

*A Review of Early-weaning – Effects on Calf Performance, Digestive System Development, Sexual Development, Animal Behavior, Carcass Quality and Economics*

*Christoph E. Weder Msc. – 206066*

*Table of Contents*

	<i>Page</i>
<i>Introduction</i>	<i>1</i>
<i>Early-weaning &amp; Calf Performance</i>	<i>2</i>
<i>Early-weaning &amp; Ruminant Digestive System Development</i>	<i>7</i>
<i>Rumen</i>	<i>7</i>
<i>Reticulum</i>	<i>8</i>
<i>Omasum</i>	<i>8</i>
<i>Abomasum</i>	<i>8</i>
<i>Factors Affecting Stomach Development</i>	<i>11</i>
<i>Digestive System Inoculation</i>	<i>13</i>
<i>Early-weaning and Sexual Development</i>	<i>14</i>
<i>Early-weaning and Animal Behavior</i>	<i>16</i>
<i>Early-weaning and Carcass Quality</i>	<i>21</i>
<i>Early Weaning and Economics</i>	<i>25</i>
<i>Summary and Conclusion</i>	<i>27</i>
<i>Literature Cited</i>	<i>30</i>

***Introduction:***

Traditional cow/calf production systems in Canada and for that matter North America are based on late winter to spring calving, rearing the calf along side of the cow for the summer and then weaning the calf in late October to early November. In Alberta the average starting date for the calving season is the March 1<sup>st</sup> and on average weaning occurs around October 28<sup>th</sup>, AAFRD (1999), which makes the average age of calves weaned in Alberta around 210 days or 7 months.

The traditional production system of weaning calves at 7 months has worked well for many Alberta cow/calf producers. If forage resources and quality are adequate, weaning in late October will likely provide adequate calf gains and leave the dam with sufficient body condition so that no excessive supplementation is required prior to next year's calving and breeding season. However in many years drought and or seasonal dry periods can cause pasture growth and resources to dwindle, forcing the producer to either feed hay or grain in order to maintain cow body condition and desired calf weight gain. If this form of supplementation is needed during the summer, the economic loss can be devastating due the costs associated with purchasing and delivering feed. Drought may not be the only circumstance were early-weaning of calves is warranted. The quality of fall pasture is often another situation where there may be insufficient quality and or quantity in order to maintain calf weight gain and cow body condition. Creep feeding in these situations has been used effectively to offset the negative effects of poor pasture quality. However, creep feeding is time consuming, it requires that feeders be moved as the cattle are rotated from one pasture to another, and most importantly it does little to improve the cow body condition going into the winter because the calf is still nursing.

The most important factor affecting ranching profitability is the rebreeding rate success – having cows with adequate body condition prior to calving will have the greatest influence in how well these cattle will breed back (Bellows et al. 1974).

Early weaning (90-180 days) has been shown as a possible solution for short-term forage quality and production shortfalls (Lusby et al. 1981; Peterson et al. 1987; Myers et al. 1999). However, on a longer-term basis, the cattle industry faces severe price competition from poultry and pork. It is unlikely that beef cattle will ever be able to compete on a price per pound of product basis with either, especially poultry. Of all the costs of producing beef, the largest single cost is the investment in the land for the cowherd, followed by costs for purchased feed and harvested forage. Therefore, management practices that reduce nutrient requirements of the cowherd and offer the potential for more efficient utilization of pasture resources need to be adopted by cattle producers; early-weaning of beef calves is one of those management practices.

***Early-Weaning & Calf Performance:***

Feed costs account for 54 to 75% of the annual cost of keeping a cow (Taylor, 1984). Energy is the feed component required in the greatest quantity by beef cattle, with about 70% of the energy consumed by a cow going to maintenance (Ferrell and Jenkins, 1984). Peterson et al. (1987) reported that early-weaned cowcalf pairs (110 days) were 43% more efficient in converting total digestible nutrients into calf gain than were normal weaned cow-calf pairs (210 days). In this same study, Peterson et al. (1987) also found that early-weaned cows consumed 20% less total digestible nutrients than non-weaned pairs after weaning.

Although the benefits of early-weaning on improving reproduction and reducing feed inputs to the cow have been recognized for many years, the factors limiting practical application of early-weaning, has been management of the early-weaned calf. In fact, most of the research that has studied early-weaning of spring born calves has looked at drylot feeding programs to manage these calves (Lusby et al. 1981; Fluharty et al. 1996; Myers et al. 1999). Recently Myers et al. (1999) examined three weaning scenarios in spring born beef calves. The steer calves were either 1) early-weaned (170 d) and placed on a finishing diet (EW), 2) supplemented with grain for 55 d on pasture (170 to 225d of age) while nursing their dams and then placed on a finishing diet (NWC), or 3) on pasture for another 55 d while nursing their dams (170-225) and then placed on a finishing diet (NW). Myers et al. (1999) found that in the first 55 d (d 170-225) EW steers gained 100% faster ( $P=0.0001$ ) than the average of NWC and NW steers. When NWC and NW steers were compared, NWC steers had a 32% faster ( $P=0.02$ ) rate of gain. Once the calves were placed on feed EW steers had lower intakes (7.70 vs. 8.16 kg/d,  $P=0.008$ ) and better gain:feed conversions (.170 vs.153,  $P=0.002$ ) than the average of NWC and NW steers. At the time of normal weaning cows with EW calves were 40 kg heavier than NWC and NW ( $P=0.0001$ ). Early weaned cows also had .23 units higher BCS (scale 1-9,  $P=0.04$ ) than NWC and NW.

Fluharty et al. (1996) studied the 1) effects of weaning (100 vs 205 d), 2) nutritional regimen, and 3) the diet prior to 205 days on steer performance and carcass characteristics. Steers were allotted to one of two treatments early-weaned (100 d) or normal-weaned (205 d). The early weaned steers were then split into one of four nutritional regimens 1) 100% concentrate @ 12% CP, 2) 100% concentrate @ 16% CP,

3) 90% concentrate @ 16% CP and 4) 60% concentrate @ 16% CP. The balance of the ration in treatments 3 & 4 was made up of peanut hulls as a source of fiber. Normal-weaned calves remained with their dams throughout the summer, at 60 prior to weaning, the pairs were split into two treatments 1) creep (60% concentrate pellet @ 16% CP) and 2) non-creep fed control. At 205 days the normal-weaned steers were weaned and all calves were placed on a 90% concentrate ration @ 14% CP until they reached 900 lbs, the ration was then adjusted to a 90% concentrate @ 12.5% CP till the steers reached the target market weight of 1175 lbs.

The effects of diet and creep status on weight and ADG of calves from 100 to 205 days of age are shown on Table 1. Early weaned calves that were fed either 100% or 90% concentrate diets had heavier ( $P<0.01$ ) weights at 205 days of age and had greater ( $P<0.001$ ) ADG from 100 to 205 days of age compared with normal-weaned calves. Early-weaned calves fed a 60% concentrate diet were intermediate in 205-d weight and ADG.

Further evaluation of the weaning treatments found that early-weaned calves fed either 100% or 90% concentrate diets had greater overall ADG ( $P<0.01$ ) and feed efficiency ( $P<0.001$ ) compared with calves fed 60% concentrate diets. There were no differences ( $P>0.10$ ) in dry matter intake (DMI).

**Table 1. Effects of diet and creep status on weight and ADG of calves from 100 to 205 days of age, (Fluharty et al. 1996).**

Item	<u>Early-weaned</u>				<u>Normal-weaned</u>	
	100 % Conc. 12%CP	100% Conc. 16% CP	90 % Conc. 16% CP	60 % Conc. 16% CP	Non - creep	Creep-fed
<b>Initial wt lbs.</b>	328.0	317.0	314.0	318.0	340.0	335.0
<b>Final wt lbs.</b>	610.0 <sup>a</sup>	605.0 <sup>a</sup>	611.0 <sup>a</sup>	569.0 <sup>ab</sup>	558.0 <sup>b</sup>	558.0 <sup>b</sup>
<b>ADG</b>	2.76 <sup>c</sup>	2.82 <sup>c</sup>	2.90 <sup>c</sup>	2.47 <sup>d</sup>	2.18 <sup>e</sup>	2.18 <sup>e</sup>
<sup>ab</sup> Means within a row with different superscripts differ (P<0.01)						
<sup>cde</sup> Means within a row with different superscripts differ (P<0.01)						

There were also no differences ( $P > 0.10$ ) in finishing period performance due to diet prior to 205 days of age. However, some early-weaned steers stopped growing late in the finishing period. Twenty percent of the steers fed the 100% concentrate diet @ 12% CP failed to reach the 1050 compared with no steers fed the 60% concentrate diet or weaned at 205 days of age that failed to reach the 1050 pounds. No liver scores were reported in this research trial.

The authors concluded that early-weaning of calves onto a 100% concentrate diet might cause problems late in the feeding period. Carcass characteristics were also studied, steers fed the 90% concentrate @ 16% CP had a greater ( $P < 0.05$ ) marbling score compared with calves weaned at 205 days of age. Steers that were fed a 100% concentrate at either 12% or 16% CP had back fat measurements of 0.71 and 0.69 inches respectively and grades of 4.2. The authors concluded these back fat and yield grade values may be unacceptable to the beef industry compared with the 60% concentrate and calves weaned at 205 days of age. The author also concluded that evaluating the calves for breed type, frame score and perhaps using a more aggressive implant program may be warranted with early-weaned calves fed high-concentrate diets.

Lusby et al. (1981) studied the effects of very-early-weaning (<90 days) and back-grounding using 63 first calf Angus x Hereford crossbred pairs. The pairs were assigned to one of three treatments that consisted of 1) normal-wean (NW - 205 d), 2) early-wean drylot (EWD -56 days) and 3) early-wean drylot-pasture (EWDP – 56 days). The calves that were early-weaned were split at 135 days; one group remained in the drylot while the others were placed on native pasture with access to a 70% concentrate-creep.

**Table 2. Weight gains, weaning weights, and feed efficiencies of suckled and early-weaned calves, (Lusby et al. 1981).**

Item	Treatments		
	Suckled	Drylot	Drylot-Pasture
Number of calves	30	16	13
Weight at early weaning - kg		56.3	57.2
Gain d 56 – 135	57.6	48.1	28.1
Weight at normal weaning - kg	169.3	169.8	149.8
Feed : Gain ratio		4.2	4.3
Feed costs/calf		\$82.19	\$64.49
Pasture charge			\$10.00
Total costs		\$82.19	\$74.49

Weaning weights (Table 2) were similar for NW and EWD calves. Early-weaned drylot-pasture calves were 20 kg lighter at the time of normal-weaning than NW and EWD calves, suggesting that calves of this age must have either a complete mixed diet or a better quality forage than that used in this study to make adequate gains without milk.

Feed costs (Table 2) were \$82.19 for EWD calves and \$64.49 for EWDP. The authors concluded that the economic feasibility of early-weaning will depend upon the expected rebreeding potential and the amount of supplemental feed required for the cow herd or in the case of drought the amount of purchased feed required to maintain the cow

herd. Any economic comparison will also have to consider the expected calf crop for the succeeding year after early-weaning. In the case of this study, the difference in conception rates between normal-weaned and early-weaned was 59.4% versus 96.8%.

In general most literature (Wyatt et al.; 1976; Lusby et al. 1981; Lusby and Wettemann 1986; Lusby et al., 1990) agrees that feeding programs for young (2-7 month old) calves need to be “growing programs” that hold ADG levels similar to those achieved on the cow. These rates of gain will generally range from 2 to 2.5 lb/day range depending on frame size and growth potential of the calves. Otherwise, full-fed early-weaned calves will not finish at the acceptable slaughter weights.

### ***Early-weaning & Ruminant Digestive System Development:***

To understand the variances in performance of early-weaned calves a clear understanding of the changes and development in the postnatal rumen is needed. What makes the ruminant animal distinctive is the four separate stomach compartments in the digestive system; the rumen, reticulum, omasum and abomasum. This four-stomach system is what allows ruminants to subsist on high quantities of roughage – that are high in lignified material and hemi cellulose. To better understand the importance of the changes that occur within the ruminant digestive system a quick review of the primary functions is needed.

#### ***A. Rumen***

In a newborn calf, the rumen is very small and the calf is functionally a monogastric. The rumen only starts to grow at two to three weeks of age and growth will continue until about six months of age; thereafter any subsequent growth will be proportional to the total growth of the animal. This early period of growth is where the

specialized function of the rumen is first established. The primary function of the rumen is to serve as a fermentation vat where microorganisms (bacteria, protozoa, fungi, etc.) break down the feed. Eventually the rumen in a mature cow becomes very large and in many cases is capable of holding 160-200 liters of material.

#### *B. Reticulum*

The reticulum is an extension of the rumen. The reticulum, by means of regular contractions, aids in keeping the feed in the rumen mixed with water and saliva until it has a consistency that can pass into the lower digestive tract.

#### *C. Omasum*

The omasum serves mainly as a dehydration area. As the feed passes through the omasum it is squeezed and compressed by the contractions of the omasum. This removes 60 to 70 percent of the water from the partially digested feed (ingesta). The omasum also serves for absorbing an estimated 40-69% of all volatile fatty acids (Gray et al. 1954). Once water and the volatile fatty acids are absorbed into the lining of the omasum they are then shuttled into the blood stream and are recirculated throughout the body.

#### *D. Abomasum*

The abomasum is referred to as the “true stomach” it is the stomach that most closely represents the stomachs found in monogastrics. As the feed passes into the abomasum, gastric juices secreted by the abomasum are mixed with the ingesta, producing a material about the same consistency of that in the rumen. The high acid content of the gastric juices lowers the pH rapidly and kills the protozoa and many of the bacteria. The ingesta passes rapidly through the abomasum into the lower tract, where digestion is completed in a similar manner to simple monogastrics.

During the early period of postnatal growth, the specialized function of the rumen is established. Tamate and co-workers (1962) were one of the first group of researchers to study the stomach development of early-weaned calves. Their work was based on dairy calves, which under normal management practices are weaned off milk at 8 weeks or less. Observations indicated that a rapid development occurred in the reticulo-rumen as early as 4 weeks of age. At 8 weeks, it occupied the entire left half of the abdominal cavity, except for a small space filled by the anterior part of the body of the abomasum, and extended considerably into the right half. The differential development of the compartments of the stomach in bovines have been investigated by a number of authors (Church 1975). Data from several of those researchers have been compiled in Table 3.

**Table 3. Percentage of bovine stomach tissues contributed by each compartment in dairy calves, (Church, 1975).**

	<u>Age in weeks</u>						
	<b>0</b>	<b>4</b>	<b>8</b>	<b>12</b>	<b>16</b>	<b>20-26</b>	<b>34-38</b>
<b>Reticulo-rumen</b>	38	52	60	64	67	64	64
<b>Omasum</b>	13	12	13	14	18	22	25
<b>Abomasum</b>	49	36	27	22	15	14	11

The information compiled in Table 3, indicates a rapid increase in the size of the reticulo-rumen as soon as the animal starts to ingest dry feed. The abomasum regresses in relative size, although not in absolute size and the omasum develops slowly, taking longer to reach relative mature size than the reticulum or rumen. The reticulo-rumen of dairy calves makes its most rapid relative growth prior to 8 week of age, and the relative mature size probably is attained by 12 weeks. Variances in the size of the reticulum and rumen will also be dependent upon feeding regime that the animal is under (milk vs. dry feed) (Church 1975).

At wk 34-38 the omasum is still increasing in relative size while the abomasum is still regressing. If ruminant species are compared the changes in growth and size with respect to age can be quite marked. In lambs data show that the reticulum has reached its relative mature size by 30 days. Rumen growth is more marked and it is of mature relative size by 8 week of age. As for the omasum it is still undersized at 8 or 9 wk, although the abomasum is of relative mature size (Church 1975).

Most of the early work on stomach development in ruminants was done in the late 50s and early 60s, it focused mainly on cattle and sheep, little research was done outside of these species. However, from the information available there appears to be a positive relationship between the length of the gestation period and the time required for stomach development (Church 1975). There is probably also a correlation between development and the length of the normal nursing period. Data cited by Warner and Flatt (1965) indicated that the stomach content in adult cattle is distributed 81-87% in the reticulo-rumen, 10-14% in the omasum, and 3-5% in the abomasum. Chandler et al.(1964) found the stomach contents of 15 wk-old calves were distributed 86, 7 and 7% respectively, figures which agree well with those of adults. Hodgson (1973) studied the stomach contents of 10-13-week-old calves on various types of roughage diets. He found that 79-92% of the wet digesta was recovered from the reticulo-rumen, 3.4-11.3% from the omasum, and 1.9-10.6% was from the abomasum.

### ***Factors Affecting Stomach Development:***

When a calf is born it is for all intensive purposes a monogastric and does not have a functional rumen. The rumen is present but it is very small. While the calf is nursing the cow and consuming primarily cow's milk, the rumen does not develop very quickly. The milk, for the most part, is shuttled past the reticulo-rumen into the abomasum and on down the digestive system. This shuttling continues even as the calf grows and the rumen develops. Research has shown that the nursing effects creates what is referred to as an esophageal groove that acts like an extension of the esophagus, helping the milk by-pass the first compartments and the digestive activities contained within. This helps the milk to be digested in a more complete form farther down the digestive tract (Church 1975).

Normal development of the stomach is an orderly process, presumably mediated by the endocrine glands. At a given age and weight and when an animal is on a roughage diet, the approximate relative development of the stomachs can be predicted with reasonable accuracy. In addition to species differences, age and weight, there are also a number of other factors that can influence stomach development.

Restriction of young ruminants to a liquid diet of milk or milk replacer will delay the development of the reticulo-rumen. The reticulo-rumens of such animals will usually be smaller than normal for their age, with thinner walls, lower capacity, and will lack normal development and coloration of papillae (Warner et al. 1956; Loe et al. 1959; Neidermeier et al. 1959; Church 1975). Harrison et al. (1960) reported that rumen papillae regress in size and number when an animal is changed from a grain-hay ration back to a milk diet. Other reports have also indicated that some regression in rumen

papillae occurs after birth and probably continues until the consumption of roughages begins (Church 1975). In the dairy industry calves are weaned at birth from the cows and from milk replacer as young as 4 weeks (very-early-weaning). Young dairy calves are offered free choice hay and high-concentrate grain from the day of birth on; perhaps these feeds prevent and or stop any papillae regression if Church's theory holds true. Ample evidence is available from experimental studies that shows that ingestion of roughages is stimulatory to development of the reticulo-rumen in terms of weight and thickness of the tissues and the development of normal papillae (Warner and Flatt 1965). Concentrates may, however result in greater stimulation than will roughage of papillae in early life (Harrison et al. 1960; Stobo et al. 1966; Peron 1970; Church 1975). In grazing beef calves suckling their dam's, it has been shown that little rumen development occurred by 9 weeks of age (Stewart, 1971), as indicated by rumen weight, papillary development, and rumen contents. Stewart's theory may hold true depending upon circumstances; should the dam's milk production be limited the calf would be forced to find feed elsewhere, mainly grazing, this grazing would then result in accelerated papillae development.

The stimulus of roughages and concentrates on papillae development was first thought of as a bulk theory. In other words, the physical contact of these feeds with the rumen walls stimulated papillae development. This theory was studied by Flatt and coworkers (1958). In these experiments, rumen papillary development was relatively normal when salts from volatile fatty acids (VFA) were introduced into rumen-fistulated milk-fed calves. Plastic sponges inserted into the control animals to add bulk density were ineffective in stimulating rumen development. Therefore at least part of the stimulus

for the development of papillae is the presence of organic VFA found in the rumen of adult animals. In other words feed is ingested and at some point in time there are enough ruminal bugs present to allow fermentation to start which then causes the release of VFAs. Roughages and concentrates differ in their production capabilities and ratios of the specific VFAs acetic, butyric, propionic, and valeric. Warner and Flatt (1965), found that butyrate was more effective than propionate, followed by acetate in stimulating the development of rumen papillae. The difference in VFA production capabilities may perhaps be the reason why concentrates may stimulate more papillae development than roughages; due to their higher potential for butyrate and propionate production (Harrison et al.1960; Stobo et al. 1966; Peron 1970; Church 1975).

Another method for changing the VFA potential would be feeding an ionophore. Randel (1990) found that propionate levels could be altered by feeding monensin; feeding monensin should then also prove positive for enhancing the development of ruminal papillae. Candau (1971) found that ammonia also worked as a stimulatory to papillae development. This solution however leads to another question – “To get VFAs and ammonia there needs to be fermentation, to get fermentation there needs to be an inoculated rumen – Which comes first?”

### ***Digestive System Inoculation:***

Young ruminants probably acquire rumen bacteria mainly through feed and interanimal contact (Van Soest, 1997). Anaerobic bacteria similar to those found in the rumen occur in nature, particularly in manure and soil. Despite the sensitivity of many rumen organisms to temperature and oxygen, they can be transferred via saliva and feed from one animal to another and escape down to the digestive tract. Inoculation probably

depends upon on the survival of only a few cells. This theorized the concept of rumen inoculation as a method of hastening rumen development; however, no consistent advantage of inoculation was ever established (Van Soest, 1997).

Rumen populations tend to be similar in animals on a given diet, although many on these microbe species may occur in relatively small numbers, and any of these may respond to a dietary change. Existing bacteria can adapt or mutate to accommodate a new substrate and changes in rumen conditions. The normal adaptation period is about one to two weeks. For example, in the case of an abrupt dietary change from hay to concentrate, rumen adjustment is facilitated by inoculation with rumen contents from an animal already on the new diet. Early-weaning of beef calves clearly results in an abrupt change of the diet for that calf. The abruptness and severity of the diet change to the calf will depend on, the calf's age, milk production of the dam and the feed resources that the calf had been exposed too. Perhaps this may suggest that another management technique for early-weaning calves is to use older animals not just as a trainer but to some how also facilitate a quicker change in the digestive flora.

***Early-weaning and Sexual development:***

Reproduction is considered the single most important factor effecting ranching productivity and profitability (Bellows et al. 1974; AAFRD 1999). The ability of a female to breed by 14 months, calve by her second birthdate and keep this routine on a 365 day cycle is key for a successful beef enterprise. Many of the reasons why early-weaning of beef calves is often not considered by industry is due to misconceptions in that early-weaned heifers will reach puberty later than normal-weaned calves.

Richardson et al. (1978) studied the reproductive and progeny performances of 458 Angus heifer calves over a 6-year period that were either weaned at 120 days or 210 days. He reported that there were no differences in sexual development in either treatment and that early-weaned calves in this trial were 10.1 kg heavier than normal-weaned calves at 210 days. Early-weaned calves also exceeded late-weaned calves in conformation. The reproductive and maternal performance of the heifers as they were moved into the cowherd was also studied (Table 4).

**Table 4. The reproductive and progeny performance classified by the age at which the cow was weaned as a calf (Richardson et al. 1978).**

Trait	<u>Cow Weaning Age</u>			
	<u>120 days</u>		<u>210 days</u>	
	Mean	SE	Mean	SE
<b>Pregnancy rate %</b>	85.6%	3.0	85.1	2.8
<b>Calving date</b>	92.1	1.7	91.2	1.7
<b>Live calf, %</b>	79.5%	3.2	75.8	3.4
<b>Calving Difficulty</b>	1.08	0.04	1.07	0.04

Richardson and coworkers (1978) found that early-weaned heifers had a slightly better pregnancy rate (0.5%) but found no differences ( $P>0.10$ ) in cyclicity and or services to first conception. There was also no difference ( $P>0.10$ ) in calving difficulty between the two groups. The difference in the percent of live calves weaned was almost 5% in favor of early-weaned dams, however due to the large standard errors, it was not significant ( $P>0.10$ ).

Calfhood weaning age of the cow was not a significant factor affecting the subsequent birth weight of her calves over the six-year experiment. However, in the second parity early-weaned cows had calves that were 2 kg heavier ( $P<0.05$ ) than those from late-weaned cows. Calfhood pre-weaning treatment of the cow by sex of calf

interaction was significant ( $P < 0.10$ ) for birth weight. Both male and female calves from early weaned cows were slightly heavier at birth but by 120 and 210 days there were no differences.

Grimes and Turner (1991b) studied the effects of early-weaning (110 day) vs normal-weaning (220 day) on a 152 fall calving cows over a 5-yr period at Ohio State University. The results they found were similar to Richardson et al. (1978). No differences in reproductive performance of the heifer calves weaned at either 110 or 220 days were noted over the 5-year study.

### ***Early-weaning & Animal Behavior:***

Early-weaning management extends beyond bovines. Farmed wapiti calves are often weaned at 3-4 months of age, whereas wild calves may continue to suckle for 7-8 months and maintain an association with the hind until the next calf is born (Haigh and Hudson 1993). Forced weaning, is a distressing experience for most animals, especially if it is performed before weaning would occur naturally (Houpt 1991). In wapiti calves it is considered stressful by sharply reducing lymphocyte counts following separation from the dam, calves can then be more susceptible to disease, and often intensely pace the fence lines (Griffin et al. 1988; Pollard et al. 1992). In bovine calves, similar animal behavioral aspects have been noted.

Early-weaning and for that matter very-early-weaning in dairy cattle is considered standard, however in the beef industry the principle of early-weaning are far less understood. What makes early-weaning in beef calves trickier is their naivete to new feeds as opposed to calves that are removed from their dams at birth. This naivete often means that calves will not feed properly for several days and often do not find the water

either. This can make early-weaned calves more prone to respiratory diseases, which can cause higher rates of morbidity and mortality. The lack of skill and extra care that must be taken to properly start early-weaned beef calves on feed is another one of the reasons its adoption has been slow.

When calves face environmental stressors (e.g. nutritional stressors, weather, weaning or handling), activation of the hypothalamic-pituitary-adrenocortical axis (HPA) causes an increase in circulating glucocorticoids that subsequently influence leukocyte dynamics (Griffin et al. 1988). Previous bovine research has demonstrated the effectiveness of lymphocyte blastogenesis and neutrophil function as a secondary measure of stress (Murata 1989; Murata and Hirose 1991). Murata et al. (1987) found that leucocyte counts obtained from Holstein calves transported by road for 4h showed a leucocytosis with neutrophilia, a decrease of T-lymphocyte population, a suppression of lymphocyte blastogenesis and an enhancement of neutrophils after the transportation. A reduction in lymphocytes would suggest a reduction in immunocompetence, and may increase susceptibility to stress-related diseases, such as bovine respiratory syncytial virus (BRSV) and pneumonia. Weaning stress would cause a similar reaction in calves.

Table 5, from Myers et al. (1999) shows the two-year health summary of steers weaned under three weaning management systems; early weaning (EW), normal-weaning with creep feeding (NWC) and normal weaning (NW). Early-weaned steers had a 91% lower respiratory morbidity ( $P=0.001$ ) compared with the average of NWC and NW steers, and NWC steers had 84% lower respiratory morbidity ( $P=0.0001$ ) than NW steers. The author concluded that the high percentage of treatment of NW steers could have been attributed to weather effects and lack of prior consumption of a high-concentrate diet. In

other words the NW calves may have had a naivete in the feedlot towards the new feed source as opposed to the NWC calves. This lack of feed consumption coupled with weather changes and a break with the maternal bond may have been enough to induce the respiratory morbidity seen in this experiment.

**Table 5. Health of steers as affected by three weaning management systems, (Myers et al. 1999a).**

Item	<u>Treatments</u>			SEM
	EW	NWC	NW	
Respiratory Morbidity %	1.2	3.6	22.8	3.1
Digestive Morbidity %	1.2	0	0	.7
Digestive Mortality %	1.2	0	0	.6
Accidental Mortality %	1.2	1.2	0	1.0

In another study by Myers et al. (1999b) calves were either weaned at 90, 152, or 215 days. In this trial a quadratic response was observed for the calves treated for respiratory morbidity (P=0.004) and for digestive morbidity (P=0.04). Myers et al. (1999b) concluded that the calves weaned at 90 d had not received a vaccination before weaning, which could account for the high percentage of calves treated for respiratory ailments. The higher sickness rates in the 215 day weaned calves was attributed to changes in the weather.

Many management practices to reduce respiratory morbidity in young calves have been studied. One of the most effective has been calthood vaccination. In a New Mexico weaning study, Parker (1993) studied the effects of vaccination at 2 months of age on blood serum titer levels. At the time of branding, serum titer levels greater than 1:4 for IBR, BVD, PI3, and BRSV infection were found in 35%, 65%, 98%, and 71% of calves respectively. In this trial half of the calves were vaccinated at branding and revaccinated twice at weaning, whereas the remaining calves were vaccinated twice, only at weaning.

By 28 days postweaning, 81% of the calves vaccinated at branding and 63% of the calves vaccinated only at weaning had shown a positive response to the feedlot vaccination. The study revealed that vaccination at branding, even when calves are carrying passively acquired antibodies, tended to produce increased antibody responses to those viral antigens when the calves were revaccinated on arrival in the feedlot.

Vaccination protocol however is only one management tool for managing morbidity and mortality in early-weaned calves; stress is a larger contributor and stimulant. Attempts to reduce the stress of weaning calves have included: creep feeding (Wilson 1966), early handling (Boissy and Bouisson 1988), housing animals indoors (Boivin et al. 1994), trainer animals (Pollard et al. 1992), allowing fence line contact (McCall et al. 1985) and interval weaning (Houpt 1991; Church 1997).

All of the mentioned stress/weaning management practices have shown promise. Creep feeding allows the animal to become accustomed to the new feed source, which helps to reduce the naivete of the calves. It also helps to reduce the amount of time that the animal takes to get back on feed following the weaning process. Properly introducing calves to a new water source is even more important. An animal that becomes dehydrated will be more prone to sickness and morbidity. Fluharty et al. (1996) studied the effects of trainer animals on the performance of newly weaned calves after arrival at the feedlot. Six mature cows and six mature steers were used in the study as babysitter animals to examine the performance and morbidity of freshly weaned calves. On day 1, more ( $P < 0.05$ ) calves in the cow group (81.7%) were observed eating compared with either the steer trainer group (60%) or the control group containing no trainer animal (48.3%). Furthermore, newly arrived calves in both the cow and steer trainer groups consumed

more meals ( $P < 0.05$ ) compared with the control group (1.4 and 1.5 vs 0.9, respectively). On day 2, more ( $P < 0.05$ ) calves were observed eating in both the cow and steer trainer groups compared with the control group (68.3% and 63.3% vs 38.3% respectively). From days 3 to 7 there were no longer any differences ( $P > 0.10$ ) in the percentage of calves eating between the cow trainer group and the control group. Although the calves from both trainer groups consumed more meals and were observed eating more times than control calves, there were no differences ( $P > 0.10$ ) in animal performance over the 28 day feeding period. There were also no differences ( $P > 0.10$ ) in morbidity due to trainer animals. The authors concluded that calves without trainers compensated for any decrease in ADG early in the receiving period by having an increased ADG in the subsequent weeks.

Church, (1997) studied the effects of abrupt vs. interval-weaning on behavior, weight gain and neutrophil/lymphocyte ratios of beef calves. One hundred calves (180 d; 218 kg) were either abruptly-weaned or interval-weaned. Immediately following weaning of all the calves in the interval group, all of the calves were relocated to feeding pens and fed ad libitum and observed for behavioral changes. Interval-weaned calves gained more weight than abrupt-weaned calves during the first week, the reverse was true during the second week. At the end of the 28d feeding period, there were no significant ( $P > 0.10$ ) differences between abrupt and interval-weaned calves for ADG. Interval-weaned calves spent less time standing and pacing and more time eating compared to abrupt-weaned calves. Neutrophil/lymphocyte ratios were higher in the abrupt-weaned calves compared to the interval-weaned calves (0.81 vs.0.51;  $P < 0.05$ ). In addition, the ratios were also considerably higher in male calves than in female calves. There was no difference

( $P > 0.10$ ) in morbidity between the treatments. Church (1997) concluded that the behavioral observations of abrupt and interval-weaned calves indicate that the different weaning management regimes can cause behavioral differences.

Two physiological forces governing behavior at weaning include the filial/maternal bond and social facilitation with other members of the herd (Houpt 1991). Usually “social facilitation” is a term applied to the phenomenon in which the mere presence or behavior of another organism produces an increase in the probability, rate, or frequency of a behavioral pattern in another organism (Dewsbury 1978). However, Zajonc (1965) found that the presence of another organism can result in an interference with performance of a behavior rather than facilitation of it. Therefore, the presence of conspecifics may be utilized as a management tool to prevent undesirable behavior. When a calf’s dam is removed, the filial/maternal bond is broken and the separation is distressing to both the cow and calf. But while interval-weaned calves may have suffered anxiety by removal of their dam, the presence of conspecifics appears to have dampened the effect. Conversely, abrupt-weaned calves experienced the distressing separation of their dams simultaneously, and hence the stress of removal of the dam appears to be exacerbated by social facilitation. Church, (1997) concludes that interval-weaning is recommended on welfare grounds if not productivity. Fence line weaning would cause similar behavioral reactions as observed in interval-weaning.

#### ***Early-weaning & Carcass Quality:***

The definition of carcass quality is as diverse as the management practices used in the cow/calf industry. Increasingly, carcass quality as defined within the North American context refers to the carcass yield and marbling score as the method for rating the merits

of one carcass over another. Within the confines of a value-based marketing system, the competitive ability of beef could be enhanced by raising cattle that produce high yielding and highly marbled beef in a shorter period of time.

Traditional management of early-weaning beef calves often denotes that there is a higher level of management and feeding associated. Most early-weaning research (Lusby et al. 1990; Fluharty et al. 1997; Myers et al. 1999), has shown that the best nutritional performance (ADG & feed:gain) responses occurred with calves that are fed high-concentrate rather than high-roughage diets. The reasons for the improved performance of high-concentrate diets are many, they include; improved papillae growth brought on by the changes in VFA ratios (Warner and Flatt, 1965), increased energy densities of feed ingested (Fluharty et al.1997), and a decreased need for additional rumen capacity (Myers et al. 1999). Early weaned calves placed on high-concentrate diets after weaning have had greater gain, lesser intakes, better feed:gain ratios and were younger at slaughter. Cost of production and feed efficiency are the most important factors affecting the profitability within the beef industry (AAFRD, 1999). If early-weaned calves have all the above factors in their favor should that not be reason enough to switch the entire beef production system in North America to early-weaning? What about carcass quality?

Myers et al. (1999), examined three weaning scenarios in spring born beef calves. The steer calves were either 1) early-weaned (170 d) and placed on a finishing diet (EW), 2) supplemented with grain for 55 d on pasture (170 to 225d of age) while nursing their dams and then placed on a finishing diet (NWC), or 3) on pasture for another 55 d while nursing their dams (170-225) and then placed on a finishing diet (NW). They found that EW steers had lower intakes (7.70 vs. 8.16 kg/d,  $P=0.008$ ) and better gain:feed

conversions (.170 vs.153, P=0.002) than the average of NWC and NW steers. However using USDA standard quality grading techniques the responses of the treatments were mixed (refer to Table 6).

**Table 6. Effects of three weaning management systems on carcass quality, (Myers et al. 1999).**

Item	<u>Treatments</u>				<u>Contrast ; P=</u>	
	EW	NWC	NW	SEM	EW vs NWC & NW	NWC vs NW
<b>Carcass weight</b>	283	276	272	4	.04	.42
<b>Est. KPH, %</b>	2.3	2.2	1.9	.1	.0005	.001
<b>Avg. Yield Grade</b>	2.71	2.67	2.57	.04	.03	.03
<b>Yield Grade 1, %</b>	12	5	16	4	.70	.02
<b>Yield Grade 2, %</b>	49	66	57	7	.13	.23
<b>Yield Grade 3, %</b>	39	29	27	5	.07	.83
<b>Marbling Score</b>	1,168	1,124	1,122	13	.004	.89
<b>Choice, %</b>	95	87	91	4	.16	.39
<b>Average, Choice %</b>	81	58	58	6	.003	.99
<b>Prime, %</b>	15	10	2	4	.06	.15

The EW steers had a 9-kg heavier carcass (P=0.04), however there were no differences between the NWC and NW calves. The EW steers had 12% more kidney, pelvic, and heart fat (P=0.0005) than the average of NWC and NW steers, and NWC steers had 16% more (P=0.001) than the NW steers. The differences in kidney, pelvic, and heart fat are reflected in differences in yield grades. The NW calves had a greater yield grade than EW and NWC (P=0.02). Conversely, EW improved the percentage of steers grading Average Choice or higher by 40% (P=0.003) over the average of NWC and NW treatments. The EW improved (P=0.06) the percentage of steers grading Prime or higher by 150% over the average of NWC and NW. No differences in percentage of steers grading Prime were observed between NWC and NW. The results between NWC and NC were opposite to the results found by Deutscher and Style (1978) and Faulkner et

al. (1994), where they observed an improvement in quality grade for creep-fed calves compared with controls. Myers et al. (1999) concluded that the NWC steers were slower getting started on the creep and they were fed for a shorter period of time than Faulkner et al. (1994).

Similar results of high marbling scores and low yield grades on early-weaned calves (110-d) were found by Fluharty et al. (1996). They concluded that early-weaning of calves onto a 100% concentrate diet might cause problems late in the feeding period. Steers that were fed a 100% concentrate at either 12% or 16% CP had back fat measurements of 0.71 and 0.69 inches respectively and grades of 4.2 (scale 1 to 5). He also concluded these back fat and yield grade values may be unacceptable to the beef industry and that evaluating the calves for breed type, frame score and perhaps using a more aggressive implant program may be warranted with early-weaned calves fed high-concentrate diets.

The differences in body fat composition and subsequent carcass yield of early-weaned, normal-weaned and creep-fed animals may partially be explained by another study from Myers et al. (1999c). Myers et al. compared the visceral and digestive tract weights of early-weaned steers receiving a high concentrate diet or grown on pasture before finishing. They found that pasture steers tended ( $P=0.15$ ) to have a 12% larger liver weight and 14% larger ( $P=0.01$ ) rumen weight than steers fed on a high concentrate diet. Myers et al. (1999c) concluded that these organs have higher energy requirements per unit of mass than the body average. In other words when feed intake increases, hypertrophy occurs in the organs that have greater energy expenditures per unit of weight. Daily energy intake may be similar for both treatments, but because the early-weaned

calves on a high concentrate diet had lower energy requirement for gut maintenance due to a lower gut weight more could energy could be partitioned to fat deposition and growth.

Although early-weaning shows significant advantages on the feeding side of the equation; on the carcass side it is left open. Depending on the goals for the finished carcass – high marbling or high yield, it is difficult to have both without sacrificing one or the other. Placing early-weaned calves on feed will need careful consideration in order to achieve both the desired carcass traits and feeding efficiencies.

***Early-weaning and Economics:***

Aside from the biological and physiological aspects of early-weaning beef calves, the economics of feeding the young calves must also be considered. The questions that need to be answered are, “What is the profitability in feeding the early-weaned calf, how and what should they be fed and what special handling is necessary?”

Landblom et al. (1986) published the results of a 1-year study in which 82 early-weaned (average age 84-d) were weaned onto one of 4 diet types: 1) Commercial, 2) Commercial – switch to Home grown oat base, 3) Home grown oat base, and 4) Home grown barley base. The commercial as well as all the home grown rations were blended to maintain a nutrient digestibility of between 71 and 73 percent. Protein levels during the early part of the feeding study ranged between 15.5 and 16 percent and were lowered to 14 percent as the calves matured.

The calves were weighed at the start of the trial and at the conclusion and all the information summarized in Table 7.

**Table 7. Summary of gains, feed consumption, ration economics, and net return over feed costs for early-weaned calves fed four different ration types, (Landblom et al. 1986).**

	<u>Rations</u>			
	Commercial	Commercial / Home Grown Oat Base	Home Grown Oat Base	Home Grown Barley Base
<b>No Head</b>	21	21	20	20
<b>Days Fed</b>	142	142	142	142
<b>Initial wt. – lb.</b>	155	158	152	159
<b>Final wt. – lb.</b>	490	459	434	421
<b>Gain</b>	335	301	282	262
<b>ADG</b>	2.36	2.12	1.98	1.84
<b>Feed : Gain</b>	5.08	4.39	5.50	5.19
<b>Cost / head / day</b>	\$1.24	\$0.73	\$0.70	\$0.62
<b>Cost / cwt of gain</b>	\$51.03	\$32.88	\$33.65	\$32.46
<b>Return per head</b>	\$216.47	\$267.83	\$251.78	\$249.68

When the four diets were evaluated in terms of economic efficiency and resultant profitability; overall animal performance was not the deciding factor. Although, the early-weaned calves on the Commercial ration had a superior ADG at 2.36 lb/day vs a range of 2.12 – 1.84 lb/day for the other rations it did not prove to be the most economical. Comparative costs associated with not weaning the calves were not given. The author concluded that in this case feeding a lactating cow during a drought and the costs associated with an increase in the percentage of open cows would have been far greater than the costs of feeding these calves. What was not factored into the costs of this experiment was the additional expense of increased management and facility use that resulted from the decision to early-wean calves.

Ultimately finding a low-cost system for growing early-weaned calves that could achieve reasonable gains, reduce the dependency upon purchasing feeds, and minimize the amount of overhead in terms of facilities and management needed would be ideal.

Purvis et al. (1996) looked at utilizing winter wheat pastures in Oklahoma for growing out early-weaned, fall-born (80 d; 215 lb) calves. The authors hypothesized that grazing winter wheat would help reduce overhead and purchased feed expenditures. Winter wheat was also a feed resource readily available to most area cow/calf producers. Calves were weaned initially into a drylot for 2 weeks and then moved back to winter wheat pastures for a 150 days. Overall ADG for the two year trial was 1.85 lb /day while the calves grazed winter wheat. There was a positive ( $P<0.05$ ) relationship between ADG, age, weight and morbidity as the calves got older. The authors concluded that special care be taken with light weight calves and that a management technique of short term conditioning with a high-concentrate diet during the receiving period may be warranted for calves under 300 lbs. Young calves in this trial had above normal rates of respiratory infection and shipping fever; the authors concluded this was due to the trucking stress associated with hauling the calves 14 miles away to winter wheat pastures and management error because the calves were not properly settled following weaning.

***Summary and Conclusion:***

Early weaning (90-180 days) is a viable management tool that exists for improving profitability during periods of drought, reduced feed quality and (or) poor conditioned dams. It has been proven effective in improving cow reproductive performance the next breeding season by decreasing the late season lactational / nutritional demands and improving pre-calving body condition scores (Bellows et al. 1974). Very-early-weaning (<90 days) will be reserved for young cows especially first-calf heifers that may have the potential for dramatically reduced rates of conception due to high 3<sup>rd</sup> month lactational demands, poor pasture quality and quantity, and low-body

conditions. Weaning in either situation provides a way to decrease grazing pressure and reduce the energy demands by 15 to 20% as compared with cows nursing calves. The production advantages of having cows in moderate to high body condition at the next calving season are improved conception rates, decreased reproductive culls, decreased replacement heifer costs, decreased winter supplementation costs, and increased weaning weights the next year, compared with thin cows at calving.

The considerations to early-wean beef calves are many. Calf performance and ADG can be maintained or improved by early-weaning however evaluation of the costs associated with the supplementation and extra management must also be considered. Many studies have shown that early-weaning does not have any negative effect compared to normal 205-210 day weaning weights, and often the EW calves have better pre and post-feeding feed efficiencies, ADG and morbidity rates than normal-weaned calves. Depending upon the weaning age of the calf; the nutritional program must be specifically tailored. When designing early-weaning rations, particularly for younger calves (<120 days), keeping the hay content of the ration low and keeping the concentrate, protein and palatability levels high is very important. Volatile Fatty Acid production has profound effects on rumen and gut development.

Animal behavior and management is also important. Any method of settling calves, reducing their naivete, bunk breaking and (or) pre-immunization will help to improve the overall calf performance, morbidity and mortality rates. Consumption of feed in the first four to five days should be high at 3 to 3.5% of body weight. After about 30 days moving the calves to high quality forage or pasture could be an option or depending on the age of the calves, type and (or) growth potential they could be put on a

finishing diet. However, consideration of the feeding program and the effects of the diet on the finishing and carcass characteristics of animal must also be taken. With heifers there has been no negative effects of early-weaning on reproductive and sexual development.

Early-weaning as a management tool for cow calf operations has shown many positive results. Understanding the principals in managing these young calves is key for any Alberta cow calf managers considering this management option.

***Literature Cited:***

AAFRD, 1999 – Alberta Agriculture Food and Rural Development. In: *1999 Alberta beef cow/calf audit*.

Boissy, A., and M.F. Bouisson. 1988. Effects of early handling on heifers' subsequent reactivity to humans and unfamiliar situations. *Appli. Anim. Behavi. Sci.* 20:259.

Boivin, X., P. Le Neindre, J.P. Garel, and J.M. Chupin. 1994. Influence of breed and rearing management on cattle reactions during animal handling. *Appli. Anim. Behav. Sci.* 39:115.

Bellows, R.A. and R.E. Short and G.V. Richardson. 1974. Effects of early weaning on postpartum reproduction of the dam and growth of calves born as multiples or singles. *J. Anim. Sci.* 39:589.

Candau, M. 1971. *Ann. Biol. Anim. Bioch. Biophys.* 11:284.

Chandler, P.T., E.M. Kesler, and R.D. McCarthy. Use of polyethylene to measure nitrogen absorption in calves. 1964. *J. Anim. Sci.* 23:870.

Church, D.C. 1975. Digestive Physiology and Nutrition of Ruminants. In: Volume 1; *Digestive Physiology*.

Church, J.C. 1997. The effects of production practices on the behavior of ruminant animals (*Bos taurus*, *Bison bison*, and *Cervus elaphus*) Ph.D. Thesis – University of Alberta.

Deutscher, G.H., and A.L. Slyter. 1978. Crossbreeding and management systems for beef production. *J. Anim. Sci.* 47:19.

Dewsberry, D.A. 1978. *Comparative Animal Behavior*. McGraw-Hill, New York.

Faulkner, D.B., D.F. Hummel, D.D. Buskirk, L.L. Berger, D.F. Parrett, and G.F. Cmarik. 1994. Performance and nutrient metabolism by nursing calves supplemented with limited or unlimited corn or soyhulls. *J. Anim. Sci.* 72:470.

Ferrell, C.L. and T.G. Jenkins. 1984. Energy utilization by mature, nonpregnant, nonlactating cows of different types. *J. Anim. Sci.* 58:234.

Flatt, W.P, R.G. Warner and J.K. Loosli. Influence of purified materials on the stomach development of ruminant stomach. 1958. *J. Dairy Sci.* 41:1593.

Fluharty, F.L., T.B. Turner, S.J. Moeller, and G.D. Lowe. 1996. Effects of weaning and diet on growth of calves. In: *Ohio State University Research and Reviews*. Research Bulletin 156, Columbus, OH.

Gray F.V., A.F. Pilgrim and R.A. Weller. 1954. *Journal of Experimental Biology*. 31:49.

Griffin, J.F.T., L.R. Bisset, and M.L. Fisher. 1988. Influence of management stress on immunity in farmed deer. *Proc. Deer Course for Veterinarians, Deer Branch, N.Z. Vet. Assoc.* 5:145.

Grimes, F.J. and T.B. Turner. 1991a. Early-weaning of fall-born beef calves: I. Prewaning calf and cow performance. *J. Prod. Agric.* 4:464.

Grimes, F.J. and T.B. Turner. 1991b. Early-weaning of fall-born beef calves: II. Postweaning performance of early- and normal-weaned calves. *J. Prod. Agric.* 4:468.

Haigh, J.C. and R.J. Hudson. 1993. *Farming Wapiti and Red Deer*. Mosby, St. Louis.

Harrison, H.N., R.G. Warner, E.G. Sander, and J.K. Loosli. Change in the tissue and volume of the stomachs of calves following the removal of dry feed or consumption of inert bulk. 1960. *J. Dairy Sci.* 43:1301.

Hodgson, J. 1973. The effect of physical form of the diet on the consumption of solid food by calves, and the distribution of food residues in their alimentary tracts. *Animal Prod.* 17:129.

Haupt, K.A. 1991. *Domestic Animal Behavior for Veterinarians and Animal Scientists*. 2<sup>nd</sup> Edition. Iowa State University Press, Ames, Iowa.

Lanblom, D.G., J.L. Nelson, and W.D. Slinger. 1986. System for feeding early-weaned beef calves. *North Dakota Farm Research* 43(5):7.

Loe, W.C., O.T. Stallcup and H.W. Colvin. The effect of various diets on the rumen development of dairy calves. 1959. *J. Dairy Sci.* 42:395.

Lusby, K.S., R.P. Wettemann, and E.J. Turman. 1981. Effects of early weaning calves from first-calf heifers on calf and heifer performance. *J. Anim. Sci.* 24:494.

Lusby, K.S. and R.P. Wetteman. 1986. Effects of limit fed protein creep feed or early-weaning on performance of fall-born calves and their dams. Oklahoma State University. 1989. *Animal Science Research Report*. p. 202.

Lusby, K.S., D.R. Gill, D.M. Anderson, T.L. Gardner and H.G. Dolezal. 1990. Limit feeding vs full feeding high concentrate diets to early-weaned calves – effects on performance to slaughter. *Okla. Agric. Exp. Sta. Res. Rep.* MP – 129. Stillwater.

McCall, C.A., G.D. Potter, and J.L. Kreider. 1985. Locomotor, vocal and other behavior, spatial relationships and responses to varying methods of weaning foals. *Appl. Anim. Behav. Sci.* 14:27.

- Murata, H. 1989. Suppression of lymphocyte blastogenesis by sera from calves transported by road. *Br. Vet. J.* 145:257.
- Murata, H and H. Hirose. 1991. Suppression of bovine neutrophil function by sera from cortisol-treated calves. *Br. Vet. J.* 147:63.
- Murata, H., H. Takahashi, and M. Matsumoto. 1987. The effects of road transportation on peripheral blood lymphocyte subpopulations, lymphocyte blastogenesis and neutrophil functions in calves. *Br. Vet. J.* 143:166.
- Myers S. E., D.B. Faulkner, F.A. Ireland, L.L. Berger, and D.F. Parrett. 1999. Production systems comparing early-weaning to normal-weaning with or without creep feeding for beef steers. *J. Anim. Sci.* 77:300.
- Myers S. E., D.B. Faulkner, F.A. Ireland, and D.F. Parrett. 1999b. Comparison of three weaning ages on cow-calf performance and steer carcass traits. *J. Anim. Sci.* 77:323.
- Myers S. E., D.B. Faulkner, T.G. N, L.L. Berger, D.F. Parrett and F.K. McKeith. 1999c. Performance and carcass traits of early-weaned steers receiving a pasture growing period or a finishing diet at weaning. *J. Anim. Sci.* 77:311
- Niedermeier, R.P., N.N. Allen, and R.W. Bray. 1955. A comparison of feeding methods as they affect veal production and carcass quality *J. Dairy Sci.* 38:622.
- Parker, W.L. 1993. Effects of vaccination at branding on serum antibody titers to viral agents on bovine respiratory disease (BRD) in newly weaned New Mexico Calves. In: 1993. *Proc. Western Section, American Society of Animal Scientists*, Champaign, Ill P.232
- Peron, N. 1971. *Revista Cubana de Ciencia Agr.* 5:195.
- Peterson, G.A., T.B. Turner, K.M. Irvin, M.E. Davis, H.W. Newland, and W.R. Harvey. 1987. Cow and calf performance and economic considerations of early-weaning fall-born beef calves. *J. Anim. Sci.* 64:15.
- Pollard, J.C., R.R. Littlejohn, J.M. Suttie. 1992. Behaviors and weight change of red deer calves during different weaning procedures. *Appl. Anim. Behav. Sci.* 35:23.
- Purvis, H.T., K.S. Lusby, and G.W. Horn. 1996. Performance of early-weaned fall born calves grazing winter wheat pasture. *Oklahoma Agr. Exp. St. An. Sci. Res Rprt.* #951/96:109.
- Randel, R.D. 1990. Nutrition and Postpartum rebreeding in cattle. *J Anim.Sci.* 68, 853.

Richardson, A.T., T.G. Martin, and R.E. Hunsley. 1978. Weaning age of heifer calves as a factor influencing calf and cow performance. *J. Anim. Sci.* 47:6.

Stewart, A.M. 1971. *Rhod. J. Agr. Res.* 9:53.

Stobo, I.J.F., J.H.B. Roy, and J.H. Gaston. 1966. *Br. J. Nutr.* 20:171.

Tamate, H., A.D. McGillard, N.L. Jacobson and R. Getty. 1962. Effect of various dietaries on the anatomical development of the stomach in the calf. *J. Dairy Sci.* 45:408.

Taylor, R.E. 1984. Beef production and the beef industry: A beef producers perspective. p 127. Burgess International Group Inc., Edina, MN.

Van Soest, P. 1997. *Nutritional Ecology of the Ruminant*.

Warner, R.G. and W.P. Flatt. 1965. *Physiology of digestion in the ruminant*. Butterworths Pub. Co.

Warner, R.G., W.P. Flatt and J.K. Loosli. 1956. *J. Agr. Food Chem.* 4:788.

Wilson, L., 1966. *Comparison of early-weaning, creep feeding and non-creepfeeding for fall calves at the Southern Indiana Forage Farm*. Purdue University, Agricultural Experiment Station, Lafayette, Indiana.

Wyatt, R.D., R.P. Wetteman, M.B. Gould, L. Knori and R. Totusek. 1976. Effect of singlr vs twin rearing on cow and calf performance. *Okla. Agri. Exp. Sta.* MP-96:43.

Zanjoc, R.B. 1965. Social Facilitation. *Science*, 149:269.