Mechanism of Fat to puberty initiation?

BODY ENERGY RESERVES AT PUBERTY IN BEEF HEIFERS

Chad C. Chase, Jr., Robert B. Simpson, Andrew C. Hammond,
Mimi J. Williams and Timothy A. Olson
USDA, Agricultural Research Service,
Brooksville, FL 34605-0046 and
University of Florida, Gainesville 32611.

Introduction

Efficient development of breeding animals is necessary to sustain productive and profitable livestock enterprises. A primary expense to producers of beef cattle involves raising replacement heifers. In most regions of the U.S., management practices have been intensified to calve heifers first at 24 months of age, which requires heifers to initiate estrous cycles prior to 15 months of age. Breed, nutrition (or weight gain) and season are factors that have been shown to affect age at puberty in beef heifers. How these factors, particularly nutrition, impinge upon the coordinated involvement between the hypothalamus, pituitary and ovaries to initiate estrous cycles has not been fully elucidated.

Frisch (1976) hypothesized that a critical body composition, specifically a critical level of body fat, initiates estrous cyclicity/puberty. Recently this hypothesis has been examined in beef heifers (Brooks et al., 1985; Yelich et al., 1991ab; Yelich et al., 1992; Hall et al., 1993; Hopper et al., 1993). Related to this subject, there is a current Southern Regional Research Project "Improving Reproductive Efficiency in Cattle" (S-248). Two of the objectives of this regional project are 1) to determine the effect of growth rate on body energy reserves at puberty in heifers and 2) to elucidate mechanisms by which body energy reserves regulate reproductive function in heifers. The purpose of this paper is to review reported research results that have concentrated on the body composition of heifers at puberty, to summarize our results from the Subtropical Agricultural Research Station, and to report on the progress of S-248.

Body Composition of Heifers at Puberty

Several experiments have been conducted to evaluate body composition of beef heifers at puberty. Each of the studies discussed have included a nutritional component and some also had a breed component. Brooks et al. (1985) determined the effect of energy level on body composition at puberty in heifers. These authors estimated the body composition of 120 heifers at puberty in a two year study (year 1: 40 Hereford, 7 Angus, 6 Simmental and 19 Shorthorn x Charolais x Hereford and year 2: 24 Hereford, 13 Shorthorn x Charolais and 11 Charolais x Hereford). In both years, heifers were weaned and fed 80, 100 or 120% of energy requirement during a winter feeding phase followed by a spring pasture phase (tall fescue - red clover pasture). Puberty was determined by rectal palpation for the presence of a corpus luteum at two-week intervals. Body composition was estimated using a whole body counter to measure the naturally occurring radioactive isotope of potassium (^{40}K) in the live animal. The amount of ^{40}K in an animal is directly related to muscle mass of that animal. In year 1 of their study, energy level had no effect on age at puberty (Table 1). However, as the energy level was increased from 80 to 120% of the maintenance energy

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requirement, body weight at puberty and the percentage of body fat at puberty increased, while the percentage of body protein decreased. In year 2 of their study, energy level did not affect any variables measured (mean measurements at puberty were 429 days of age, 661 lb body weight, 15.7% body fat and 19.0% body protein). These authors indicated that their results did not support a critical body composition/body weight hypothesis in beef heifers.

The effect of postweaning weight gain on body composition at puberty in beef heifers was investigated by Yelich et al. (1991ab; 1992). This research was a contribution to the S-248 regional project. These researchers fed a total of 38 heifers to gain either 1) 3 lb/day until puberty (n = 13), 2) 1.5 lb/day until puberty (n = 12), or 3) .4 lb/day for 16 weeks and then fed to gain 3 lb/day until puberty (n = 13). Heifers were considered pubertal when plasma concentrations of progesterone were greater than 1 ng/mL for two consecutive weeks. Total body fat was determined by physical separation of intramuscular and subcutaneous fat from one side of the carcass, plus total omental, perinephric and udder fat. The percentage of separable fat was expressed on a carcass basis. These authors reported that heifers fed to gain 3 lb/day reached puberty earlier and at a heavier body weight than heifers fed to gain 1.5 lb/day, or heifers fed to gain .4 lb/day for 16 weeks then 3 lb/day until puberty (Yelich et al., 1992; Table 2). Furthermore, the heifers fed to gain 3 lb/day had a higher body condition score and higher percentage of separable fat (29.4%) in their carcasses than heifers fed to gain 1.5 lb/day (19.4%), or .4 lb/day for 16 weeks then 3 lb/day until puberty (18.9%). These authors concluded that other factors in addition to the percentage of body fat regulate puberty in beef heifers.

Recently, Hopper et al. (1993) determined the effect of postweaning weight gain and breed on carcass composition at puberty in beef heifers. In their study, complete data were reported on 14 Angus and 8 Santa Gertrudis heifers that gained 1.2 lb/day or 1.9 lb/day from weaning through puberty. Puberty was defined as the time when serum progesterone concentrations were greater than 1 ng/mL in two consecutive weekly samples. Carcass composition of heifers at puberty was estimated by component separation and chemical analysis of the 9th-10th-11th rib section. These authors observed no difference in age at puberty between the breeds, but heifers gaining 1.9 lb/day tended ($P < .11$) to be younger at puberty than heifers gaining 1.2 lb/day (492 vs 513 days; Table 3). Angus heifers weighed less at puberty than Santa Gertrudis heifers (787 vs 904 lb) and had more subcutaneous fat in the 9th-10th-11th rib section (4.4 vs 3.0 oz). Heifers gaining 1.9 lb/day were heavier at puberty and had more subcutaneous fat in the 9th-10th-11th rib section (4.5 vs 3.0 oz). The predicted percentage of total lipid in the carcass was greater in Angus (20.8%) than Santa Gertrudis (17.0%) and tended ($P < .09$) to be greater in heifers gaining 1.9 lb/day (20.2%) than heifers gaining 1.2 lb/day (17.6%). These authors suggested that, if a critical level of body fat content was necessary for puberty, that breed differences in the level of fat may exist.

Hall et al. (1993) investigated the effect of sire breed and nutrition on body composition at puberty. In their study, 31 crossbred heifers sired by Charolais (n = 15) or Hereford (n = 16) bulls were fed to gain 1.3 or 2.2 lb/day from weaning through puberty. Puberty was defined as estrus followed by formation of a functional corpus luteum and was determined by ultrasonography and blood progesterone greater than 1 ng/mL. Empty body composition was determined by chemical analysis of the right half-carcass and entire noncarcass fraction of each heifer. These authors reported that heifers fed to gain 2.2 lb/d reached puberty at an earlier age and heavier body weight than heifers fed to gain 1.3 lb/day (Table 4). Heifers fed to gain 2.2 lb/day had more fat as a percentage of empty body weight (22.3%) than heifers that were fed to gain 1.3 lb/day (19.1%). Breed of sire did not affect age at puberty, but Charolais-sired heifers were heavier at puberty than Hereford-sired heifers. These authors concluded that puberty did not occur at a constant body composition in beef heifers.

Body Composition of Hereford and Senepol Heifers at Puberty

At the Subtropical Agricultural Research Station in Brooksville, Florida, we are investigating the effects of management inputs (nutrition) on pubertal traits among breeds of heifers. It is well established that both breed and nutrition can influence age at puberty in beef heifers. The concept that a critical level of body fat may be required for the onset of puberty (Frisch, 1976), was also of interest. This work was a part of the Southern Regional Research Project, S-248.

The Senepol is a *Bos taurus* breed developed during the early 1900s on St. Croix, U.S. Virgin Islands, from crosses between the N'Dama and Red Poll breeds (Hupp, 1981). The Senepol appears to be as tolerant to heat as the Brahman (Hammond, 1993). Little information is available on age, weight, and body composition at puberty in Senepol heifers. Therefore, the objective of this study was to determine the effect of nutrition on pubertal traits including body composition in Senepol and Hereford heifers.

Procedure. Hereford (n =12), Senepol (n = 15) and reciprocal-crossbred (Hereford X Senepol and Senepol X Hereford; n = 14) heifers (277 $\pm$ 3 days of age and 529 $\pm$ 11 lb) were used to determine body composition at puberty, defined as day of first conception. Heifers from two consecutive calf crops (spring, 1991 and spring, 1992) were used in this study. Following a postweaning adjustment period, by November of each year, heifers were stratified by breed, age and body weight among winter treatments consisting of either either 5 lb/heifer/day of a 75% cracked corn and 25% soybean meal mixture (CORN) or 2 lb/heifer/day of soybean meal (SBM) in addition to bahiagrass hay offered free-choice and 150 mg monensin/heifer/day. Heifers in each treatment group were divided into two pasture replicates. Supplements were fed on Monday, Wednesday and Friday of each week. As soon as pasture availability was adequate in the spring of each year, one-half of the heifers from each winter treatment were allotted to either a continuous or rotational grazing system on bahiagrass pasture. The continuous system included a 40 acre pasture and the rotational system included four-10 acre pastures that were rotationally grazed at about weekly intervals. Each grazing system was replicated twice.

Heifers were exposed to fertile Angus bulls equipped with chin-ball markers throughout the study. Date at first conception was determined from calving date minus 284 days for gestation. Heifers were weighed and body condition scored (1 to 17 scale) at 28-day intervals. Beginning 60 days after the start of the study and at 56-day intervals thereafter, heifers were subjected to urea space measurements and fat thickness over the ribeye was determined by ultrasound.

Urea space was used to predict the body composition of heifers (Hammond et al., 1984; Hammond et al., 1988). Within two weeks of each urea space measurement, four contemporary heifers were slaughtered to determine gut fill and facilitate empty body weight estimation of all heifers. Empty body water, protein and fat were calculated for each heifer using the mixed breed equations from Hammond et al. (1984; 1988). Body composition over time was estimated for each heifer using regression, and body composition at first conception was interpolated.

Analysis of variance was used to statistically evaluate treatment and breed effects on puberty. Regression procedures were used to statistically evaluate the relative importance of body weight, body condition score, fat over the ribeye, and body composition on age at first conception.

Results and Discussion. Heifers fed CORN had higher ($P < .08$) daily gains from the start of the study to first conception than heifers fed SBM (.9 vs .7 lb/day). At puberty, heifers fed CORN tended to be younger ($P = .12$) and were lighter ($P < .03$) than heifers fed SBM, 467 vs 554 days and 681 vs 694 lb, respectively (Table 5). Treatment did not affect body condition score or fat over the ribeye at puberty. As a percentage of empty body weight, body fat at puberty was similar between heifers fed CORN (15.8%) and those fed SBM (14.5%).

These results were not unexpected considering differences between how this and the previous studies were conducted. Previous studies showing nutritional (or weight gain) effects on body composition at puberty in beef heifers were conducted at much higher nutritional inputs and daily gains than the present study (Yelich et al., 1992; Hall et al., 1993; Hopper et al., 1993). In most instances, these previous studies were being conducted at locations that typically develop heifers to calve first at two years of age. In the present study, we were examining planes of nutrition that were more typical of Florida conditions under which heifers would calve first at three years of age. Furthermore, the difference in daily gain between treatments in the present study was smaller than the differences reported in previous studies. Thus the difference in body composition of heifers gaining .7 vs .9 lb/day might be expected to be smaller than in heifers gaining 1.5 vs 3 lb/day (Yelich et al., 1992) or 1.3 vs 2 to 2.2 lb/day (Hall et al., 1993; Hopper et al., 1993).

Daily gain from the start of the study to puberty was higher ($P < .05$) for Hereford (.9 lb/day) and crossbred (.9 lb/day) heifers than Senepol (.6 lb/day) heifers. Although crossbred heifers reached puberty 68 and 61 days earlier than Hereford and Senepol heifers, respectively, breed differences in age at puberty were not significant (Table 6). Breed did not affect body weight at puberty. At puberty, fat over the ribeye was greater ($P < .05$) for crossbred heifers (.18 in) than Hereford (.14 in) or Senepol (.15 in) heifers. Both body condition score and the percentage of body fat followed a similar pattern as fat over the ribeye (i.e., were numerically higher for crossbred than straightbred Hereford or Senepol heifers). However, breed differences were not significant for body condition score or the percentage of body fat. The percentage of fat expressed on an empty body weight basis averaged 14.6, 14.5 and 16.3% for Hereford, Senepol and crossbred heifers, respectively. Hopper et al. (1993) reported that Angus had a greater percentage of fat in the carcass at puberty than Santa Gertrudis. Although both Senepol and Santa Gertrudis are tropically adapted, Senepol are a Bos taurus breed without Brahman (Bos indicus) influence (Hupp, 1981). Thus, in the present study, lack of a difference in body composition at puberty may be attributed to both breeds of the heifers being of Bos taurus origin.

When the relative importance of body weight, body condition score, fat over the ribeye and body composition at puberty on age at puberty was tested, body condition score and body weight accounted for 55% of the variation in age at puberty ($P < .0001$). Fat over the ribeye and the percentages of empty body fat, protein and water did not contribute significantly to the variation in age at puberty. This suggests that under the conditions of this experiment, body condition score and body weight at puberty were the most informative factors for predicting age at puberty.

Southern Regional Research Project, S-248

Data summarized above from the Subtropical Agricultural Research Station, and Oklahoma State University (Yelich et al., 1991ab; Yelich et al., 1992) were contributions to the S-248 regional project concerning the effect of growth rate on body composition in beef heifers. Further investigations are planned to determine relationships between metabolic hormones and the onset of puberty in beef heifers, to determine pubertal traits in other breeds of cattle, and to determine the effect of breed on percentage of mature weight at puberty (target body weight). As additional carcass information is tabulated in sire summaries and when distinct high and low carcass fat bulls can be identified, studies on the effect of selecting heifers for decreased carcass fat on puberty may be conducted.

Summary

Several studies have been conducted to determine if a critical body fat content initiates puberty in beef heifers. Postweaning level of nutrition or weight gain was shown to affect body composition and body fat at puberty. If a critical threshold of body fat is required to initiate puberty, then puberty should have been reached at a similar body fat content. This was not the case in the majority of the studies. Body weight and body condition score may be useful as predictors of age at puberty. However, these measurements at puberty, like body composition, were shown to be influenced by nutrition. Other factors in addition to body composition, body weight and body condition score initiate the onset of puberty in beef heifers.

In order to calve heifers first at two years of age, it has been a general recommendation that each heifer weigh 65% of their mature weight by the start of the first breeding season. Rate of gain needed from weaning to first breeding can be calculated from weaning weight, target weight at breeding, and days from weaning to the start of the breeding season. In most instances this will require heifers to gain more than 1.2 lb/day and closer to 1.5 lb/day from weaning to first breeding. Some breeds, such as the Brahman, may have difficulty in reaching puberty by 15 months of age. In this situation, alternatives would be to calve these heifers first at three years of age or have a spring and fall calving season.

Year 1 Only; Year 2 showed no differences

Table 1. Effect of energy level on age, weight and the percentages of body fat and protein at puberty[a,b]

ADG?

	Energy level, % of requirement		
Trait at puberty	80	100	120
No. of heifers	24	24	24
Age, days	406	393	409
Body weight, lb	514[c]	571[d]	628[e]
Fat, %	13.4[c]	15.6[d]	18.2[e]
Protein, %	19.4[c]	19.0[d]	18.3[e]

[a]Data adapted from Trial 1 of Brooks et al., 1985.
[b]Body fat and protein estimated by measuring the naturally occurring radioactive isotope of potassium (^{40}K) in the live animal.
[c,d,e]Means within a row lacking a common superscript differ ($P < .01$).

Table 2. Effect of postweaning rate of gain on age, body weight, condition score and the percentage of fat in the carcass at puberty[a]

	Rate of gain		
Trait at puberty	3 lb/day	1.5 lb/day	.4 lb/day for 16 weeks then 3 lb/day to puberty
No. of heifers	13	12	13
Age, days	371[b]	412[c]	405[c]
Body weight, lb	776[d]	681[e]	672[e]
Condition score	6.5[d]	5.6[e]	5.4[e]
Fat, %	29.4[d]	19.4[e]	18.9[e]

[a]Data adapted from Yelich et al., 1992.
[b,c]Means within a row lacking a common superscript differ ($P < .10$).
[d,e]Means within a row lacking a common superscript differ ($P < .05$).

Table 3. Effect of breed and postweaning rate of gain on age, weight, amount of subcutaneous fat in the 9th-10th-11th rib section and predicted percentages of total lipid, protein and water in the carcass at puberty[a,b]

	Treatment					
	Gain 1.2 lb/day		Gain 1.9 lb/day		Probability	
Trait at puberty	Angus	Santa Gertrudis	Angus	Santa Gertrudis	Trt[c]	Brd[d]
Age, days	509	517	486	498	.11	-
Body weight, lb	750	888	824	919	.05	.05
Subcutaneous fat,oz	3.7	2.3	5.2	3.8	.05	.05
Total lipid, %	20.0	15.3	21.7	18.7	.09	.05
Protein, %	16.2	16.0	15.8	16.2	-	-
Water, %	59.8	64.8	58.6	61.2	.05	.05

[a]Data adapted from Hopper et al., 1993.
[b]Data include complete observations on 14 of 14 Angus and 8 of 11 Santa Gertrudis that reached puberty during the experiment.
[c]Trt = treatment.
[d]Brd = breed.

Heavier & Greater [Fat]

Table 4. Effect of breed of sire and postweaning rate of gain on age, weight, and the percentages of fat and water in the empty body at puberty[a]

	Treatment					
	Gain, lb/day		Breed of sire		Probability	
Trait at puberty	2.2	1.3	Charolais	Hereford	Gain	Breed
No. of heifers	15	16	15	16		
Age, days	386	416	406	395	.08	-
Body weight, kg	877	747	888	738	.01	.01
Fat, %	22.3	19.1	20.7	20.7	.001	-
Water,%	55.3	58.1	56.4	57.0	.001	-

[a]Data adapted from Hall et al., 1993.

↑
Same fat % but different BW at puberty

Table 5. Effect of treatment on daily gain, age, body weight, condition score, fat over the ribeye (FOE) and the estimated percentages of fat, protein and water on an empty body weight basis at puberty[a]

	Treatment[b]		
Trait at puberty	CORN	SBM	SE
No. of heifers	22	19	
Daily gain, lb/day[c]	.9	.7	.02
Age, days[d]	467	554	13
Body weight, lb[e]	681	694	.4
Condition score	7.9	7.4	.1
FOE, in	.17	.15	.008
Fat, %	15.8	14.5	1.0
Protein, %	18.0	18.3	.2
Water, %	61.1	62.1	.7

[a]Data from the Subtropical Agricultural Research Station, Brooksville, Florida.
[b]CORN = 5 lb/heifer/day of a 75% corn and 25% soybean meal mixture, SBM = 2 lb/heifer/day of soybean meal.
[c]Effect of treatment (P < .08).
[d]Effect of treatment (P = .12).
[e]Effect of treatment (P < .05).

Table 6. Effect of breed on daily gain, age, body weight, condition score, fat over the ribeye (FOE) and the estimated percentages of fat, protein and water on an empty body weight basis at puberty[a]

	Breed			
Trait at puberty	Hereford	Senepol	Crossbred[b]	SE
No. of heifers	12	15	14	
Daily gain, lb/day	.9[c]	.6[d]	.9[c]	.06
Age, days	535	528	467	37
Body weight, lb	670	688	708	22
Condition score	7.4	7.5	8.0	.3
FOE, in	.14[c]	.15[c]	.18[d]	.008
Fat, %	14.6	14.5	16.3	1.0
Protein, %	18.2	18.2	18.0	.2
Water, %	62.0	62.1	60.8	.7

[a]Data from the Subtropical Agricultural Research Station, Brooksville, Florida.
[b]Crossbred = Hereford X Senepol and Senepol X Hereford.
[c,d]Means within a row lacking a common superscript differ ($P < .05$).

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