2002

Serum Concentrations of IGF-1 and Steroids in Growing Boars, Barrows and Gilts.

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SDSU

SWINE 2001-16

Introduction

It is known that boars, barrows, and gilts grow at different rates and with varying efficiencies. Gilts generally eat less, grow slower, but are more efficient and have leaner carcasses than. One way in which growth may be regulated in pigs is through changes in circulating IGF-I and (or) IGF binding proteins (IGFBPs). Insulin-like growth factor-I has been shown to stimulate amino acid and glucose uptake and increase protein synthesis, while IGFBPs can function to inhibit or potentiate the actions of IGFs.

Estradiol has been demonstrated to regulate expression of the IGF system. Administration of estradiol increased serum concentrations of IGF-I and relative amounts of IGFBP-3 and-4 in the ewe. Boars produce more estradiol than gilts or barrows and also exhibit greater serum concentrations of IGF-I and IGFBP-3. Boars produce more testosterone than gilts or barrows, which may work in concert with estradiol to increase circulating levels of IGF-I and IGFBP-3 similar to what is observed in implanted steers. The objectives of the current experiment were to determine 1) if serum concentrations of IGF-I, estradiol-17β, testosterone, and relative amounts of IGFBPs differ in growing boars, barrows, and gilts, and 2) if growth rate and circulating levels of IGF-I and relative amounts of serum IGFBPs were related to serum concentrations of estradiol and testosterone.

Materials and Methods

Animals: Crossbred (Hampshire x Duroc x Yorkshire x Landrace) boars (n=11), barrows (n=11), and gilts (n=12) of similar age (67.6 ± .7 d) and weight (31.2 ± .4 kg) were stratified by litter in this experiment. Beginning at 70 d of age and continuing through 140 d of age, pigs of similar sex were housed in pens (1.2 x 2.4 m) of 3 or 4 pigs/pen and given ad libitum access to water and a 17% CP corn-soybean meal diet containing .9% lysine and 3.3 Mcal ME/kg. Pigs were weighed and blood samples obtained by jugular venipuncture every 14 d beginning at 70 d of age. Feed disappearance was recorded at 14 d intervals at 1400 beginning at 98 d of age. Rate of live weight gain was calculated as the average daily rate of live weight change from 70 to 140 d of age. Gain: feed ratios were calculated for each sex (boars, barrows, and gilts) as the ratio of live weight gain to feed disappearance from 98 to 140 d of age. *Measurement of IGF-I:* Serum concentrations of IGF-I were determined in duplicate in all blood samples by RIA. Serum concentrations of estradiol-17β were determined in duplicate by RIA in all samples from gilts and boars. Serum concentrations of testosterone were determined in duplicate by RIA in all blood samples of boars. Relative amounts of serum IGFBPs were analyzed by one-dimensional SDS-PAGE and ligand blot analysis.

Statistical Analyses. The effects of sex and age on serum concentrations of IGF-I, estradiol-17β, and relative amounts of serum IGFBPs were analyzed by least squares for a split-plot design. The effect of age on serum concentrations of testosterone in boars was analyzed by one-way ANOVA. The effect of sex on gain:feed ratios, feed disappearance, and ADG from 98 d of age to 140 d of age were analyzed by one-way ANOVA.

Results

Mean serum concentrations of IGF-I were similar ($P > .05$) in boars, barrows, and gilts at 70 d of age (Table 1). By 84 d of age mean serum concentrations of IGF-I were greater ($P < .05$) in boars than in barrows and gilts and continued to be greater through 140 d of age. Mean serum concentrations of IGF-I did not differ ($P > .05$) among barrows and gilts except at 112 d of age when mean serum concentrations of IGF-I were greater ($P < .05$) in gilts than in barrows. Age related differences in serum concentrations of IGF-I were also observed within each sex. Serum concentrations of IGF-I were greater in boars 84 d of age compared to boars 70 d of age, with boars at 126 d of age having the greatest serum concentrations of IGF-I. Serum concentrations of IGF-I were greater ($P<.05$) in barrows at 84, 126, and 140 d of age compared to barrows at 70 d of age; however, serum IGF-I in barrows at 98 and 112 d of age were similar ($P>.05$) to barrows at 70 d of age. Serum concentrations of IGF-I in gilts 84, 112, 126, and 140 d of age were greater ($P<.05$) than in gilts at 70 d of age, but serum IGF-I was similar ($P>.05$) between gilts at 70 and 98 d of age.

Five IGFBPs of different molecular masses were detected in the serum. On the basis of the similarity of the molecular weights and results of immunoprecipitation of IGFBPs in porcine serum, these serum IGFBPs were identified as the 24 and 28 kDa forms of IGFBP-4, the 41 and 46 kDa forms of IGFBP-3, and 34 kDa IGFBP-2. Relative amounts of the 24 kDa form of IGFBP-4 and the 41 kDa form of IGFBP-3 were less ($P<.05$) in gilts than in barrows and boars at 70 d of age (Figure 1), whereas no difference was detected in relative amounts of the 46 kDa form of IGFBP-3, or the 28 kDa form of IGFBP-4 among boars, barrows, and gilts at 70 d of age. Relative amounts of the 46 kDa IGFBP-3 (Figure 2A), 41 kDa IGFBP-3 (Figure 2B), and the 28 kDa IGFBP-4 (Figure 2C) were greater ($P<.05$) in boars than in barrows or gilts from 84 to 140 d of age. No difference was detected ($P>.05$) in relative amounts of these IGFBPs between barrows and gilts from 84 to 140 d of age. Relative amounts of IGFBP-2 were greater ($P<.05$) in barrows than boars or gilts at 70 d of age (Table 2). Relative amounts of IGFBP-2 in boars and barrows were similar ($P>.05$) at 84 d of age, but relative amounts were greater ($P<.05$) in boars than in gilts. Relative amounts of IGFBP-2 were greater ($P<.05$) in barrows at 98 d of age compared to boars and gilts. Relative amounts of IGFBP-2 were similar ($P>.05$) among boars, barrows, and gilts at 112 d of age. Relative amounts of IGFBP-2 were similar ($P>.05$) in boars and barrows at 126 d of age, however, relative amounts were less ($P<.05$) in gilts compared to barrows. By 140 d of age, relative amounts of IGFBP-2 were less in gilts than in boars or barrows. Relative amounts of IGFBP-2 decreased ($P<.05$) in boars, barrows, and gilts from 70 to 140 d of age. Relative amounts of the 24 kDa IGFBP-4 did not differ ($P<.05$) among sexes or with age after 70 d of age (data not shown).

Mean serum concentrations of estradiol-17β were similar ($P>.05$) between gilts and boars at 70 d of age (Figure 3). Beginning at 84 d of age, and continuing through 140 d of age, mean serum concentrations of estradiol-17β were greater in boars ($P<.05$) than in gilts. Mean serum concentrations of estradiol-17β increased ($P<.05$) with increasing age in boars.

Mean serum concentrations of testosterone increased ($P<.05$) with increasing age in boars (Figure 4). Mean serum concentrations of testosterone were similar at 70 and 84 d of age, but by 98 d of age serum concentrations of testosterone were greater ($P<.05$) than at 70 d of age. Mean serum concentrations of testosterone were greater at 126 and 140 d of age compared to 70, 84, and 98 d of age.

Gain:feed ratios from 98 to 140 d of age were greater ($P<.05$) in boars (.41 ± .02) than in gilts (.29 ± .02) or barrows (.33 ± .02). Gain:feed ratios were similar ($P>.05$) between gilts and barrows. Average daily gain was similar ($P>.05$) between boars (1.14 ± .02 kg) and barrows (1.11 ± .02 kg) and each was greater ($P<.05$) than gilts (.93 ± .02 kg). Feed disappearance was similar ($P>.05$) between barrows (3.41 ± .18 kg/d) and gilts (3.23 ± .18 kg/d) and each was greater ($P<.05$) than boars (2.71 ± .18 kg/d).

Discussion

It is well established that boars generally grow faster and more efficiently than barrows and gilts. Because IGF-I stimulates amino acid and glucose uptake, part of the reason for the increased growth rate and efficiency in boars over barrows and gilts may be due to differences in circulating levels of IGF-I. Serum concentrations of IGF-I are positively correlated with growth rate in pigs and other animals, and changes in serum concentrations of IGF-I and relative amounts of IGFBPs occur as pigs grow. In the present experiment, serum concentrations of IGF-I were similar in boars, barrows, and gilts at 70 d of age but from 84 through 140 d of age serum concentrations of IGF-I were greater in boars than in barrows or gilts. Boars were also more feed efficient than barrows and gilts as evidenced by greater gain to feed disappearance ratios. An overall increase in serum concentrations of IGF-I was observed with age in all sexes. This same phenomenon has been reported in sheep, where greater serum concentrations of IGF-I were found in rams compared to ewes. Increased serum concentrations of IGF-I in boars may partly be responsible for their increased growth performance over that observed in barrows and gilts.

The role of IGFBPs can be to inhibit or stimulate the actions of IGF-I. Five different IGFBPs of varying molecular masses were found in the serum of boars, barrows, and gilts in this experiment.

Relative amounts of the 46 and 41 kDa forms of IGFBP-3, the predominant IGFBP found in serum, increased with increasing age in boars in the present study. Increased relative amounts of IGFBP-3 are likely due to the increased serum concentrations of IGF-I found in boars as they age. The function of a large amount of IGF-I bound to IGFBP-3 might allow the complex to serve as a reservoir of IGF-I. If IGFBP-3 provides a more stable serum reservoir of IGF-I, more IGF-I would be available to increase nitrogen retention, protein synthesis, and total body protein accretion. These anabolic effects of IGF-I, working alone or in concert, could then contribute to the increased growth efficiency of boars over that of barrows and gilts as was evidenced in this study.

Boars in the present study grew more efficiently than barrows and gilts as evidenced by greater G:F ratios and decreased feed disappearance. Feed disappearance was negatively correlated with relative amounts of both forms of IGFBP-3 and the 24 kDa form of IGFBP-4. Increased relative amounts of these serums IGFBPs may have allowed boars to reduce feed intake and gain more efficiently. These IGFBPs, especially IGFBP-3, may increase the half-life of endogenous IGF-I, thus, increasing its bioavailability.

Serum concentrations of estradiol-17β and the 28 kDa form of IGFBP-4 were greater in boars than gilts from 84 to 140 d of age. Perhaps the increase in relative amounts of the 28 kDa form of IGFBP-4 in boars acts to protect cells from over-stimulation by binding with IGF-I and preventing it from interacting with its receptor. This proposed mechanism might be necessary if rising serum concentrations of estradiol-17β increase serum concentrations of IGF-I in boars, as in the ewe.

The fact that steroids, and in particular estrogens and androgens, have the ability to enhance lean growth in ruminant animals has been established. However, less is known about how endogenously produced steroids affect growth in non-ruminants and the pig in particular. In the present study boars had greater serum concentrations of IGF-I than either barrows or gilts. Administration of estradiol-17β to ewes has been shown to increase serum concentrations of IGF-I. Coincident with the increase in serum concentrations of IGF-I in boars in this study was an increase in serum concentrations of estradiol-17β. Boars naturally produce more estradiol-17β than gilts or barrows. Perhaps some of the enhanced growth effects in boars could be attributed to increased serum concentrations of IGF-I resulting from increased serum concentrations of estradiol-17β.

While it is tempting to speculate that estradiol-17β caused the increase in serum concentrations of IGF-I in boars over that observed in barrows and gilts, the possible effects of testosterone cannot be discounted. Relative amounts of serum IGFBP-2 in boars decreased at a time coincident with an increase in serum concentrations of testosterone. Insulin-like growth factor binding protein-2 is normally believed to function to inhibit the activity of IGF-I. Thus, if rising serum concentrations of testosterone function to decrease an inhibitory IGFBP (IGFBP-2) and estradiol-17β functions to increase serum IGF-I, the net effect may be manifested by an increase in growth performance of boars over barrows and gilts due to the anabolic effects of IGF-I. Exact roles and mechanisms by which steroids regulate the IGF system and subsequent growth require further investigation.

Results of this study indicate that increased serum concentrations of IGF-I may play a role in the increased growth performance seen in boars compared to barrows and gilts. The increase in serum concentrations of steroids concomitant with increases in serum IGF-I and changes in relative amounts of specific IGFBPs suggests estrogens and androgens may be involved in enhancing lean growth through changes in components of the IGF system. This information may lead to ways in which lean growth in barrows and gilts could be enhanced to achieve levels similar to that observed in boars.

TABLE 1. [a]MEAN SERUM CONCENTRATIONS OF IGF-I (NG/ML) IN BOARS (n=11), BARROWS (N=11), AND GILTS (N=12) FROM 70 TO 140 D OF AGE.

	Sex		
Age, d	Boar	Barrow	Gilt
70	$110.63 \pm 10.72^{b/f}$	$98.37 \pm 12.22^{b/f}$	$125.55 \pm 11.48^{b/f}$
84	$222.38 \pm 10.13^{c/f}$	$169.99 \pm 10.14^{c/g}$	$155.91 \pm 9.7^{c/g}$
98	$182.04 \pm 10.13^{d/f}$	$128.49 \pm 10.75^{b/g}$	$135.34 \pm 9.7^{bd/g}$
112	$189.23 \pm 10.13^{d/f}$	$128.28 \pm 10.14^{b/g}$	$159.65 \pm 9.7^{cd/h}$
126	$254.29 \pm 10.75^{e/f}$	$157.52 \pm 10.14^{c/g}$	$164.26 \pm 9.7^{c/g}$
140	$224.41 \pm 10.75^{c/f}$	$148.06 \pm 10.14^{a/g}$	$148.06 \pm 9.7^{bcd/g}$

[a]Means are least-square means ± SEM
[bcde]Means with different letters within a column differ by age (P<.05)
[fgh]Means with different letters within a row differ by sex (P<.05)

TABLE 2. [a]MEAN RELATIVE AMOUNTS OF SERUM IGFBP-2 IN BOARS (n=11) AND GILTS (n=12) FROM 70 TO 140 D OF AGE

	Sex		
Age, d	Boar	Barrow	Gilt
70	$.98 \pm .03^{b/e}$	$1.24 \pm .03^{b/f}$	$1.02 \pm .03^{b/e}$
84	$.98 \pm .03^{b/e}$	$.91 \pm .03^{c/ef}$	$.85 \pm .03^{c/f}$
98	$.83 \pm .03^{c/e}$	$.95 \pm .03^{c/f}$	$.80 \pm .03^{c/e}$
112	$.83 \pm .03^{c/e}$	$.83 \pm .03^{d/e}$	$.81 \pm .03^{c/e}$
126	$.83 \pm .03^{c/ef}$	$.96 \pm .03^{c/e}$	$.84 \pm .03^{c/f}$
140	$.83 \pm .03^{c/e}$	$.83 \pm .03^{d/e}$	$.69 \pm .03^{d/f}$

[a]Means are least-square means ± SEM. Values are expressed in arbitrary densitometer units (ADU).
[bcd]Means with different letters within a column differ by age (P<.05)
[ef]Means with different letters within a row differ by sex (P<.05)

Figure Legends

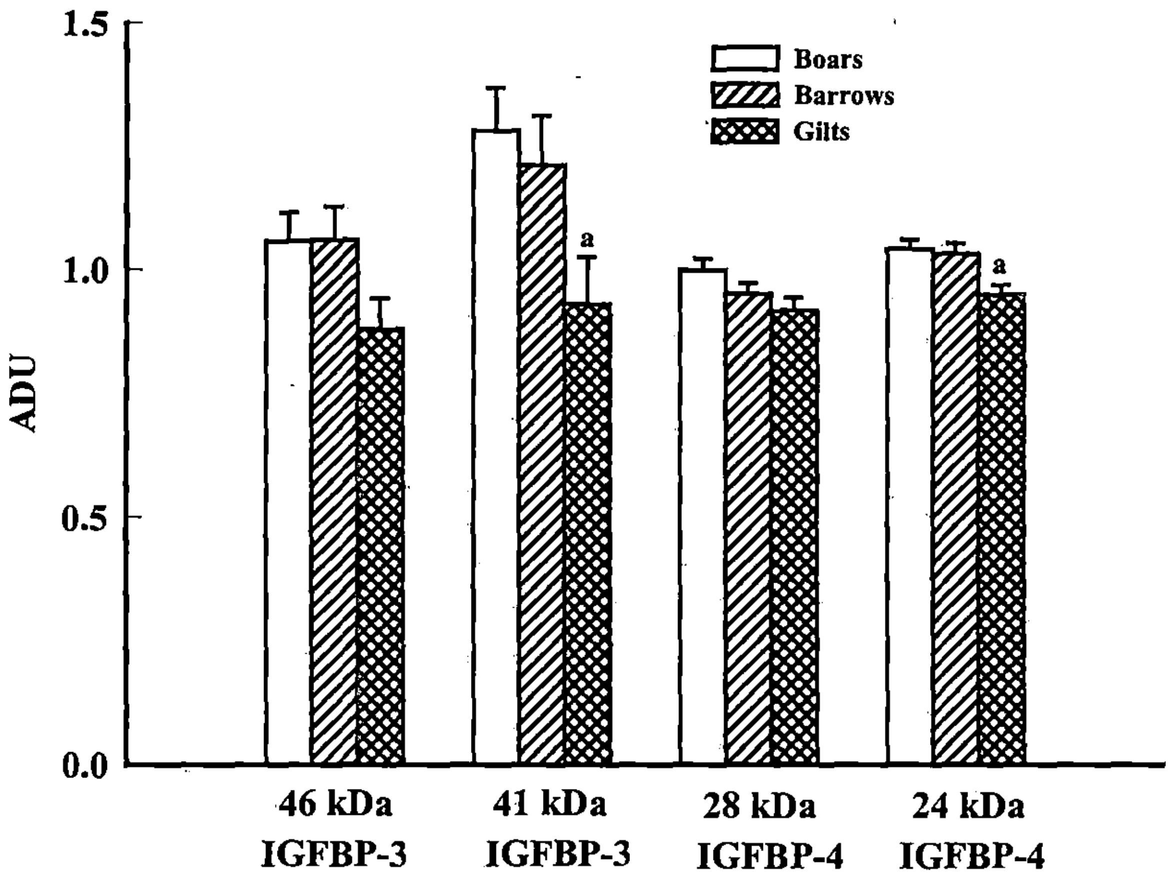
- Figure 1. Relative amounts of IGFBPs in serum of boars (n=11), barrows (n=11), and gilts (n=12) at 70 d of age. Means are least-square means ± SEM. Data are expressed in arbitrary densitometer units (ADU). Means with the letter "a" differ (*P*<.05).

- Figure 2. Relative amounts of 46 kDa IGFBP-3 (A), 41 kDa IGFBP-3 (B), and 28 kDa IGFBP-4 (C) in serum of boars (n=1), barrows (n=1), and gilts (n=12) from 84 to 140 d of age. Means are least-square means ± SEM. Data are expressed in arbitrary densitometer units (ADU). Means with the letter "a" differ according to sex (*P*<.05).

- Figure 3. Mean serum concentrations of estradiol-17β in boars (n = 11), and gilts (n = 12) from 70 to 140 d of age. Means are least-square means ± SEM. Means with different letters differ according to sex and (or) age (*P*<.05).

- Figure 4. Mean serum concentrations of testosterone in boars (n=11) from 70 to 140 d of age. Means are least-square means ± SEM. Means with different letters differ according to age (*P*<.05)

Figure 1.



1.5
1.0
0.5
0.0
ADU
Boars
Barrows
Gilts
a
a
46 kDa
IGFBP-3
41 kDa
IGFBP-3
28 kDa
IGFBP-4
24 kDa
IGFBP-4

Figure 2.

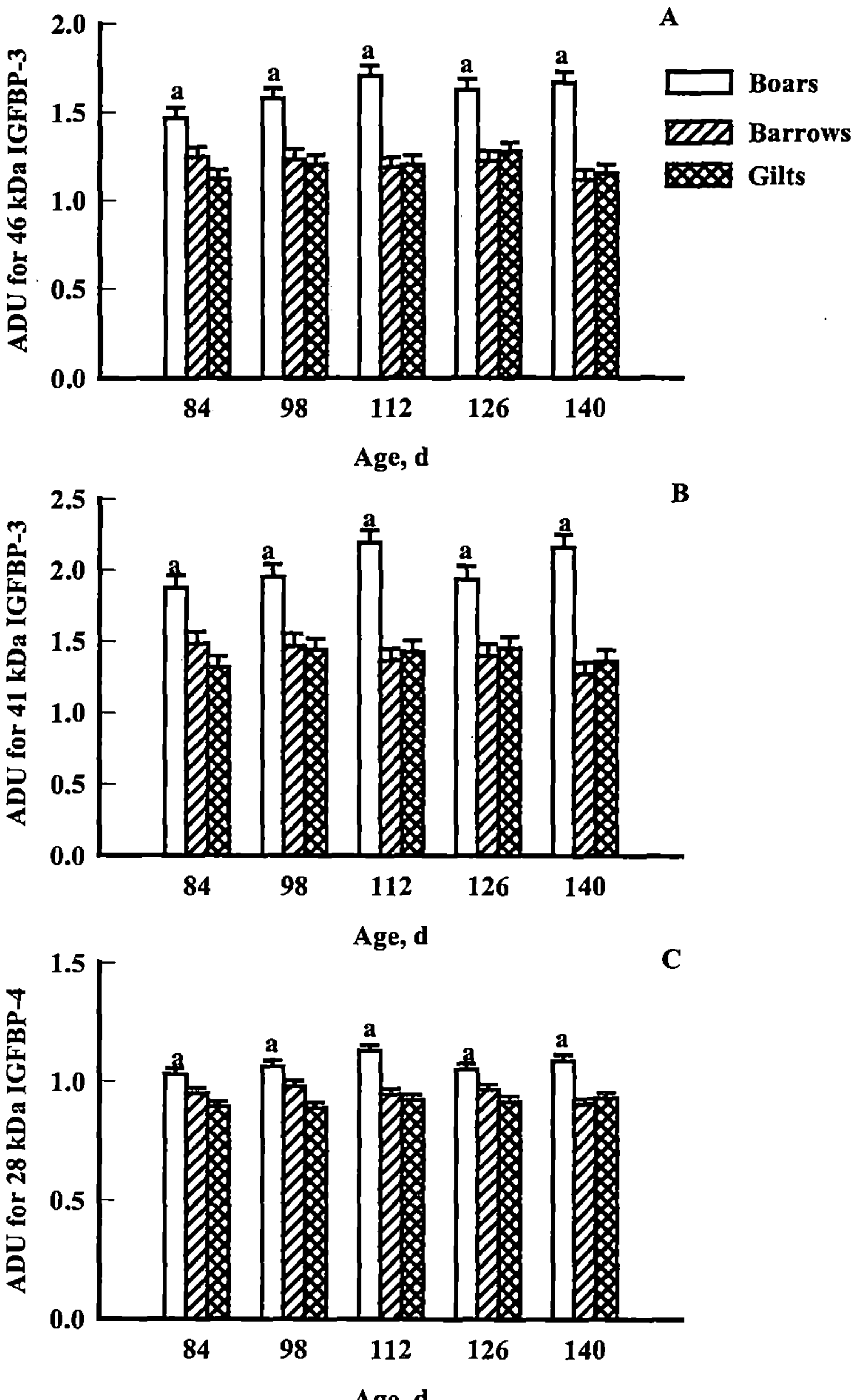

A
B
C
Boars
Barrows
Gilts
ADU for 46 kDa IGFBP-3
ADU for 41 kDa IGFBP-3
ADU for 28 kDa IGFBP-4
Age, d
84
98
112
126
140
a

Figure 3.

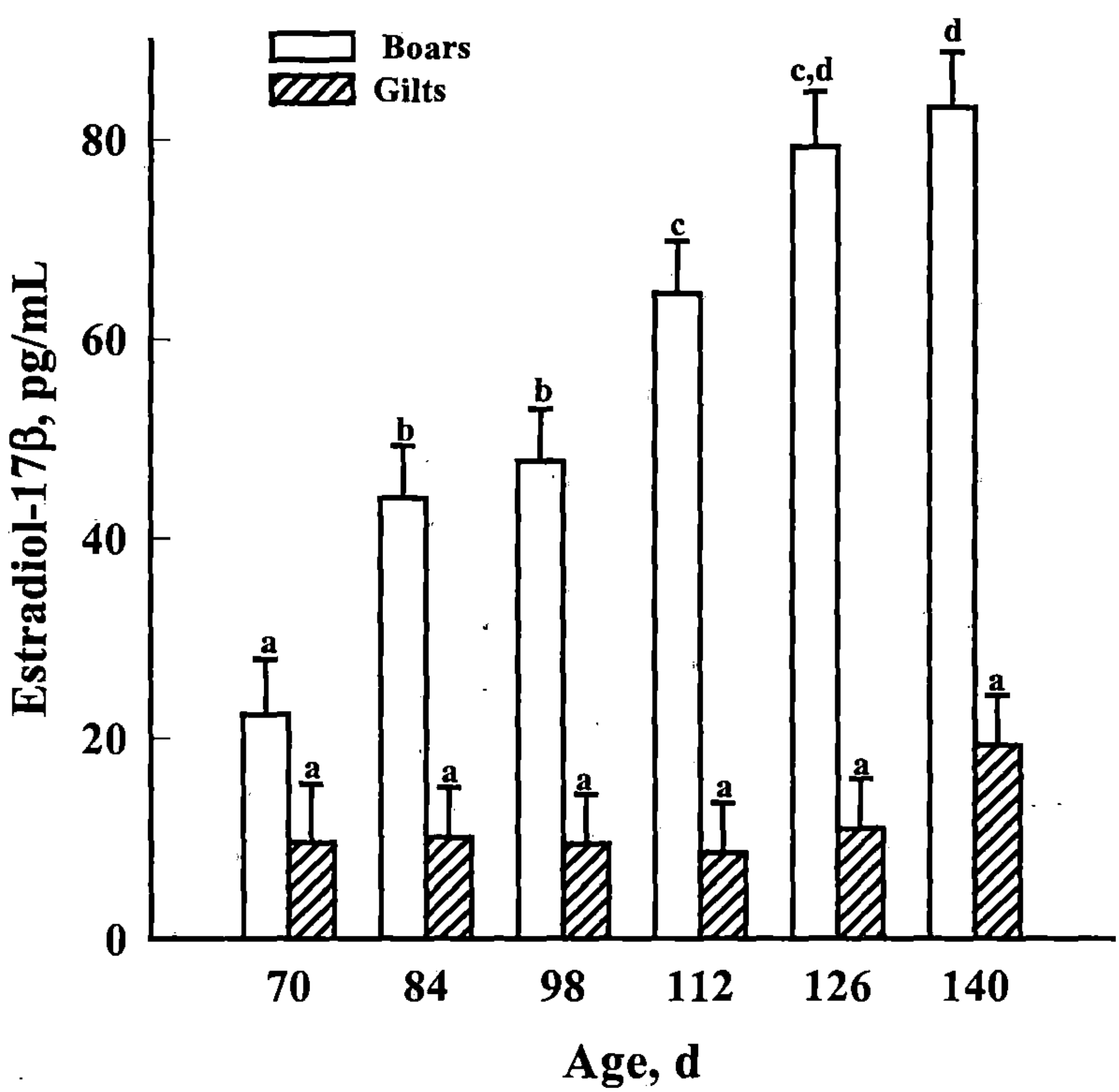
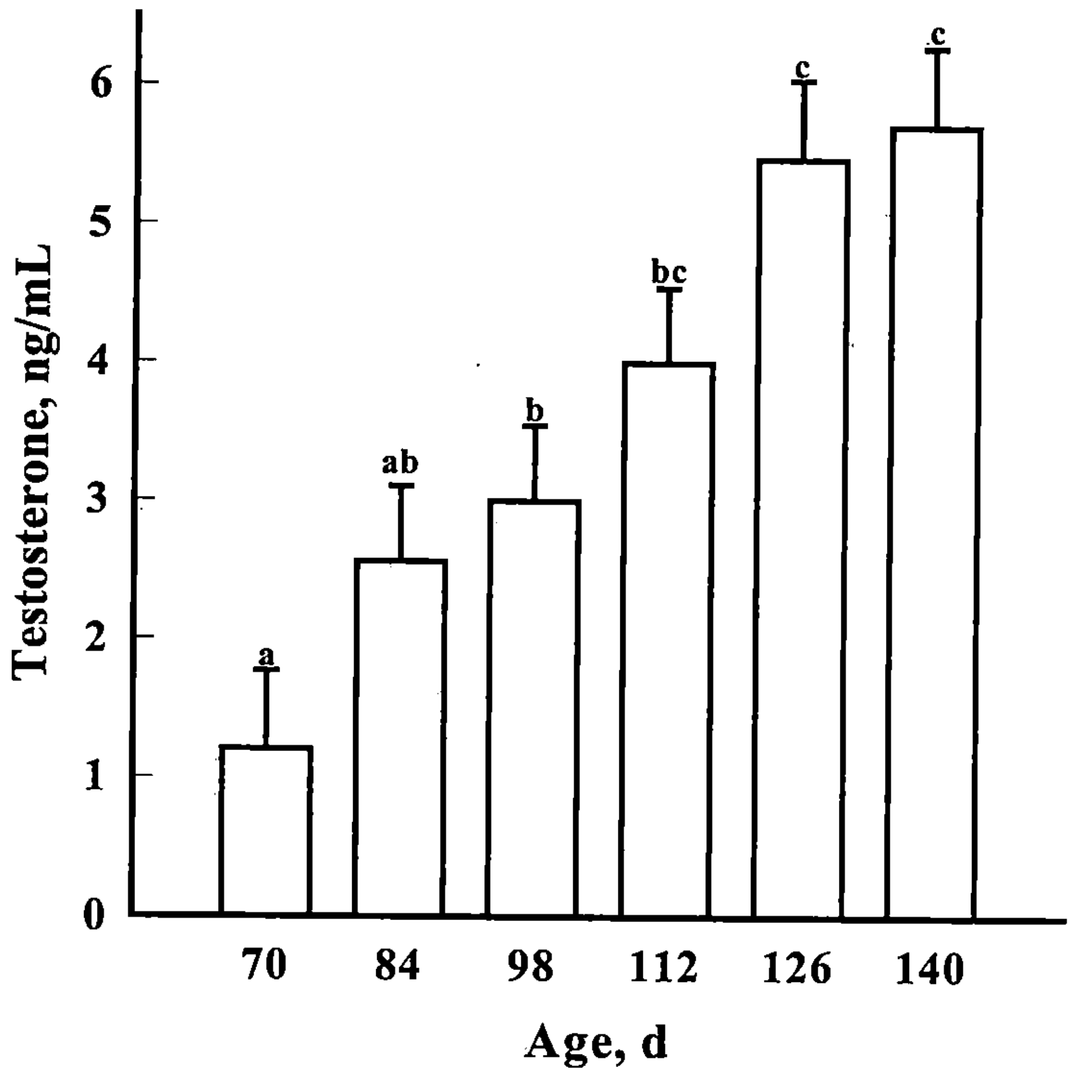

Boars
Gilts
Estradiol-17β, pg/mL
80
60
40
20
0
a
a
b
a
b
a
c
a
c,d
a
d
a
70
84
98
112
126
140
Age, d

Figure 4.



Testosterone, ng/mL
0
1
2
3
4
5
6
a
ab
b
bc
c
c
70
84
98
112
126
140
Age, d