Effects of Nutrition and Management of the Dry and Fresh Cow on Fertility

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The interrelationship between nutrition and reproduction is a topic of increasing importance and concern among dairymen and veterinarians.

In the past, it has been felt that although nutrition plays an important role in normal reproduction, and that nutritional deficiencies can severely affect the process, such deficiencies should be rarely, if ever, seen under modern feeding conditions. Early research indicated that in most cases conditions must be quite severe before reproductive problems are encountered. The recommendation has, therefore, been to feed cows for top production and then the nutrient requirements for reproduction will be adequately met.

Today, however, many veterinarians and nutritionists are pointing to feeding programs as the cause of breeding problems in dairy cows. Deficiencies of various trace minerals, inadequate vitamin intakes, energy-protein imbalances and excessive protein intakes are mentioned as contributing to infertility and poor reproductive performance. Data are available on the effects of severe deficiencies of a few nutrients. However, relatively little is known regarding the possible effects of long term marginal deficiencies, the interaction of many nutrients, especially trace minerals, and the effect of excessive intakes of some of these nutrients. These factors and others not identified may be of increasing importance as production per cow increases, feeding programs change, and dairy farming becomes more intensive. It, therefore, seems important that the effects of nutrition on reproduction should receive increasing emphasis.

When studying reproductive problems in dairy herds, two concepts must be kept firmly in mind:

1. Nutrition is only **one** possible cause. Other possibilities should not be neglected, and some, like poor heat detection and poor sanitation and hygiene at calving, should be ruled out before looking for a nutritional cause for breeding problems.
2. Relatively little is known with certainty about the complex interaction between nutrition and reproduction. Often the best recommendation that can be made is to feed a ration that is balanced for all nutrients (energy, protein, minerals and vitamins).

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Management and Nutrition of the Dry Cow for Optimum Reproductive Performance

Dry cow management has become an important topic of research and discussion. Higher quality feeds, higher producing cows and the need to control metabolic diseases, reproductive disorders and mastitis have forced dairymen and researchers to pay more attention to the late lactation and dry cow.

The primary goals of dry cow management programs are: 1) the control of mastitis; 2) the provision of nutrients for a growing fetus; 3) the construction of a firm nutritional foundation that will promote and sustain high milk production, good health and high levels of reproductive efficiency during the following lactation; 4) evaluation of feet and legs; and 5) environmental management.

The first two goals are easily attained. Effective dry cow therapy is accepted as an essential part of any mastitis control program. Dry cow treatment coupled with teat dipping and good milking management minimizes mastitis incidence.

The nutrient requirements of the developing fetus are small in comparison to those of the lactating, high producing cow. They can easily be met using forages produced on today's dairy farms.

The third goal presents the challenge to dairymen, veterinarians and nutritionists. Research has demonstrated the need for proper calcium, phosphorus and selenium nutrition for dry cows in order to prevent postpartum metabolic diseases and reproductive problems, but there are still unanswered questions and controversy. More recently research and experience have shown a relationship between body condition (degree of fattening) of dry cows and production, postpartum health and reproductive efficiency. In order to maximize production and profit and minimize problems associated with managing the dry cow to prevent overconditioning the dry period should be limited to 40-70 days. Long calving intervals often dictate that the dry period be 90 days or more because a profitable level of production

cannot be maintained. Thus, reproductive efficiency is an important determinant of the length of the dry period. Most cows should be pregnant between 70 and 120 days after calving. Then, the farmer, not the cow, will determine dry period length. Calving intervals from 12-13 months for most cows will result in maximum productive efficiency and profit and prevent problems associated with overconditioning which readily occurs when dry periods are excessively long.

Feet should be trimmed during the dry period. Lastly, the environment of the dry cow should reduce stress and be conducive to recovery from lactation.

The Importance of Dry Cow Body Condition

For maximum milk production, good health and efficient reproduction, cows must be neither too fat nor too thin at calving. Adequate body reserves must be available for mobilization to sustain high levels of milk production during the early lactation period of negative energy balance when nutrient consumption cannot meet the demands of milk production. When nutrient reserves are not restored prior to calving, milk yield is reduced (1, 2).

In contrast, the cow must not be overconditioned at calving. Severely overconditioned, obese cows have more calving difficulties and metabolic disorders, especially milk fever, ketosis and downer cow syndrome (3, 4). They have an increased incidence of displaced abomasum (5), retained placenta and metritis (4). The immune response is impaired in fat cows (4, 6) making them more susceptible to disease. Mortality may be high due to poor response to therapy (4) and reproductive performance is poor (3, 4).

One of the consequences of severe overconditioning and (or) rapid weight loss after calving is fatty liver infiltration. Recently, it has been suggested that the severity and (or) duration of the fatty liver syndrome are associated with impaired reproductive performance (7). This concept is supported by other evidence (8) linking impaired liver function to reduced fertility in dairy cows.

Body Condition Scoring as a Method for Monitoring Body Condition

Recently, a body condition scoring system has been used to access body condition and to monitor changes therein during the lactation cycle (9, 10). This system does not rely on visual appraisal but is instead based on palpation to assess the amount of tissue covering the back and hind quarters. Particular attention is given to the chine, loin, rump, tail head, hook bone and pin bone regions.

In this system, cows are scored on a scale of 1-5. A score of 1 indicates severe underconditioning as might be seen in a cow that has recently suffered a D.A. A score of 5 is given to a severely overconditioned, obese cow; the classical candidate for fat cow syndrome problems. Cows in good milking condition will score in the 3 range. Cows should dry off in the high 3 to low 4 body condition score range. Limited data suggest scores of less than 3 will severely limit milk production while scores of 5 will result in fat cow problems.

Condition Score 1. Individual short ribs have limited flesh covering. Bones of the chine, loin and rump regions of the backbone are prominent. Hook and pin bones are sharp with almost no flesh covering, and there are deep depressions between hook and pin bones. The area below the tail head and between the pin bones is severely depressed causing the bone structure of the area to appear extremely sharp and the ligaments and vulva to be prominent.

Condition Score 2. Individual short ribs can be felt, but are not prominent. The ends of the ribs are sharp to touch, but have greater flesh covering. The short ribs do not have as distinct and overhanging shelf effect. The individual bones of the chine, loin, and rump regions of the backbone are not visually distinct, but are easily distinguished by touching them. Hook and pin bones are prominent, but the depression between them is less severe. The area below the tail head and between the pin bones is somewhat depressed, but the bone structure has some flesh covering.

Condition Score 3. Short ribs can be felt by applying slight pressure. Together, the short ribs appear smooth and the overhanging shelf effect is not noticeable. The backbone appears as a rounded ridge with firm pressure being necessary in order to feel individual bones. The hook and pin bones are rounded and smooth. The area between the pin bones and around the tail head appears smooth without signs of fat deposition.

Condition Score 4. The individual short ribs are distinguishable only by firm palpation. The short ribs appear flat or rounded with no overhanging shelf effect. The ridge formed by the backbone in the chine region is rounded and smooth. The loin and rump regions appear flat. The hooks are rounded and the span between the hooks is flat. The area around the tail head and the pin bones is rounded, with evidence of fat deposition.

Condition Score 5. The bone structure of the backbone, short ribs, hook and pin bone region is not apparent and subcutaneous fat deposits are very evident. The tail head appears buried in fatty tissue.

Target Body Condition for Each Stage of Lactation

1. Cows at calving: 3+ to 4–
   This allows cows to calve with adequate but not excessive body fat reserves.
2. Early lactation: 3– to 3+
   This maximizes intake of high-energy ration so that body condition changes and negative energy balance will be minimized.
3. Mid-lactation: 3
   Feed to maintain body condition in 3 range and maximize milk production.
4. Dry: 3 to 4–

Preventing Overconditioning in the Dry Cow

How much condition should the cow be carrying at the start of the dry period? Unfortunately, the optimum body condition for the dry cow has not been precisely defined. Obviously, she must have enough reserve to maintain production during the early lactation period of negative energy balance. But, condition must be limited to prevent health and reproduction problems associated with fat cows.

Data suggest that cows should gain 150-200# over their minimum postcalving body weight. However, body weight cannot be accurately monitored on most farms.

Nutrient requirements for a 1,300 pound cow in different physiological states are compared in table 1. Note that the requirements for the dry cow are 30 to 100% greater than for maintenance of a mature lactating cow. During the first 7 months of growth, the fetus has acquired approximately 40% of its birth weight. Thus, during the dry period added nutrients must be supplied to meet fetal growth requirements. Fetal demands for nutrients during the last 2 months of pregnancy are about equal to requirements of the mammary gland to produce about 10 lb of milk per day.

TABLE 1. Daily nutrient requirements of a 1300 lb. mature cow[1].

Nutrient	Physiological State		
	Maintenance[2]	Dry, Pregnant	30 lbs. milk[3]
Crude protein, lbs.	1.06	2.03	3.52
NE L, Mcal	9.57	12.44	18.87
Calcium, gm	20.9	36.3	56.3
Phosphorus, gm	16.8	25.9	41.3

[1]Adapted from reference 11.
[2]Mature lactating
[3]3.5% BF.

The requirements of the dry cow are only about 60% of those of the cow producing 30 lb of milk per day. This makes it very difficult, if not impossible, to adequately control feed intake and prevent overconditioning in dry cows that are not separated from the milking herd. Immediately upon drying off, cows in good condition should be removed from the milking herd where animals are housed in groups. In conventional barns feed intake should be restricted to prevent overconditioning. Some farmers with conventional barns have found it necessary to group dry cows within the barn or move them to another location during the dry period in order to develop a sound dry cow management program.

On farms where dry cows are fed in groups rather than individually, an accurate estimate of dry matter intake is needed if dry cow feeding programs designed to prevent overconsumption of nutrients are to be successfully developed. Research indicates that the dry cow will consume dry matter at a rate of between 1.3 and 2.1% of body weight daily (12, 13).

Control of energy intake is difficult. In one study (5), when complete feeds with 95:5 and 80:20 forage to concentrate ratios were fed ad libitum, dry cows consumed 118 and 130% of calculated energy requirements. Forage in these diets was supplied as 50% corn silage and 50% hay crop silage and dry matter intakes were about 2% of body weight.

These results indicate that feed intake must be restricted if overconsumption and overconditioning are to be avoided. Dry matter intake of high quality forage, especially corn silage, must be limited or forage energy must be diluted with low energy materials such as low quality hay. However, dry matter intake must **not** be limited to the extent that reduced gut fill makes the cow more susceptible to abomasal displacement. Many farmers are finding that a diet based on medium to low quality long hay fed free choice and balanced with concentrate to meet the protein and mineral needs of the cow makes an excellent dry cow feeding program.

Intakes of corn silage and concentrates must be severely restricted to prevent overconditioning and the resultant health and reproductive problems (14, 15). However, when properly balanced and fed to requirements, diets based on corn silage as a sole source of roughage can be successfully fed over several lactations (16, 17). In these studies, corn silage was fed throughout the lactation and dry periods if the latter did not exceed 8 weeks in length. By carefully balancing the ration to meet, but not exceed nutrient requirements and limiting corn silage intakes during long dry periods, overconditioning and its detrimental effects on health and reproduction were avoided.

What about cows that are overconditioned (score 4-5) or underconditioned (score 2) at the time of drying off? Obviously, it would be advisable to correct these situations prior to calving. However, it is difficult to manipulate body condition during the dry period by adjusting the intake of a silage based ration (18). The overfat cow loses weight very slowly in spite of severe restriction. The underconditioned cow is equally difficult to change without her becoming too fat. The addition of low quality long hay to the dry cow ration or the use of pasture in season may promote more rapid weight loss in overfat cows. But, it has recently been suggested that overconditioned cows should not be severely restricted to induce weight loss unless the dry period exceeds 90 days in length (19). It is thought that the added stress of a "crash diet" might cause more problems. In one study, preliminary results indicate no detrimental effects of energy restriction and weight loss during a 6-9 week dry period (18).

Protein, Mineral and Vitamin Nutrition in Dry Cows

Protein Nutrition:

Research conducted at the Ohio State University (20) suggests that excess protein intake during the dry period resulted in abortions and postpartum health problems (retained placenta, milk fever, DA) that may secondarily reduce reproductive efficiency in cows fed high protein diets (15%) compared to those fed low protein (8%) diets. Cows fed excess protein and energy during the dry period had more metritis, more cystic follicles and delayed return to

estrus after calving.

Additional studies confirming or denying these results have not been reported. However, the results do suggest that elevated consumption of protein as well as energy should be avoided during the dry period. The question is academic in the practical sense since overconsumption of protein is usually not an economically sound practice.

Recommendation:

Dry cows should be fed a **good quality,** grass hay or grass hay crop silage and balance so that the protein in the diet is between 10-12%.

Mineral Nutrition

Calcium Phosphorus:

The major concern in the mineral feeding of dry cows relates to the provision of optimum levels of calcium and phosphorus in order to limit the occurrence of milk fever. Since retained placenta and subsequent uterine infections often follow milk fever, this is an important consideration in maximizing reproductive efficiency.

Debate continues regarding the optimum calcium to phosphorus ratio in dry cow diets. Numerous studies have been conducted using widely varying ratios (2) but no one ratio was clearly superior. While calcium to phosphorus ratio is important, the actual quantities of each mineral fed are at least equally important.

Hutjens (22) surveyed 4 feed companies and 8 colleges regarding calcium and phosphorus feeding during the dry period. There was considerable variation, probably due to the lack of clear-cut research results, but in general, recommendations were to *limit calcium intake to less than 100 grams per day and feed phosphorus at the rate of 30-50 grams per day.* These guidelines provide a *calcium to phosphorus ratio ranging from approximately 1.5:1 to 2.5:1* and can generally be met by feeding medium quality hay and/or corn silage rations with proper mineral supplementation. Large amounts of high quality legume forages should be avoided due to their high calcium content.

Selenium:

Selenium deficiency in dry cows has been reported to cause retained placenta. Incidence was lowered from 50% to 10% when selenium deficient cows with low blood selenium levels (2.4 μg/100 ml or less) received supplemental selenium (50 mg) and Vitamin E (680 IU) at 20 days prior to calving (23, 24). Similar results were obtained by increasing selenium intake to 1 mg/day (25). Similar results were observed in a Michigan study (26) but selenium-Vitamin E injection did not reduce the incidence of retained placenta in Maryland (27), Virginia (28) or New York (29) studies.

It was concluded from these studies that retained placenta could be reduced by selenium supplementation when, and only when, the condition was an expression of selenium deficiency and not related to infections, twinning, milk fever or some of the other factors known to increase the incidence of retained placenta.

Vitamin A:

A deficiency of vitamin A has been reported to result in an increased incidence of retained placenta, shortened gestation periods, abortion and the birth of dead or weak calves (30, 31). However, one study using 957 cows in 9 herds demonstrated that supplementation of vitamins A (2,500,000 USP Units), D (500,000 USP Units) and E (250 IU) by dry period injection gave no significant reduction in the incidence of milk fever, retained placenta, metritis or other postpartum health disorders compared to saline treated controls (32). Treatment also did not improve reproductive performance. This study demonstrates that most herds will have adequate levels of these vitamins to prevent major postpartum health and reproductive problems.

Vitamins A and D should be supplemented in the dry cow ration at the rate of 50,000 units and 10,000 units per day, respectively. Proper vitamin and mineral balance must be provided in dry cow diets where diets are restricted or low quality forage is fed to control or reduce body condition. To ensure adequate intake they should be fed in small amounts of low energy concentrates or mixed in a complete dry cow ration. Dry cows fed only poor quality hay for extended periods of time without supplementation may benefit from vitamin A injections.

Prepartum Concentrate Feeding

Research indicates that milk production does not increase when liberal amounts of concentrates are fed during the dry period. The amount of grain required to maximize production during the subsequent lactation will be determined by the body condition of the cow at drying off and the quality of the forages being fed. On most farms, forages can provide adequate energy and protein through most of the dry period, *but, a small amount of low energy feed may be recommended as a carrier for vitamins and minerals.* However, it is recommended that grain be introduced during the two weeks before expected parturition to prepare the digestive system for the concentrate diets fed during early lactation. Gradually increasing grain intake to 0.5 to 1.0 pound per 100 pounds of body weight will be adequate.

Management and Nutrition of the Lactating Cow for Optimum Reproductive Performance

Energy Intake

It is well known that many high producing cows are in negative energy balance during early lactation because they cannot consume enough feed to meet the nutrient requirements of high levels of milk production. Tissue energy stores are mobilized and weight losses occur during the several

weeks preceding and somtimes including the period during which the cow should be inseminated and become pregnant. Factors associated with this negative energy balance, weight loss, and their associated stresses have been suggested as cause of reproductive failure.

In support of this, lower breeding efficiency and poor reproductive performance have been associated with weight loss in dairy cows. A recent study, of high producing cows (75# milk/day) demonstrates the importance of minimizing the stress of negative energy balance in early lactation. The results indicate that the resumption of postpartum reproductive cycles is dependent upon the average negative energy balance during the first three weeks of lactation; the greater the average negative energy balance, the longer the interval from calving to first ovulation.

For top reproductive performance the interval to first postpartum ovulation must be minimized. Shorter intervals increase the number of estrous cycles prior to breeding. Florida research suggests that cows that have more estrous cycles prior to breeding require fewer services per pregnancy and have shorter calving intervals (33).

Conception rates in dairy cows gaining weight at time of service are higher than in those losing weight. Conception rate was 67% in cows that were gaining weight during the month of conception but only 44% in cows that lost weight during this period. Services per conception for the two groups were 1.5 and 2.3, respectively (34).

These data and others associating negative energy balance, low energy intake, low blood glucose and anemia with impaired reproduction emphasize the importance of feeding a balanced, highly palpatable ration during the early lactation period. Ration formulation should be based on complete forage and concentrate analysis. Maximal intakes must be maintained in order to minimize the detrimental effect of prolonged, severe negative energy balance on reproductive performance.

It has been suggested that energy intake and body condition are the most important nutritional determinants of reproductive efficiency on most farms. In summary, inadequate energy intake and poor body condition have been associated with the following conditions:

1. Delayed onset of puberty.
2. Diminished intensity of estrus and more silent heats.
3. Anestrus—heifers on diets composed mainly of poor quality hay will not show signs of heat during late winter. If grain or adequate pasture is provided they will resume normal estrous activity.
4. Prolonged interval from calving to conception.
5. Delayed return to estrus and ovulatory activity (follicle growth and ovulation) after calving.
6. Decreased conception rate—reduced number and size of follicles and poor fertilization of ova.

The problem on many farms is that the amount of feed consumed is often over-estimated. The result can be an energy deficiency. Accurate feed intakes and forage analysis are required to develop feeding programs that provide adequate energy for the high producing dairy cow.

Protein:

There is evidence that prolonged, inadequate protein intake reduces reproductive performance, but short-term deficiencies can be met using protein reserves in the cow's body. Blood serum from cows fed adequate amounts of protein contains 3.0-3.5 g albumin, 4-5 g globulin and 10-20 mg urea nitrogen/100 ml. Both urea N and albumin decline markedly during periods of prolonged protein deficiency. One study (36) using 350 lactating cows demonstrated that services per conception were greatest in cows with low albumin levels and high globulin levels. As albumin levels rose and globulin levels declined, fewer services were required. Low blood albumin levels and poor reproductive performance have been observed in cows with severe fatty liver condition (37).

The NRC publication (11) indicates that excess protein intake is not harmful to the cow. However, recent work suggests that feeding 10-30% excess protein may impair reproductive performance. In a field study (38), it was observed that cows receiving excess protein required more services/conception. In controlled experiments (39), it was reported that dairy cows fed complete, silage-based rations and protein at levels that exceeded requirements by 10-15% were observed in heat sooner, but required more services per conception and had longer intervals to conception than cows fed 90% of their protein requirement.

However, these results could not be repeated in a Cornell study where first calf heifers consumed protein at levels that were 15-20% in excess of requirements (18). Excess protein may cause reproductive problems in some situations but the relationship remains to be clarified. Regardless of a possible effect on reproductive performance, over-feeding protein should be discouraged simply because it is costly and wasteful.

One of the possible reasons for high protein feeding causing infertility is the high rumen ammonia (and thus stress) from soluble nitrogen results. Since urea is 100% soluble, it is reasonable to assume that there might be stress and reproductive problems related to its utilization. Most of the urea research (40) does not indicate this to be a problem. However, in an extensive long term study with first and second lactation cows, it was determined that feeding urea at levels exceeding 0.5 pounds per day might result in increased reproductive problems such as retained placentas and abortions. No differences were found in ovarian function or services per conception. The bottom line seems to be that feeding urea at recommended levels does not cause reproductive problems in most situations.

Diets based mainly or entirely on fermented forages (silage) also can provide large amounts of soluble nitrogen and may result in high ammonia loads and stress that might affect reproduction. When concentrates with high protein solubility are used in these rations or anhydrous ammonia is

added at ensiling the situation may be made worse. This idea has not been tested but perhaps should be considered in some problem herds.

Another factor that needs to be investigated is the amount of degradable protein in the ration. It is possible to formulate a ration using alfalfa, hay crop silage, high moisture corn and soybean meal that not only has too much soluble protein, but also an insoluble protein that is rapidly degradable. This can cause both an excess of ammonia and a protein deficiency if the ration has been balanced to meet protein requirements.

Minerals

Phosphorus

Phosphorus is the mineral that has been most commonly associated with reproductive disorders in dairy cows. Inactive ovaries (anestrus), delayed sexual maturity and low conception rates have been associated with low phosphorus intakes. Mineral supplements should be provided to ensure adequate phosphorus intakes.

A recent study indicates that the NRC recommendations (0.3%) are adequate to maintain growth and reproductive function in heifers (41). In one experiment increasing phosphorus supplementation from .4 to .6% of the ration had no effect on days to first estrus or services per conception (42). In a field study where heifers received only 70-80% of their phosphorus requirements and serum phosphorus levels were 3.9 mg/100 ml, phosphorus supplementation reduced services per conception from 3.7 to 1.3 (43).

In contrast, Michigan workers reported that reproductive performance in lactating cows was not affected when phosphorus levels were either 85% or 135% of NRC recommendations (44). An interesting finding was that cows fed excess phosphorus produced less milk. For top performance phosphorus supplementation should meet, but not exceed requirements.

The relationship between nutrition, fertility, and blood composition was studied in 400 cows from commercial farms (45). Higher levels of concentrates were related negatively to overall conception rate, and a higher proportion of dietary roughage was positively related to conception rate. Lower levels of inorganic phosphate was found in the blood of cows with low fertility and these cows contained higher levels of lipids.

Calcium

Most experimental work relating calcium to reproduction has centered on the effect of the calcium-phosphorus ratios. Controlled experiments demonstrated no effect of altered Ca:P ratios on reproduction in heifers or lactating cows (46). Calcium-phosphorus ratios between 1.5:1 and 2.5:1 should not result in problems. Remember that the **amount** of calcium and phosphorus consumed is probably more important than the ratio. The ratio can be fine but cows can be consuming excess of deficient amounts.

Calcium levels in lactating cow diets have been increased 25% over NRC values due to lower absorptive efficiency. NRC uses a value of 45% availability while new research suggests 36 to 37% availability. Practical ways to adjust for this difference is to increase requirements by 20-25% or reduce the level of forage calcium by 40%. *Calcium in the lactating ration should be approximately 0.8%. Phosphorus should be fed at a level of 0.45%.*

Selenium

The soils in parts of Virginia are deficient in selenium. Therefore, crops grown here are also low in selenium. As dairy farmers have begun to rely more on home grown grains and forages and less on purchased feeds, the need for selenium supplementation has been recognized.

Adequate selenium is required for good health and reproduction. In one study, fertilization rate of eggs collected from selenium deficient beef cows was low. Supplementation with selenium and Vitamin E increased plasma selenium level from 3.6 to 6.7 mg/100 ml and improved fertilization rate (47). The incidence of retained placenta is increased in selenium deficient animals and selenium deficiency has been related to sporatic abortions, a high incidence of embryonic-fetal loss, poor fertility, increased incidence of metritis and mastitis and a higher level of general infection in some problem herds. Blood selenium levels in these herds have generally been 5 μg/100 ml or lower. The exact role of selenium and its importance in causing these problems in dairy cattle has **not** been determined.

Nevertheless, based on the information that is currently available selenium supplementation seems advisable. *Diets should contain at least 0.1-0.2 ppm selenium on a dry matter basis.* In some herds higher levels may be required to maintain blood levels above 8-10 μg/100 ml (note that the blood level above which problems are not encountered is not precisely known). Alternatively, feed sources may be supplemented with selenium injections. When levels are extremely low injections are often required to rapidly return levels to normal.

Selenium is a toxic substance. Excessive supplementation must be avoided. Therefore, supplementation by feeding levels higher than 0.2 ppm or by injection in addition to feed supplementation should be based on blood analysis to determine the selenium status of the herd.

Iodine

Iodine influences reproduction via its action on the thyroid gland. Iodine deficiency impairs reproduction and iodine supplementation has been recommended. Low thyroid function reduces conception rate and ovarian activity (48). *The cows should consume 15-20 mg of Iodine per day.*

More recently, the effects of excessive iodine intakes have been recognized. Actually, today it appears that iodine

toxicity may be a more important problem than iodine deficiency. The problem is most often associated with feeding several mineral mixes each of which contain EDDI for the prevention of foot rot. Excessive iodine intakes have been associated with various health problems including abortion and decreased resistance to infection and disease (49).

EDDI has never been adequately proven to prevent foot rot and its feeding for this purpose should be discontinued. Iodine levels in the diet should be maintained at *less than 50 mg/day.*

Potassium

Limited research suggests that feeding high levels of potassium may delay the onset of puberty, delay ovulation, impair CL development and increase the incidence of anestrus in heifers (50). In this study the ration contained approximately 5% potassium on a dry matter basis. It was fed for one year. Other studies report lower fertility in cows fed high levels of potassium or diets in which the potassium-sodium ratio was too wide.

Other Minerals

Copper and manganese deficiencies have been associated with impaired ovarian function, silent heats and abortions (11). Fluoride toxicity lowers fertility (51).

Vitamins

The vitamin requirements of dairy cows are met by a combination of rumen and tissue synthesis, natural feeds and feed supplementation. Most commercial concentrates contain supplemental vitamins so the probability of infertility due to a vitamin deficiency is greatly reduced.

Vitamin A

Vitamin A is required for maintaining healthy tissue in the reproductive tract. In deficient cattle, delayed sexual maturity, abortion or the birth of dead or weak calves, retained placenta and metritis have been reported. *The recommended daily supplementation for dairy cows is 30-50,000 units.* In herds feeding commercial concentrate mixes, these levels are usually provided. Excessive vitamin A supplementation should be avoided as the normal metabolism of the vitamin A precursor, B-carotene, may be impaired.

Vitamin D

This vitamin is required for normal calcium and phosphorus metabolism. However, deficiencies are seldom encountered in commercial herds. Cows receiving a normal amount of natural light manufacture their own vitamin D. *Most commercial concentrates contain supplemental vitamin D in amounts sufficient to meet the cows requirement of 10,000 IU per day.*

Vitamin E

To date there is no documented evidence that vitamin E deficiency is a significant cause of reproductive failure in dairy herds. Moreover, the vitamin E requirement of milking cows is not known with certainty. In one experiment, cows were fed low vitamin E rations for 4 generations. There were no measurable effects on reproduction (52).

Interest in vitamin E has increased recently with the observation that selenium may be important in health and reproduction in dairy cows because actions of vitamin E and selenium are closely related. The thought is that marginal or deficient selenium status may increase the requirement for vitamin E supplements at currently recommended levels in the feed, make sure selenium status is adequate and search elsewhere for solutions to infertility problems.

B-Carotene

B-carotene is the substance found in many plants that the cows converts to vitamin A. It is known to be in high concentrations in fresh green roughages while grains contain relatively low amounts (18). Silages, especially alfalfa, contain moderate levels while corn silage is a poor source. Dry hay, especially alfalfa, is an excellent source of carotene. Despite high levels at harvest, B-carotene levels decrease during storage, with the extent of destruction being dependent on storage condition.

The interest in B-carotene stems from research done in Germany (18) suggesting that dairy cows and heifers consuming diets low in B-carotene suffered reproductive problems: 1) delayed uterine involution; 2) delayed first estrus after calving; 3) delayed ovulation; 4) increased incidence of cystic ovaries; and 5) more early embryonic death and abortion.

B-carotene supplementation (300 mg/kg body weight) reportedly restored reproductive function to normal, but vitamin A was not effective. It is interesting to note that control animals in some of these studies actually received excessive amounts of vitamin A.

In a later study Israeli researchers attempted to repeat the German results (18). They were not successful. In their experiment, dairy heifers showed no differences in duration of standing estrus, length of the estrous cycle, hormone (LH and progesterone) concentrations, and the interval between LH peak and ovulation when deficient animals were compared to supplemented heifers.

Limited field studies using small numbers of animals tend to support the German results. But, the B-carotene status of cows in commercial herds has not been adequately determined and the effects of supplementation have not been adequately documented under field conditions in this country.

Until more information is available it can only be recommended that B-carotene supplementation be considered in well fed herds when all other possible causes of reproductive problems have been eliminated. At current

prices ($.20-$.30/day) and *recommendations (300 mg/day until conception occurs)* costs will be $20-$30/cow. Hopefully, experiments currently being conducted will provide the basis for better recommendations in the future.

Summary

It is clear that nutrition is closely related to reproduction in the dairy cow. Nutrient deficiencies, excesses or imbalances have all been shown to be capable of altering reproduction. The basic problem is that the degree of the excess, deficiency or imbalance which is required to alter reproduction is unclear. Research studies with high producing dairy cows are needed to help clarify the roles of individual nutrients and their interactions on reproductive performance.

The best recommendation at present is to provide a feeding program for dairy cows which is balanced and meets all known nutrient requirements. The NRC publication (19) can be used as the base for designing the program in conjunction with forage and feed analysis information. Avoid the temptation to think that if a little bit is good, twice as much must be better. The effects of excessive intakes of vitamins, minerals and protein are not well understood and may be detrimental to good health and reproduction. Reputable, knowledgeable nutrition consultants should be consulted regularly; not just when a problem is suspected.

This approach must be used on a long term, continuing basis in the herd if it is to be successful. The same approach must also be used for dry cows since some of the reproductive problems related to nutrition may develop over a long period of time.

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