Reproductive efficiency of range beef cows fed differing sources of protein during gestation and differing quantities of ruminally undegradable protein prior to breeding
by Daniel Vincent Dhuyvetter

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Animal Science
Montana State University

Abstract:
Three experiments utilizing 165 crossbred multiparous beef cows grazing native spring range were conducted to determine the effects of pre- and postpartum protein supplementation on nutrient status, milk production, and subsequent calf and reproductive performance. In experiment one, two and three, pregnant cows were fed 20% crude protein supplements formulated with alfalfa or canola every other day at 1.82 kg/hd from 12-5-91 until calving. In the third experiment using three-year-old cows, a third treatment was added, which was designed to serve as an energy control consisting only of 1.6 kg beet pulp/hd fed on alternate days. After parturition cows in all three experiments were fed one of two iso-nitrogenous and iso-energetic supplements. One experimental supplement designated ruminally undegraded (UD) was formulated to contain .245 kg of ruminally degradable and .245 kg of ruminally undegradable protein daily. The second supplement designated ruminally degraded (RD) was formulated to supply . 371 kg ruminally degradable protein and . 119 kg undegradable protein daily. These supplements were fed on alternate days at 1.82 kg/hd until the breeding season. Experiment 1 consisted of late calving cows that grazed spring range and were individually fed supplement postpartum. Experiment 2, composed of early calving cows, and experiment 3, consisting of three year old cows moved from the Montana State University Livestock Center after calving, were group fed supplement on alternate days and daily fed one-half ration of medium quality hay (10.5% CP) . In Exp. 1 BUN concentration was 1.8 mg/dl higher ($P < .01$) on day 53 postpartum for UD fed cows. Milk production did not differ due to prepartum or postpartum treatments. Prepartum weight gain was greater for canola-fed cows ($P < .001$) compared to alfalfa. Group-fed cows experienced less postpartum weight loss prior to the breeding season when fed UD supplement ($P < .001$). Preweaning calf gain, cow fecal output and fall pregnancy rates were unaffected by pre- and postcalving supplementation. Three year old cows fed beet pulp prepartum were less ($P < .001$) frequently serviced in the first 21 days of the breeding season (54.5%) than the canola- or alfalfa-fed cows (95% and 96% respectively). Overall, pre- and postpartum protein supplementation affected cow weight change and allowed for high reproductive performance between cows fed either RD or UD protein supplement postpartum.

REPRODUCTIVE EFFICIENCY OF RANGE BEEF COWS FED DIFFERING SOURCES OF PROTEIN DURING GESTATION AND DIFFERING QUANTITIES OF RUMINALLY UNDEGRADABLE PROTEIN PRIOR TO BREEDING

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Dan Dhuyvetter

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

Three experiments utilizing 165 crossbred multiparous beef cows grazing native spring range were conducted to determine the effects of pre- and postpartum protein supplementation on nutrient status, milk production, and subsequent calf and reproductive performance. In experiment one, two and three, pregnant cows were fed 20% crude protein supplements formulated with alfalfa or canola every other day at 1.82 kg/hd from 12-5-91 until calving. In the third experiment using three-year-old cows, a third treatment was added, which was designed to serve as an energy control consisting only of 1.6 kg beet pulp/hd fed on alternate days. After parturition cows in all three experiments were fed one of two iso-nitrogenous and iso-energetic supplements. One experimental supplement designated ruminally undegraded (UD) was formulated to contain .245 kg of ruminally degradable and .245 kg of ruminally undegradable protein daily. The second supplement designated ruminally degraded (RD) was formulated to supply .371 kg ruminally degradable protein and .119 kg undegradable protein daily. These supplements were fed on alternate days at 1.82 kg/hd until the breeding season. Experiment 1 consisted of late calving cows that grazed spring range and were individually fed supplement postpartum. Experiment 2, composed of early calving cows, and experiment 3, consisting of three year old cows moved from the Montana State University Livestock Center after calving, were group fed supplement on alternate days and daily fed one-half ration of medium quality hay (10.5% CP). In Exp. 1 BUN concentration was 1.8 mg/dl higher ($P < .01$) on day 53 postpartum for UD fed cows. Milk production did not differ due to prepartum or postpartum treatments. Prepartum weight gain was greater for canola-fed cows ($P < .001$) compared to alfalfa. Group-fed cows experienced less postpartum weight loss prior to the breeding season when fed UD supplement ($P < .001$). Preweaning calf gain, cow fecal output and fall pregnancy rates were unaffected by pre- and postcalving supplementation. Three year old cows fed beet pulp prepartum were less ($P < .001$) frequently serviced in the first 21 days of the breeding season (54.5%) than the canola- or alfalfa-fed cows (95% and 96% respectively). Overall, pre- and postpartum protein supplementation affected cow weight change and allowed for high reproductive performance between cows fed either RD or UD protein supplement postpartum.

CHAPTER 1

INTRODUCTION

Two areas which can increase commercial beef cow-calf producer profitability are:

1) reduction in feed costs for cow maintenance.

2) increase reproductive efficiency.

(Dickerson, 1969)

The first area of economic consideration is self-explanatory, while the second can simply be defined as total number of calves weaned per cow exposed to a bull. The most important factor reducing net calf crop is the failure of cows to become pregnant (Dzuik and Bellows, 1983). This can be taken one step further and used to explain the impact of postpartum interval. As the length of the postpartum interval increases, total pounds of calf weaned will decrease in the subsequent year due to younger calves or fewer calves resulting from a defined breeding season.

Inadequate precalving and/or postcalving energy or protein nutrition lowers pregnancy rates as well as first-service conception rates and extends the postpartum interval in suckled beef females (Randel, 1990). Dietary restrictions during the late prepartum period results in weight loss and decreased maternal tissue at calving, which lowers the number of cows that return to estrus early in a defined breeding season (Whitman, 1975; Wettemann et al., 1982; Dziuk and Bellows, 1983). Similar observations have been reported when postpartum dietary restrictions have occurred (Rutter and Randel, 1984; Rakestraw et al., 1986; Richards et al., 1986).

Energy intake of the brood cow has been studied in greater detail than other nutrients. There are disagreements as to the most strategic period for increased energy intake in order to maintain reproductive efficiency.

The mechanism regulating rebreeding performance in the beef cow is unclear at this time. Dziuk and Bellows (1983) and Richards et al. (1986) have suggested a minimum body condition score of greater than or equal to 5 (range of 1 to 9) at calving for acceptable reproduction. This minimum guideline was recommended to insure that body stores of nutrients are adequate for demands of postpartum reproductive performance and lactation. This recommendation may be expensive if in fact there are mechanisms which regulate reproduction that do not require this storage of nutrients.

Rutter and Randel (1984) found that loss of body condition, not necessarily body weight, after calving greatly increases the time to first estrus. The conclusions of Sasser et al. (1988) were similar to those of Rutter and Randel (1984). However, Sasser manipulated postpartum nutrient intake by decreasing protein consumption in contrast to Rutter and Randel (1984). Sasser et al. reported that first service conception and overall pregnancy rates were lower for the protein restricted heifers.

Types of protein (Halfpop et al., 1988; Hunter and Magner

1988) have also been shown to influence reproductive responses. The site of digestion of the protein supplement seems to have an affect on the length of time to first estrus and pregnancy rate early in the breeding season. In another study (Wiley et al. 1991) prepartum heifers fed a restricted nutrient intake compensated in body weight after calving by having a more rapid weight gain than heifers fed ad libitum. While heifers that were fed to maintain body weight prepartum showed estrus sooner than those loosing weight, there was no difference in fall pregnancy rate. Cows receiving a ruminally undegradable protein supplement postpartum had fewer days to first estrus and a higher breeding rate early in the breeding season (Wiley 1991) regardless of their prepartum nutrition (restricted or ad libitum).

Since undegradable protein has been shown to influence postpartum reproduction regardless of prepartum energy levels, beef cows grazing winter and spring range would be an ideal model to test this supplemental regime because of the variability in the nutrient supply that range provides as well as the difficulty in providing energy supplements to cows grazing range. Furthermore, by formulating the supplements to be iso-nitrogenous, quantity vs. site of protein utilization could be investigated.

If manipulation of protein intake after parturition shortened the postpartum interval then more cows would become pregnant early in the breeding season. This should result in an increase in total pounds of calf weaned per cow exposed and possibly a reduction in cows culled due to infertility.

With the above mentioned goals in mind, the objectives of these experiments were: 1)determine the effect of ruminally undegraded protein fed postpartum on reproductive performance of lactating beef cows grazing spring range, (ie. days to first estrus, first service pregnancy rate, overall pregnancy rate); 2)determine milk production, cow and calf weight changes, and cow body condition scores as influenced by cow intake of postpartum ruminally undegradable protein.

CHAPTER 2

LITERATURE REVIEW

Postpartum infertility in beef cattle can be attributed to four factors: general infertility, lack of uterine involution, short estrous cycles and anestrus (Short et al. 1990). Anestrus is the major component of postpartum infertility which is largely affected by suckling and nutrition. These factors can have a direct influence as well as interact with one another to control postpartum anestrus or postpartum interval.

Nutrition, specifically the energy component, has received the most research emphasis in the past and is most commonly measured to describe nutrient intake. It has generally been concluded that prepartum nutrition is more important than postpartum nutrition in determining the postpartum interval (Dunn and Kaltenbach, 1980; Dziuk and Bellows, 1983). Body condition scores have been used as an indirect measure of nutrient reserves and subjectively indicate the energy status of the cow (Lowman et al., 1973; Wiltbank et al., 1962). Dziuk and Bellows (1983) and Richards et al. (1986) have suggested a minimum body condition score greater than or equal to 5 at calving. This recommendation is made to insure that body stores are adequate for postpartum reproductive performance.

Other researchers have found that postpartum body weight/condition gain or loss determines postpartum rebreeding performance (Rutter and Randel, 1984; Somerville et al., 1979; Rakestraw et al., 1986). Houghton et al. (1990) found that pre- and postpartum energy levels fed interacted to affect postpartum anestrous. Cows which were fed low energy intake prepartum followed by a higher intake postpartum had fewer days (P <.05) to first estrus than all other energy combinations. Richardson et al. (1976) suggested that rebreeding performance is related more to an actual body weight at breeding, rather than the rate of change in body weight from calving to breeding. Sommerville et al. (1979), on the other hand, indicated that body weight loss postpartum was more important than a fixed body weight in determining rebreeding performance. Richards et al. (1986) suggested that cows with a body condition score of four or less at calving had a higher cumulative percentage exhibiting estrus by day 20, 40, and 60 of the period when fed a high, moderate or low/flush nutritional regime, compared to those fed a low nutrient intake. This suggests that cows in thin condition will still breed back if flushed or fed a high nutrient intake. Louw and Thomas (1988) also found that cows will become cyclic when fed a diet for weight gain after they became acyclic due to severe weight loss. Wiltbank et al. (1962) found it difficult to explain similarities in the indicators of estrus between groups fed high and low levels of energy pre- and post calving. Cows fed low energy seemed to have adequate follicular development to promote estrus, but did not cycle. Houghton et al. (1990) showed that cattle in fleshy condition may have a shorter postpartum interval, but their first service conception rates were lower than thin and moderately fleshed cows.

It appears nutrition plays a significant role influencing postpartum interval; however, the mechanism(s) have yet to be revealed. Feeding energy to achieve specific body condition scores may mask the actual required nutrient or nutrients which are specifically needed for successful postpartum reproduction. Discretion must be used in the interpretation of body condition score or energy status as it relates to postpartum fertility. These measures may, or may not, be cause and effect, but simply correlated events.

Circulating LH is low immediately following parturition (Arije et al. 1974), and the frequency and amplitude of LH pulses increase with the onset of the first postpartum estrus. This increase in LH, synchronized with FSH, stimulates follicle maturation and is brought about by increasing concentrations of estradiol-17β (Hafez 1985). The pre-ovulatory rise in estrogen induces LH release through gonadotropin releasing hormone (GnRH) in the hypothalamus (Beck and Convey, 1977). The mechanisms by which nutrition impacts this system are under investigation.

Suckling has been demonstrated to inhibit the release of LH in the postpartum beef cow (Short, et al., 1972; Wright, et al., 1987). Calf separation at birth (Short, et al. 1972), or at some time prior to first estrous (Walters, et al. 1982), will influence the return to estrus within a few days. The suckling effect in these studies was thought to act similarly to progesterone in inhibiting LH secretion via the brain since the pituitary would still respond to a GnRH challenge. Early weaning is an accepted management practice adopted by the dairy industry and accelerates the return to first estrus. It would be difficult for range beef operations to institute this practice when maximizing the nutrient resource of the range and decreasing supplemental inputs.

Lactation, primarily in first lactation heifers, greatly influences the return to estrus due to the requirements needed for it and growth (Whittier et al. 1988). Hunter and Magner (1988), concur with this observation. Harrison et al. (1989) has also attributed a suppression of estrous behavior to cows with high milk production. Bellows and Short (1978) found that by feeding high energy diets postpartum to cows fed a low plane of energy prepartum, days to first estrus were extended. They speculated that this may have stimulated milk production at the expense of reproduction. Hunter and Magner (1988) fed postpartum beef heifers a supplement composed of formaldehyde-treated casein, and found that supplemented heifers, returned to estrus 5 weeks earlier than unsupplemented heifers, had a faster rate of gain and a lower milk yield in the second half of a 16 week lactation period. They suggested nutrients were partitioned to cause a decrease of nutrients for milk production while enhancing maternal realignmentation, thereby improving reproductive success.

Ionophores such as monensin have been shown to affect the postpartum interval of the beef cow (Turner et al., 1977; Belcher et al., 1980; Hardin and Randel, 1983; Mason and Randel, 1983). The proposed reasoning for the improvement in postpartum interval is the shift in volatile fatty acid (VFA) production to propionate without affecting total fatty acid production in the rumen. A shift in VFA production in monensin fed cows is suspected to be partly responsible for improved energy efficiency and feed utilization. If a shorter postpartum interval is an effect of increased ruminal proprionate production then an increase in total energy intake should elicit the same response. This has not always been the case (Rutter and Randel, 1984; Richards et al. 1986; Randel, 1990), suggesting that the effect of monensin was, at best, only partially explained by altered VFA production.

Both endocrine and ovarian function have been manipulated with the quantity of fat in the diet (Williams, 1988; and Hightshoe et al. 1991). By increasing the lipid content of the diet postpartum, Williams (1988) found higher concentrations of progesterone during an induced cycle as well as a CL lifespan being nearly twice as long as those fed lower levels of lipid. Hightshoe et al. (1991) demonstrated that cows fed a postpartum supplement containing calcium soaps of fatty acids which escape degradation in the rumen had increased concentrations of LH and enhanced follicle growth, in addition to greater progesterone concentrations also found by Williams (1988). It appears that these researchers are stimulating the reproductive processes in the postpartum beef cow by increasing the quantity of cholesterol for the synthesis of gonadotropin hormones which can then exert their effects on the hypothalamus. The cost, storage and delivery systems of these supplements are factors which may inhibit their acceptance by beef cow-calf range operations if other alternatives can be incorporated to achieve reproductive success.

Metabolizable protein intake can be confounded with energy intake or efficiency. Feeding ruminally degradable protein has also been shown to have a positive effect on reproduction (Sasser et al. 1988) when compared to feeding smaller quantities. As dry matter or energy intake increases there is an increase in microbial protein synthesis resulting in a greater amounts of protein presented to the small intestine for absorption. This could lead one to the alternate interpretation that reproductive responses, which have been previously attributed to increased energy intake, could also be due to an increase in metabolizable protein availability affected by increased ruminal microbial protein synthesis. Conversely, protein supplementation can cause increased dietary intake and forage digestibility (Raleigh and Wallace, 1963; Turner, 1985).

In earlier research, protein was not considered an important factor regulating reproductive success (Wiltbank et al. 1962). Recent research has indicated that reproduction is influenced by protein in the postpartum beef cow (Sasser et al. 1988). They fed protein at either restricted levels or adequate both pre and postpartum. Restricted levels of protein were shown to extend postpartum intervals and increase the days to conception. Nolan et al. (1988) attributed this response to reduced gonadotropin release from the anterior pituitary following an estradiol-17β challenge. This could be due to a lack of estradiol receptors or improper storage or synthesis of GnRH within the hypothalamus.

There has been a greater research effort investigating protein nutrition as it relates to reproduction in the dairy cow. Ferguson and Chalupa (1989), in a review article, predicted from a computerized model that young cows, still growing, are more sensitive to absorbed amino acids than products from excess ruminal ammonia, ie. undegradable protein. Furthermore it is suggested that these young growing females tend to partition absorbed nutrients for growth rather than milk production (Hunter and Magner 1988; and Wiley et al. 1991). Mature cows will generally increase milk production rather than divert nutrients towards maternal tissues (Bellows and Short, 1978; Chalupa, 1984; Roffler and Thacker, 1983; Oldham, 1984). High concentrations of ruminally degradable protein in diets fed to older dairy cows has been shown to be detrimental to reproduction. These diets are characterized by elevated ruminal ammonia, blood urea nitrogen and other nitrogenous compounds in body tissues. Impaired fertility has resulted from the toxic effects of urea on sperm and ova (Kaim et al. 1983).

Progesterone concentration in the midluteal phase of the cycle prior to breeding has been correlated with conception rate (Folman et al. 1973). Ferguson and Chalupa (1989) presented data from three separate studies (Jordan and Swanson, 1979; Blauwiekel et al., 1986; Snoderman et al., 1987) which showed a reduction in serum progesterone as crude protein increased from 13 to 15 percent, but changed little as crude protein increased from 15 to 20 percent. Folman et al. (1981) found that in isonitrogenous diets, type of protein influenced reproductive success postpartum. Cows fed a ruminally undegradable protein treatment had fewer breedings per conception and fewer days not pregnant than those cows fed a highly rumen degradable protein supplement. The site of protein utilization has also shown positive effects on reproductive parameters by shortening the postpartum interval of young beef cows and heifers (Hunter and Magner 1988; Halfpop et al. 1988; Wiley et al. 1991). These reports suggest that future studies must be designed to control energy status and protein source for studying and improving animal performance.

Protein plays a role in the P-450 enzyme systems which are involved in the production and catabolism of steroid hormones (Waterman et al., 1986; Rodgers et al., 1986; Jefcoate, 1986; Singh et al., 1988; Thomford and Dziuk, 1988). Specific amino acids have been shown to stimulate these enzyme systems (Truex et al. 1977). This stimulation could be one explanation of how protein supplementation influences reproduction (Smith 1988). Specific amino acids have not been accounted for in previous studies which may explain a portion of the variation of the effects of nutrition on reproduction. A well controlled experimental design must be adapted before an assessment of supplementation with excess protein or specific amino acids can be made. Furthermore, because the cytochrome P-450 enzymes can be anabolic as well as catabolic with regards to steroid hormones, additional studies are needed to find out the specific nutrients that will affect synthesis and regulation.

The metabolic status of a cow changes, particularly in adipose tissue, as she approaches parturition to prepare for lactation. In late pregnancy and early lactation, insulin and glucose are unable to alter the basal and catecholamine-stimulated rates of lipolysis (Metz and van den Bergh, 1977). High concentrations of growth hormone, (GH), during lactation are believed to facilitate the diversion of nutrients, at least glucose and lipid, to the mammary gland (Hart 1983). Although the mechanism for this effect is not known, one aspect of it deals with GH inducing insulin-resistance in maternal tissues. In lactating animals, insulin secretory responses to glucose and propionate are reduced (Lomax et al. 1979). These adaptations in metabolism have been hypothesized to ensure that milk production is maintained.

It is clear pregnancy and lactation complicate metabolic regulation since milk production and fetal growth are not directly regulated by maternal hormones (Brockman and Laarveld, 1986). Since glucose uptake by the uterus and mammary gland is concentration-dependent, maternal nutrient status improves when nutrient absorption exceeds fetal and/or mammary tissue demands. Hunter and Magner (1988) postulate that, by increasing the insulin levels of beef heifers postpartum with undegradable protein, they could over compensate for the desensitization of insulin by GH, thus maternal tissues would respond to the repartitioning of nutrients.

Harrison and Randel (1986) measured the effect of energy restrictions on beef heifers and found exogenous insulin increased ovulation rates in energy-deprived heifers. Cox et al. (1987) found that exogenous insulin increased ovulation rate in gilts. Plasma insulin levels have been shown to be affected by dietary energy intake (Bassett 1974), dietary protein intake (Hunter and Magner 1988), body condition (McCann and Reimers 1985), and milk production (Butler and Canfield 1989). These factors have also been implicated in achieving reproductive success. Furthermore, intravenous infusions of amino acids, abomasal infusions of casein and increased dietary intake of crude protein have been shown to increase serum insulin concentrations (Oldham, 1984; Chew et al., 1984; Blauwiekel and Kincaid, 1986; Cohick et al. 1986). Adashi et al. (1980) demonstrated that increased concentrations of insulin in tissue cultures of pituitary and luteal cells increased the output of FSH and progesterone. Insulin has also been shown to play a role in steroid hormone production (Veldhuis et al., 1986).

Because propionate is the major glucogenic source of energy derived from ruminal fermentation in the ruminant animal, insulin is more responsive to circulating levels of propionate than glucose (Van Soest, 1987). Luteinizing hormone (LH) characteristics were unaffected in postpartum beef cows infused with high levels of glucose (McCaughey et al. 1988). When these cows were administered a spike treatment of glucose there was a corresponding increase in insulin but this insulin increase rapidly declined to base line concentrations. Since low circulating serum concentrations of glucose are common in the ruminant (Mayes, 1988), this metabolite is more closely regulated and conserved especially in the postpartum cow. A slower release of nutrients, as with the case of undegradable protein, would be expected to sustain a higher endogenous insulin level throughout the supplementation period. In addition, supplementation of a concentrated energy source to cattle grazing winter and spring range may be less advantageous due to the amount required on a daily basis, reduction in range utilization and possible increase in labor and/or facilities needed.

Protein effects on reproduction in the postpartum beef cow have been demonstrated, but have yet to be explained. Since GH concentration is comparatively higher in the lactating beef cow and initiates insulin-resistance in maternal tissues, it would be antagonistic to the effect of insulin on lipogenesis, however it facilitates insulin's protein synthetic effects (Brockman and Laarveld, 1986). Protein which can by-pass the rumen could stimulate insulin release over a longer period of time. This extended release could help overcome maternal tissue resistance to insulin manifested by GH. With insulin potentially increasing maternal growth and enabling cows to achieve a positive weight gain, reproductive responses could be improved (Somerville et al., 1979; Roberson et al., 1989). This suggests that by feeding undegradable protein postpartum, the beef cow could utilize the protein to increase and extend the circulating insulin level thus increasing steroid hormone production with an earlier return to first estrus.

CHAPTER 3

MATERIALS AND METHODS

Two experiments using a 2 x 2 factorial arrangement of treatments and one experiment using a 3 x 2 factorial arrangement of treatments were used to evaluate the effect of pre and postpartum protein supplementation on beef cows grazing winter and spring range (Figure 2). In experiments one and two, two prepartum supplements were fed originating from cubed alfalfa or canola meal at 1.82 kg/hd every-other-day from December 5, 1990 until just prior to calving. They were formulated to be iso-nitrogenous (20% crude protein). In the third experiment cows were supplemented prepartum to achieve different weight gains. All supplements were individually fed and contained 3.2 kg/hd beet pulp fed on alternate days. Two supplements contained an additional source of protein from either alfalfa sun-cured cubes or canola meal pellets (20% CP), and was fed at 1.82 kg/hd on alternate days. The third supplement which was formulated to allow for minimal weight gain consisted only of beet pulp.

Mature cows were assigned to either the first or second experiment by calving date (Early vs. Late), while in the third experiment all three year old cows were used.

Experiment one, late calving cows: Sixty six multiparous crossbred beef cows ranging from four to 10 years of age, approximately 562 kg, and made up of primarily Hereford and Angus breeding, were randomly assigned to one of two dietary protein treatments as they calved (March 20 to April 23, 1991). Cows assigned to the first treatment (RD) received a protein supplement formulated to supply .371 kg ruminally degraded protein and .119 kg undegraded protein hd^{-1} d^{-1}. The second postpartum supplement (UD) was formulated to supply .245 kg of ruminally degraded protein and an equal amount of ruminally undegraded protein per hd^{-1} d^{-1}. Supplements were individually fed beginning two to five days after calving and continued up to the breeding season on alternate days at a rate of 1.82 kg per head. The last day postpartum supplements were fed was June 3, 1991. They were formulated to be iso-nitrogenous and nearly iso-energetic (Table 3). Supplements were mixed in two batches (Farr Better Feeds, Billings MT). The first batch was fed from the beginning of the study through May 19 (Table 1), and the second batch was fed from May 20 to May 28. The second batch of supplement was similar to the first batch (crude protein on an as-fed basis, 47.83% and 45.73% for UD and RD supplements respectively). Disappearance rates for dry matter and protein of the supplements were estimated in situ (Figure 1). This confirmed that the degradability of the protein was different between supplements with more protein and dry matter of feed origin being presented to the small intestine over time from the UD supplement. Cows were fed a trace mineral and salt supplement free choice and had free access to water throughout the study.

The supplementation period prior to breeding was conducted in a 256.6 ha pasture at the Red Bluff Research Ranch, located 56 km west of Bozeman Montana. Annual precipitation averages from 350 to 406 mm (USDA-SCS, 1976). Carrying capacity was estimated at 1.21 ha $animal^{-1}$ unit month (AUM; Payne, 1973). Major grass species (Turner, 1985) include blue bunch wheat-grass *(Agropyron spicatum)*, Idaho fescue *(Festuca idahoensis)*, prairie junegrass *(Koeleria pyramidata)*, and needle and thread *(Stipa comata)*.

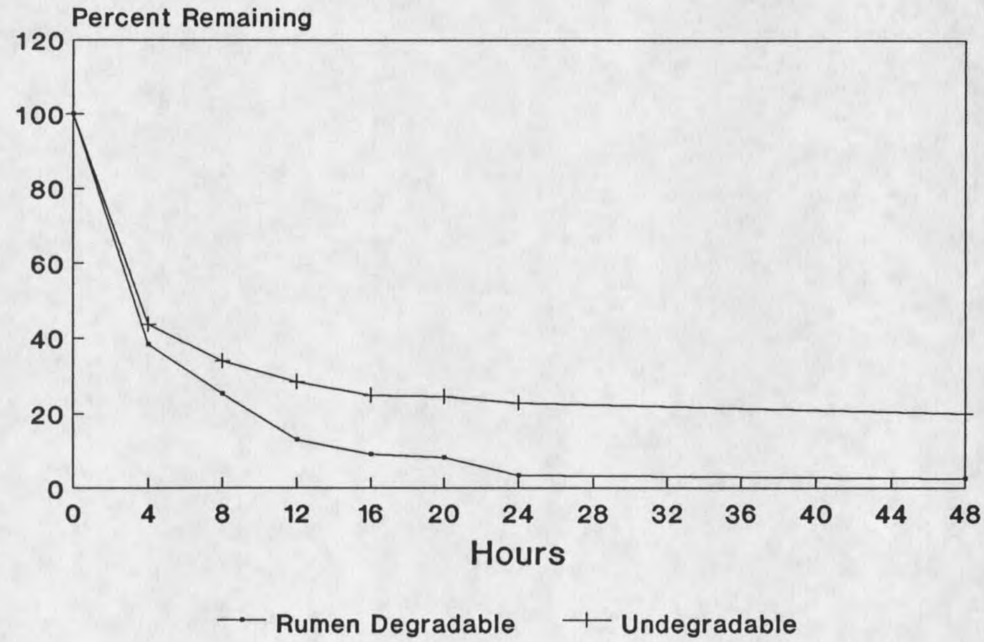

Figure 1: In situ dry matter disappearance rate describing ruminally degradable and ruminally undegradable protein supplements over 48 hours.

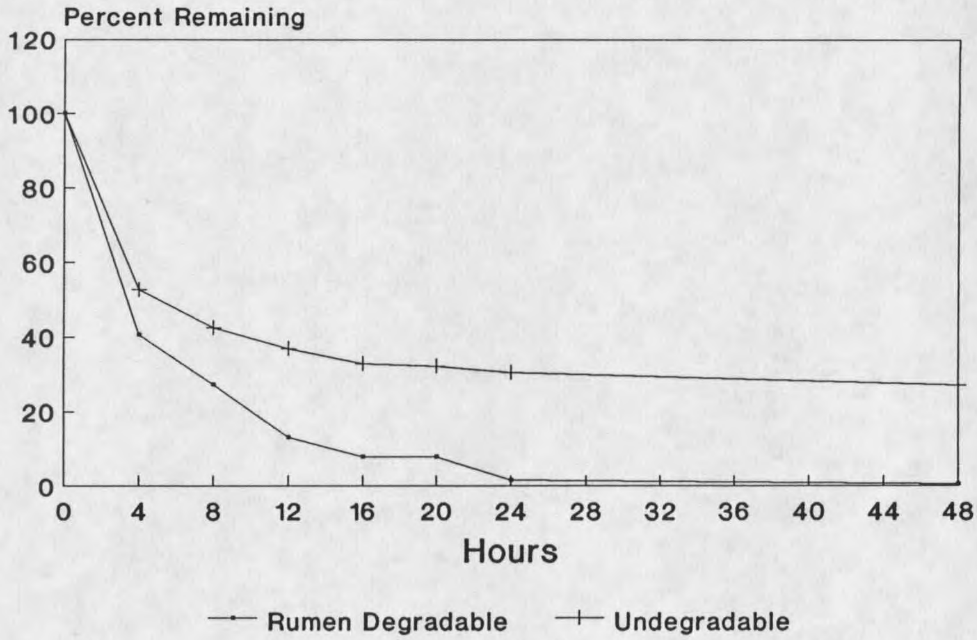

Figure 2: In situ protein disappearance rate describing ruminally degradable and ruminally undegradable protein supplements over 48 hours.

TABLE 1: FORMULATION OF PROTEIN SUPPLEMENTS FOR RUMINALLY DEGRADABLE (RD) AND UNDEGRADABLE (UD).

Ingredient	RD %	UD %
Soybean oil meal	66.00	35.00
Wheat mill run	22.00	29.50
Urea	2.00	-----
Ammonium phosp.	2.50	2.00
Molasses	6.50	6.50
Potassium chlor.	1.00	1.00
Feathermeal	-----	13.00
Blood meal	-----	13.00
Vitamin A	22,500 IU/.454 kg	22,500 IU/.454 kg

Condition scores (1 = emaciated, 9 = obese) palpated by two technicians, and cow weights were recorded on Dec. 5, 1990; prior to calving, March 5, 1991; at branding May 22, 1991 and at the end of the study, Aug. 16, 1991.

Ruminal extrusa samples were collected from two cannulated cows fed 1.82 kg/hd of supplement every-other-day, which was made up of 50% RD and 50% UD supplement. Collections were made April 30, 1991 and on May 28, 1991 in order to evaluate the grazed range forage during the postpartum period prior to breeding. Ruminal contents were evacuated and cows allowed to graze for one hour. The extrusa was then collected, air dried, ground through a 2 mm screen and prepared for lab analyses (Table 2).

TABLE 2: LAB ANALYSIS OF RUMEN EXTRUSA SAMPLES COLLECTED ON DAY 36 AND 64 FROM TWO COWS.

Percent As-Fed	Dry Matter	Crude Protein	NDF	ADIN
Day 36	91.66	5.82	66.75	.55
Day 64	89.35	12.47	56.25	.73

Ten ml of blood were collected from cows via venous/arterial puncture of the tail, centrifuged at 2000 rpm within one hour after collection and the serum frozen until later analysis by solid-phase RIA for progesterone concentrations. Serum collections began at approximately 26 days postpartum, and were continued at four day intervals until the breeding season. First estrus postpartum was determined by serum progesterone levels greater than

1 ng ml^{-1}. Intra- and inter assay coefficients of variance were 10.3% and 3.2% respectively.

Blood samples were collected by the procedure described above on day 39 and 53 of the study for analysis of serum metabolites and insulin concentrations. Blood metabolites measured included; blood urea nitrogen, (BUN), serum albumin, cholesterol, and plasma glucose. On days 39 and 53 milk production was estimated by using a six hour weigh-suckle-weigh technique (Ansotegui 1986).

Fecal output was measured by administering CapTec[1] chromic oxide slow-release boluses to 50 cows on day 27 and collecting fecal grab samples on days 35, 37 and 39. Samples were immediately frozen until later lab analysis. After samples were thawed, dry matter and organic matter were determined by AOAC (1975) procedures. The remainder of the sample was ground through a 2mm screen. Chromic oxide concentration was determined by analyzing duplicate sub-samples using the atomic absorption spectrophotometry technique (Williams et al., 1962). Fecal output was estimated from grab samples based on the percentage chromium in the feces on an organic matter (OM) basis.

Supplementation was terminated on June 2, 1991 and cows moved to a 130.3 hectare pasture for breeding.

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[1]81 Carlton Gore Road, Newmarket, Box 759, Auckland, New Zealand.

The breeding season began on June 3, 1991, with the first 21 days utilizing artificial insemination. Semen from two Angus and two Hereford sires was collected and assigned to cows based on the cows genetic make-up. Cows were observed for behavioral estrus twice daily in the pasture and bred approximately 12 hours after detection of estrus. After breeding cows were moved to an adjacent 257 hectare pasture and exposed to four Hereford bulls (1:41 bull to cow ratio) for the remainder of the breeding season. Cows not exhibiting estrus in the first 21 days were placed with the bulls following the AI period. Bulls were removed from the pasture and the 46 day breeding season terminated on July 19, 1991.

TABLE 3: RUMINALLY DEGRADABLE (RD) AND RUMINALLY UNDEGRADABLE (UD) PROTEIN SUPPLEMENT CHEMICAL ANALYSIS. (AS FED BASIS)

Analysis	RD %	UD %
Dry Matter	85.94	88.37
Protein	46.59	47.80
RD protein	35.28	23.90
UD protein	11.31	23.90
TDN	86.36	81.72
ADF	3.52	6.37
Ether Extract	.50	1.53
ADIN	.40	2.66

Data collection ended on August 16, 1991. Cows were condition scored and tested for pregnancy via rectal palpation. Both cows and calves were weighed.

Experiment two, early calving cows: Experiment two was conducted similarly to experiment one with these modifications. Sixty two of the early calving crossbred beef cows, approximately 570 kg, from the Red Bluff Research ranch were randomly assigned to one of two pastures adjacent to Exp. 1, (approx. 159 hectares each), after calving. The calving period ranged from March 4, to March 20, 1991. On March 25, 1991 supplementation was initiated with the RD supplement group fed to cows in one pasture and UD supplement group fed to cows in the other pasture at a rate of 1.82 kg/hd every-other-day. These supplements were identical to those fed to the late calving cows in Exp. 1. The number of days which supplement was fed (66) was the same for all cows. In addition, cows were fed approximately 4.5 kg of mixed grass hay (10.5% crude protein DM basis) hd^{-1} d^{-1} to May 18, 1991. Hay feeding was used to minimize confounding of supplement and pasture affects. Cows were rotated between the two pastures every eight days as another method to reduce confounding.

Estrous cyclicity prior to the breeding season was estimated by detection of an ovarian corpus luteum via rectal palpation on May 22, 1991 and then again on May 30, 1991. Postpartum cow weights were measured on May 22, 1991.

Supplementation was terminated on May 30, 1991. Cows from Exp. one and Exp. two were combined and moved to the same pasture for detection of estrus and artificial insemination.

Cows in Exp. one and two were treated similarly throughout the remainder of the trial.

Experiment three, three year old cows: Experiment three was conducted similarly to Exp. 2 with these exceptions. Forty three-year-old crossbred cows, approximately 533 kg, were fed three prepartum dietary supplements (as previously described) at the Montana State University Livestock Center in Bozeman, MT. The cows were delivered immediately post-calving to the Red Bluff ranch facilities. Cows were randomly assigned to postpartum supplemental regimes and were mixed with cows from Exp. two. Cattle fed supplements in Exp. two and three were co-mingled throughout the postpartum period.

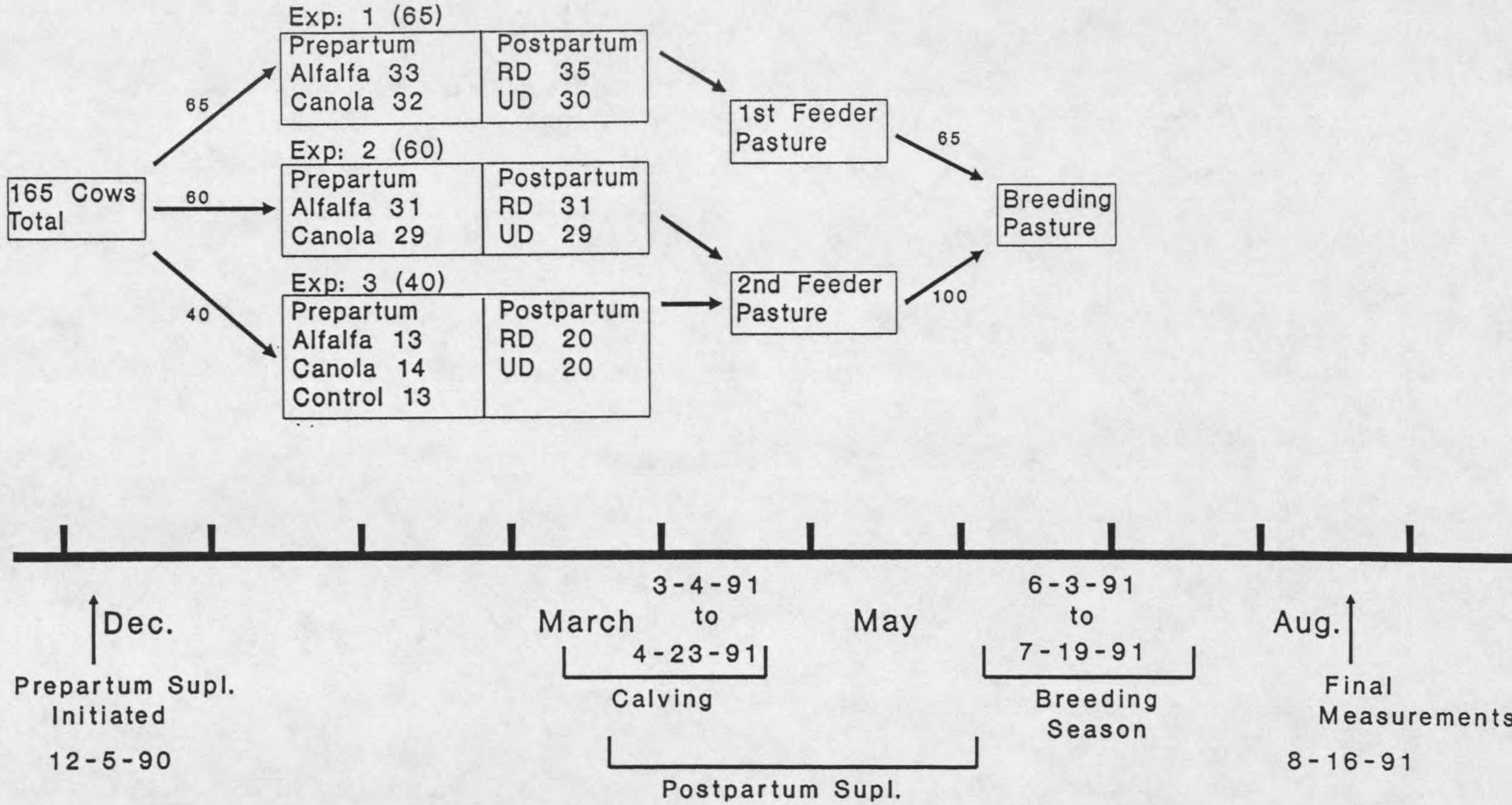

Figure 3. Experimental design and chronological order of the study.

Statistical Analysis

December and March cow weights, condition scores and their changes were analyzed with General Linear Models (GLM) analysis of variance of SAS (SAS 1988). Prepartum supplement was used as a class variable in the model and initial December cow weights or condition scores were used as co-variates within their respective analysis when analyzing March data and weight change from December to March. Postpartum cow weights, condition scores and their respective changes during the postpartum period, were also analyzed with analysis of variance GLM of SAS. Prepartum and postpartum supplement, prepartum by postpartum supplement interaction, the date of calving classified by groups, and calving group by postpartum treatment interaction were class variables. Calving date was defined in Exp. one by arranging cows into three groups (group one, March 20 to March 26, 1991; group two, March 27 to April 7, 1991; and group three, April 8 to April 23, 1991). Initial December measurements were used as their respective co-variates unless proven non-significant in which case they were deleted from the model. Calving date was used in the analysis to account for days on supplement in experiment one and three. Experiment two used the same model; however, all cows were fed supplement for identical days.

Fecal output was evaluated with GLM of SAS with pre- and postpartum supplementation and their interaction in the model.

Pre- and postpartum supplements and their interaction were used as class variables in the model for analyzing preweaning calf gain. Calf age was used as a co-variate in all experiments. Calf birth weight was used as a co-variate in Exp. two.

The GLM multivariate repeated measures analysis of variance was used for the analysis of milk production for late calving cows in Exp. one. Class variables included pre- and postpartum supplements and their interactions and sex of calf.

Insulin concentrations and blood metabolites were analyzed using the multivariate repeated measures GLM analysis of SAS with pre- and postpartum supplements and their interaction included as factors in the model.

Prepartum and postpartum supplements, their interaction, cowage and postpartum supplement by cowage interaction, calving group and calving group by postpartum supplement were used as factors in the model analyzing the number of days to first estrus in experiment one.

Pregnancy rate, percent serviced in the first 21 days of the breeding season for all experiments and percent cycling prior to the breeding season in experiment's one and two, were analyzed using the Chi-square procedure of SAS with pre- and postpartum supplements, and prepartum by postpartum supplement interaction as factors.