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ENDOCRINE-GENETIC RELATIONSHIPS IN
HOLSTEIN HEIFER CALVES

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Barbara L. Irion

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Edward M Convey

Major professor

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ENDOCRINE-GENETIC RELATIONSHIPS IN HOLSTEIN HEIFER CALVES

By

Barbara L. Irion

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ABSTRACT

ENDOCRINE-GENETIC RELATIONSHIPS IN
HOLSTEIN HEIFER CALVES

By

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The ability to identify genetically superior heifers at an early age would be a great asset to the dairy industry. In this thesis are results of an experiment designed to describe: 1) relationships among endocrine traits measured early in life and economically important traits expressed later, and; 2) changes in secretion of certain metabolic hormones with age.

Twenty Holstein heifers, born between January 1977 and March 1979, were in each of two groups differing 640 kg for sire's Predicted Difference for milk and out of dams produced by a selected breeding regimen over 11 years.

Animals were fed between 0600 and 0730 h daily. When heifers were 1,3,5 and 8 months of age, blood was collected at 15 minute intervals between 1000 and 1300 hours. All sera were assayed for insulin and growth hormone. Concentrations of total glucocorticoids were determined in sera collected at 1000, 1130, and 1300 h. Differences due to genetic groups were not significant, but there were changes in concentrations of these hormones due to age. Glucocorticoids averaged 5.0 ng/ml at 1 month and increased to 7.9, 11.0 and 9.2 ng/ml at 3, 5 and 8 months, respectively. Similarly, growth hormone increased with age from 7.7 ng/ml at 1 month to 9.1, 9.8 and 9.4 ng/ml at 3, 5 and 8 months. In

contrast, concentrations of insulin were greater at 1 month than at 3, 5 and 8 months (5.6, 1.9, 1.8 and 2.3 ng/ml, respectively). Insulin decreased from 11.3 ng/ml at 1000 h to 1.6 ng/ml at 1300 h at age 1 month, but remained unchanged throughout the day in heifers at 3, 5 and 8 months.

Concentrations of glucocorticoids, insulin and growth hormone in young dairy heifers selected for high milk production did not differ from concentrations of these hormones in heifers selected for lower levels of milk production. Therefore, these hormones would not be good criteria to select genetically superior dairy heifers at an early age.

To my Mom and Dad

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Lastly, I'd like to thank Dr. Ed Convey, not only for all the help he's given me concerning my thesis, but also for being my mentor and friend.

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ABBREVIATIONS

ACTH	adrenocorticotropic hormone
ADG	average daily gain
ANOVA	analysis of variance
B	"best"
CNS	central nervous system
DNA	deoxyribonucleic acid
FFA	free fatty acids
G	unit gravity
GH	growth hormone
GLM	General Linear Model
GnRH	gonadotropin releasing hormone
kg	kilogram
MABC	Michigan Animal Breeders Cooperative
MCR	metabolic clearance rate
ME	mature equivalent
NEFA	non-esterified fatty acid
NRC	National Research Council
RIA	radioimmunoassay
SAS	Statistical Analysis System
TRH	thyrotropin releasing hormone
W	"worst"

INTRODUCTION

As the population of the world increases, the need for economically produced, highly nutritious food becomes more acute. Milk and dairy products are good sources of nutrients, but they are not utilized to the extent they might, largely due to high costs of production. One method for lowering costs is to identify animals, at an early age, that are genetically superior for milk production. Eliminating genetically inferior animals at a young age would decrease costs of replacements. In addition, ova from genetically superior animals, collected earlier, could decrease the generation interval through embryo transfer and therefore increase the rate of genetic progress.

Milk production and growth have been shown to be heritable traits and great genetic advances in potential for milk production and growth have been made through the selection of superior sires and the use of artificial insemination. Many physiological processes, including lactation and growth are regulated by the endocrine system, especially the metabolic hormones. It seems reasonable to examine whether or not concentrations of metabolic hormones may be an index of genetic merit for traits of economic importance.

At present, it is not known whether hormonal concentrations measured at an early age have value in predicting an individual's genetic potential for milk production. In this thesis, I asked two questions. First, do concentrations in insulin, growth hormone and total glucocorticoids in blood vary relative to genetic ability of heifers to produce milk?

Second, how do concentrations of these hormones change with increasing age from birth to eight months?

LITERATURE REVIEW

ENDOCRINE METABOLISM

Ruminant animals digest cellulose via microbial fermentation in the rumen. Major products of cellulose digestion are volatile fatty acids, including acetate, propionate and butyrate. Ballard, et al. (1969) and Trenkle (1971a) found acetate, rather than glucose to be the major substrate for energy metabolism in most peripheral tissues of ruminant animals after weaning. However, Lindsay (1975) demonstrated that glucose is the principle source of energy for the central nervous system in ruminant as well as non-ruminant animals. Only small quantities of glucose are absorbed by the gut of ruminant animals and therefore glucose must be synthesized via gluconeogenesis. Substrates for gluconegenesis include propionic acid, amino acids, lactate and glycerol (Ballare, et al., 1969; Armstron, 1965; Bergman, et al., 1966; and Trenkle, 1978). Bergman, et al. (1966) and Leng, et al. (1967) demonstrated that propionic acid is a major precursor for glucose and may be sutbstrate for 50 percent of the glucose produced in the liver. According to Judson and Leng (1973a, 1973b), specific hormone changes help to maximize glucose production from propionate via gluconeogenesis in ruminant animals, thus conserving amino acids for synthesis of protein.

Insulin

Because glucose is required by the central nervous system, its

regulation is important in ruminant as well as non-ruminant animals. Since insulin is an important regulator of glucose production through gluconeogenesis, it is essential in maintaining homeostasis. Insulin is a polypeptide hormone produced and secreted by the beta-cells in the islets of Langerhan. Reid, et al. (1963) and Jarrett, et al. (1972) found that insulin deficiency, brought about by either pancreatectomy or the diabetogenic agent alloxan, will cause a diabetic condition in ruminants. This leads to impaired utilization of glucose, acetate and beta-hydroxybutyric acid and also causes ketoacidosis and death (Reid, et al., 1963; Jarrett, et al., 1972).

Acetate is the principle source of energy for peripheral tissue in ruminant animals. Effective utilization of acetate is dependent on the stimilatory effects of insulin and glucose (Ballard, 1972; Skarda and Bartos, 1969, and Yang, et al., 1973). Ballard (1972), Yang and Baldwin (1973), and Mears and Mendel (1974) have shown that insulin stimulates utilization of both glucose and acetate by adipose tissue. Horn and co-workers (1977) suggested that insulin may reduce breakdown of muscle protein rather than affect uptake of amino acids. This hypothesis has been disputed by Trenkle (1978), who suggested that insulin inhibits lipolysis and proteolysis and stimulates uptake and incorporation of amino acids into cells.

Prior and Christenson (1978) and West and Passey (1967) reported that insulin inhibits gluconeogenesis and secretion of glucose by the liver. It is likely then, that the high concentrations of insulin that occur after feeding minimize glucose production from propionate and amino acids in the liver. However, during the post-prandial period, gluconeogenesis and hepatic glucose output are increased (Katz and Bergman,

1969; Thompson, et al., 1978), suggesting that the effects of insulin are offset by other regulatory hormones or substrate availability.

Glucagon

In ruminant as well as non-ruminant animals, glucagon is probably the major hormone counteracting the effects of insulin on metabolism of glucose in the liver. Glucagon is a polypeptide hormone produced and secreted by the pancreatic alpha-cells in the islets of Langerhan. According to Trenkle (1978), glucagon favors hepatic uptake of propionate, glucogenic amino acids and lactate. Glucagon also stimulates glycogenolysis, adipose tissue triglyceride breakdown and gluconeogenesis, thereby maintaining hepatic secretion of glucose (Bassett, 1978; Brockman, et al., 1975b).

Growth Hormone

Other hormones that are involved in metabolism include catacholamines, glucocorticoids, thyroid hormones and growth hormone (GH). Of these, only secretions of GH appear to fluctuate with diets varying in energy balance. Concentrations of GH in serum of fasted animals or those fed limited amounts of feed tend to be lower than in animals fed ad libitum, suggesting that GH may play a role in mobilizing fat for energy (Carstairs, 1978). Bassett (1971, 1974b), Hove and Blom (1973), and Blom, et al. (1976) found concentrations of GH in serum to be negatively correlated with feed intake and insulin concentrations. However, Hertelendy and Kipnis (1973) observed a positive relationship between concentrations of GH and free fatty acid (FFA) in serum. This positive association with FFA suggests that GH may be involved with antagonism of glucose utilization

and promotion of lipolysis (Bassett, 1978). Growth hormone has been shown to exhibit anti-insulin like effects (Baughaday, et al., 1975), and therefore could be considered catabolic in regard to adipose tissue.

Growth hormone may play an important role in muscle development by stimulating mitosis of satellite cells. Satellite cells are mononucleated cells, lying within the basement membrane of muscle fibers. As they undergo mitosis, these nuclei become incorporated into the muscle fibers, thereby increasing the amount of DNA available to direct synthesis of protein (Mauro, et al., 1970). Post-natal increase in DNA content of muscle is arrested by hypophysectomy, but partially restored by exogenous GH, and completely restored by exogenous GH plus thyroid hormone (Trenkle, 1976).

Glucocorticoids

Reilly and Black (1973), and Reilly and Ford (1974) found that glucocorticoids promote proteolysis and increased hepatic uptake of amino acids. This process reduces availability of amino acids to extrahepatic tissues for protein synthesis, so glucocorticoids can be considered to be catabolic. McNatty, et al. (1972) observed that glucocorticoid concentrations in blood are not influenced by eating, but rather follow a circadian rhythm. Mills and Jenny (1979) reported that glucocorticoid concentrations increased during fasting. This increase has been associated with glucagon release (Marco, et al., 1973; Wise, et al., 1973; and Bassett, 1975), and coincides with low insulin levels. Thus, the endocrine balance during starvation favors degradation of muscle protein, increased uptake of amino acids by the liver, and extensive gluconeogenesis. The net effect is loss of skeletal muscle mass.

FACTORS CONTROLLING ENDOCRINE RELEASE

Insulin

Bassett (1974a, 1975) and Trenkle (1970c) both reported that insulin concentrations increase in serum after eating in ruminant animals. Lofgren and Warner (1972) and Ross and Kitts (1973) observed the insulin increase to be more pronounced in animals fed hay than those fed concentrates. Bassett, et al. (1971) and Horino, et al. (1968) found insulin concentrations in serum of sheep to be positively related to the intake of digestable organic matter and protein. The amount of food ingested seemingly influences the magnitude of serum insulin concentrations attained after feeding. However, Bassett (1975) hypothesized that the composition of the feed has little direct influence on the insulin response except through rates of digestion or amounts of nutrients absorbed. Intravenous injections of FFA, butyrate and propionate stimulate insulin secretion in fasted sheep (McAtee and Trenkle, 1971b; Trenkle, 1970c). But, it is not clear how these fatty acids participate in control of secretion under physiological conditions (Trenkle, 1978; Bassett, 1975). McAtee and Trenkle (1971a), Hertelendy and Kipnis (1973), and Davis (1972) all reported that intravenous injections of amino acids in amounts resulting in super-physiological concentrations of amino acids in the blood increased insulin in plasma. But concentrations of amino acids that are normally found in plasma after feeding do not significantly alter insulin secretion (Bassett, 1975).

Trenkle (1978) observed a biphasic change in secretion of insulin in response to feeding. The first increase occurs within one hour postprandially, and the second peaks four to six hours later. Although the

mechanism by which feeding increases insulin is not known, it has been hypothesized that the first insulin release is due to a release of cholecystokinin-pancreozmin and secretion, resulting from feed passage into the rumen (Bassett, 1974a; Trenkle, 1972). The second increase may be due to absorbtion of short-chain fatty acids from the rumen as well as absorbtion of gluconeogenic precursors from the digestive tract (Trenkle, 1978).

Although insulin is the major regulator of glucose turnover rates, concentrations of glucose in plasma may not be an important determinant of insulin secretion in ruminant animals (Chase, et al., 1977; Bhattacharya and Alula, 1975; Bassett, 1975; Trendle, 1978). A definitive statement regarding the mechanism of insulin secretion in ruminant animals can not be made at this time.

Glucagon

Glucagon secretion is stimulated by hypoglycemia, catacholamines (Bassett, 1972; Brockman and Bergman, 1975a), and glucocorticoids (Driver and Forbes, 1978; Wise, et al., 1978). There is a postprandial increase in glucagon, coinciding with increase gluconeogenic output of glucose from the liver. Bassett (1975) has hypothesized that the ratio of insulin to glucagon is important in glucose regulation, but evidence supporting this view must be considered preliminary.

Growth Hormone

Growth hormone concentrations fluctuate greatly in serum of ruminant animals, i.e. it is episodic (Bassett, 1974b; Hove and Blom, 1973; McAtee and Trenkle, 1971b). Manns and Boda (1967) observed that fasting does

not cause an increase in mean concentrations of GH in sheep, but both the amplitude and frequency of the episodic surges are greatest during this time (Bassett, 1974b; Wallace and Bassett, 1970; McAtee and Trenkle, 1971b; Driver and Forbes, 1978). In sheep, GH concentrations decrease in plasma after eating, and both the frequency and amplitude of the episodic secretions are decreased for two to four hours (Trenkle, 1967, 1978; Bassett, 1974b, 1975, 1978; Driver and Forbes, 1978). Bassett (1974a) reported that growth hormone concentrations tend to be lower in serum of sheep fed large quantities of food, and the effects of feeding relative to time of feeding are more difficult to resolve than in sheep fed limited quantities. Hove and Blom (1973) observations with cattle were consistant with those of Bassett's (1974a) findings in sheep. Secretion of GH is related inversely to availability of nutrients. Increased concentrations of growth hormone would seem to increase mobilization of energy from adipose tissue to satisfy metabolic requirements.

Glucocorticoids

The concentrations of glucocorticoids in blood change in response to fasting (Mills and Jenny, 1979; Trenkle, 1978), but not in response to feeding (Bassett, 1974b, 1975; Trenkle, 1978; Grigsby, et al., 1973). This may be due to the fact that glucocorticoids increase when an animal is stressed. Thus, the increase in glucocorticoids due to fasting may be a result of stress. Evidence for the mechanism of secretion and regulation is not clear at this time.

The effects of some metabolic hormones are summarized in Table 1.

TABLE 1.

Hormonal Effects on Metabolism in Adipose Tissue

TABLE 1.

Hormonal Effects on Metabolism in Adipose Tissue

Hormone	Fatty Acid Synthesis	Lipolysis	FFA re-Estrification	Protein Synthesis	Glucose Uptake
Insulin	⬠ ⬟	⬠ ⬟	⬠	⬠ ⬟	⬠
Growth Hormone	⬠	⬠ ⬟	⬠ ⬟	⬠ ⬟	⬠ ⬟
Glucocor.	⬠	⬠	⬠ ⬟	⬠ ⬟	⬠ ⬟
Glucagon	⬠	⬠	⬠		⬠

Hormonal Effects on Metabolism of Muscle

Hormone	Glucose Transport	Glycogen Synthesis	Glycogeno-lysis	AA Transport	Protein Synthesis	Protein Degra-dation	AA Release
Insulin	⬠ ⬟	⬠ ⬟	⬠ ⬟	⬠	⬠		⬠ ⬟
Growth Hormone	⬠		⬠	⬠ ⬟	⬠ ⬟		⬠ ⬟
Glucocor.			⬠	⬠ ⬟	⬠ ⬟	⬠ ⬟	⬠ ⬟
Glucagon							

Hormonal Effects on Metabolism of Liver

Hormone	Glycogen-olysis	Glyco-genesis	Gluconeo-genesis	Ketogenesis	Lipogenesis
Insulin	⬠ ⬟	⬠ ⬟	⬠ ⬟	⬠	⬠ ⬟
Growth Hormone			⬠	⬠	⬠
Glucocor.		⬠	⬠ ⬟	⬠ ⬟	⬠
Glucagon	⬠ ⬟	⬠ ⬟	⬠ ⬟	⬠	

⬟ Negative relationship in ruminant animals

⬠ Positive relationship in non-ruminant animals.

⬟ Positive relationship in ruminant animals.

⬠ Negative relationship in non-ruminant animals.

CHANGES IN THE CONTROL OF ENDOCRINE METABOLISM ASSOCIATED WITH AGING AND GROWTH

Insulin

Very little is known of the mechanism involved with insulin control and secretion in ruminant animals prior to the onset of rumen function. In the course of maturation, ruminant animals change from monogastrics to ruminants. Current evidence supports the view that control of insulin secretion in monogastrics and young ruminant animals is associated with variations of blood glucose concentrations. This control of insulin by glucose secretion decreases as ruminant animals age. The magnitude of insulin secretion in response to glucose injections is greater in two week old lambs than adult sheep (Manns and Boda, 1967). This may be due to the diets of young sheep as well as the mode of carbohydrate digestion in ruminant animals prior to the development of the rumen. A repeat of the aforementioned experiment (Manns and Boda, 1967) with 6-week old lambs did not produce the same results, presumably because the rumen becomes functional by then. Coinciding with the transition from a monogastric-like animal to a ruminant animal is a decrease in the ability to utilize glucose (Jarrett and Potter, 1952; McCandless and Dye, 1950). Chesrow and Bleyer (1954) and Zhukov (1956) noted increased incidences of glucose intolerances in other species where the pancreatic islets become less responsive to insulin regulation by glucose with increasing age. Manns and Boda (1967) hypothesized that decreased sensitivity of the insulin secretory apparatus in adult ruminant animals compared with young ones could partially explain the decrease glucose tolerance accompanying maturity.

Insulin concentrations have been shown to increase in serum with time when cattle were fed grain (Trenkle and Topel, 1978). Trenkle and Irvin (1970) also observed a positive relationship between insulin concentrations found in serum and fatness of the carcass and also of age in steers but not heifers. The higher concentrations of insulin in plasma in steers was thought to be due to the high grain ration fed to steers only, rather than a sexual difference. Korner (1967) hypothesized that insulin is involved in growth because in its absence, protein synthesis in skeletal muscle is reduced. More research needs to be conducted to fully understand the mechanisms involved.

Growth Hormone

Growth hormone affects growth in at least two major and well established ways. Purchas, et al. (1971) hypothesized that GH acts on the skeletal system, especially long bones causing bone formation and growth. Growth hormone also affects the rate of retention of ingested nitrogen which is essential for formation of protein containing tissue (Nalbanov, 1962). Trenkle (1974) and Purchas, et al. (1971) both observed that average daily secretion of GH in growing steers is correlated with growth of carcass lean and negatively related to gain of carcass fat. Irvin and Trenkle (1971) and Purchas, et al. (1970) both reported GH concentrations to be higher in serum of animals at birth than any other age. There is not a marked reduction in blood concentrations of GH as growth rates decline in pigs and cattle, but there is a decline in GH concentrations per unit body weight (Armstrong and Hansel, 1956; Trenkle, 1971b, 1977). Pituitary GH per unit body weight and metabolic clearance rate (MCR) per unit body weight in cattle

both decline with increasing body size (Trenkle, 1977; Purchas, et al., 1971).

Trenkle (1971b) observed GH to be higher in males than females. Anfinson, et al. (1975) and Galbraith, et al. (1978) reported GH to be higher in intact males than in castrated males. In addition, they reported that GH concentrations were greater in faster growing, later maturing breeds than in smaller, early maturing breeds of cattle.

Glucocorticoids

The effects of glucocorticoids on metabolism of protein are generally considered to be catabolic. Concentrations of glucocorticoids in serum have been shown to be negatively correlated with: 1) amount of carcass muscle (Trenkle and Topel, 1978); 2) tenderness scores of meat (Purchas, et al., 1971); and 3) growth rates of fattening heifers (Purchas, et al., 1971) and bulls (Obst, 1974). Concentrations of glucocorticoids increase in plasma with increasing body weight and age (Trenkle and Topel, 1978). But within an age group, concentrations of glucocorticoids as well as MCR are lower in faster growing heifers than in slower growing ones (Purchas, et al., 1971). Trenkle and Topel (1978) reported that glucocorticoid levels in plasma were positively related to feed required per unit gain as well as negatively correlated to average daily gain.

ENDOCRINOLOGY OF GENETICALLY DIFFERENT ANIMALS

Cows yielding large quantities of milk will preferentially direct energy towards milk production and away from deposition of body tissues. The converse applies to cows with low milk production. For example, Hart, et al., (1979) demonstrated that, in Holstein and beef cows fed

the same ration in the first 27 weeks of lactation, the Holstein cows lost weight and the beef cows gained weight. Similarly, Broster, et al., (1969) found that Holstein cows producing more milk lost weight while those with low milk production gained, when fed the same ration. Differences in energy partition both among and within breeds may be genetic in origin and may be mediated via differences in the balance of hormones responsible for the control of energy metabolism.

Insulin

Insulin concentrations in plasma collected during lactation are twice as great in beef cows as in dairy cows (Hart, et al., 1978). Kronfeld, et al. (1963) administered exogenous insulin to dairy cows and observed a decrease in both plasma glucose concentrations as well as milk yield. These researchers hypothesized that this decrease in milk yield may be due to hypoglycemia rather than insulin per se. Hove (1974) and Schwalm and Schultz (1976) suggested that insulin concentrations in plasma are low in animals deficient in energy as would be expected in high milk producing cows.

Bauman (1976) suggested that insulin is both lipogenic and anti-lipolytic. This view is supported by the fact that the relatively high concentrations of insulin in serum of cows producing low amounts of milk are accompanied by a lessor rate of fat mobilization, as measured by non-esterified fatty acid (NEFA) concentrations in serum. Increased insulin concentrations inhibit fat mobilization and divert fatty acids into body tissues, thereby reducing fat content in milk (Rao, et al., 1973). Hart, et al. (1979) reported that changes in insulin concentrations in serum were positively correlated with changes

in body weight of lactating cows which supports the hypothesis that the action of insulin is anabolic.

Hart, et al. (1975) observed insulin concentrations in serum to be twice as great in beef cows as in dairy cows throughout lactation, but blood glucose levels were not. It appears that in ruminant, as well as monogastric animals, a high concentration of insulin in the circulation is necessary to promote the conversion of glucose to glycogen and fat. However, Hart, et al. (1978) hypothesized that in the high milk yielding group, if insulin is necessary for the uptake and utilization of glucose by the mammary gland, this requirement is met by much lower concentrations of the hormone.

Growth Hormone

Growth hormone is positively associated with milk production (Hart, et al., 1978). In experiments comparing beef and dairy cows, Hart, et al. (1979) demonstrated that GH concentrations in serum are consistantly higher in dairy cows. But these differences may be due to breed differences rather than milk production, per se. Talwar, et al. (1974) hypothesized that GH may act on mammary cells, interacting with the cell membrane to increase the rate of metabolite uptake and ion transport. Growth hormone may also act by increasing the supply of precursors for milk to the mammary gland (Hutton, 1957; Machlin, 1973). Lindsay (1975) suggested that GH may enhance the availability of energy yielding metabolites for milk production by increasing the rate of fat mobilization from adipose tissue, the oxidation of NEFA or by ketosis. Growth hormone is highly correlated with blood levels of different metabolites including beta-hydroxybutyrate, NEFA, glucose and lactic acid.

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Concentrations of energy yielding metabolites may be important in controlling GH secretion and therby influence the supply of potential milk precursors.

Glucocorticoids

Johnston and Buckland (1976) reported significant sire effects of transport stress on glucocorticoid concentrations in plasma. A heritability of 82% has been found in longhorn cattle for the rise in plasma corticosteroids two hours after injection of ACTH (Eisner and Reznichenko 1977). O'Kelly (1974) observed that the adrenal glands of Africander cattle contain twice as much esterified cholesterol as those of Brahman cattle. Unfortunately, because of the functional diversity of the adrenal hormones, (control of carbohydrate-fat-protein metabolism, anti-inflammatory action, suppression of immunoglobulin synthesis, inhibition of bone formation, and actions of the CNS) it is impossible to say for certain what causes these differences between groups of genetically different animals.

MATERIALS AND METHODS

Animals

Forty Holstein heifers, born between January 1978 and March 1979 were used. The calves were the culmination of a genetics project begun in 1967. At that time, females in the Michigan State University Holstein herd were randomly assigned to one of two groups which were arbitrarily labeled "Best" and "Worst". Four bulls from Michigan Animal Breeders Cooperative (MACB) whose first evaluation on daughters' milk yield became available in 1967 were selected as mates. The two bulls with daughters yielding most milk (B_1) were assigned matings with females in the "Best" group and the two bulls with daughters yielding least milk (W_1) were assigned matings with females in the "Worst" group for two years. In the second year (1968), a new group of bulls had preliminary evaluations and the two with the largest milk yield of daughters (B_2) were assigned matings with the "Best" females along with the first class (B_1) of bulls. The two bulls with the worst evaluations of milk yield of daughters (W_2), along with W_1 bulls were assigned matings with the "Worst" group of females from the herd. Each year, two new bulls were selected for each group, based on the first evaluation of their daughters' milk yield. In addition, bulls used the previous two years were deleted. Thus, the breeding regimen was as follows:

	1967	1968	1969	1970	1976	1977
"Best" ♀ mated with	B_1	B_1	B_2	B_3	B_9	B_{10}
		B_2	B_3	B_4	B_{10}	B_{11}
"Worst" ♀ mated with	W_1	W_1	W_2	W_3	W_9	W_{10}
		W_2	W_3	W_4	W_{10}	W_{11}

where each B or W represents two bulls assigned randomly within genetic blocks of four females grouped by date of birth for heifers or date of calving for cows. Daughters of cows became members of the same group as their dams. During the seventh year of the experiment, MABC merged with Select Sires, increasing the pool of bulls to choose from and thereby diversifying the genetic groups.

First lactation of the "Best" daughters exceeded those of the "Worst" group by 1252 kg of milk in 1979. Dams of the heifers used in this experiment differed between "Best" and "Worst" groups by 737 kg. Predicted differences between milk yield of daughters of bulls B_{10} and W_{10} differed by 600 kg; PD of B_{11} and W_{11} bulls differed by 820 kg. Differences between "Best" and "Worst" bulls were reduced by using only progeny-tested bulls in each class. Some of the poorest bulls were eliminated before semen could be obtained or progeny tested. There were 5 and 11 generations of this line breeding, depending on the age of a cow at calving. Twenty heifers from "Best" and twenty from "Worst" group were used in this experiment. In order to statistically correct for seasonal variation, animals were grouped into one of four seasons

according to their birth dates. "Seasons" were as follows; Winter--December, January, and February; Spring--March, April, and May; Summer--June, July, and August; and Fall--September, October, and November. There were six animals born in Winter (4B, 2W), four in Spring (4W), 11 were born in the Summer (8B, 3W), and 19 in the Fall (8B, 11W).

Feeding, Housing, and Care of Experimental Animals

Nutrition and management of the experimental animals was standarized across genetic groups. At birth, calves' navals were immersed in 7% tincture of iodine, injections of vitamins A and D, BoSe[1], a compound of selenium and vitamin E, and Pasturella vaccines were given. Colostrum was fed to all calves within six hours of birth. Calves were housed individually for 90 days in hutches which measured 2.44 meters long, 1.22 m wide and 1.22 m high. Hutches were outside so calves were exposed to ambient temperature and natural photoperiod. A semi-circle of 10.2 cm x 10.2 cm welded wire mesh approximately 1.4 m in diameter provided an outside area into which the calf could venture. Calves were fed colostrum from their dam twice daily until three to four days of age. Thereafter, 3.6 to 4.6 kg whole milk was fed twice daily until 14 days of age, then once daily until 50 days of age. Calves were fed at 0600 h daily. A grain ration consisting of 16.7% crude protein was fed until six months of age. The ration consisted of:

[1] BoSe -- Burns Biotec Laboratories, Inc. Omaha, Neb.

37% corn	0.7% Trace Mineral Salt
14% oats	0.4% CaCo
20% soybean meal	0.4% K_2SO_4
18.3% corn and cob	0.2% Mgo
3% alfalfa	Vitamin A 22000 IU/kg
5% molasses	D 2200 IU/kg
1% Dical	K 132 IU/kg

Calves were given access to grain prior to weaning. Grain was fed ad libitum until calves were gaining approximately 2.5 kg/day. At this juncture, consumption was limited to 2.5 kg/day until calves were six months old. Alfalfa hay was offered ad libitum, beginning at one week of age.[2] Calves were housed individually until they were three months old, then kept in groups of similar age which included calves of both genetic groups.

A feeding trial, lasting 30 days was conducted, beginning when each calf reached 60 days of age. During this trial, animals were fed grain ad libitum with orts measured daily. Total and average daily gain, feed efficiency and total intake were recorded.

While calves were 6 to 13 months old, they were fed a ration of 12 to 13% crude protein, plus haylage, corn silage and hay. At about 13 months of age, grain feeding was eliminated and during the breeding period (13 to 16 months), haylage, corn silage and hay were fed in, amounts to maintain a normal growing rate according to National Research Council (NRC) standards. Animals were weighed and wither heights recorded monthly until they were 14 months old. All heifers were checked twice daily for estrous activity and inseminated at 14 months. Services per conception were recorded. After a heifer calved, she entered the

[2] Rations were formulated and balanced by Dr. J.W. Thomas, Dept. of Animal Science, Michigan State University, E. Lansing, MI

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Michigan State University milking herd where she was milked twice daily. Lactation records were calculated on a 2 x 305 ME basis.

Blood Collection Procedures

Cannulae were inserted into a jugular vein at least four h before the start of each collection period. The cannula, 7.1 cm in length (SLV-105#-249, PVC Cannula, ICO Rally Co., Palo Alto, Calif.) was inserted into a jugular vein through a 0.591 cm 14 gauge thin walled needle (gift from Abbott Laboratories, North Chicago, ILL.). Cannulae were filled with sodium citrate (3.5% in sterile water) to prevent coagulation of blood between blood samplings.

Blood was collected and discarded at 15 minute intervals for one h before the start of each sampling period to allow the heifers to acclimate to the sampling procedures. Blood was then collected at 15 minute intervals for three h beginning at 1000 h until 1300 h at which time 15 ug/100 kg body weight each of thyrotropin releasing hormone (TRH) and gonadotropin releasing hormone (GnRH) were administered via the cannulae as a single injection. Jugular blood was collected at 0, 5, 10, 15, 20, 25, 30, 60, 120 and 240 minutes relative to this challenge with releasing hormone. In this thesis, only hormone concentrations measured in serum collected before the releasing hormone challenges are reported. Animals were sampled at 1, 3, 5 and 8 months of age. Ambient temperatures were recorded at 0900, 1000, 1200, 1300, and 1400 h on the day of sampling.

Blood was allowed to clot, then stored for 24 hours at 4^{o} C. Serum was obtained by centrification (2200 x g for 15 minutes), then stored at -20^{o} C until assayed.

Hormone Assays

Concentrations of growth hormone (Purchas, et al., 1970) and insulin (Grigsby, 1973) were quantified in serum by double antibody radioimmunoassay (RIA) procedures as previously described. Samples assayed for GH and insulin were those taken at 15 minute intervals from 1000 and 1300 h. Total glucocorticoids were measured by competative protein binding assay (Smith, et al., 1972) on samples taken at 1000, 1130, and 1300 h.

Statistical Analysis

Hormone data were analyzed as a split-split plot design by the General Linear Model (GLM) of Statistical Analysis System (SAS) (Barr, et al., 1979) at Wayne State University. Selected contrasts of individual monthly hormone means were tested against a Sheffe's critical value (Gill, 1978). This conservative critical value was chosen because the contrasts were designed a posteriori. Means of feed trial data were compared between genetic groups by Student's t when variances were equal, or by the Welsh modification (Gill, 1978) of t when variances were unequal. To correct for seasonal variation, a response surface analysis was done to find the appropriate response surface equation for temperature with GH, insulin and glucocorticoids. This response surface equation was used to generate appropriate temperature values for an analysis of variance. Response surface analysis were performed for each season. Growth data was analyzed in a split plot ANOVA with repeat measure over time by the Analysis of Designed Experiments portion of Genstat (Release 4.10) program at Michigan State University. Growth means comparison between "Best" and "Worst" groups were made using Bonferoni's method (Gill, 1978).

RESULTS

Feeding Trial

During the 30 day feeding trial, total weight gained, average daily gain (ADG) and average daily feed intake were not different ($P>0.10$) for calves in the two genetic groups (Table 2). Total weight gained during this feeding trial ranged from 13.9 to 38.6 kg with a mean of 25.3 kg for all animals. Average daily gain and average daily intake were 0.83 kg/day and 3.2 kg/day, respectively. Feed efficiency, defined as the ratio of kg of gain to kg of feed was higher ($P<0.06$) in calves from the "Best" group than for those of the "Worst" group.

Growth Analysis

Body weight was not different ($P>0.10$) due to genetic groups until 9 months of age (Figure 1). From 9 to 12 months, calves from the "Best" group were heavier ($P<0.05$) than those in the "Worst" group. There were no differences ($P>0.10$) due to genetic group in the height of the withers at any of the ages examined.

Insulin

When averaged over month and time within months, concentrations of insulin were not different ($P>0.10$) in serum of calves in the "Best" and "Worst" genetic groups. Mean values were 2.8 ± 1.2 and 3.1 ± 1.2 ng/ml, respectively. However, concentrations of insulin in serum did change with age (Figures 2 and 3). Insulin concentrations averaged

Table 2. Body weight and feed intake of heifers in "Best" and "Worst" genetic groups.

	Total gain (kg)	Average daily gain (kg/day)	Average daily feed intake (kg/day)	% feed efficiency[b]
Best	26.1	.87	3.2	29.0
Worst	24.7	.81	3.1	26.2
Range	13.9-38.6	.044-1.26	2.1-4.8	14.4-35.6

[a] Animals in "Best" group were more feed efficient ($P<0.06$) than those of the "Worst" group.

[b] Feed efficiency $= \frac{\text{gain}}{\text{feed}} \times 100$

Figure 1. Body weight gain of "Best" and Worst" heifers measured monthly from one to 12 months.

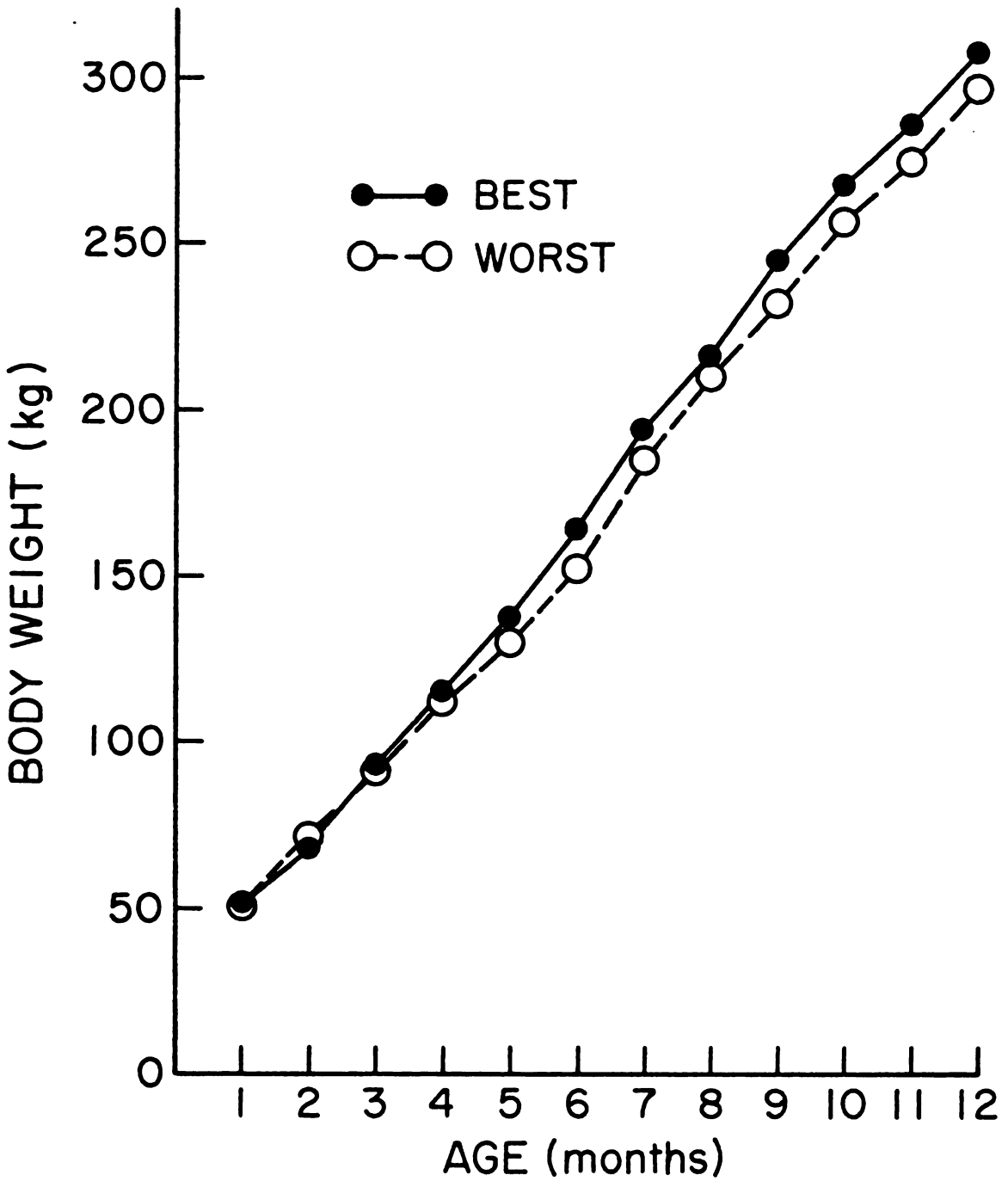

BEST
WORST
BODY WEIGHT (kg)
300
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12
AGE (months)

Figure 2. Insulin concentrations in serum of "Best" heifers in a month by time interaction. Standard errors calculated from pooled mean square error for comparisons 1) between genetic groups = ± .4 ng/ml, 2) between months = ± 1.1 ng/ml and 3) among times within months = ± .5 ng/ml.

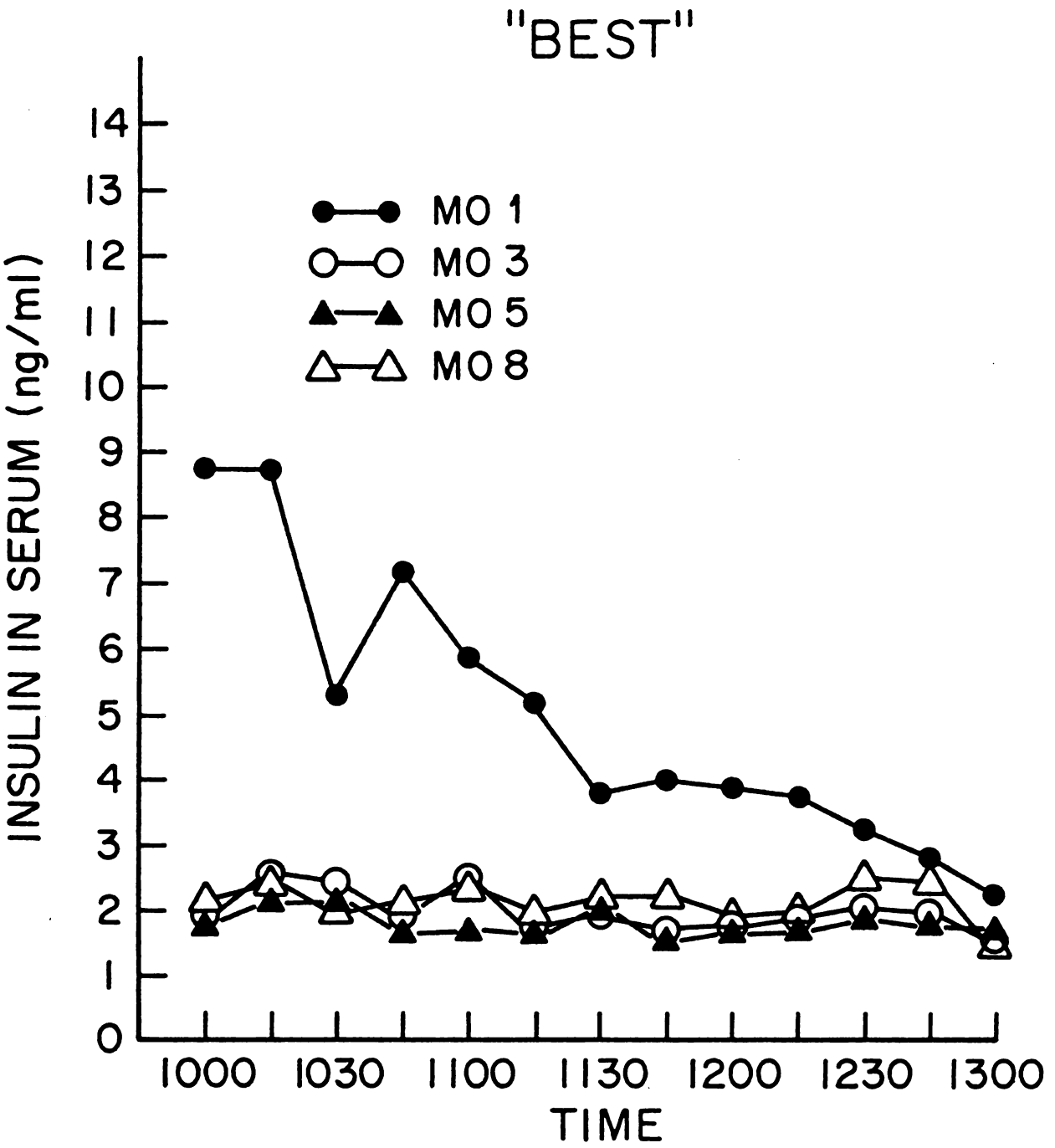
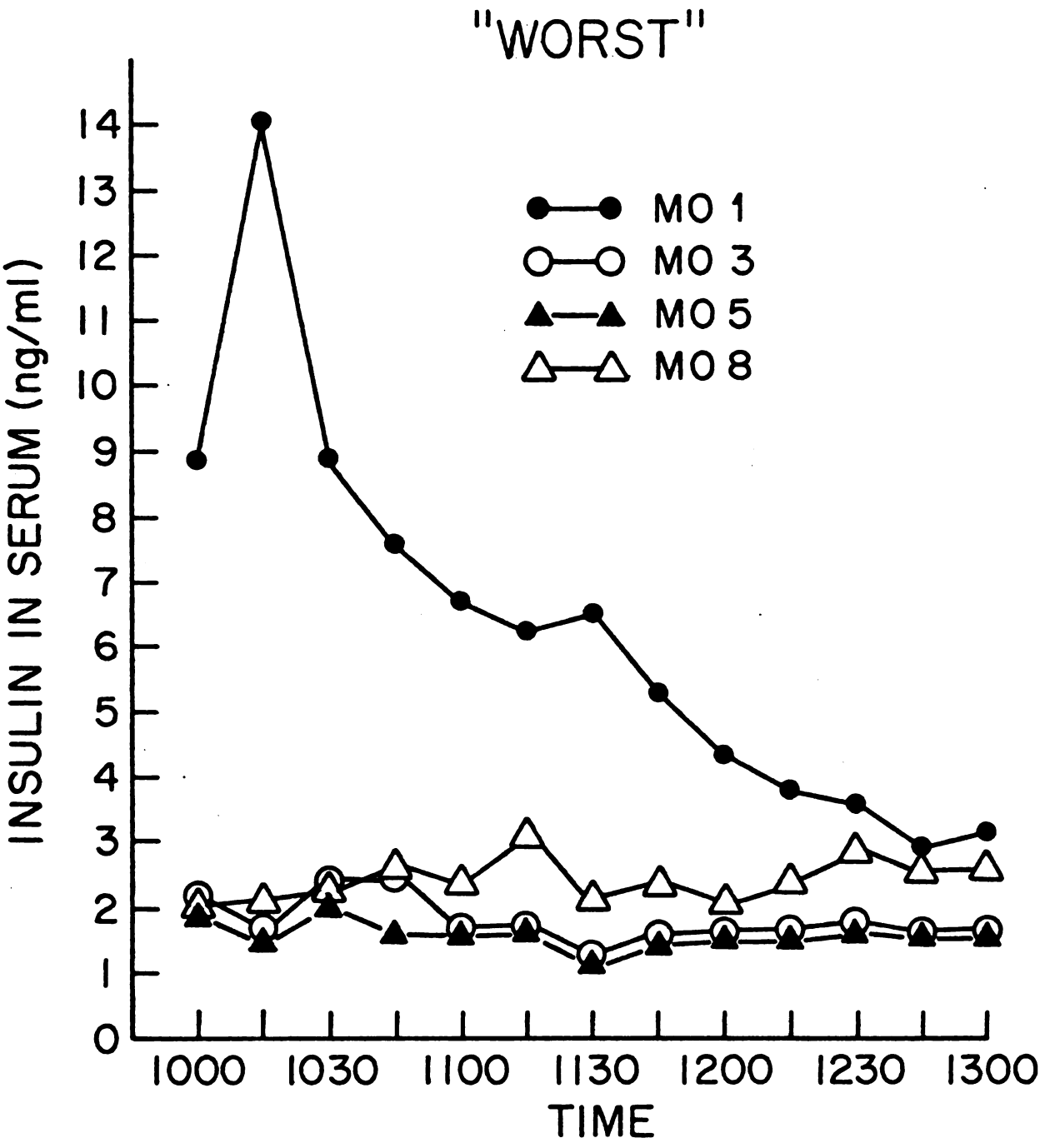

"BEST"
INSULIN IN SERUM (ng/ml)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
MO 1
MO 3
MO 5
MO 8
1000
1030
1100
1130
1200
1230
1300
TIME

Figure 3. Insulin concentrations in serum of "Worst" heifers in a month by time interaction. Standard errors calculated from a pooled mean square error for comparisons 1) between genetic groups = ± .4 ng/ml; 2) between months ± 1.1 ng/ml and; 3) among times within months = ± .5 ng/ml.


"WORST"
INSULIN IN SERUM (ng/ml)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
1000
1030
1100
1130
1200
1230
1300
TIME
MO 1
MO 3
MO 5
MO 8

over time of day were 5.6 ± .7 ng/ml at one month of age, then decreased ($P<0.01$) to 1.9 ± .2, 1.8 ± .1 and 2.3 ± .2 ng/ml at 3, 5 and 8 months of age, respectively (Figures 2 and 3). Concentrations of insulin at one month of age were higher at the start of sampling. This peak was followed by a decline during the interval from 1000 h to 1300 h.

Growth Hormone

When averaged over months and time within months, concentrations of GH in serum did not differ ($P>0.10$) between genetic groups. Averages for "Best" and "Worst" were 8.8 ± 2.0 and 9.2 ± 1.9 ng/ml, respectively. However, GH was affected by age, i.e., lower ($P<0.05$) in serum collected at one month than at 3, 5 and 8 months of age (Figure 4). Mean concentrations were 7.7 ± 0.5, 9.1 ± 0.7, 9.8 ± 0.5 and 9.4 ± 0.6 ng/ml at 1, 3, 5 and 8 months of age, respectively. There was no change ($P>0.10$) in GH concentrations throughout the four hour sampling period at any of the ages examined.

Glucucorticoids

Serum total glucocorticoid concentrations, when averaged over months and time within months, were not affected by genetic groups. However, glucocorticoid levels did change with age ($P<0.05$). Mean glucocorticoid levels were 5.0 ± 0.7, 7.9 ± 1.3, 11.6 ± 1.6 and 9.3 ± 0.9 ng/ml for ages 1, 3 5 and 8 months, respectively (Figure 5), with serum concentrations being higher ($P<0.05$) at five months of age than at one month. There was no change ($P>0.10$) in total glucocorticoid levels over time of sampling within age.

Figure 4. Growth hormone concentrations in serum of "Best" and "Worst" heifers by month. Standard errors calculated from pooled mean square error for comparisons; 1) between genetic groups = ± .62 ng/ml, 2) between months = ± 1.6 ng/ml and; 3) among times across months = 2.3 ng/ml.

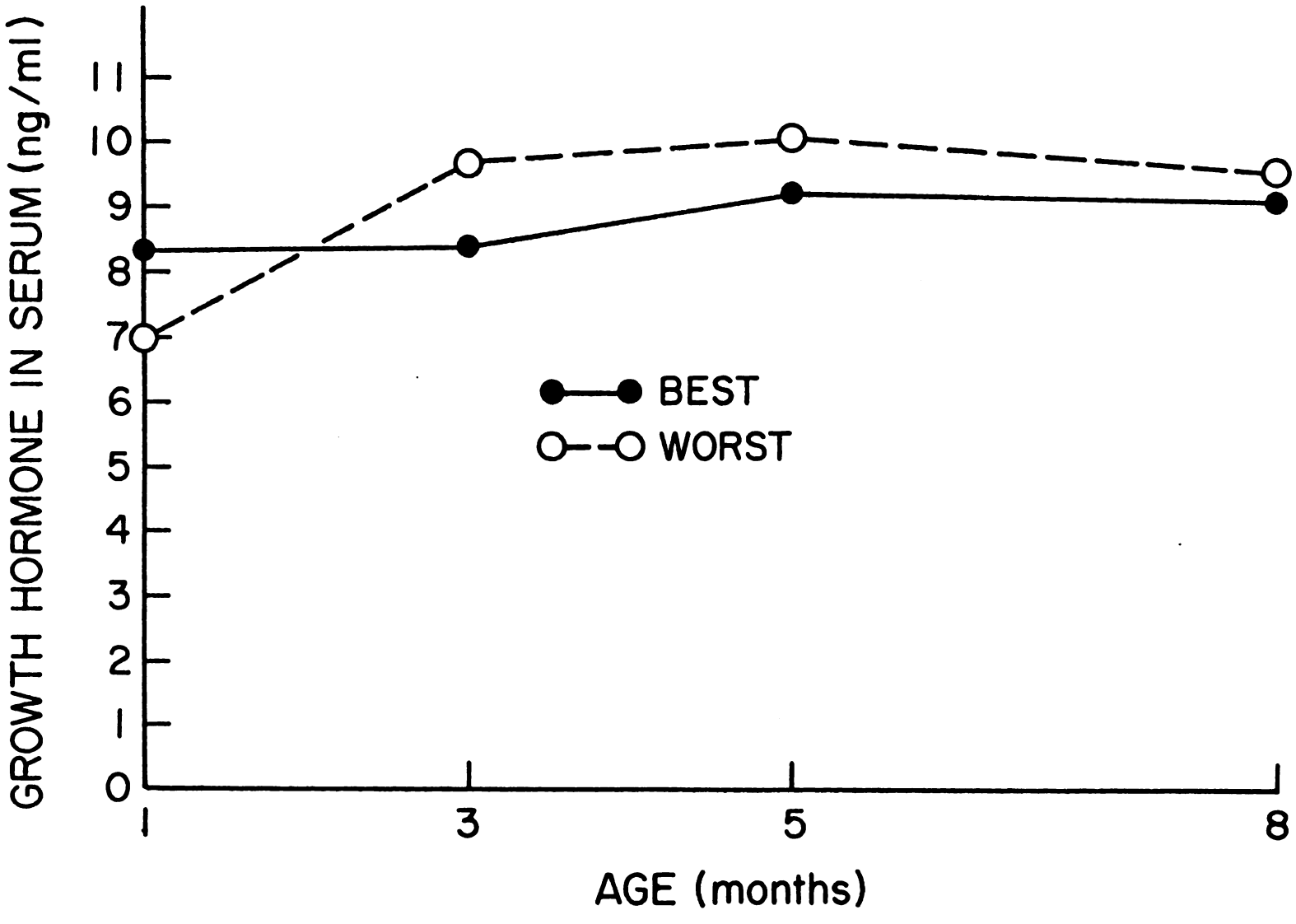
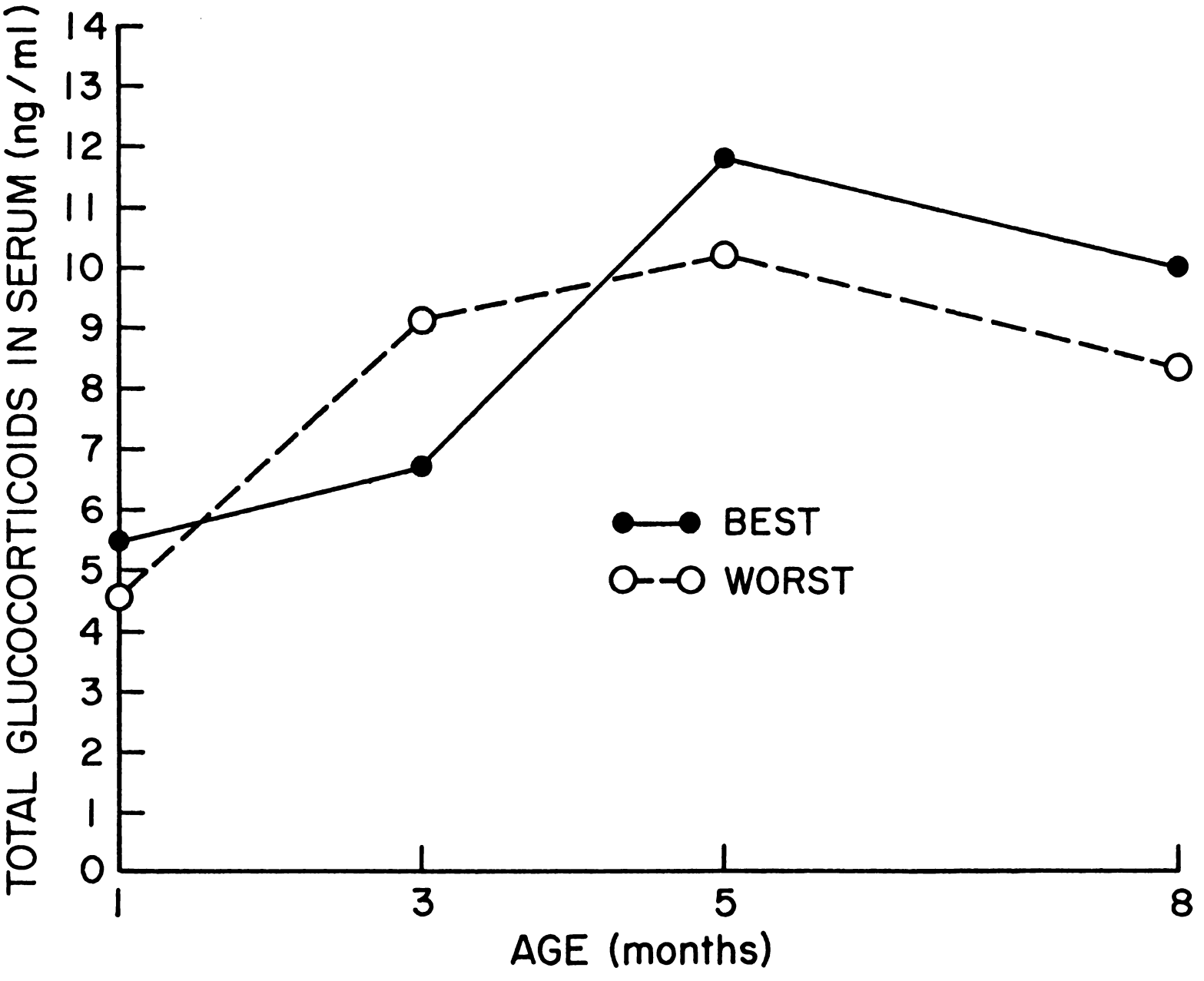

GROWTH HORMONE IN SERUM (ng/ml)
0
1
2
3
4
5
6
7
8
9
10
11
1
3
5
8
AGE (months)
BEST
WORST

Figure 5. Total glucocorticoid concentrations in serum of "Best" and "Worst" heifers by month. Standard errors calculated from pooled mean squared error for comparisons; 1) between genetic groups = ± 1.1 ng/ml; 2) between months = ± 1.6 ng/ml and; 3) among times across months = ± 8.4 ng/ml.


TOTAL GLUCOCORTICOIDS IN SERUM (ng/ml)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
1
3
5
8
AGE (months)
BEST
WORST

DISCUSSION

One objective of this thesis was to determine if relationships exist between traits measured in individuals early in life and their breeding value for milk yield. If animals with high breeding value could be identified at an early age, costs of rearing replacements could be reduced by eliminating genetically inferior animals. For example, if inferior bulls could be identified and eliminated at an early age, the costs to maintain them until information regarding their daughters' first lactation performance became available would also be reduced.

Based on data presented, there is no difference in concentrations of insulin, GH or total glucocorticoids between the two groups of heifers which were compared. Failure to detect any differences in these hormones may indicate that the hormones measured are not related to genetic ability to produce milk. On the other hand, milk producing ability may not be related to a single hormone, but rather a complex interaction among several hormones. Clearly, other hormones, such as prolactin, thyroid hormones, and parathyroid hormones are involved in milk production and metabolism which were not studied. Perhaps one or more of them would be a better indicator of a young animal's potential to produce milk.

An alternative explanation for these data is that absolute concentrations of any one hormone in serum may not be as important in regulating metabolism as the response it elicits from certain tissues. Responses may be regulated by changes in receptor concentrations or affinity, or by changes in the amplification systems involving cyclic nucleotides,

protein kinases or protein gradients.

Since no differences in growth were observed between "Best" and "Worst" heifers until nine months of age, perhaps hormonal differences do not occur until this time also. Any such differences would have gone undetected in this study as blood sampling was discontinued after heifers were eight months of age.

Based on 305 ME 2 x lactational records, heifers in the "Best" group produced 1004 kg more milk than those in the "Worst" group, averaging 6994 kg and 5990 kg, respectively. Seven heifers were culled before their first lactation records were available; four voluntarily and three involuntarily. It is important to keep in mind that the two groups of heifers used in this study were genetically different from each other based on an 11 year breeding program utilizing bulls of diverse genetic backgrounds. Nevertheless, the possibility remains that differences in milk production potential between groups were not sufficient for differences in endocrine measures to be resolved. Dams of the heifers used in this experiment differed between "Best" and "Worst" groups in milk production by 737 kg.

Broster, et al. (1969) reported that Holstein cows producing large quantities of milk will preferentially direct energy toward milk production and away from body tissues. The converse is true for Holstein cows producing lesser quantities of milk (Broster, et al., 1969) and for beef cows (Hart, et al., 1979). Hart, et al. (1978) also observed that Holstein cows have higher GH, NEFA, and beta-hydroxybutyrate concentrations than do beef cows, but beef cows have higher insulin concentrations throughout lactation than do dairy cows. Partition of energy between the mammary gland and other tissue is based on rate and

direction of metabolism which is regulated through endocrine control. Perhaps the endocrine differences that exist between dairy and beef cows cause the differences in partition of energy described above. Alternatively, endocrine differences may result from metabolic differences rather than cause them. When evaluating data of the type reported by Hart, et al. (1978), it is important to keep in mind that dairy and beef cows differ in many ways in addition to differences in ability to produce milk. Thus, it is impossible to attribute endocrine variation to a single characteristic or class of characteristics such as metabolism.

Failure to detect any hormonal differences attributable to selection in these young (1 to 8 month old) growing heifers may be explained if important measurable endocrine differences occur only at the tme of lactogenesis or lactation. In support of this view, Hart, et al. (1978) reported that differences in growth hormone and insulin concentrations in serum were resolved between beef and dairy cows during lactation, but not during the dry period. Being able to discern endocrine variations in adult lactating cattle would not be particularly useful in selection of genetically superior milk producing animals at a young age.

The second objective of this thesis was to describe changes in secretion of insulin, GH and glucocorticoids in dairy heifers as they age. Concentrations of insulin in serum of one month old calves are higher than at 3, 5 or 8 months. Insulin concentrations also change with time of day at one month of age, but not at any other age examined.

This increase at one month may be due to increased release of insulin in response to feeding. For example, Trenkle (1978) observed a biphasic increase in insulin in serum postprandially in sheep. The

first increase was detected within one h of eating and was thought to be due to release of gastrointestinal hormones from a neural response to the act of eating. The second increase in insulin occurred four to six h postprandially. A similar insulin response to time post-feeding was observed when calves in the present study were one month old, but not at 3, 5 or 8 months. This may be due to a combination of factors. First, these calves were fed at 0600 h until they were two months old, and at one month of age, insulin concentrations in serum were greatest at 1000 h, or approximately four h after eating. By three months of age, calves are no longer fed meals, but rather grouped with animals of similar size and fed ad libitum. Feed being available at all times would tend to mask insulin response to meal feeding.

Also, at one month of age, calves were being fed whole milk which contains lactose. Lactose is digested in the gut to galactose and glucose, both of which cause an increase in blood insulin. By three months, the diets of these calves did not contain lactose and therefore an insulin response due to digestion of sugars was not expected or observed.

The decline in insulin concentrations after 1000 h at one month of age may be in response to decreased absorbtion of nutrients from the gut. The gradual decrease in insulin cannot be attributed to metabolic clearance following a single transient release of insulin because the $t_{\frac{1}{2}}$ of insulin is less than 10 minutes (R. Nachreiner, personal communication).

Concentrations of GH were lower in serum of calves at one month of age than at 3, 5 or 8 months. Irvin, and Trenkle (1971) and Purchas, et al. (1970) reported that age did not influence GH concentrations in

plasma. However, Trenkle (1970a) reported that concentrations of GH were greater in serum of eight week old Hereford calves than in serum of older calves. In addition, Keller et al. (1979) reported that concentrations of GH in serum are greater in Hereford calves at one month than at three or seven months of age. Results of these experiments by Trenkle (1970) and Keller, et al. (1979) do not agree with those presented herein. Possible explanations for these differences are as follows. Trenkle (1970) and Keller, et al. (1979) both sampled jugular blood via venipuncture once daily. Since GH secretion is thought to be episodic, one sample would not necessarily give an accurate account of the hormone concentrations in young calves. Also, in both experiments, (Trenkle, 1970; Keller, et al., 1979), Hereford calves were used. Irvin and Trenkle (1971) found no evidence to support the view that GH varies between breeds. But those measurements were across beef breeds and crossbred beef breeds only i.e., beef and dairy breeds were not compared. Perhaps a difference in GH secretion exists between beef and dairy breeds that has not yet been reported.

After the first month, there was no change in concentrations of insulin or GH associated with aging in this study. Growth hormone is known to exhibit anti-insulin effects and perhaps the increase in GH seen after one month of age may be related to the decrease in insulin concentrations found in serum at the same time. The lower levels of GH found at one month of age compared to 3, 5 and 8 months may be due to changes in diet or differences in mode of digestion of nutrients associated with onset of rumen function. Lower mean concentrations of GH observed at month one may also be related to heifers being meal-fed. While both Trendle (1967) and Bassett (1974a) observed a decrease in

concentrations of GH postprandially in sheep, it must be kept in mind that hormone levels of those experimental animals were measured after they were starved for three to five days, then fed. This experimental design would not necessarily reveal physiologically normal hormone responses to feeding.

Anfinson, et al. (1975) observed that secretion of growth hormone is episodic. Similarily, GH secretion in the present study was episodic at all ages studied. However, average concentrations of GH did not change with time of day at 1, 3, 5 or 8 months of age.

To the author's knowledge, no one has previoulsy described changes in total glucocorticoid concentrations relative to growth and aging of cattle. Glucocorticoids maintain blood glucose (Long and Lukens, 1936; Lumley and Nice, 1930) and liver and muscle glycogen stores by stimulating production of glucose via gluconeogenesis. Calves at one month of age would have less need for glucose than would older calves since they are still ingesting milk and have no funcional rumen. This may explain why concentrations of glucocorticoids were lower in serum collected from calves at one month than at 3, 5 or 8 months of age.

Higher concentrations of glucocorticoids observed at five months are difficult to explain. In agreement with the present results, Leung (1979) observed an increase in glucocorticoids with age in dairy calves with a peak observed at approximately five months. This increase may be associated with onset of puberty. For example, Desjardins and Hafs (1969) observed a rapid increase in ovarian weight from birth to five months, followed by a plateau from five to eight months and resumed ovarian growth from 8 to 12 months of age. Since age at onset of puberty in Holstein heifers is 8 to 12 months (Morrow, 1968), the plateau of

ovarian growth observed at five to eight months of age may be an indication of prepubertal ovarian development.

A role for adrenal steroids in puberty has been established for humans and rats. Ducharme, et al. (1976) hypothesized that, in humans, a prepubertal increase in the adrenal steroids dehydroepiandrosterone, andresteindione and estrone may be responsible for the change in gonadal hormone levels necessary for the onset of pubertal development. In addition Collu and Ducharme (1978) reported that adrenal steroid secretion increased three to four years prior to onset of puberty in humans. These authors hypothesized that the adrenal steroids, especially aldosterone, are important in the process of maturation of the hypothalamus. The relationship they observed between adrenal and gonadal steroids is evidence in favor of a role for adrenal steroids in the maturation of the central nervous system mechanisms which lead to puberty. Gorski and Lawton (1973) demonstrated that adrenalectomy of immature rats at 19 and 25 days of age, but not at 35 days, significantly delayed time of onset of puberty. They also found that autotransplantation of the adrenals at 18 days prevented this delay. These data were interpreted as evidence that during a certain period, the adrenals play a role in maturation of the hypothalamic-pituitary-gonadal axis. Perhaps the increase in total glucocrticoids we observed in dairy heifers at five months of age is an indication of prepuberal maturation.

Alternatively, the increase in glucocorticoid concentrations at five months may have been due to management procedures. Calves were group housed by age beginning at three months of age. At approximately five months of age, heifers were moved into a pen of older calves, thereby putting them into a group in which they were the smallest

animals. This could have posed a stressful situation for the calves, resulting in an increase in adrenal glucocorticoids. Because a complete understanding of the actions of the glucocorticoids is not available at this time, it is not possible to explain for certain what significance the changes in these hormones associated with aging may entail.

SUMMARY AND CONCLUSIONS

The relationship between insulin, growth hormone and glucocorticoid concentrations measured in serum early in life of Holstein heifers and their genetic potential to produce milk was studied. In addition, changes in hormone concentrations with age through eight months was determined. These heifers were the culmination of a genetics project begun in 1967 whereby cows in the Michigan State University herd were divided into two groups and arbitrarily labeled "Best" and "Worst". The cows were then bred to sires selected on the basis of the first evaluation of daughters' milk yield. Predicted differences between milk yield of daughters of bulls in the 10^{th} class (B_{10} and W_{10}) differed by 600 kg; PD of bulls from the 11^{th} class (B_{11} and W_{11}) differed by 820 kg. Dams of these heifers differed between "Best" and "Worst" groups in milk production by 737 kg. Daughters of cows became members of the same group as their dams. First lactation records of heifers used in this experiment differed between "Best" and "Worst" by 1004 kg of milk.

During a 30 day feeding trial when calves were 60 to 90 days old, total weight gained, average daily gain and average daily feed intake were not different between the genetic groups. Feed efficiency, defined as the ratio of kg of gain over kg of feed, was higher in calves from the "Best" group than for those in the "Worst" group.

Heifers were weighed and height of withers recorded monthly until 12 months of age. Rate of gain of body weight was not different due to genetic background until 9 months of age, after which time calves

from the "Best" group gained weight faster and were heavier than calves in the "Worst" group. There was no difference between genetic groups in wither heights at any of the ages examined.

Blood was collected when heifers were 1, 3, 5 and 8 months of age. Concentrations of insulin, GH and total glucocorticoids in serum were not different due to genetic background at any of the ages examined. But, there were changes in all hormone concentrations attributable to aging. At one month of age, insulin was higher and GH concentrations were lower than at other ages. Insulin concentrations in serum also changed with time of day when heifers were one month old, i.e., highest at approximately 1000 h and declining linearly until 1300 hours. The effects of age and/or time of day may be due to a change in the response of the pancreas to feeding. No changes in hormone concentrations throughout the day were observed for GH or glucocorticoids at any age, and none for insulin after one month of age.

Total glucocorticoid concentrations in serum increased from 5.0 ng/ml at one month to 11.6 ng/ml at 5 months, followed by a slight decrease to 9.3 ng/ml at 8 months of age. This peak in glucocorticoid concentrations in serum observed at 5 months of age may be an indication of prepuberal maturation.

We conclude that there is no difference in insulin, GH or total glucocorticoids in serum of genetically diverse groups of dairy heifers when examiined at 1, 3, 5 or 8 months of age. Possible explanations for failure to see differences include; 1) hormones different than those measured or ratio of hormone concentrations or hormone/receptor relationships may be better indices of genetic potential; 2) endocrine differences between animals selected for milk production may not exist

until lactation begins, and 3) genetic diversity of these heifers was not adequate to detect endocrine differences. Therefore, these methods will not provide a system to identify superior animals early in life.

Changes observed in insulin and GH concentrations in serum associated with aging seem to be related to change in diet, time of feeding, and maturation of the digestive system from a monogastric-like animal to that of a ruminant animal. Changes in total glucocorticoid concentrations in serum may be related to general maturity or specifically related to processes leading to puberty.

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