MONTANA STATE UNIVERSITY

Production from first calf beef heifers fed a high or low level of prepartum nutrition and ruminally undegradable protein postpartum
by Jon Scott Wiley

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Animal Science
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Abstract:
Two experiments were conducted in consecutive years to determine the effects of prepartum nutrient level and postpartum ruminally undegraded protein intake on nutrient status, milk production, subsequent calf and reproductive performance of 126 English crossbred primiparous beef heifers. Prepartum treatments were low nutrient intake (LN) (approx. 2.5 kg TDN, .5 kg CP hd-1 d-1 and high nutrient intake (HN) (5 kg TDN, 1 kg CP hd-1 d-1) which were fed for 75 days prior to calving. Postpartum dietary treatments were supplements designated ruminally degradable protein (RD) and ruminally undegraded protein (UD) which supplied 250 g additional UD crude protein hd-1 d-1 compared to the RD supplement. Cholesterol was lower (P < .01) for UD than RD. Blood urea nitrogen was higher (P < .01) for UD fed heifers compared to RD and LN heifers were higher (P < .06) than HN heifers. Milk production or composition did not differ due to LN, HN, UD or RD. Postpartum cow weight gain was greatest (P < .01) for UD heifers and for LN heifers. Heifers bred during the first estrous cycle of the breeding season was greater (P < .02) for UD than for RD regardless of LN or HN. Overall, prepartum nutrition level had no effect on postpartum interval while UD increased cow weight gain postpartum and reduced postpartum interval.

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Two experiments were conducted in consecutive years to determine the effects of prepartum nutrient level and postpartum ruminally undegraded protein intake on nutrient status, milk production, subsequent calf and reproductive performance of 126 English crossbred primiparous beef heifers. Prepartum treatments were low nutrient intake (LN) (approx. 2.5 kg TDN, .5 kg CP hd^{-1} d^{-1} and high nutrient intake (HN) (5 kg TDN, 1 kg CP hd^{-1} d^{-1}) which were fed for 75 days prior to calving. Postpartum dietary treatments were supplements designated ruminally degradable protein (RD) and ruminally undegraded protein (UD) which supplied 250 g additional UD crude protein hd^{-1} d^{-1} compared to the RD supplement. Cholesterol was lower (P < .01) for UD than RD. Blood urea nitrogen was higher (P < .01) for UD fed heifers compared to RD and LN heifers were higher (P < .06) than HN heifers. Milk production or composition did not differ due to LN, HN, UD or RD. Postpartum cow weight gain was greatest (P < .01) for UD heifers and for LN heifers. Heifers bred during the first estrous cycle of the breeding season was greater (P < .02) for UD than for RD regardless of LN or HN. Overall, prepartum nutrition level had no effect on postpartum interval while UD increased cow weight gain postpartum and reduced postpartum interval.

CHAPTER 1

INTRODUCTION

To cow-calf producers, the most important factor influencing productivity (and profitability) is reproductive efficiency of females. Total pounds of calf weaned per cow exposed to a bull during the breeding season is an accurate measure of reproductive efficiency. Dickerson (1969) stated feed costs above maintenance and reproductive rate of beef cows were two areas, which if improved could increase producer profitability. If management schemes could be developed to improve reproductive success while decreasing feed input costs and maintaining total pounds of calf weaned per cow, profitability of beef producers would be greatly enhanced.

For many years, it has been accepted that interaction between reproduction and nutrition in beef cows has been controlled by energy intake and body energy stores of the beef cow (Wiltbank, et al. 1962). These findings have been widely interpreted to mean that body condition of the beef cow both prior to and following calving is important in predicting rate of reproductive success of the beef cow. Much research effort has been expended with limited success in an attempt to provide biological mechanisms by which energy intake and body condition influences reproduction. In addition, reproductive rate of the national cow herd has not significantly improved (Williams, 1990) since research conducted in the 1960's which concluded that reproduction is controlled by energy intake and

status of the animal.

Recently protein intake (Sasser et al., 1988) and type of protein (Halfpop et al., 1988; Hunter and Magner, 1988) have been shown to influence reproductive responses to nutrition. The role of protein nutrition has been overlooked in previous research and earlier reports were confounded by the quality, quantity or ruminal synthesis of protein with intake or concentration of energy in the diet.

The objectives of this experiment were 1) to determine the effect of restricted nutrient intake during the third trimester of pregnant beef heifers on reproductive rate, milk production, nutrient status and calf performance, 2) determine the effect of ruminally undegraded protein fed in the postpartum period on reproductive rate, milk production, nutrient status and calf performance and 3) determine if an interaction exists between prepartum nutrient intake and postpartum ruminally undegraded protein fed to first calf beef heifers on reproductive rate, milk production, nutrient status and calf performance.

CHAPTER 2

LITERATURE REVIEW

Reproduction of cattle is a complex and not completely understood biological phenomena. Postpartum infertility has been attributed to four factors: general infertility, lack of uterine involution, short estrous cycles and anestrus (Short et al., 1990). To fully understand the mechanisms controlling the length of the postpartum interval (or the time from calving to first estrus), the control of the estrous cycle must be understood. In order for estrus and ovulation to occur in a normal cyclic female, a preovulatory increase of estradiol-17ß must occur which stimulates LH release. The LH pulse height and frequency then increases, causing ovulation to occur (Martin, 1985; Foote, 1974). Progesterone and estradiol-17ß have a negative effect on gonadotropin releasing hormone (GnRH) during the luteal phase of the estrous cycle or the phase of the cycle when corpora lutea are present on the ovary. Progesterone has a negative effect on GnRH during pregnancy to stop the cyclicity and maintain pregnancy. Most of the steroid hormones are placental in origin during pregnancy (Foote, 1974). Following parturition, LH is low and release in cows is episodic and infrequent (Peters and Perera, 1989). Follicular maturation is brought about by increasing LH pulse frequency resulting in pre-ovulatory increases of estradiol-17ß and the LH surge followed by ovulation. Progesterone concentrations are low in the postpartum cow

(Rawlings, et al., 1980) and remain low for an extended period of time. Progesterone levels will eventually begin to rise, fall to low levels and then rise to normal luteal phase levels when the cow ovulates and maintains a functional corpus luteum (Donaldson et al., 1970; Corah et al., 1974). The transient rise in progesterone may have an organizing effect on the endocrine pattern of the postpartum cow (Rawlings, et al., 1980) and has been positively associated with the fertility of the first estrus (Folman et al., 1973; Corah et al., 1974).

Research has shown that an interaction exists between nutrition (Wiltbank et al., 1962; Dunn, et al., 1969; Sasser, et al., 1988; Randel, et al., 1990; Short, et al., 1990), lactation (Oxenreider and Wagner, 1971; Bruckental, et al., 1989; Harrison, et al., 1989; Williams, 1990), body condition (Rutter and Randel, 1984; Richards, et al., 1986; Louw and Thomas, 1988; Selk, et al., 1988) and reproductive activity of the postpartum cow. These factors can also interact with each other to affect reproduction (Short et al. 1990).

The effects of lactational output and suckling on reproduction are significant. Lactation imposes an accelerated metabolic demand on the cow (Oxenreider and Wagner, 1971). An even greater strain is placed on first lactation heifers because of the additional demand of metabolites needed for growth (Whittier et al, 1988). Huszenicza et al. (1987) reported higher frequencies of ovarian disturbances among dairy cows with high lactational output. Harrison et al.

(1989b) concluded dairy cows with high milk production suffered from a suppression of estrous behavior rather than reduced ovarian activity. However, Stevenson and Britt (1980) reported increased milk yield or increased milking frequency resulted in a delayed rise in serum LH, reduced number of episodic LH peaks and longer postpartum intervals. A positive correlation between length of the anestrous period and milk production was reported for lactating beef heifers by Hunter and Magner (1988). Cortisol has also been linked to high milk yield and postpartum anestrus. Harrison et al. (1989a) suggested that although cortisol concentration increased over time in high producing dairy cows, cortisol level seemed to be more closely associated with energy status of the animal than the exhibition of estrus. Moberg and Stoebel (1980) infused cortisol and depressed LH secretion, suggesting cortisol could inhibit ovulation. Based on research using two distinct (high and low) lines of beef cattle differing in levels of fertility, Hetzel et al. (1989) suggested lower milk production of cows belonging to the high fertility line led to higher fertility rate compared to higher milk producing cows from the low line.

Suckling appears to have a greater impact on reproduction than relative milk production (Short, et al., 1972). Williams (1990) proposed a model where suckling inhibited LH release. Wright, et al. (1987) also reported depressed LH release when cows were suckled compared to periods of calf separation but

calf separation had no effect on FSH or prolactin release. It has also been documented that cows that have their calves weaned at birth will have shorter postpartum intervals than cows with suckling calves (Short et al., 1972). Perhaps the effect of lactation on reproduction has been confounded with the frequency or duration of suckling.

Body condition (BC) of females at time of parturition has been linked to reproductive performance (Short et al., 1990). Maintaining body condition through gestation is costly due to lower efficiency of diet utilization in cattle of higher body condition (Jones and Garnsworthy, 1989). Also, the use of body condition has become synonymous with energy status as energy intake determines body condition (Wiltbank et al., 1962) and the use of body condition scores have been used to estimate stored energy (Randel, 1990). Short et al. (1990) concluded that precalving condition of cows is more important than condition following calving and that reproductive response to BC is nonlinear; cattle with body condition < 4 or > 7 (scale 1 to 10) will have longer postpartum intervals. Houghton et al. (1990) concluded that even though cattle of fleshy body condition would have shorter postpartum anestrous periods, they have lower first service conception rates and lower pregnancy rates compared to thin and moderately conditioned cows. A degree of caution should be used when interpreting body condition relationships to fertility, as both measures may be an effect due to nutritional status of

the animal, and not a cause and effect of each other.

Rutter and Randel (1984) concluded postpartum interval is more a function of the cows' ability to maintain or gain body condition during the postpartum interval, not the relative body condition of the animal at calving time. Cows maintaining condition had shorter postpartum interval, higher levels of basal LH and higher GnRH induced peak LH concentrations. Ruttle and Randel (1984) also demonstrated that whether a cow loses or maintains body condition after calving is more dependent upon her individual metabolic requirements than upon calculated NRC requirements.

Louw and Thomas (1988) subjected cattle to weight loss situations until anestrus occurred. It was concluded that cattle can be subjected to severe weight loss (21-31% of initial body mass) and normal reproductive ability will resume with restoration of higher nutritional levels, although the body condition will be higher when cyclicity resumes than it was when anestrus occurred. In a similar study, Richards et al. (1986) showed duration of weight loss affected fertility because cows losing weight early after calving and then fed to gain weight (flushed) were more fertile than cattle that continued to lose weight postpartum. Cattle with a body condition score (BCS) <4 that were flushed had highest first service conception rates. Cows with BCS < 4 had longer postpartum anestrus than cows with BCS > 5 but required the same number of days postpartum to conceive. In that study,

although days to first estrus was longer for thin cows, a higher percentage conceived on first service so days to conception was similar for fleshy and lower body condition cows. The results presented by Houghton et al. (1990) duplicated results and conclusions of Richards et al. (1986). Cows in the experiment of Houghton et al. (1990) in lower body condition had higher first service conception rates than cows in moderate or fleshy body condition. From that experiment, Houghton suggested fleshy and thin cows at parturition be managed to approach moderate body condition before the breeding season.

Selk et al. (1988) conducted an analysis of 5 years of calving data on Hereford cows. In that study, prepartum nutrition level did not affect days to conception, but a cubic response was observed between precalving body condition and pregnancy rate in the fall. This was due to a higher pregnancy rate for cows fed to maintain weight throughout the study, lower pregnancy rate for cows fed to lose weight throughout the study, and intermediate pregnancy rates for cows fed to lose weight prior to calving and then fed (flushed) to maintain weight or gain weight after parturition. Following calving, all cows used by Selk et al. (1988) were fed to maintain body weight. A decrease in body condition from November to January was negatively correlated with days to conception, but it should be noted that cows that lost weight during the fall were then fed to maintain the January weight

and not allowed to gain weight postpartum. Dunn and Kaltenbach (1980) reported postpartum body weight gain shortened the postpartum interval. Monensin, an ionophore that increases the efficiency of energy usage, has also been shown to have a positive affect on weight gains and reproductive rate in beef cattle (Turner et al., 1977; Harrison et al., 1982).

Although current accepted theory proposes energy intake and body condition have an affect on reproductive rate in beef cattle, the mechanism by which the response is elicited has not been demonstrated. Similar serum progesterone concentrations have been reported (Corah et al. 1974) between heifers fed two levels of energy, and another report shows higher concentrations of serum progesterone in energy deprived heifers (Donaldson et al., 1970). Likewise, serum levels of LH have also been shown (Gombe and Hansel, 1973) to be similar between energy restricted and energy adequately fed heifers in some experiments while others (Beal et al., 1978; Wright et al., 1987) have shown positive linear responses of LH secretion to plane of energy in the diet. Roberson et al. (1989) hypothesized changes in hormone secretion patterns in energy restricted heifers is dependent upon direction of weight change, not a critical body weight. This theory would be in agreement with that of Rutter and Randel (1984) who concluded that it is not the relative weight or condition of the animal that dictates reproduction but the ability of the animal to maintain or gain weight in the postpartum period.

The experiment reported by Rutter and Randel (1984) was designed to define hormonal differences between cows fed differing levels of nutrition. No differences were found for LH characteristics between groups of cows until the data was blocked by cows that maintained body condition (BC) or lost BC from calving through d 20 postpartum. Cows maintaining body condition had shorter postpartum intervals, higher basal levels of LH and higher total LH released.

McCaughey et al. (1988) infused glucose into postpartum beef cows and could not elicit a response in pituitary release of LH. Cruikshank et al. (1988) infused glucose into ewes and did not change ovulation rate of those ewes compared to ewes infused with water. Harrison and Randel (1986) infused insulin into heifers on either a low or a high energy diet. Energy deprived heifers given exogenous insulin had higher ovulation rate but similar LH parameters as other treatment groups. Beal et al. (1978) concluded energy restriction may influence LH release directly at the pituitary as well as indirectly through effects on steroid hormone production. Others (Donaldson et al. 1970; Gombe and Hansel, 1973) have suggested the stimulus for the increase in LH was a reduction in negative feedback associated with decreases in progesterone synthesis.

Monensin has been shown to affect prepartum plasma steroid concentration (Chew et al., 1978), FSH induced ovulation rate (Harrison et al., 1982), LH response (Randel

and Rhodes, 1980) and postpartum interval (Turner et al., 1977). If improved efficiency of energy usage induced by monensin can create these responses, increased total energy fed should elicit the same responses, however, increased energy has not always demonstrated the same responses (Rutter and Randel, 1984; Richards et al., 1986; Randel, 1990). Possibly, the contradiction of reported results could be due to a limited interpretation of the experimental nutrient intake. Energy intake and ionophores influence are confounded with quantity or quality of protein reaching the small intestine for absorption.

Protein has been considered unimportant in the reproduction of beef cattle (Wiltbank et al., 1962). Recently, research results have presented evidence that protein does play a crucial role in reproductive performance of beef cattle (Sasser et al., 1988). In the experiments of Sasser et al. (1988) diets were isocaloric and heifers were either restricted or given adequate protein during pre- and postpartum time periods. Heifers that were restricted had longer postpartum intervals and longer days to conception. This response was attributed to reduced gonadotropin release from the anterior pituitary and decreased pituitary responsiveness to GnRH by protein restricted heifers (Nolan et al., 1988). With lactating dairy cows fed isocaloric diets, Jordan and Swanson (1979) reported lower progesterone concentrations and higher basal LH levels in cows fed a higher

percentage (16.3% and 19.3% vs 12.5%) of crude protein in the diet. Blauwiekel et al. (1986) concluded high protein diets did not have an impact on LH or progesterone concentrations of dry dairy cows. This apparent contradiction in findings could be due to differences in design, because Jordan and Swanson (1979) utilized high producing lactating cows with great nutritional needs while Blauwiekel et al. (1986) used nonlactating cows with lower energy and protein requirements. Also, Blauwiekel et al. (1986) compared 15% CP diets to 25% CP diets. Jordan and Swanson (1979) reported differences comparing diets of 12.5%, 16.3% and 19.3% CP. Possibly, results could have been similar if Blauwiekel et al. (1986) would have had a diet with lower CP content to compare to the 15% and 25% CP diets.

Hunter and Magner (1988) demonstrated that addition of formaldehyde-treated casein, a ruminally undegraded protein source to a roughage diet fed to beef heifers, significantly shortened the anestrous period possibly by repartitioning nutrients from milk production to maternal growth via insulin and growth hormone responses to supplementation. Ruminally undegradable protein has improved weight gain in dairy heifers fed a low TDN diet compared to heifers receiving a high TDN diet (Tomlinson et al., 1989) while also improving fat corrected milk production. Halfpop et al. (1988) also reported a shortened postpartum anestrous period of beef heifers fed ad libitum hay and pasture when supplied with ruminally

undegraded protein compared to a ruminally degraded crude protein. The response in that study did not appear to be a repartitioning of nutrients as Halfpop et al. (1988) reported increased milk production from the heifers receiving the ruminally undegraded protein. Fish meal supplementation (Bruckental et al., 1989) improved pregnancy rate of high producing Holstein cows compared to soybean meal supplementation along with greater weight gains in both primiparous and multiparous cows fed similar levels of energy.

Protein could also account for the observations seen in other experiments (Corah et al.,1974) where no difference was seen in conception rate or postpartum interval due to energy level of the diet. Crude protein content of the diet was similar in the study of Corah et al. (1974). Other studies have not accounted for the production of microbial protein synthesis in the rumen from the energy sources in the diet and non-protein nitrogen (Nocek and Russell, 1988). Caution should be used when supplying dietary protein to postpartum cattle. Ferguson et al. (1988) and others (Bruckental et al., 1989; Thompson et al., 1973) have reported decreased pregnancy rates and increased services to conception of cattle fed high levels of protein during the breeding season. This has been attributed to the concentration of urea nitrogen in vaginal mucous which is detrimental to sperm survival. Smith (1988) suggested protein supplementation of ewes during the prebreeding flushing period be terminated before breeding.

Ovulation rate in ewes was not affected by discontinuing protein supplementation before breeding (Smith et al., 1983).

Dietary protein has also been found to influence cytochrome P-450 enzyme systems (Singh et al., 1988; Thomford and Dziuk, 1988). The cytochrome P-450 enzymes are the rate-limiting enzymes in the production of steroid hormones (Waterman et al., 1986; Rodgers et al., 1986; Jefcoate, 1986) as well as the catabolism of steroid hormones. Others (Singh et al., 1988; Wiley, et al., 1990) demonstrated that quality and quantity of dietary protein affect the enzyme systems. Trzeciak et al. (1986) explained the effects of FSH on granulosa cells in the ovaries of rats. Follicle stimulating hormone appears to induce the formation of cytochrome P-450$_{scc}$ which is the enzyme required for the formation of progesterone from cholesterol. A similar response has been observed in bovine granulosa cells (Funkenstein et al., 1984). Specific amino acids have been shown to induce the cytochrome P-450 enzyme system (Truex et al., 1977) as well as the size and activity of mice ovaries (Pitkow and Davis, 1980). Possibly, the route through which dietary protein exerts its influence on reproduction is through these enzymatic pathways for production or catabolism of steroid hormones (Smith, 1988). This theory could help explain the inconsistencies observed in results of experiments involved with the interaction between nutrition and reproduction. No experiments to date have dealt with supplementation of excess protein or specific amino acids

while maintaining equal energy status between animal units and assessing their role in the nutrition-reproduction interaction. Also, the poor conception rates of dairy cattle fed high protein diets during the breeding season (Ferguson et al., 1988) could be due to protein stimulating the hepatic cytochrome P-450 system that catabolizes steroid hormones. If plasma progesterone is not maintained in early pregnancy, embryonic mortality could occur in those cattle consuming a high protein diet (Parr et al., 1987).

Another factor which has not been taken into account, is the effect of insulin on reproductive function. Plasma insulin concentration can change due to dietary energy intake (Granner, 1988), dietary protein intake (Hunter and Magner, 1988), body condition (McCann and Reimers, 1985a) and milk production (Butler and Canfield, 1989), all factors which have been shown to influence postpartum reproduction. The metabolic effect of insulin has also been shown to differ between obese and lean heifers (McCann and Reimers, 1985b) in response to exogenous glucose. Insulin release in ruminant animals is more responsive to circulating propionate than glucose as propionate is the primary energy source of ruminants and glucose is very highly regulated (Van Soest, 1987). Also, Richards, et al. (1989) demonstrated that cattle experiencing weight loss have declining plasma insulin.

The role of insulin in the production of steroid hormones has been demonstrated by Veldhuis et al (1985). Insulin

stimulates cytochrome $P-450_{scc}$ which is the rate limiting enzyme in the production of the steroid hormones necessary for normal reproductive function (Waterman, 1986). Possibly, by feeding additional amino acids in the form of ruminally undegradable protein, insulin levels would increase (Hunter and Magner, 1988), thus stimulating the production of steroid hormones. This increase in steroid hormones would then allow an anestrous cow to become cyclic. Also, a repartitioning of nutrients away from milk production to maternal body growth would metabolically adjust cows into a positive weight gain which has also been shown (Roberson et al, 1989) to improve reproductive responses in cattle. Harrison and Randel (1986) reported thin heifers responded with higher ovulation rates compared to heifers in higher body condition when they received exogenous insulin infusions. With this in mind, it may be possible to feed cattle a low level of prepartum nutrition followed by ruminally undegradable protein postpartum to increase insulin secretion, thereby improving ovulation rate, cow weight gain and reproductive rate regardless of body condition of the animal.

CHAPTER 3

MATERIALS AND METHODS

Experiment 1. Seventy one pregnant, primiparous beef heifers of primarily Angus and Hereford breeding (average weight 466 kg) were randomly allotted to two treatments on November 21, 1988. Heifers designated low prepartum nutrient intake (LN) were group fed approximately 5.5 kg hd^{-1} d^{-1} of medium quality grass hay (10.1% CP) to restrict nutrient intake and create a sufficient nutrient deficiency to impose weight loss prior to calving (March 1, 1989). Heifers fed the high prepartum nutrient intake (HN) diet received approximately 9.1 kg hd^{-1} d^{-1} of the hay fed LN plus 2.3 kg hd^{-1} d^{-1} of ground barley during the coldest part of the winter to maintain sufficient nutrient intake to avoid loss of body weight and condition. Heifers were weighed and condition scored (1 = emaciated, 10 = obese) monthly. On January 5, sixteen of the heifers from each group were placed in pens and trained to the use of the Calan-Broadbent individual feeding gates for a 3-week training period. Following calving, these 32 heifers were individually fed the postpartum diet and used intensively to monitor nutrient status, milk production and reproduction. The 39 heifers not housed in the individual feeding pens were used for determination of pregnancy rate and calf weaning weight. Nine heifers were removed from the study due to deaths of the calves (5) or culling (4) not related to treatment effects. One heifer of the HN group aborted and was

removed from the study.

At calving, calf birth weight, dystocia score and calf vigor score was recorded for each heifer. Dystocia scores were scored based upon 1) no assistance, 2) mild assistance, 3) difficult, great assistance, and 4) caesarean section. Calf vigor scores were assigned as 1) no assistance, 2) assistance in getting up and suckling, 3) great assistance requiring feeding with a tube, and 4) dead at birth. Cows were assigned to one of two postpartum treatments by prepartum energy group, birth date, birth weight, and sex of the calf.

Dietary treatments administered postpartum were 1) ruminally undegraded protein supplement (UD) or 2) ruminally degradable protein supplement (RD). The supplements were formulated to be isocaloric and isonitrogenous for ruminally degradable protein. The UD supplement was calculated to provided an additional 250 g per day of ruminally undegradable protein above that supplied by the RD supplement (Table 1). The supplements were fed at a rate of 1043 g hd^{-1} d^{-1}. Laboratory analysis reported UD as 56% CP and RD 22% CP. Rumen degradability and rate of disappearance of each supplement was estimated using a nylon bag technique (Miner and Petersen, 1989). Estimated degradability at 24 h was 16 % for UD and 89% for RD. Rate of disappearance was .8 and 12% h^{-1} and for UD and RD respectively.

The 32 individually fed heifers were weighed and a blood sample taken by venous/arterial puncture of the tail for

determination of blood metabolites (blood urea nitrogen, albumin, cholesterol and creatinine) within 24 h of calving. Samples were also taken on d 14, 31 and 51 postpartum for determination of these same metabolites plus insulin concentration (Sanson and Halford, 1984). In addition, a blood sample was taken at d 14, 31 and 51 for determination of glucose concentration. Following calving, the heifers were placed into the individual feeding barn and fed on the basis of 2.5% of their January 15 prepartum body weight of a medium quality hay (10.1% CP, 63% NDF). The purpose of feeding as a function of body weight and to exceed NRC (1984) requirements was to maximize control of energy intake and minimize the potential of confounding dietary intake, energy density of the diet, and body condition with source of protein supplement. This feeding regime provided LN heifers with approximately 113% of NRC (1984) TDN requirements and HN heifers with 116% of requirements for a 454 kg 2-yr-old nursing cow.

TABLE 1. FORMULATION OF RATIONS FOR RUMINALLY UNDEGRADED (UD) AND DEGRADABLE (RD) PROTEIN SUPPLEMENTS

Ingredient	UD	RD
	------------- % -------------	
Blood meal	21.90	–
Corn gluten meal	56.78	–
Wheat mill run	–	68.20
Soybean meal	9.57	19.10
Molasses	9.57	9.50
Urea	–	.98
Ammonium phosphate	1.95	1.95
Vitamin A	.10	.10
T.M. salt	.10	.10

Supplementation of UD to hay provided heifers with 180% of the

CP requirements and RD combined with the hay provided 125% of the CP requirements for a 454 kg nursing 2-yr-old. The group fed heifers were fed similar hay ad libitum and group fed the supplements. Supplementation continued for 60 d postpartum. The 32 individually fed heifers were blocked into two sampling groups dependent upon calving date for ease of sample collection. Sampling time was determined by the mean calving date of each group. Weekly heifer weights were recorded. Commencing on d 30 postpartum, the cattle were bled from the tail every three days for progesterone (analysis conducted at LARRL, Miles city, MT.) and palpated by a qualified technician for ovarian structures once weekly, for determination of first estrus. Progesterone concentrations were determined by solid-phase RIA provided by commercially available kits[1]. Limit of sensitivity for the progesterone RIA was 40 pg ml^{-1}, and the inter- and intra-assay coefficients were 3.3 and 6.3% for a sample containing 15 ng ml^{-1} and 2.5 and 10.8% for a sample containing 1 ng ml^{-1}. Serum progesterone concentration of 1 ng ml^{-1} were used to indicate ovulation had occurred and a functional CL was present on the ovary. This scheme continued until start of the breeding season (June 3).

On d 30 and 50 postpartum, indwelling jugular catheters were inserted by aseptic procedures into each heifer. Following injection with lidocaine hydrochloride, the jugular vein was punctured and the catheter inserted. On d 31 and 51,

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[1]Diagnostic Products Corp., Los Angeles, CA.

blood samples were taken from the catheters every 20 min of an 8 h period approximately 2 h post feeding. Samples were analyzed for LH concentration (Staigmiller et al., 1979) (LARRL, Miles City, Mt.)[2]. Peak LH height, peak frequency and a baseline LH level was calculated for each heifer by the method of Almond and Dial (1990). In addition, insulin concentration of the samples taken on d 51 were performed (Sanson and Halford, 1984)[3] and the method of Almond and Dial (1990) used to calculate insulin baseline concentration and mean values for samples taken. Area under the curve was also calculated for insulin release in the 8 h time period (McCann and Reimers, 1985b).

On day 21, 45 and 60 postpartum, milk production was estimated using a modified weigh-suckle-weigh technique. After feeding, the calves were removed from the cows and following an injection of 40 USP units of oxytocin intra-muscular, the cows were milked using a portable milking machine (Beal et al., 1990). After 4 h of calf separation, the cows were milked as described above. Milk was weighed and a subsample taken for determination of fat, lactose, protein, and solids not fat (Dairy Herd Improvement Association laboratory, Veterinary Research, Bozeman Mt.).

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[2]Author wishes to acknowledge the assistance of Ann Darling of LARRL for assay of hormones

[3]Appreciation expressed to Dr. Dennis Halford, New Mexico State University Endocrine Laboratory for analysis of insulin concentration

On day 60 postpartum, protein supplementation was terminated and the individually fed animals were group fed ad libitum with the other group fed heifers. On June 3 (approx. 90 d postpartum), breeding began. For 21 days, the cattle were observed by technicians to determine behavioral estrus twice daily and the cattle bred by artificial insemination. Following this breeding period, bulls were placed with the cows for an additional 21 days. On October 12, calves were weaned and weighed. Cows were tested for pregnancy via rectal palpation and weighed.

Experiment 2. Experiment 2 was conducted similarly to Experiment 1 with these modifications. On October 12, 1989, 64 pregnant yearling heifers were randomly assigned to the LN or HN treatment. Heifers were allowed to graze pastures. Heifers in the LN treatment group were placed in a pasture with low pasture allowance and heifers in the HN group were placed into a pasture with higher pasture allowance and group fed 2.3 kg of pelleted beet pulp hd^{-1} d^{-1} mixed with 2.3 kg of chopped hay. Additional hay was provided HN heifers beginning on November 13 on alternating days at a rate of 9.1 kg hd^{-1}. On December 13, hay was fed at the same rate every day to HN heifers and LN heifers received approximately 5 kg hd^{-1} d^{-1} of the same hay. Beet pulp was fed to HN heifers until January 30. At this time, the beet pulp was replaced with ground barley fed at the same rate until time of calving.

In addition to blood samples taken for metabolites on day

of calving, days 14, 31 and 51, a sample was also taken approximately 14 days prior to calving. Insulin concentration was performed on the blood samples taken for metabolites. Glucose samples were taken as in Experiment 1. Serial bleeding for LH was not performed in Experiment 2.

The breeding season in Experiment 2 consisted of 30 d of artificial insemination and 17 d of natural service. During the AI portion of the breeding season, vasectomized bulls were placed with the cows for detection of estrus. Two heifers were removed from this experiment due to death of the calf.

Statistical Analysis

Cow condition score, initial and final weights, calving scores, insulin release area parameters and LH peak parameters were analyzed with General Linear Models of SAS (SAS,1988). Cow initial and final weights, cow condition scores, LH parameters and insulin release parameters were analyzed with prepartum nutrition level, postpartum protein source, the interaction between pre- and postpartum nutrition and calving date included in the model. Postpartum location (whether group fed or individually fed postpartum), location x prepartum nutrition level and location x postpartum protein source were included in the model for analysis of June cow weights. Calf birth weight, calf vigor and dystocia scores had prepartum nutrition level, sex of calf, birth date and sire included in the model. Birth weight was included in the model for the

analysis of dystocia and calf vigor, and dystocia was included in the analysis of calf vigor. Cow weekly weights, milk production and composition, insulin concentration of samples taken the same days as blood metabolites and blood metabolites were analyzed using the repeated measures analysis of variance for split-split plot designed experiments with General Linear Models of SAS (SAS, 1988) with prepartum nutrition, postpartum protein and the interaction between pre- and postpartum nutrition included in the model. Calving date was included in the model for milk production and milk composition, cow weight change, and calf weight change. Sex was included in the model for calf weight change. Pregnancy rate, the percent exhibiting estrus prior to breeding and percent bred during the first 21 d of the breeding season were analyzed with Chi-square analysis of SAS with LN, HN, RD, UD and year as factors. Results of Experiment 1 and Experiment 2 were pooled with year included in the model.

CHAPTER 4

RESULTS AND DISCUSSION

Cow weight was affected by prepartum nutrition level. Heifers fed LN had lighter (P < .01) weights (Table 2) in December, January, and at breeding (June 1) but cow weight gain from calving to breeding was greater (P < .01) for LN treated heifers (Figure 1).

TABLE 2. THE EFFECT OF PREPARTUM NUTRIENT LEVEL AND POSTPARTUM RUMINALLY UNDEGRADED PROTEIN ON COW WEIGHT (WT) AND CONDITION SCORE (CS) OF FIRST CALF BEEF HEIFERS[a].

	---------- Treatment -------------				
	LN	HN	UD	RD	SE[b]
Measurement					
October					
wt (kg)	445.3	452.7	–	–	3.7
cs	5.5	5.5	–	–	0.07
December					
wt[c] (kg)	472.1	501.0	–	–	3.5
cs[c]	5.6	6.5	–	–	0.05
January					
wt[c] (kg)	419.8	487.0	–	–	3.0
cs[c]	4.4	5.8	–	–	0.05
June					
wt[c] (kg)	432.1	481.9	460.0	454.1	4.5
cs[c]	4.6	5.0	4.9	4.7	0.1

[a]LN = low nutrition prepartum, HN = high nutrition prepartum, UD = bypass protein postpartum, RD = rumen degradable protein postpartum
[b]Standard error of estimate
[c]LN vs HN, P < .01

Restriction of feed prior to calving and subsequent weight loss would reduce body size and thus maintenance requirements of LN fed heifers. Following calving, all nutrients were fed in excess of NRC (1984) requirements. But cattle fed LN gained approximately .1 kg hd^{-1} d^{-1} while HN fed cattle were losing approximately .09 kg hd^{-1} d^{-1} of weight with additional feed. With lower maintenance requirements, LN treated heifers would

have a greater supply of nutrients than HN fed heifers in
excess of maintenance and lactation demands, so a greater
portion of dietary intake could be used for growth. By
limiting the amount of feed supplied to LN fed heifers
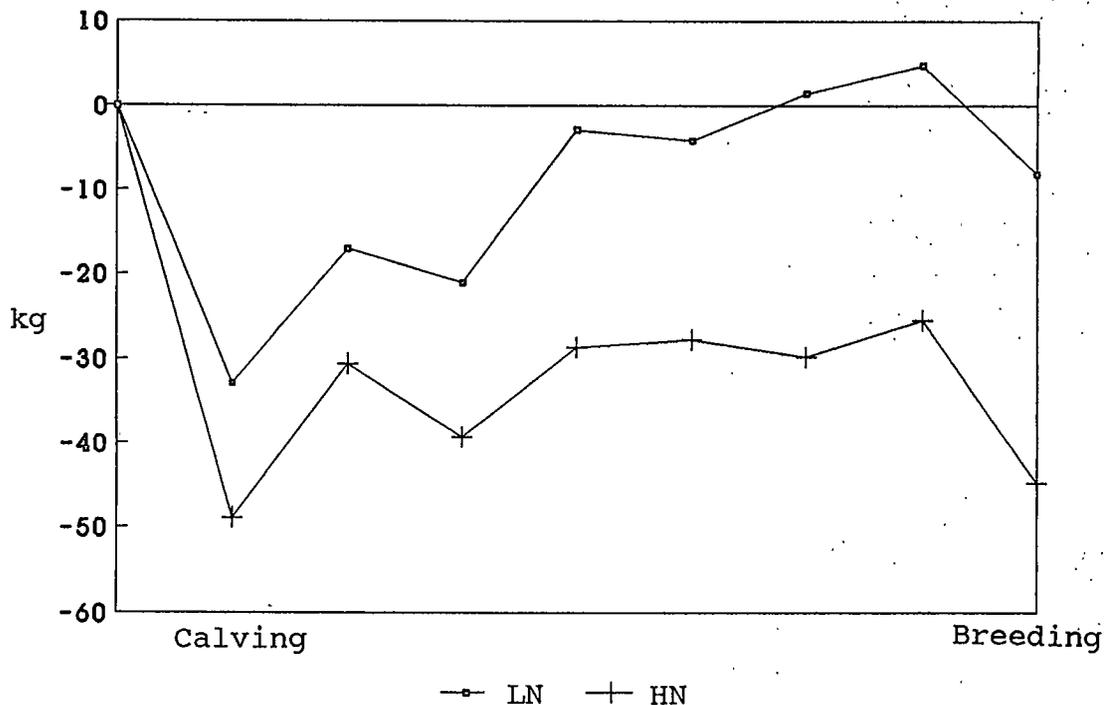
Figure 1. The effect of prepartum nutrition level on
postpartum cow weight gain in relation to January 15 cow
weight.

precalving, a compensatory type weight gain is seen when
nutrients are then supplied in excess.

Postpartum protein source also affected cow weight
change. Heifers fed UD had improved (P < .01) weight gain
during the postpartum period (Figure 2). This could be due to
a repartitioning of nutrients that was reported by Hunter and

Magner (1988) who suggested that ruminally undegradable protein repartitioned nutrient use away from milk production
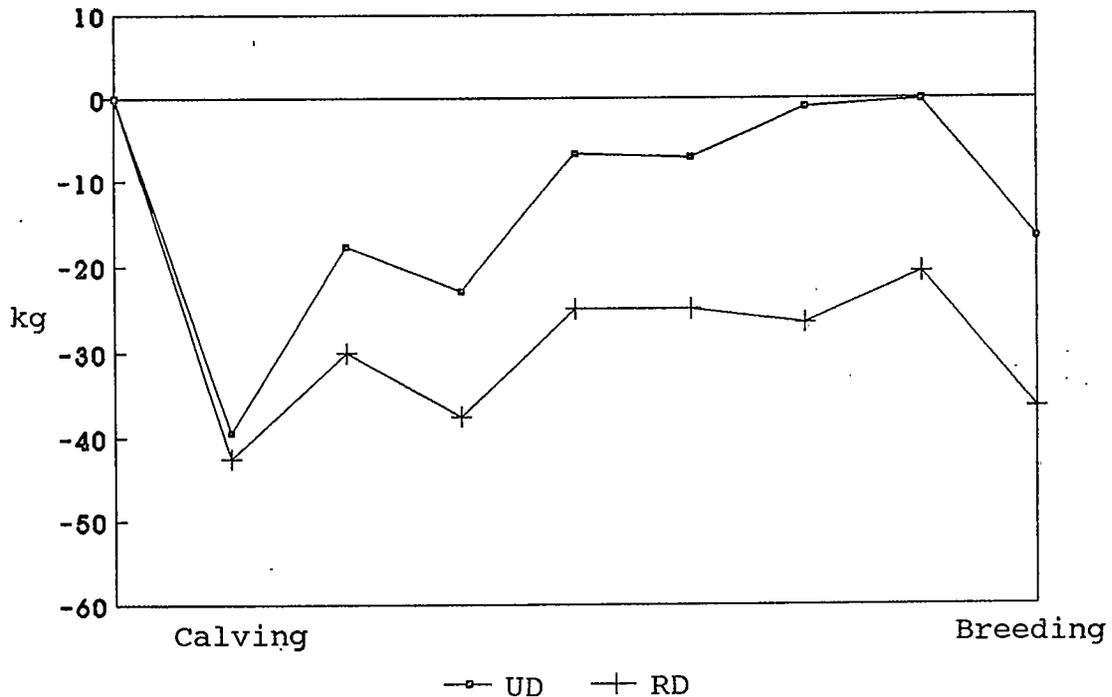
Figure 2. The effect of postpartum protein source on postpartum cow weight gain in relation to January 15 cow weight.

to maternal growth by insulin and growth hormone responses to dietary protein. Bailey (1989) compared steers consuming a predominantly forage diet to steers given a similar diet plus undegradable protein. It was concluded that steers given the undegradable protein in addition to the forage had a higher rate of gain of carcass muscle, bone and protein as a result of increased amounts of protein absorbed in the small

intestine and these steers were energetically more efficient for gain. This improvement in cow weight change due to UD could be of importance to reproduction as Rutter and Randel (1984) suggested reproductive success was dependent upon the ability of the cow to maintain or gain weight postpartum, not the absolute body condition of the animal. In addition, Roberson et al. (1989) suggested the direction of body weight change influences secretion of gonadotropins, rather than a critical body weight. They compared two groups of beef heifers weighing the same but one group was losing weight while the other was gaining weight. They found differences in secretion of LH and FSH between the groups. Butler and Canfield (1989) and Ferguson et al. (1989) concluded dairy cows in high negative energy balance early in lactation had poorer reproductive responses than cows in moderate negative energy balance. Possibly by supplying the additional undegradable protein, more nutrients were available to meet maternal needs, placing the cow in a more favorable nutrient balance and allowing reproduction to occur sooner. No interaction was detected between prepartum nutrition level and postpartum protein source on postpartum cow weight gain.

Calf birth weight, calf vigor and dystocia score were not affected by prepartum nutrition level (Table 3). Although not different (P > .1), LN cows had numerically lighter birth weight calves and fewer dystocia problems. This is in agreement with earlier data (Wiltbank et al., 1962; Sasser et

al., 1988; Houghton et al., 1990). All of these researchers reported that cows on restricted intake prior to calving tended to have calves of lighter birth weight. In this study, cows may have received a less severe feed restriction prior to calving compared to other studies. If severity or duration of prepartum feed restriction was greater, the difference between LN and HN fed animals could become greater.

TABLE 3. THE EFFECT OF PREPARTUM NUTRITION LEVEL OF FIRST CALF BEEF HEIFERS ON DYSTOCIA, CALF VIGOR AND CALF BIRTH WEIGHT.

	--- Treatment ---		
MEASUREMENT	LN	HN	SE[b]
Dystocia	2.2	2.3	0.16
Calf vigor	1.1	1.0	0.12
Birth weight (kg)	32.0	32.9	1.2

[a]LN = low prepartum nutrition, HN = high prepartum nutrition
[b]standard error of estimate

Wiltbank et al. (1964) cautioned that low energy intake prior to calving could have detrimental effects on calf performance. Houghton et al. (1990) reported calves from cows fed a low energy prepartum diet were lighter at 60, 105, and 205 d after birth. In the present study, calf weights for

TABLE 4. THE EFFECT OF PREPARTUM NUTRITION LEVEL AND POSTPARTUM PROTEIN SOURCE ON CALF WEIGHTS.

	------------ Treatment[a] --------				
WEIGHT (kg)	LN	HN	UD	RD	SE[b]
Birth	32.0	32.9	-	-	1.2
30 d	60.9	62.3	60.5	62.4	1.2
60 d	75.6	80.1	76.8	78.8	2.5
90 d	95.9	102.9	98.1	100.7	3.1
Weaning	225.3	230.4	230.4	225.3	3.8

[a]LN = low prepartum nutrition, HN = high prepartum nutrition, UD = ruminally undegradable protein, RD = ruminally degradable protein
[b]standard error of estimate

calves born of LN heifers tended to be lighter (P < .12) at all times prior to the start of the breeding season (Table 4). At weaning (Table 4), calves born from UD fed cows tended to be heavier (P < .17) and overall, neither prepartum nutrition level or postpartum protein source affected calf performance.

Milk production was not affected by either prepartum nutrition level or postpartum protein source (Table 5) although a trend existed at d 20 for UD fed heifers to milk less (P < .16). This is in agreement with results of Hunter and Magner (1988) who reported that feeding casein treated with formaldehyde to first calf heifers did not influence milk production during the first 8 wk of lactation. They did report that cows fed the ruminally undegraded protein did have significantly less milk produced in the second half of lactation. They concluded this was due to a repartitioning of nutrients from milk production to maternal body growth via an insulin and growth hormone response in animals fed the undegradable protein. No interaction was observed for milk production between prepartum and postpartum dietary treatments.

Lactose concentration of milk was not affected by LN, HN, UD or RD (Table 5). Protein concentration of milk (Table 5) was decreased by LN at d 20, d 45 and d 60 milkings (P < .06, P < .16, P < .11, respectively). This could be due to more feed protein going to compensatory maternal growth rather than towards milk in LN treated heifers. Milk fat was reduced (P <

.02) by LN at d 60. Also, UD fed heifers had lower (P < .09)

milk fat at d 20 postpartum (Table 5). These responses could

be seen as a result of more dietary energy going towards

maternal growth and away from milk fat production. The LN fed

TABLE 5. THE EFFECT OF PREPARTUM NUTRITION LEVEL AND POSTPARTUM RUMINALLY UNDEGRADED PROTEIN ON MILK PRODUCTION AND COMPOSITION OF FIRST CALF BEEF HEIFERS[a].

| | ----------- Treatment[b] ----------- | | | | |
Measurement	LN	HN	UD	RD	SE[c]
Milk (g)					
d 20[d]	1131.7	1224.3	1107.3	1248.6	71.2
d 45	1111.9	1189.4	1166.2	1135.1	66.2
d 60	1028.9	1076.7	1060.2	1135.1	70.2
Lactose (g)					
d 20	60.1	63.1	58.7	64.5	3.2
d 45	59.0	60.8	59.7	60.1	2.8
d 60	52.8	57.5	55.1	55.2	2.8
Protein (g)					
d 20[e]	34.9	40.3	36.3	38.9	1.9
d 45[f]	33.3	36.5	34.8	35.0	1.5
d 60[g]	29.5	33.2	31.7	30.9	1.5
Fat (g)					
d 20[h]	47.7	43.4	42.4	48.7	2.5
d 45	44.7	46.3	43.4	47.6	2.5
d 60[i]	38.8	47.7	41.8	44.6	2.5
Solids not fat (g)					
d 20	103.2	111.9	103.0	112.1	5.6
d 45	100.2	105.6	102.4	103.4	4.6
d 60[j]	89.4	98.6	94.3	93.7	4.7

[a]4 hour weigh-suckle-weigh
[b]LN = low prepartum nutrition, HN = high prepartum nutrition, UD =   ruminally undegraded protein postpartum, RD = rumen degradable protein postpartum
[c]standard error of estimate
[d]UD vs RD, P < .16
[e]LN vs HN, P < .06
[f]LN vs HN, P < .16
[g]LN vs HN, P < .11
[h]UD vs RD, P < .09
[i]LN vs HN, P < .02
[j]LN vs HN, P < .18

heifers also tended to have lower (P < .18) solids not fat in

milk by d 60 (Table 5).

Blood metabolites sampled at d 0, 14, 31 and 51 postpartum indicated that blood urea nitrogen (BUN) was affected by prepartum nutrition level (P < .06) and postpartum protein source (P < .01) with no interaction between factors (Table 6). Cattle fed LN had higher BUN concentrations at d 14, 31 and 51 postpartum (P < .1, P < .2 and P < .05 for d 14, 31 and 51 respectively) compared to HN fed cattle. This could be due to a reduced maintenance requirement of LN fed heifers for crude protein. The reduced protein requirement of LN fed heifers would then allow for more of the dietary protein to be deaminated and used as glucose precursors and hence, the higher nitrogen levels in the blood. The LN fed heifers also tended to have lower (P < .2) milk protein concentrations, possibly indicating that more of the dietary protein is diverted to compensatory growth of protein tissues. Postpartum BUN concentration of the UD fed heifers would be expected to be higher than RD fed heifers since the UD fed heifers are receiving 250 g of additional protein per day. Even though BUN levels were higher (all P < .01) on d 14, 31 and 51 for the UD fed cattle, differences did not appear to be of important biological events, possibly indicating that more of the undegradable protein is being used by the animal as amino acids rather than for oxidative metabolism. Also, cattle fed the RD were losing weight postpartum which could increase BUN concentrations due to catabolism of protein tissue.

TABLE 6. THE EFFECT OF PREPARTUM NUTRITION LEVEL AND POSTPARTUM RUMINALLY UNDEGRADED PROTEIN ON BLOOD METABOLITES OF FIRST CALF BEEF HEIFERS.

Measurement	LN	HN	Treatment[a] UD	RD	SE[b]
Urea nitrogen (mg/dl)					
d 0	12.79	12.78	12.01	13.55	0.88
d 14[c]	22.14	20.29	23.28	19.15	0.74
d 31[d]	21.88	20.68	22.64	19.91	0.63
d 51[e]	22.58	20.81	23.15	20.24	0.59
Cholesterol (mg/dl)					
d 0	95.26	95.00	95.23	95.03	2.44
d 14[f]	99.41	96.79	90.48	105.72	2.82
d 31[g]	116.03	107.94	104.63	119.34	3.37
d 51[h]	115.07	108.09	105.71	117.49	3.80
Albumin (mg/dl)					
d 0	3.85	3.93	3.85	3.93	0.05
d 14[i]	2.78	2.98	2.84	2.92	0.05
d 31[j]	3.91	4.06	4.02	3.95	0.05
d 51[k]	3.81	3.90	3.70	3.92	0.05
Creatinine (mg/dl)					
d 0	1.82	1.74	1.76	1.80	0.05
d 14[l]	2.63	2.78	2.69	2.71	0.05
d 31	1.46	1.49	1.46	1.49	0.03
d 51[m]	1.37	1.45	1.39	1.44	0.03
Glucose (mg/dl)					
d 14	67.18	67.97	68.31	66.84	1.52
d 31	67.92	68.09	68.15	67.85	1.28
d 51	64.62	64.25	63.95	64.91	1.27

[a]LN = low prepartum nutrition, HN = high prepartum nutrition, UD = ruminally undegraded protein postpartum, RD = rumen degradable protein postpartum
[b]standard error of estimate
[c]LN vs HN, P < .09; UD vs RD, P < .01
[d]LN vs HN, P < .19; UD vs RD, P < .01
[e]LN vs HN, P < .04; UD vs RD, P < .01
[f]UD vs RD, P < .01
[g]LN vs HN, P < .1; UD vs RD, P < .01
[h]UD vs RD, P < .04
[i]LN vs HN, P < .02
[j]LN vs HN, P < .06
[k]UD vs RD, P < .1
[l]LN vs HN, P < .04
[m]LN vs HN, P < .09

Glucose concentration was not affected by either prepartum nutrition level or postpartum protein (Table 6).

Glucose is a highly regulated metabolite in the ruminant animal therefore, it would require large differences in nutrient content of supplements or animal metabolism to cause differences in serum glucose concentration. Since BUN content was higher in both LN and UD fed heifers, it may be theorized that additional amino acids were used as glucose precursors, but glucose concentrations are similar and no interaction was seen between prepartum nutrition level and postpartum protein source.

Serum albumin was affected by prepartum nutrition level (P < .05) but not postpartum protein source. Creatinine serum levels were not affected by prepartum nutrition level or postpartum protein source, indicating that skeletal muscle metabolism was similar among all treatment groups.

Cholesterol levels were affected by postpartum protein source with UD fed heifers having lower (P < .05) concentrations of cholesterol at d 14, 31 and 51 postpartum. The lower cholesterol concentration found in UD fed cows may be due to increased amino acids fed which may have stimulated ovarian cytochrome P-450 enzymes and enhanced the synthetic rate of steroid hormones from cholesterol, thus reducing serum cholesterol concentration. Also, cattle fed RD were in a slight weight loss situation which could elevate their serum cholesterol levels from catabolism of fatty tissues, however this relationship was not shown between LN and HN fed heifers.

Insulin concentration of LN fed heifers in blood samples

taken prior to calving, on day of calving and at 14 d postpartum were lower (P < .01, P < .03, P < .01, respectively) than HN fed heifers (Table 7). A trend (P < .12) was detected for UD to increase insulin at d 51. Overall, LN fed heifers had lower (P < .01) insulin concentrations postpartum, and a trend (P < .14) was found for LN fed heifers to have a lower total response area of insulin secreted when sampled at 20 min intervals for 8 h (Figure 3, Table 7). McCann and Reimers (1985a) reported thin heifers had lower insulin concentration compared to obese heifers and obese heifers were resistant to the glucoregulatory affects of exogenous insulin. The mean insulin concentration of samples taken every 20 min showed a trend to be higher (P < .3) with UD supplementation, and response area tended to be higher (P < .3) for UD compared to RD fed heifers (Figure 4). An interaction between prepartum and postpartum treatments was not observed. Hunter and Magner (1988) reported insulin concentration was greater in non-pregnant, non-lactating cattle fed casein treated with formaldehyde. Also, Hunter and Magner (1988) reported a negative correlation with plasma insulin and milk yield. In this study, cattle fed UD tended to milk less at d 20 postpartum although plasma insulin concentration was similar to RD fed cattle. In the study of Hunter and Magner (1988), supplementation increased insulin concentration more in the last 8 wk of lactation than in the first 8 weeks of lactation. In this study, it appeared the

same effect may have occurred as UD fed heifers had a trend

for higher (P < .14) insulin concentration at d 51 postpartum.

Also, previous studies which measured insulin concentration

(McCann and Reimers, 1985a) sampled from fasted animals. In

this study, heifers were not fasted prior to the start of

sampling. Therefore, the magnitude of differences seen in this

study could be minimized since all animals were fed a daily

ration prior to sampling. Small differences observed in

samples collected in this manner (unfasted animals) could be

large differences in fasted animals.

TABLE 7. SERUM INSULIN CONCENTRATIONS, INSULIN RELEASE AREA
AND MEAN OF 8 h SAMPLING OF FIRST CALF BEEF HEIFERS FED LOW
(LN) OR HIGH (HN) PREPARTUM NUTRITION LEVEL AND UNDEGRADABLE
(UD) OR DEGRADABLE (RD) PROTEIN POSTPARTUM.

| | ---------- Treatment ------------ | | | | |
Measurement	LN	HN	UD	RD	SE[a]
Insulin (ng/ml)					
prepartum[b]	0.59	0.91	–	–	0.03
calving[c]	0.77	0.95	0.88	0.84	0.05
d 14[d]	0.67	0.95	0.82	0.79	0.06
d 31	0.95	1.04	1.04	0.95	0.07
d 51[e]	0.82	0.92	0.94	0.81	0.05
Release area[f]	225.51	274.62	265.32	234.81	24.04
mean[g]	0.45	0.54	0.53	0.46	0.05
baseline[h]	0.40	0.49	0.48	0.41	0.04

[a]Standard error of estimate
[b]LN vs HN, P < .01
[c]LN vs HN, P < .03
[d]LN vs HN, P < .01
[e]UD vs RD, P < .14
[f]LN vs HN, P < .17
[g]LN vs HN, P < .17
[h]LN vs HN, P < .13

Butler and Canfield (1989) suggest insulin exerts actions

on ovarian tissues similar to pituitary gonadotropins. Insulin

stimulated androgen production and enhanced LH receptor binding. Therefore, increasing insulin concentration could increase responsiveness to LH pulses and pulse frequency in cattle with higher insulin concentration compared to cattle with lower insulin concentration and similar LH pulse frequency.
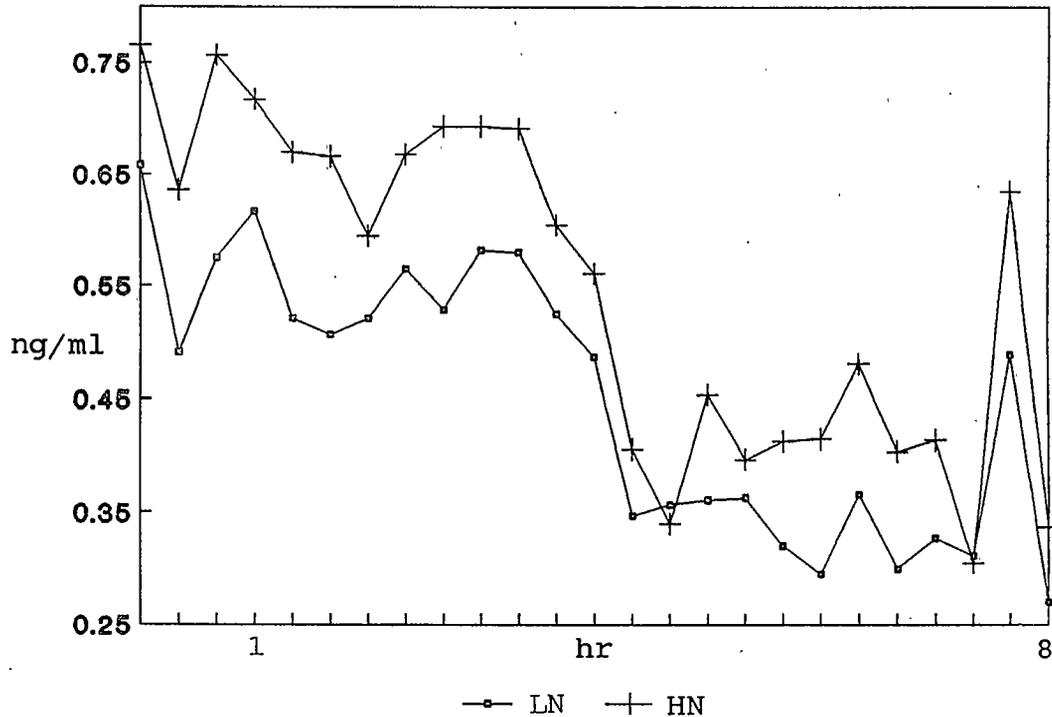

Figure 3. The effect of prepartum nutrition level on insulin release during 8 h sampling.

The percentage of the heifers exhibiting estrus prior to the start of the breeding season as determined by progesterone concentration was affected by prepartum nutrition level (Table

8). Fewer (P < .01) LN fed heifers were cyclic prior to the
onset of breeding than HN fed heifers with no difference due
to postpartum protein source. This would be in agreement with
reports from other researchers (Houghton et al., 1990) who
have shown that prepartum restriction of nutrients can
lengthen postpartum interval and the percentage of the cattle
that are cyclic prior to the breeding season. However,
Houghton et al. (1990) reported no difference in cycling
activity between low prepartum-high postpartum fed cattle and
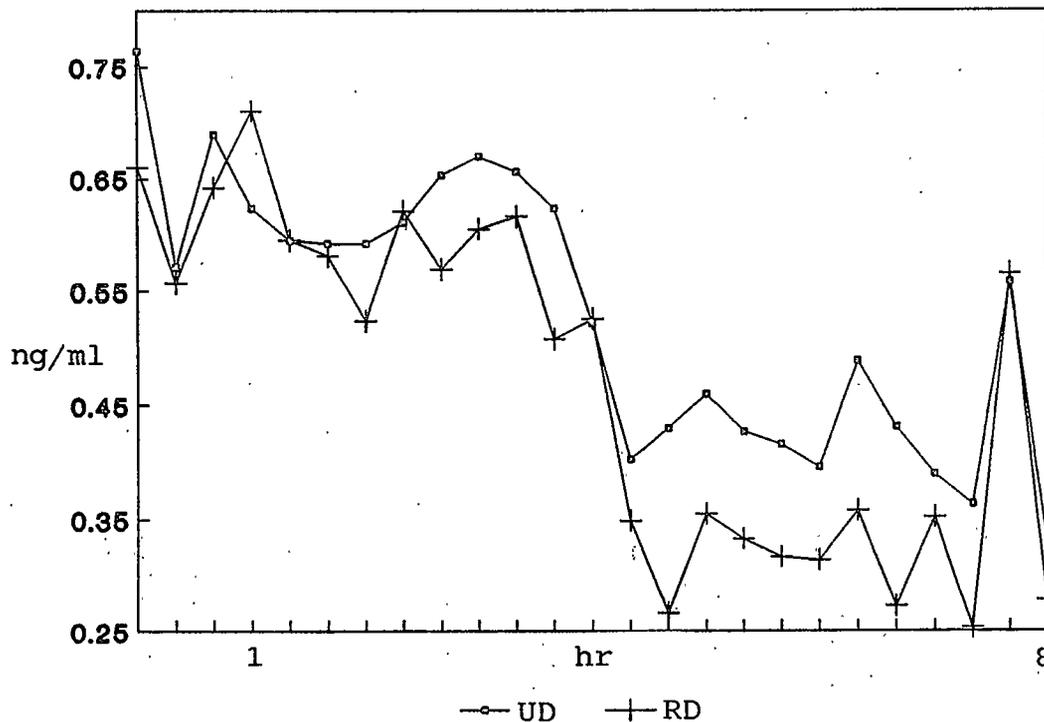high prepartum-high postpartum fed cattle.

Figure 4. The effect of postpartum protein source on
insulin release in 8 h sampling

The percentage of cattle bred during the first 21 d of

the breeding season (Table 8) was affected by postpartum protein source with a higher (P < .02) percentage of UD fed heifers being bred. Prepartum nutrition level had no significant affect (P > .6) on breeding. The lack of an effect due to prepartum nutrition does not agree with others (Wiltbank, et al. 1962; Corah, et al. 1974) and can be explained by the amount of feed fed postpartum. All treatment combinations postpartum in this study were in excess of NRC (1984) crude protein and total digestible nutrient requirements for a 2-year-old nursing cow. Therefore, treatment combinations used in this study were similar to the high prepartum-high postpartum and the low prepartum-high postpartum treatment combinations used in the studies of

TABLE 8. THE EFFECT OF PREPARTUM NUTRITION LEVEL AND POSTPARTUM RUMINALLY UNDEGRADED PROTEIN FED TO BEEF HEIFERS ON PERCENT SHOWING ESTRUS, PERCENT BRED DURING FIRST 21 DAYS, AND FALL PREGNANCY RATES.

	Treatment[a]			
Measurement	LN	HN	UD	RD
	%			
Estrus[b]	31.2	71.8	59.3	43.7
Bred[c]	52.5	56.4	65.5	43.3
Pregnancy	84.7	75.8	78.6	81.6

[a]LN = low prepartum nutrition, HN = high prepartum nutrition, UD = ruminally undegraded protein postpartum, RD = rumen degradable protein postpartum
[b]percentage showing estrus prior to breeding, LN vs HN, P <.01
[c]percentage bred during first 21 d, UD vs RD, P < .02

Wiltbank et al. (1962), Corah et al. (1974) and Houghton et al (1990). When those two treatment combinations (low-high and high-high) were compared using the data of Wiltbank et al.

(1962), they found no affect due to low vs. high prepartum nutrition level. Only when cattle are fed a low level of nutrition postpartum does reproduction seem to suffer.

Even though fewer of the LN cattle exhibited estrus prior to breeding, an equal percentage were bred in the first 21 d of breeding postpartum as HN cows. Houghton et al. (1990) reported cattle of thin body condition had higher first service conception rates compared to cattle of moderate or fleshy condition. Even though fewer of the LN cattle were cyclic prior to breeding, there was no difference between LN and HN cattle bred during the first 21 days, therefore days to conception were not different between LN and HN fed cattle. Pregnancy rate was not affected by either prepartum nutrition level or postpartum protein source.

Baseline LH concentration or the number of pulses in 8 h were not affected by prepartum nutrition level or postpartum protein source at d 31 or 51 postpartum, although LN fed cows tended to have lower (P < .15) baseline levels of LH (Table 9). This would disagree with the data of Rutter and Randel (1984) who reported that cattle of a similar weight but able to gain or maintain weight postpartum had higher basal levels of LH. In this study, LN fed cows gained more weight postpartum but did not have higher levels of baseline LH. However, LH peak height and LH amplitude were affected by prepartum nutrition with heifers fed HN having higher maximum LH peak height (P < .03) and LH amplitude (P < .03) at both d

31 and 51. The higher peak values of heifers fed HN may be the
cause or an effect of a greater percentage of HN fed cows
cycling prior to the breeding season.

Heifers fed UD tended to have lower LH peak heights and
lower amplitude values for LH on d 31. By d 51, values for UD
fed heifers had increased to similar values for RD fed
heifers. More UD heifers were cyclic by d 51, accounting for
higher values at d 51 compared to d 31 for those cows. Jordan
and Swanson (1979) reported increasing levels of crude protein

TABLE 9. THE EFFECT OF PREPARTUM NUTRITION LEVEL AND
POSTPARTUM RUMINALLY UNDEGRADABLE PROTEIN ON LH PEAK HEIGHT,
LH BASELINE, LH AMPLITUDE AND LH PULSE FREQUENCY (Exp. 1)

		Treatment[a]			
Measurement	LN	HN	UD	RD	SE[b]
			ng/ml		
Peak height					
d 31[c]	2.72	5.92	3.43	5.20	0.89
d 51[d]	3.06	8.03	5.55	5.54	1.18
Baseline					
d 31[e]	0.25	0.39	0.32	0.32	0.06
d 51[f]	0.32	0.62	0.38	0.56	0.12
Amplitude					
d 31[g]	2.47	5.52	3.11	4.88	0.87
d 51[h]	2.74	7.41	5.17	4.97	1.05
Pulses/ 8 h					
d 31	2.44	2.86	2.79	2.51	0.23
d 51	2.49	3.20	2.79	2.89	0.35

[a]LN = low prepartum nutrition level, HN = high prepartum
nutrition level, UD = ruminally undegradable protein
postpartum, RD = ruminally degradable protein postpartum
[b]Standard error of estimate
[c]LN vs HN, P < .03, UD vs RD, P < .17
[d]LN vs HN, P < .02
[e]LN vs HN, P < .15
[f]LN vs HN, P < .15
[g]LN vs HN, P < .03, UD vs RD, P < .16
[h]LN vs HN, P < .02

in the diet increased LH secretion. This effect could be

possibly due to a lowering of serum progesterone. No parameters for LH secretion were different between heifers fed UD and RD, but more of the heifers fed UD were cyclic prior to the start of the breeding season, possibly indicating that heifers fed UD were more responsive to LH secretion than heifers fed RD. Butler and Canfield (1989) suggested cattle with higher plasma insulin concentrations would be more responsive to LH pulse frequency. By d 51, UD fed cattle tended to have higher ($P < .14$) plasma insulin concentrations (Table 7) and therefore could be more responsive to similar LH secretion.

The total amount of feed supplied during the 150 d of these two experiments (Table 10) shows an enormous amount of feed given cattle fed HN prior to calving compared to LN fed cattle. Heifers fed HN prepartum and RD postpartum (HN-RD) were fed in a more conventional manner. These HN-RD heifers were kept in good body condition and the feeding management was similar to guidelines suggested by other researchers (Wiltbank et al., 1962; Short et al., 1990) for maximum reproductive rate of first calf beef heifers. However, reproductive rate was improved for cattle fed LN prepartum and UD postpartum compared to the conventional method with a major reduction in feed inputs. This savings in feed inputs could greatly improve the profitability of cow-calf operations. Fall pregnancy rate was unaffected by prepartum nutrition level or postpartum protein supplement. Therefore, it could be

concluded that NRC (1984) nutrient requirements for third trimester pregnant beef heifers are overstated as reproductive performance of cows fed LN and HN were similar.

TABLE 10. COMPARISON OF TOTAL FEED INPUTS SUPPLIED TO LOW NUTRITION (LN) LEVEL AND HIGH NUTRITION (HN) LEVEL COWS.

| | Year 1 | | Year 2 | |
	LN	HN	LN	HN
Feed (kg)				
Prepartum				
hay	602	1204	385	1157
barley	–	60	–	64
beet pulp	–	–	–	255
Postpartum				
hay	614	696	630	730
supplement	62	62	62	62
Total	1278	2022	1077	2268

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CHAPTER 5

CONCLUSION

Results of this experiment indicate that ruminally undegradable protein fed postpartum to 2-year-old beef cows increased postpartum cow weight gains and increased reproductive efficiency of those cows, regardless of prepartum nutrition level. Cows receiving the low nutrition level prepartum performed just as well as cows receiving the high level of nutrition prepartum when fed the undegradable protein postpartum. No interactions were detected between prepartum nutrition levels and postpartum protein sources. Prepartum nutrition levels used in these experiments had no effect on calf performance, calving difficulty or calf vigor. The low prepartum nutrition level did influence the number of cows that were cyclic prior to the breeding season, however, the number of these cows bred in the first 21 d of the breeding season was not affected by treatment. Therefore, when given undegradable protein postpartum, thin or moderate condition cows were more reproductively efficient than those cows managed in a more conventional manner (high nutrition prepartum followed by degradable protein and adequate energy postpartum), and the total amount of feed inputs during the last trimester of gestation are nearly half that of the conventional system. It appears that the published NRC (1984) requirements are above actual requirements for third trimester, pregnant beef heifers.

The response seen in this study could be explained by the role of insulin in metabolic pathways. Cows restricted in nutrients prepartum and postpartum would have lower plasma insulin concentrations (McCann and Reimers, 1985a). With lower insulin concentrations, the ovaries of these cows may not respond to the LH signal nor would they be stimulated to increase production of steroid hormones vital to reproduction. This relationship between nutrition, insulin and ovarian function may explain why other researchers have concluded low levels of prepartum nutrition adversely affect reproduction. Restricting nutrition reduces plasma insulin concentration. By providing cattle, regardless of body condition, with additional undegradable protein, the pancreas is stimulated to increase insulin secretion (Kaneko, 1989). The concurrent increase in plasma insulin concentration caused a partitioning of nutrients away from milk production (since the udder is not insulin dependent), milk fat and milk protein, toward maternal growth and development, causing greater weight gains of cows postpartum (Hunter and Magner, 1988). The rise in plasma insulin also increases the production of steroid hormones by stimulating cytochrome P-450$_{scc}$ in ovarian tissue and increasing the LH receptor binding of the ovary (Butler and Canfield, 1989). This would make the cow more responsive to LH secretion and therefore become cyclic in fewer days postpartum. This response would occur to a greater extent in moderately thin cows as they are more responsive (McCann and

Reimers, 1985a) to insulin secretion compared to fleshy cows. Ruminally undegradable protein may act more as a catalyst of enzymatic activity rather than a nutrient.

This management scheme could potentially increase the economic efficiency of beef cows by decreasing winter feed costs while maintaining or decreasing postpartum interval. Also, in times of feed shortages such as with drought, producers could utilize this management scheme to ensure reproductive success on a limited supply of nutrients during the third trimester of pregnancy. Possibly, cow longevity may be increased with this type of management by supplying first calf heifers and older cows that have a lower fertility rate with ruminally undegraded protein postpartum to increase fertility rate and thereby increasing cow productivity and longevity.

LITERATURE CITED