0.60
Bone fresh weight (g)					
Femur	226.4^{a}	207.2^{b}	3.89	14.14	0.02
Tibia	133.9^{a}	130.2^{a}	4.98	18.10	0.62
Humerus	199.5^{a}	192.2^{a}	3.77	13.72	0.23
Bone dry weight (g)					
Femur	128.3^{a}	117.4^{b}	2.71	9.84	0.04
Tibia	79.8^{a}	74.0^{a}	2.83	10.29	0.21
Humerus	117.7^{a}	112.7^{b}	0.87	3.17	0.01
Tibia mineral content					
Ash %	46.6^{a}	47.0^{a}	0.64	2.34	0.66
Ca%	37.2^{a}	36.6^{a}	0.59	2.16	0.51
P%	16.3^{a}	17.6^{a}	0.61	2.23	0.21
Mg%	0.56^{a}	0.52^{a}	0.13	0.48	0.88
Slaughter age (days)	130.75^{a}	130.75^{a}	1.49	3.67	1.00

SEM = Standard error of means. LSD = Least Significant Difference; ^{a,b} Means within the same row having different letters differ significantly; $P < 0.05$

Table 5. Means and standard errors of lengths, widths, weights and mineral content of bones of pigs weaned at 28 days of age, raised under intensive system and slaughtered at 70 kg body weight

Variable	Male	Female	SEM	LSD	P value
Bone length (cm)					
Femur	17.1^{a}	17.2^{a}	0.27	0.98	0.86
Tibia	15.7^{a}	15.9^{a}	0.28	1.00	0.74
Humerus	14.9^{a}	15.4^{a}	0.28	0.99	0.36
Bone width (mm)					
Femur	22.6^{a}	23.4^{a}	0.68	2.42	0.67
Tibia	20.2^{a}	22.0^{a}	0.96	3.41	0.26
Humerus	25.1^{a}	26.0^{a}	0.50	1.77	0.23
Bone fresh weight (g)					
Femur	236.2^{a}	241.9^{a}	10.86	38.73	0.88
Tibia	141.7^{a}	149.9^{a}	8.39	29.94	0.61
Humerus	207.3^{a}	216.1^{a}	8.69	31.00	0.61
Bone dry weight (g)					
Femur	144.7^{a}	140.2^{a}	7.90	28.17	0.39
Tibia	89.4^{a}	88.5^{a}	5.51	19.67	0.75
Humerus	129.3^{a}	125.9^{a}	6.10	21.77	0.50
Tibia mineral content					
Ash %	48.4^{a}	46.7^{a}	0.63	2.23	0.11
Ca%	37.8^{a}	36.7^{a}	0.51	1.81	0.19
P%	18.1^{a}	18.5^{a}	0.66	2.34	0.61
Mg%	0.44^{a}	0.52^{a}	0.13	0.45	0.76
Slaughter age (days)	133.75^{a}	135.50^{a}	1.82	3.83	0.52

SEM = Standard error of means. LSD = Least Significant Difference; ^{a,b} Means within the same row having different letters differ significantly; $P < 0.05$

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Table 6. Means and standard errors of lengths, widths, weights and mineral content of bones of pigs weaned at 35 days of age, raised under intensive system and slaughtered at 70 kg body weight

Variable	Male	Female	SEM	LSD	P value
Bone length (cm)					
Femur	17.1[a]	17.8[a]	0.32	1.03	0.32
Tibia	15.8[a]	16.2[a]	0.35	1.14	0.34
Humerus	15.6[a]	15.6[a]	0.25	0.79	0.80
Bone width (mm)					
Femur	23.2[a]	22.9[a]	0.42	1.36	0.34
Tibia	20.0[a]	21.6[a]	0.48	1.54	0.06
Humerus	25.3[a]	27.1[a]	0.66	2.12	0.09
Bone fresh weight (g)					
Femur	216.5[a]	231.1[a]	8.74	28.10	0.34
Tibia	129.9[a]	136.0[a]	4.40	14.15	0.51
Humerus	195.3[a]	213.1[a]	10.11	32.51	0.26
Bone dry weight (g)					
Femur	124.7[a]	132.7[a]	5.53	17.78	0.62
Tibia	77.1[a]	83.7[a]	2.38	7.65	0.35
Humerus	113.8[a]	123.5[a]	5.85	18.81	0.39
Tibia mineral content					
Ash %	51.7[a]	52.9[a]	1.42	4.55	0.52
Ca%	38.2[a]	38.5[a]	0.51	1.66	0.43
P%	17.3[a]	17.4[a]	0.85	2.72	0.78
Mg%	0.43[a]	0.44[a]	0.14	0.46	0.81
Slaughter age (days)	133.0[a]	141.0[a]	3.10	2.87	0.18

SEM = Standard error of means. LSD = Least Significant Difference; [a,b] Means within the same row having different letters differ significantly; P < 0.05

Bone width

Sex had no significant (P>0.05) effect on bone width of pigs weaned at 21, 28 and 35 days of age (Tables 4 to 6). These results agree with Wiseman (2006) who found that femur thickness was not significantly affected by sex. However, in the current study, males tended to have wider tibia (21.6 mm) than females (20.9 mm) for pigs weaned at 21 days. Similarly, males tended to have wider humeri (26.0 mm) than females (25.7 mm) but narrower femurs (23.0 mm) than females (23.1 mm). Dikić et al. (2007) found the diameter of humeri and femurs to be 27.7 mm and 25.6 mm respectively for Swedish Landrace pigs. In the current study, females that were weaned at 28 days tended to have wider femur, tibia and humerus than males. In addition, female pigs that were weaned at 35 days of age tended to have wider tibia and humerus than males (Table 6).

Bone weight

Fresh weight: Sex had significant effect (P<0.05) on fresh weight of femur from pigs weaned at 21 days of age (Table 4). Females had significantly heavier femur (226.4 g) compared to males (207.2 g). However, tibia and humerus fresh weight of pigs weaned at 21 days was not affected by sex. The current results on tibia and humerus fresh weight disagree with Essien and Fetuga (1988) who reported significant difference in the weights of tibia and humerus between male and female pigs. The present results on tibia and humerus are partially consistent with Richmond et al. (1972) who reported no significant influence of sex on fresh weight of femur, humerus and tibia of pigs weaned at 21 days and slaughtered at 68 kg. In the current study, sex had no significant influence on fresh weight of bones of pigs weaned at 28 and 35 days of age although females tended to have heavier bones than males. This variation in bone weights could be due to the differences in stage of skeletal maturity between the pigs at time of slaughter (Richmond et al., 1979).

Dry weight: Sex had significant (P<0.05) effect on dry weight of femur and humerus for pigs weaned at 21 days of age (Table 4). Males had significantly heavier femur (128.3 g) and humerus (117.7 g) compared to females. The current results agree with Richmond et al. (1979) who found significant difference in the weights of individual bones of male and female pigs. However, bone dry weight in the present study was not influenced by sex in pigs weaned at 28 and 35 days of age. However, males from pigs weaned at 28 days tended to have heavier dry bones while females from pigs weaned at 35 days of age tended to have heavier dry bones (Tables 5 to 6).

Bone mineral content

Sex did not significantly affect tibia mineral content at 21, 28 and 35 days weaning ages (Tables 4 to 6). However, males tended to have higher Ca and Mg contents than females for pigs weaned at 21 days. Females weaned at 28 days tended to have higher P and Mg contents while males tended to have lower content of ash, Ca, P and Mg (Tables 3 and 4). These results disagree with Bollen et al. (2006) who found that bone Ca, P, and Mg were significantly different between sexes, with females expressing higher values than males.

To cite this paper: Ganelang B., Moreki J.C., Nsoso S.J., Tsopito C.M. 2014. Effect of weaning age and sex on bone development of pigs raised under intensive system and slaughtered at 70 kg body weigh. *Online J. Anim. Feed Res.*, 4 (5): 113-120.
Scienceline/Journal homepages: http://www.science-line.com/index/; http://www.ojafr.ir

Slaughter age

Sex did not significantly (P >0.05) influence slaughter age (Tables 4 to 6). However, females took more days to reach slaughter weight (70 kg) compared to males. These findings disagree with Serrano et al. (2009) who found females to be superior in growth performance to their castrated male counterparts. Latorre et al. (2003), Morales et al. (2011) and Piao et al. (2004) argued that males consume more feed and hence grow faster than their female counterparts.

CONCLUSION

Weaning age and sex did not affect bone length, width, weight and mineral composition of pigs raised under intensive system. Piglets can be weaned at 21, 28 or 35 days of age under intensive system without negatively affecting bone development. Twenty one days weaning age is recommended as pigs weaned at this age reach slaughter weight earlier than other weaning ages.

ACNOWLEDGEMENTS

The authors would like to thank Botswana government for the financial assistance and management of Chemae farm for providing the facilities to carry out trials. We also thank the University of Botswana, Ministry of Agriculture (Botswana) and Botswana National Food Research and Technology Centre for their assistance in analyzing samples and data.

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