PARADOXES ASSOCIATED WITH EARLY CALVING OF REPLACEMENT HEIFERS

Patrick C. Hoffman, Dairy Specialist
Department of Dairy Science
University of Wisconsin

I. Introduction

One definition of paradox is "exhibits contradictory results". This is also an appropriate definition of the challenges associated with early calving (< 24 months) of dairy replacement heifers. This paper will explore these challenges. Little or no discussion will be offered on calving replacement heifers > 24 months because there is little or no biological (1) or economic (2) justification.

II. Economics

The main reason for calving replacement heifers early is economics. Economic assessments (2) have demonstrated that heifer rearing cost increases $50.00 to $60.00 each month calving is delayed. In addition, older calving ages result in the need for more heifers for herd replacement. These classic concepts are presented in Table 1. Conceptually, as calving age is reduced there is a linear reduction in rearing cost, heifers required, and yearly herd replacement cost (Table 1). It is the opinion of this author that this type of economic analysis works well to analyze the economics of reducing older (> 24 months) calving ages to 24 months, but may not accurately assess the economics of early calving ages.

There are two flaws in this type of economic analysis. First, economics of first lactation or lifetime milk yield is not considered. Second, herd culling rate is assumed to be equal across all calving ages. This assumption is false. There are numerous factors in early calving replacement heifer management programs that could increase first lactation culling rate, thereby increasing herd culling rate.

III. Early Calving – First Lactation/Cull Rate Relationships

There is a paucity of information available to quantitate the relationships between early calving and its effects on first lactation or herd culling rates. While difficult to quantitate, the following heifer management issues could have profound effects on first lactation or herd culling rates.

Body Size

Early calving of replacement heifers is not achieved by simply breeding heifers earlier. Growth rates of heifers must be accelerated to assure heifers are of adequate body size at calving. Failure to achieve adequate body size at calving will result in decreased milk yield (4) and increased dystocia (3). Increased dystocia has been demonstrated to have a direct effect on retained placenta, metritis, and breeding efficiency, and ultimately increases herd culling rates (3).

Recent research has greatly aided the ability to define optimum body size criteria of replacement heifers. A compilation of this research (6) is presented in Table 2. Producers and growers implementing early calving regimens should pay special attention to meeting skeletal measurements defined in Table 2 because they may be more related to milk yield than body weight (7) when heifers calve at ages < 24 months.

Body Composition

To understand the role body composition plays in early calving replacement heifer management programs, a basic understanding of heifer growth is required. To achieve the same body weight at calving at a younger age, a diet higher in energy/protein must be fed, thereby accelerating growth. Accelerating growth increases body protein and frame growth, but deposition of fat will be proportionately higher (8). Simply, the faster a heifer grows, the faster a heifer becomes fat.

This concept was recently investigated in our laboratory (9) by feeding Holstein heifers control or accelerated diets containing 62.5 or 68.5% TDN (17% CP) from 10 months until calving. Heifers fed the accelerated diets calved earlier (21.7 vs 24.6 months) and weighed the same at calving (1418 vs 1435 lbs) as the control heifers. Heifers fed accelerated diets were shorter at the withers and mobilized more body fat from 10 days prepartum until 7 days postpartum, resulting in lower true body size during lactation. As a result, heifers fed accelerated diets had lower milk yields of fat corrected milk (Table 3). Heifers fed accelerated diets had higher dystocia indexes (3.5 vs 3.1), which were related to higher body condition scores (3.7 vs 3.5).

Data from our experiment suggest heifers with similar prepartum body weights but dissimilar body composition perform differently. Grummer et al. (10) also investigated effects of body composition of replacement heifers at first calving on lactation performance by feeding a standard or high energy diet from 19.0 months until calving (24.7months). Heifers fed high energy diets were heavier (1530 vs 1463 lbs), had high condition scores (3.7 vs 3.5) and mobilized more fat. Dry matter intake tended to be lower post calving and there was no effect on milk yield. Lacasse et al. (11) and Waltner et al. (12) have also reported similar observations.

Biological aspects of body composition as it relates to early calving are a true paradox in replacement heifer management. The complete logic is as follows:

1 To achieve optimum body weight at an earlier age, growth must be accelerated (1).
2 Accelerated growth yields a heifer with a higher proportion of body fat (8).
3 Excessive fat increases dystocia, fat mobilization, ketosis, and displaced abomasums, and decreases dry matter intake (3, 5, 9, 10).
4 Dystocia, ketosis, displaced abomasums, etc., increase herd culling rates (3).

These problems have led investigators to seek replacement heifer management strategies that increase growth without increasing body fat. One investigated strategy is inclusion of undegraded intake protein (UIP) in replacement heifer diets. Steen et al. (19) fed Holstein replacement heifers from 9 to 20 months of age hay and a concentrate mixture containing either 32 or 42% of CP as UIP. Average daily gain and feed efficiency of heifers was not improved by feeding additional UIP. Feeding UIP had no effect on body fat, body protein, or skeletal development of Holstein replacement heifers at the conclusion of the trial (20 months). Tomlinson et al. (20) fed four levels of UIP (55, 50, 43, and 31% of CP) to Holstein replacement heifers and observed increased feed efficiency when dietary UIP was increased. Body composition of heifers, estimated by urea space measurements, was not altered by feeding additional UIP.

Increasing dietary UIP concentration has improved growth of replacement heifers in some studies (21, 22), but not in others (22, 24, 25, 26). To date, studies investigating increased UIP content of replacement heifer diets have not observed consistent improvements in growth or body composition.

Another method to alter body composition is to alter body protein demand. Nutrient partitioning agents such as bovine somatotropin (bST) have been demonstrated to increase growth and body protein accretion without increasing body fat in growing ruminants (27, 28). The economic and productive potential of bST to alter growth, body composition, and subsequent milk yield of early calving replacement heifers warrants further investigation.

Breeding Efficiency

To successfully implement an early calving management program, accelerated growth is required to achieve optimum body size at calving. Accelerated growth coupled with poor breeding efficiency can lead to disastrous results. Simply stated, if heifers are fed to calve at 22 months of age and do not conceive until 15 to 16 months of age, heifers will be on feed an extra 60 to 90 days. Breeding delays can result in obese heifers, often weighing more than 1500 lbs at calving. Heifers fed and bred under this program are extremely prone to ketosis, displaced abomasums, and poor feed intake during transition (3, 10).

In a recent study conducted at the University of Wisconsin (9), a high incidence of dystocia was observed in delayed bred heifers fed a diet to accelerate growth. The lessons learned from these experiments (5, 9, 10) are this: If an accelerated feeding program is implemented to decrease calving age (e.g., from 25 to 22 months), breeding efficiency must be nearly perfect to avoid delayed conception. If conception is delayed, days on feed increase, increasing body weight and condition at calving. Increased or excessive body condition at calving will result in increased calving and metabolic problems, which can increase culling rates.

IV. Early Calving/Milk Yield Relationships

First Lactation Milk Yield

There have been numerous studies which have examined the effects of calving age and first lactation milk yield. Many of these studies are outdated or utilized different breeds of dairy cattle, making inferences to the modern Holstein genotype difficult. Figure 1 represents five recent studies (9, 13, 14, 15, 16) examining the effect of calving age on first lactation milk production. The studies of Heinrichs et al. (15) and Ptak et al. (16) examine the relationship between calving age and first lactation milk yield in commercial dairy herds. The study of Hoffman et al. (9) manipulated calving age by accelerating postpubertal growth. The study of Peri et al. (13) accelerated prepubertal growth, and Gardner et al. (14) accelerated growth throughout the entire rearing period. Regardless of experimental design, first lactation milk yield is reduced when Holstein heifers calve at ages less than 23 to 24 months. Each of the authors offers a plausible explanation for the negative relationship between early calving and first lactation milk yield, but explanations offered by each author fail to explain the results of others' research. For example, Peri et al. (13) associated the reduced milk yield to problems associated to prepuberty mammary development. This explanation does not offer a valid explanation for the results of Hoffman et al. (9), Heinrichs et al. (15), or Ptak et al. (16) because none of these studies altered prepuberty growth rates of heifers.

These data (9, 13, 14, 15, 16) suggest the effects of early calving on first lactation milk yield are predictable, but causative mechanisms are not predictable. It is, however, important to remember that all of these studies demonstrate that there is little or no benefit to first lactation milk yield by delaying calving beyond 24 months.

Calving Age and Lifetime Milk Yield

Determining the success or failure of early calving management programs based solely on first lactation milk yield is misleading. Lin et al. (17) demonstrated that Holstein heifers calving at 23 months as compared to 26 months had more days of productive life (730 vs 623) and had higher lifetime milk yields. Amir and Halevi (18) demonstrated this concept in a commercial dairy herd (Table 4). Holstein heifers calving at 20 months of age had lower first lactation milk production, but higher 1310 day milk yields and higher milk yield per day of life.

Like first lactation milk yield, lifetime milk yield data may be misleading in determining optimum calving ages. The data of Amir and Halevi (18) demonstrates the positive benefits of early calving ages on milk yield per day of life, but also demonstrates negative factors such as increased dystocia, increased days open, increased calf and dam loss, and lower herd life for heifers calving at 20 and 21 months of age. All of these factors have a direct effect on first lactation and herd culling rates, which increases the number of heifers needed for replacement (2).

V. Economics Revisited

As previously suggested, calculating economic advantages of early calving based on rearing cost and lifetime milk yield can be misleading. These common arguments used to demonstrate the advantage of early calving fail to account for the effect calving age may have on the herd culling rate. It is well known that miscues in early calving programs can have a dramatic effect on postpartum metabolic problems, feed intake, dystocia, and other herd health problems. All of the aforementioned issues are directly or indirectly related to herd culling rates. While there is limited information to quantitate this issue, a theoretical example is presented in Table 5. Table 5 is identical to Table 1, except that the effects of increased culling rates are theorized by the author for the 20 and 22 month calving ages. Theorizations are based on the data of Hoffman et al. (9), Amir and Halevi (18), and Sieber et al. (5). Under these theoretical assumptions, herd replacement costs are lowest at 22 months of age. Yearly herd replacement costs rise when heifers calve at 20 months because problems associated with early calving increase herd culling rates, thereby increasing the number of heifers required to calve each year to satisfy herd replacement. Yearly herd replacement costs rise at later calving ages ($\geq$ 24 months) because heifer rearing costs rise.

VI. Conclusions

The relationship between calving age and profitability is not a simple linear relationship. When replacement heifers calve at extremely young ages, important biological systems (reproductive, milk synthesis, parturition, feed intake, health) may fail. Reasons for these failures are debatable, but any and all failures result in increases in herd culling rates. An increase in herd culling rates results in more heifers needed, and correspondingly, increases yearly replacement cost.

Based on current research information, calving ages of 22 to 23 months are biologically feasible and should enhance profitability under good management. Calving ages less than 21 months may be feasible, but the risk of increasing herd culling rate rises and must be weighed in the decision making process. Calving ages greater than 24 months are economically unsound and biologically unjustified.

REFERENCES

1. Hoffman, P. C., and D. A. Funk. 1992. Applied dynamics of dairy replacement growth and management. *J. Dairy Sci.* 75:2504.

2. Crowley, J., N. Jorgensen, T. Howard, P. Hoffman, and R. Shaver. 1991. Raising dairy replacements. Univ. Wisconsin-Extension, North Central Reg. Ext. Publ. No. 205, Madison.

3. Erb, H. N., R. D. Smith, P. A. Oltenacu, C. L. Guard, R. B. Hillman, P. A. Powers, M. C. Smith, and M. E. White. 1985. Path model of reproductive disorders and performance, milk fever, mastitis, milk yield and culling in Holstein cows. *J. Dairy Sci.* 68:3337.

4. Keown, J. F., and R. W. Everett. 1986. Effect of days carried calf, days dry, and weight of first calf heifers on yield. *J. Dairy Sci.* 69:1891.

5. Marksusfeld, O. 1985. Relationship between overfeeding, metritis and ketosis in high yielding dairy cows. Vet. Rec. 116:489.

6. Hoffman, P. C. 1997. Optimum body size of Holstein replacement heifers. *J. Anim. Sci.* 75:836.

7. Sieber, M., A. E. Freeman, and D. H. Kelley. 1988. Relationship between body measurements, body weight and productivity in Holstein dairy cows. *J. Dairy Sci.* 71:3437.

8. Waldo, D. R., A. V. Capuco, and C. E. Rexroad, Jr. 1989. Feeding dairy replacements for optimum milk production. *In* Proc. 50th Minn. Nutr. Conf., p 46, Bloomington, MN.

9. Hoffman, P. C., N. M. Brehm, S. G. Price, and A. Prill-Adams. 1996. Effect of accelerated postpubertal growth and early calving on lactation performance of primiparous Holstein heifers. *J. Dairy Sci.* 79:2024.

10. Grummer, R. R., P. C. Hoffman, M. L. Luck, and S. J. Bertics. 1995. Effect of prepartum and postpartum dietary energy on growth and lactation of primiparous cows. *J. Dairy Sci.* 78:172.

11. Lacasse, P., E. Block, L. A. Guilbault, and D. Peticlerc. 1993. Effect of plane of nutrition on dairy heifers before and during gestation on milk production, reproduction, and health. *J. Dairy Sci.* 76:3420.

12. Waltner, S. S., J. P. McNamara, and J. K. Hillers. 1993. Relationship of body condition score to production variables in high producing Holstein dairy cattle. *J. Dairy Sci.* 76:3410.

13. Peri, I., A. Gestler, I. Bruckental, H. Barsh. 1993. The effect of manipulation in energy allowance during the rearing period of heifers on hormone concentrations and milk production in first lactation cows. *J. Dairy Sci.* 76:742.

14. Gardner, R. W., L. W. Smith, and R. L. Park. 1988. Feeding and management of dairy heifers for optimal lifetime productivity. *J. Dairy Sci.* 71:996.

15. Heinrichs, A. J., and M. Vazques-Anon. 1993. Changes in first lactation dairy herd improvement records. *J. Dairy Sci.* 76:671.

16. Ptak, E., H. S. Horst, and L. R. Schaeffer. 1993. Interaction of age and month of calving with year of calving for production traits of Ontario Holsteins. *J. Dairy Sci.* 76:3792.

17. Lin, C. Y., A. J. McAllister, T. R. Batra, A. J. Lee, G. L. Roy, J. A. Vesely, J. M. Wauthy, and K. A. Winter. 1988. Effects of early and late breeding heifers on mulitple lactation performance of dairy cows. *J. Dairy Sci.* 71:2735.

18. Amir, S., and A. Halevi. 1984. Early breeding of dairy heifers under farm conditions. Rehovot (Israel), 21-23 Febr. 1984. Ed.INRA Publ., 1984.

19. Steen, T. M., J. D. Quigley, III, r. N. Heitmann, and J. D. Gresham. 1992. Effects of lasalocid and undegraded protein on growth and body composition of Holstein heifers. *J. Dairy Sci.* 75:2517.

20. Tomlinson, D. J., R. E. James, and M. L. McGillard. 1990. Effect of ration protein undegradability on intake, daily gain, feed efficiency and body condition of Holstein heifers. *J. Dairy Sci.* 73(Suppl. 1):169 (Abstr.).

21. Amos, H. E. 1986. Influence of dietary protein degradability and energy concentration on growth of heifers and steers and intraruminal protein metabolism. *J. Dairy Sci.* 69:2099.

22. Casper, D. P., D. J. Schingoethe, M. J. Brouk, and H. A. Maiga. 1994. Nonstructural carbohydrate and undegradable protein sources in the diet: Growth responses of dairy heifers. *J. Dairy Sci.* 77:2595.

23. Smith, T., J. W. Siviter, and R. J. Merry. 1985. Further comparisons of energy and protein sources for growing cattle. *J. Agric. Sci*. 104:485.

24. Mantysaari, P. E., C. J. Sniffen, T. V. Muscato, and M. L. Thonney. 1989. Performance of growing dairy heifers fed diets containing soybean meal or animal by-product meals. *J. Dairy Sci.* 72:2107.

25. Van Amburgh, M. E., D. M. Galton, D. G. Fox, D. E. Bauman, L. E. Chase, H. N. Erb, and R. W. Evertt. 1994. Effect of prepubertal growth rate in Holstein heifers on first lactation milk yield. *J. Dairy Sci.* 77(Suppl. 1):185. (Abstr.).

26. Bethard, B. L., R. E. James, and M. L. McGilliard. 1995. Effect of energy and quantity and quality of undegraded intake protein on growth and feed efficiency of growing Holstein heifers. *J. Dairy Sci.* 78(Suppl. 1):163. (Abstr.).

27. Early, R. J., B. W. McBride, and R. O. Ball. 1990. Growth and metabolism in somatotropin-treated steers: II. Carcass and non carcass tissue components and chemical composition. *J. Anim. Sci.* 68:4144.

28. Neathery, M. W., C. T. Crowe, G. F. Hartnell, J. J. Veenhuizen, J. O. Reagen, and D. M. Blackmon. 1991. Effects of sometribove on performance, carcass composition, and chemical blood characteristics of dairy cows. *J. Dairy Sci.* 74:3933.

Table 1. The effect of calving age on herd replacement cost (100 cow herd).

Calving Age	Daily Cost	Rearing Cost [1]	Heifers Required [2]	Replacement Cost	Heifers Calvings
-months-	-$/day-	-$/heifer-	-#-	-$/year-	-#/year-
20	1.63	1094	64	42,100	38.5
22	1.60	1173	71	45,200	38.5
24	1.57	1249	77	48,100	38.5
26	1.54	1321	83	50,800	38.5
28	1.51	1389	90	53,500	38.5
30	1.48	1454	96	56,000	38.5

[1] Calf cost = $100.00.
[2] 35% Herd Cull Rate + 10% Heifer Morbidity/Mortality.

Table 2. Optimum body size criteria of Holstein replacement heifers at first calving.

		Genetic Range	
Criteria	Average	Lower	Upper
Body weight, lb (14 d prepartum)	1366	1312	1422
Body weight, lb (7 d postpartum)	1231	1182	1280
Body weight, lb (30 d postpartum)	1148	1102	1193
Wither height, in	54.9	54.2	55.5
Body length [1], in	67.3	66.5	68.0
Pelvic area, cm^2	> 260	> 260	> 260
Body condition score	3.5	3.5	3.5

[1] Measured from the point of shoulder to the ischium.

Table 3. Effect of early calving on development and lactation performance of Holstein replacement heifers.

	Treatment	
Item	Accelerated	Control
Calving age, mo	21.7	24.6
ADG, lb/d (Post-puberty)	2.0	1.7
Prepartum BW, lb	1418	1435
Postpartum BW, lb	1255	1303
Height, in	53	54
Body condition	3.7	3.5
Perpartum pelvic area, cm^2	267	280
Dystocia index [1]	3.5	3.1
Lactation performance		
Milk Yield, lb/305 d	16965	18035

[1] 1-5 system: 1 = unassisted; 2 = some assistance, normal birth; 3 = difficult birth; 4 = extremely difficult birth; 5 = veterinarian required.

Table 4. The effect of calving age on productive traits in a commercial dairy herd.

	Milk Yield (lbs)			Herd Health			
Calving Age	1st Lactation	1310 days	Day of Life	Dystocia Index 1	Calf & Dam Loss (%)	Days Open	Herd Stay (years)
20	12380	27380	20.9	3.4	12.3	118	4.0
21	12900	26730	20.5	2.8	7.7	111	4.2
22	13270	26340	20.2	2.5	9.0	109	4.7
23	13440	25850	19.8	2.7	10.5	122	4.5
24	13540	24230	18.5	2.6	11.0	126	4.4
25	14140	23760	18.2	2.9	15.9	199	4.5

[1] 1-5 system: 1 = unassisted; 2 = some assistance, normal birth; 3 = difficult birth; 4 = extremely difficult birth; 5 = veterinarian required.

Table 5. The theoretical effect of calving age and culling rate on herd replacement cost (100 cow herd).

Calving Age	Daily Cost	Rearing Cost [1]	Herd Culling Rate	Heifers Required [2]	Replacement Cost	Heifers Calving
-months-	-$/day-	-$/heifer-	-%-	-#-	-$/year-	-#/year-
20	1.63	1094	40.0	73	48100	44.0
22	1.60	1173	36.5	75	47500	40.5
24	1.57	1249	35.0	77	48100	38.5
26	1.54	1321	35.0	83	50800	38.5
28	1.51	1389	35.0	90	53500	38.5
30	1.48	1454	35.0	96	56000	38.5

[1] Calf cost = $100.00.
[2] Herd Cull Rate + 10% Heifer Morbidity/Mortality.

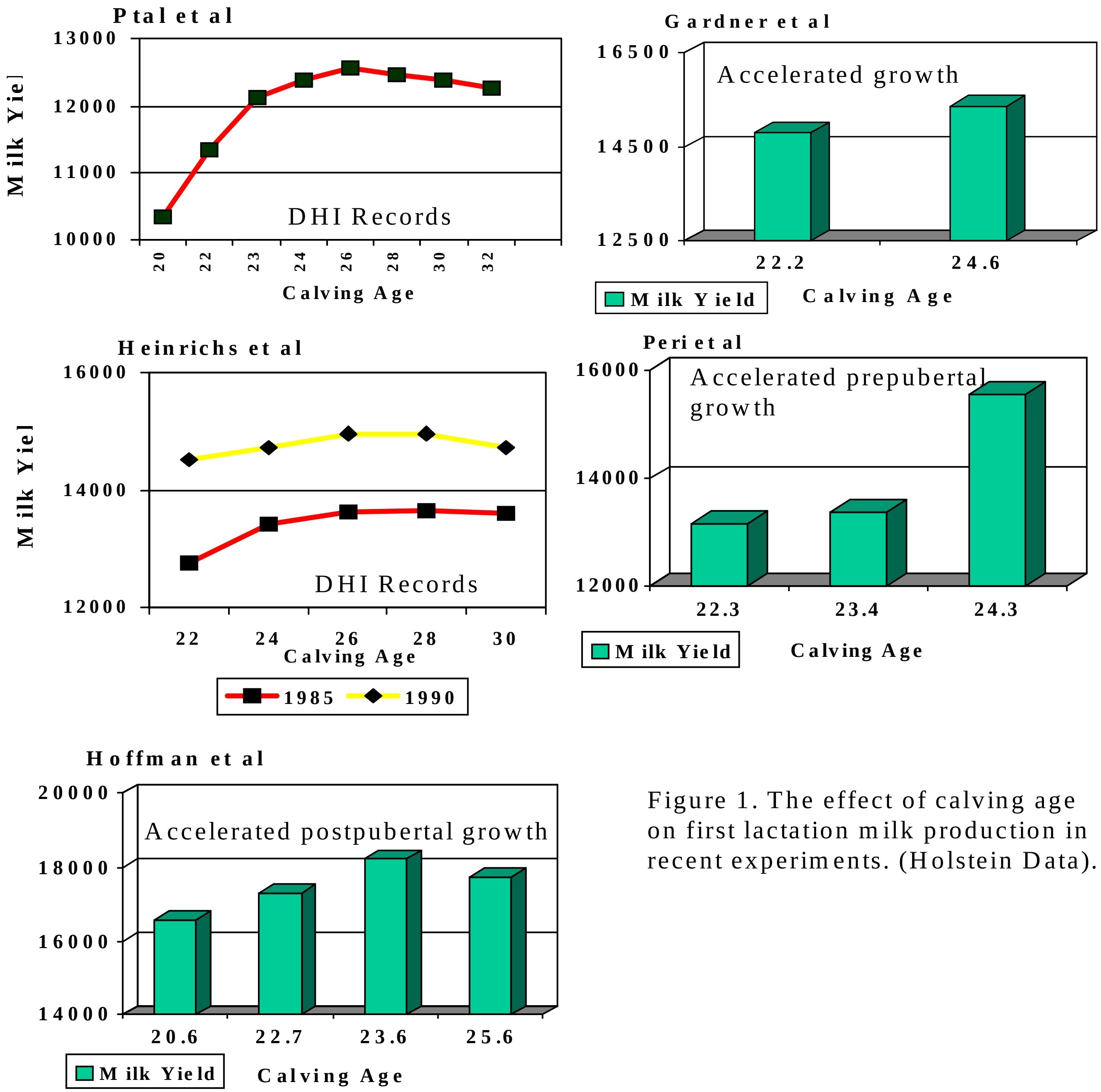

Figure 1. The effect of calving age on first lactation milk production in recent experiments. (Holstein Data).