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Factors Affecting the Calcium, Phosphorus and Magnesium Status of Dairy Cattle.

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Calcium, phosphorus and magnesium are three minerals used in relatively large amounts by dairy cattle. They are also the three minerals most often supplied in supplemental form to the concentrate portion of a cows ration, and they are most often associated with some common problems of dairy cattle including milk fever, infertility, and "downess syndrome." They are also associated with other physiological processes that can affect milk production and the general health of the cow.

Recently, I completed a survey of dairy cows on the northern Oregon Coast to determine the status of several minerals including calcium, phosphorus and magnesium. What I would like to do this morning is to show you the variation that I observed and discuss with you some of the factors associated with this variation.

The survey involved the bleeding of 126 cows in 21 herds in the fall of 1974, at the end of the pasture season, and again the following spring as the cows were turned onto pasture. An attempt was made to bleed cows in early, mid, and late stages of lactation at the time of the fall bleeding in order to observe any effect stage of lactation may have upon the mineral status of these cows.

Let's look at the information on calcium first. From table 1, we can see that the average plasma calcium values are lower in the spring than the previous fall, and that the difference is greater for cows in herds fed silage as the main form of roughage during the winter. All values are within the normal range for plasma calcium, 9 to 12 mg %, except the spring value for cows fed mainly silage. The average calcium value for all cows in the spring was 1.1 mg % lower than in the fall, and reflects the fact that 38% of the cows bled in the spring had plasma calcium values below 9 mg % compared to only 6% in the fall. Alfalfa hay contains more calcium than most feedstuff eaten by dairy cattle. Therefore, it is surprising to find the calcium status of these cows to be lower in the spring than in the fall since all of the cows in this survey received some alfalfa hay during the winter. Cattle regulate their blood calcium level within a rather narrow limit by varying the rate of absorption from the gut, the rate of excretion through the kidneys, and by the rate of mobilization or deposition of calcium salts of their bones. When a significant change occurs, it is brought about by conditions which have existed for weeks, or perhaps even months. Low blood calcium has been observed in cattle fed excess as well as inadequate amounts of calcium. Also, cattle fed an excess as well as an inadequate amount of phosphorus will have lowered plasma calcium. Since excesses or inadequate amounts of calcium and phophorus affect the utilization of both minerals, we are confronted with the problem not only of supplying both inadequate amounts but also of supplying them in a proper balance. It is suggested that high producing cows should be fed a total ration containing 0.7 to 1.0% calcium and 0.5% phosphorus; giving a calcium to phosphorus ratio of 1.4:1 to 2:1.

Because phosphorus is involved in any interpretation of the calcium data, let's take a look at the phosphorus status of these same herds. In table 2, we see that the average plasma phosphorus values in the spring are lower than in the fall, and that the average value from cows fed silage as the main source of roughage is lower in the spring than that of cows fed alfalfa hay only. The relationship is the same as for the calcium values. Although all these average values are within the normal range for plasma phosphorus (4-8 mg %), the average difference of 1.08 mg % reflect the fact that 18% of the cows had plasma phosphorus values below 4 mg % in the spring compared to 5% in the fall. Apparently a sizable proportion of the cows are in a negative balance for both calcium and phosphorus during the winter months.

Dairymen identify a concentrate mixture by its crude protein content, and because of this feed mills make up and promote their concentrate on the protein basis. The mineral composition of these concentrates are generally maintained at a level which are judged suitable for the average herd maintained under typical conditions. But, like a suit tailored to fit the average size man, it exactly fits the need of only a few. Table 3, illustrates the difficulty involved here. If a concentrate mixture is balanced to meet the needs of a herd fed alfalfa hay as the only roughage, as in example A, it is inadequate for a herd fed silage as a major source of roughage. The reverse is also true, as in example B. When either concentrate is used with the wrong forage feeding program, poor utilization of both calcium and phosphorus will result. The ultimate consequence could be a higher incidence of milk fever and lower fertility.

A discussion of the role of calcium and phosphorus in the diet of dairy cattle is incomplete without including a third ingredient: vitamine D.

Vitamine D is involved in the absorption of calcium from the gut and in its storage and movement within the body. The vitamine D status of the cattle in this survey is not known, nor do we have a very good idea of how much of this vitamine is needed by adult dairy cattle. A natural source of vitamine D results from the action of sunlight upon the sterol compounds found in the skin of animals. In fact, dairy cattle seem to be adequately supplied by this means in summer if they are out on pasture. However, a very real possibility of vitamine D deficiency may exist when they are confined, especially in winter in areas with long and frequent periods of cloudiness. The relationship between calcium, phosphorus and vitamine D is illustrated in table 4. When phosphorus is in balance with calcium, adding vitamine D to the ration increases the rate of storage of both calcium and phosphorus in the cow. When phosphorus is inadequate, the addition of vitamine D reduces both calcium and phosphorus storage.

Another factor associated with the change in calcium status of the dairy cattle in this study was stage of lactation. The bottom part of table 1 shows the average plasma calcium for cows in early, mid, and late lactation. Obviously cows in early lactation have greater demand for calcium due to their higher milk production. It is also possible that the hormonal balance of these cows may have an effect for the majority of these cows are still open.

A third mineral of concern to dairymen in the northwest is magnesium. In table 5 we see that, like in the case of calcium and phosphorus, the plasma values in spring are less than in the fall, but, in contrast to that of calcium and phosphorus, the greater difference was in those cows fed alfalfa hay as the only roughage. It is of interest to note that although these values are within the normal range for cattle (1.8 - 3.2 mg %), they are below that of studies conducted elsewhere: Minnesota, 2.13 mg %; England, 2.58; Sweden, 2.2. Over 25% of the cows were below the value of 1.8 mg % both in the fall and spring. It has been shown experimentally that diets high in calcium depress plasma magnesium. This is a possible explanation for the lower spring magnesium values of cows fed alfalfa hay only.

It has been demonstrated that dairy cattle on the coast of Oregon need magnesium added to their diets. Table 6, shows the effect upon plasma magnesium values of supplementing the ration of a dairy herd with 0.8 lb. of magnesium per ton of concentrate. These cows were given an average of 2 1/4 tons of concentrate per year. In just over one years time, the magnesium status of this herd changed from very deficient, where some cows had died of hypomagnesia tetni, to normal.

Balancing a ration for minerals is a more complicated job than balancing a ration for crude protein or energy for two reasons. As discussed above, an excess of a mineral as well as an inadequate amount of a mineral can have a marked effect upon the availability of other minerals. Also, the mineral composition of feeds vary much more widely than does crude protein or energy.

Table 1. Variation in Plasma Calcium of Cows in Herds on the Oregon Coast

Herds fed:	No. Herds	Fall	Spring	Diff.
		mg %		
Alfalfa hay only	8	10.3	9.4	-0.9
Silage mainly and some alfalfa	13	10.0	8.8	-1.2
All herds	21	10.1	9.0	1.1

Avg. for cows milking:	mg %
<100 days	9.4
100 to 200 days	9.7
>200 days and dry	9.8

Table 2. Variation in Plasma Phosphorus in Herds on the Coast

Herds fed:	No. Herds	Fall	Spring	Diff.
		mg %		
Alfalfa hay only	8	6.25	5.25	1.0
Silage mainly and some alfalfa	13	5.78	4.65	1.13
All herds	21	5.96	4.88	1.08

Table 3. The Change in Calcium and Phosphorus Content of a Ration When One Concentrate Mixture is Used with Different Forages

Needed for 1350 lb. cow milking 70 lbs./day		Calcium-105g.	Phosphorus-78g.
Example A:			
Alfalfa hay	30 lbs.	153g.	28g.
Concentrate	20 lbs.	10g.	61g.
		163g. (+55%)	89g. (+14%)
		ratio = 1.8:1	
Grass silage	70 lbs.	24g.	30g.
Alfalfa hay	10 lbs.	51g.	9g.
Concentrate	20 lbs.	10g.	61g.
		85g. (-23%)	100g. (+28)
		ratio = 0.85:1	
Example B:			
Alfalfa hay	30 lbs.	153g.	28g.
Concentrate	20 lbs.	30g.	39g.
		183g. (+74%)	67g. (-14%)
		ratio = 2.7:1	
Grass silage	70 lbs.	24g.	30g.
Alfalfa hay	10 lbs.	51g.	9g.
Concentrate	20 lbs.	30g.	39g.
		105g.	78g.
		ratio = 1.4:1	

Table 4. Relation of Phosphorus Balance to Calcium and the Response to Vitamine D Feeding*

	Phosphorus (+)		Phosphorus (-)	
	No Vit. D	Fed Vit. D	No Vit. D	Fed Vit. D
Phosphorus balance (g/day)	5.7	7.6	2.8	-3.7
Calcium balance (g/day)	21.6	32.2	15.5	5.9
Calcium absorbed (%)	31.0	38.0	23.0	17.0

*from Hibbs and Conrad. 1966. J. Dairy Sci. 49:243

Table 5. Variation in Plasma Magnesium of Cows in Herds on the Oregon Coast

Herds fed:	No. Herds	Fall	Spring	Diff.
		mg %		
Alfalfa hay only	8	2.12	1.88	-0.24
Silage mainly and some hay	13	1.89	1.84	-0.05
All herds	21	1.98	1.85	-0.13

Table 6. Effect of Supplemental Magnesium at the Rate of 1.8 lbs. Per Head Per Year Upon Plasma Magnesium Level of Dairy Cows

Cow Number	Before Supplement	13 mos. after Supplement
41	1.9	1.9
110	1.0	1.9
141	1.7	2.1
145	1.9	2.3
146	1.3	1.5
147	1.1	2.1
154	1.6	2.2
157	0.9	2.4
160	1.4	2.2
Avg.	1.42	2.07

Management and Dairy Cattle Fertility

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Lower breeding efficiency is one of the most serious and frustrating problems confronting dairy management--serious because of economic losses, frustrating because the problems are well concealed and difficult to correct. Gross income suffers because of reduced milk production and fewer calves; greater replacement costs, veterinary services, and insemination fees increase production costs. Consequently, net income shrinks substantially. Breeding problems cost California milk producers approximately $59 per cow in 1974. That year is used as a reference period because a rather comprehensive study in Virginia[5] that year estimated the cost of low fertility to be $59.22. Apparently their higher milk prices were offset by lower milk production as compared to our data.

The basic factors responsible for this costly problem were quite clearly identified in a California study[7] completed a few years ago--low conception and delayed first service. The average conception rate on first service for almost 13,000 gestations was 44.6 percent. Almost one-third of these cows received their first service later than 90 days after calving. Heat detection failure was clearly identified as the predominant reason for this delay in first service. The combined effect of heat detection failure and low conception rate is long lactations or dry periods (or both) with reduced milk production and fewer calves the ultimate consequences. More than one-third of the cows were open longer than 120 days after calving, one-eighth were open longer than 180 days. Perhaps of even greater consequence, 7.7 percent of the cows were sold because they remained open 150 days or more; these are the cows that boost replacement costs.

The importance of culling low-producing cows to maintain or improve the herd average is widely recognized. This culling potential is greatly reduced in herds with breeding problems because of the greater number of cows that must be sold due to breeding failures and because fewer replacements are born. Breeding problems tend to discourage the use of bulls with a high predicted difference that demand a premium, particularly for repeat services.

Hopefully, this brief review of pertinent data will provide an adequate springboard for the remainder of this discussion.

Influence of Herd Size on Breeding Efficiency

Several studies have shown that breeding efficiency is lower in lar herds than in small herds. In a Cornell University study,[8] herds with less than 50 cows exceeded herds with 90 cows or more by 4.7, 5.8, and 10.7 percentage units in conception rate on first, second, and third service. A New Zealand study[6] provides a more detailed herd size breakdown.

Table 1. EFFECT OF HERD SIZE ON NONRETURN RATE

Herd Size (cows)	% of Herds	% Nonreturn Rate (49 days)
20-50	112	63.9
51-100	622	62.7
101-150	343	60.2
151-200	90	57.4
201-250	27	57.4
251-822	10	52.3

The California study scarcely suggested a herd size influence but it must be recognized that all but two of our herds were in the large herd category on the standards of published studies encountered. So what does this tell us? Large herd managers must concentrate on their breeding programs more than small herd owners if they expect to achieve average breeding efficiency.

The daily routine in one of our dairy herds of over 2000 cows demonstrates the type of concentration being given the breeding program in more and more of our large dairy herds. The cows are locked in their stanchions at the hay manger following the morning milking and each cow is closely observed. One man rides an electric cart down the feed alley. A card file on this cart has each cow's complete breeding history. This "record man" calls off such information as calving date, last heat period, last service date, treatment, etc. The "technician" walks behind the rear of the stanchioned cows and reconciles the data with status of the cow. If the cow is in heat and it is time to breed her, she is inseminated. If she needs treatment, she is treated. If she has not exhibited symptoms of heat within a logical period, she is palpated. What needs to be done is done; the records and cows are market accordingly. This procedure is reviewed only to show the degree of concentration that can be given the breeding program. It is not being recommended that everyone go the complete route.

Heat Detection Accuracy

What possibly could be the reason why large herds are at a disadvantage in nonreturn and conception rate? It is not likely to be a matter of semen quality, is it? And a cow is a cow regardless of herd size. Missed heat periods will lengthen calving interval but can't possibly affect conception rate because no insemination takes place if the cow is not detected in heat. So, by the process of elimination, heat detection accuracy becomes a strong suspect. The New Zealand work[6] strongly suggests that errors in heat detection were responsible for many estrous cycles of less than 18 days which were more prevalent in large herds.

Table 2. ARTIFICIAL INSEMINATION VERSUS NATURAL SERVICE

Item	A.I.	Natural
Herds	9	9
Bulls	376	57
1st services	4,528	403
Conception, 1st service	2,136	253
Conception, 1st service (%)	47.2	62.8
Services	8,468	1,527
Conceptions	3,643	777
Services per conception	2.32	1.97

Inaccurate heat detection may explain in part why natural service in our California study had such a distinct advantage in conception rate on first service (62.8%) compared to artificial insemination (47.2%).

Clemson University[4] reported similar results in 1974. The pregnancy rate for A.I.was 54.0 percent in contrast to 68.7 percent for natural service (based on fertile service periods). With A.I. a cow erroneously diagnosed in heat is added to the line-up for service, and it is not likely that she will conceive. In contrast, if the same cow is presented for natural service, she and the bull are allowed to make the final judgment whether the time is now. Heat detection accuracy may also explain why Foote[2] reported that cows marked by marker bulls appeared to conceive at a higher rate following insemination (64% pregnant) than those only observed by the dairyman (45% pregnant).

Unfortunately, we have no direct evidence indicating the frequency of inaccurate heat detection and its influence on conception rate, but the circumstantial evidence facing us demands attention.

How Do Inaccuracies in Heat Detection Occur?

Some problems leading to inaccurate heat detection became evident while field testing a heat detector developed by the New Zealand Dairy Board. The Dairy Board's A.I. and Herd Recording organizations were very much concerned with identification errors--just as our A.I. and DHIA groups. If identification errors are prevalent in New Zealand herds of 75 to 125 cows managed and milked by the owner, isn't it likely that our identification errors are at least as great with large herds involving primarily hired labor?

It is difficult to understand why identification errors are still prevalent in spite of the emphasis on this problem until the factors involved are recognized--fuzzy number brands, worn neck chain tags, smeared or dirty number tags, light reflection, distance, angle of observation, etc. Simple transposition of digits in reading or transcribing of numbers is another source of error. Identification errors can be reduced with easily read tags or number brands and deliberate verification--proof reading, if you wish. Verification is effective and cheap. To err is human--but do we have to be quite that human?

Standing Heat is a Source of Error

Standing heat is the most widely accepted identification of estrus. Many consider standing heat to be adequate proof that the cow is in heat--but it is not. It is not uncommon for cows approaching estrus to allow themselves to be mounted.

Table 3. FALSE HEATS

Percent of Detectors	Percent False Heats
16	5
6	2

In New Zealand heat detection trials, 16 percent of the detectors were activated on cows not observed being mounted. However, about a third of these cows were probably not in heat at the time their detector was activated because they were observed in standing heat from one to three days later. Six percent of the cows were observed being mounted before the detectors were activated but about a third of these cows had activated detectors within a few days. From this circumstantial evidence one might conclude that 5 to 7 percent of the cows will allow themselves to be mounted at least once before they are truly in heat; Baker's data[1] indicate 5.5 percent.

That some cows allow themselves to be mounted before they are truly in heat increases their chances of being bred too soon if artificial insemination is used. The herd's conception rate will suffer accordingly. But--if a cow inseminated today is noted in heat again (or still) within a few days of the first service during the heat period, why not breed her again? This will not improve the percent conception on first service but it may shorten some calving intervals. Some of our dairymen have been doing this routinely; the evidence available would tend to support this practice.

Before a cow is determined to be in standing heat, it is important to note accurately whether the cow being mounted stands voluntarily or tries to escape. Furthermore, escape in heavy traffic--a crowded holding pen, for example--is not always possible. Many dairymen cut their "hot cows" out after milking. Isn't it possible and probable that some of the cows who decided it was easier to stand than to buck the heavy traffic ahead of them are being turned into the holding pens for service?

Standing heat means just that; being mounted on the run, or when escape is impossible, does not constitute standing heat.

Heat Detection Aids

Heat Mount Detectors

Many dairymen have reported that heat mount detectors are quite helpful. One such device, when properly placed on the rump of a cow, becomes activated and turns red upon impact when a cow in heat is mounted by other cows. Hence, the cow in heat is easily detected. This device has been tested by several institutions and found to be a good heat detection aid. One of the most favorable trials was reported by the University of Melbourne, Australia.[9] Herdsmen were able to correctly identify 90 percent of the cows in heat with the aid of this detector in contrast to only 56 percent of the cows in heat that were not fitted with detectors.

The primary disadvantage of these heat detectors is cost and labor. Some detectors will be activated prematurely because some cows allow themselves to be mounted--by choice or by force--before they are actually in heat. A few are likely to be triggered accidentally and some drop off. Clipping the hair at the sight of installation does not reduce this drop-off as one might think; it is more likely to increase the drop-off rate. Detectors are less likely to drop off if the cow's hair is dry when the detectors are put on. The usefulness of the detector can be improved with supplemental marking--with a crayon or a colored tail band, for example. A cow so marked without a detector can be observed closely for other symptoms of heat because many detectors lost are knocked off during estrus by the mounting cows.

Marking Crayon

A streak of marking crayon over the tail head provides a good and inexpensive heat detector. When a cow so marked is in heat and is mounted by others the crayon streak is smeared, sometimes nearly rubbed off, by the mounting cows. Cows with these crayon streaks scarcely smeared should be observed carefully for other symptoms of heat because they have not been mounted frequently, perhaps only once, and may not yet be in true estrus. In contrast, a streak that is well smeared or almost rubbed off indicates that the cow has been mounted repeatedly and, consequently, is likely to be in true estrus or early metestrus.

Unfortunately, this technique has not been tested experimentally but it shows considerable promise. By far the best record of heat detection encountered in our project used this technique, however. It has become almost standard practice among southern California herds.

DHIA Option

Some DHIA data processing centers are providing as an option a printout of cows open and the length of time they were open on the last test day. This is a very useful tool if used properly. It allows the dairy manager to give priority attention to these cows approaching the critical period and to employ heat detection aids if he chooses to do so. This report helps to reduce the number of cows with unrecorded heat periods and delayed first services because someone "didn't think a cow had been fresh long enough to breed." It also helps to detect problem cows that need veterinary assistance before time runs out and they must be sold for slaughter.

Marker Bulls

Vasectomized bulls, fitted with chin-ball markers are used extensively in New Zealand and a third of the herds with which I worked used them. Such surgically altered bulls maintain their libido and actually breed the cows but conception does not occur because no sperm is delivered. The chin-ball apparatus marks the mounted cow and she is easily detected subsequently for artificial insemination.

As vasectomized bulls actually breed the cows, there is a danger of transmitting veneral diseases from one cow to another. To overcome this risk, several other surgical procedures have been developed which actually prevent intercourse. Such marker bulls are receiving more consideration and are being more widely advocated than in years past. But they too have their practical limitations. The added cost is considerable because of surgery, feed, marking apparatus, and ink. A loose bull running with the cows can be a nuisance as well as a menace. Even though most marker bulls serve their function reasonably well, a wide variation in bull performance must be expected. A few bulls may have little or no interest in sex and, consequently, fail to mark cows in heat. Some may follow one cow and ignore the others in heat. The marking apparatus also must be checked, serviced, and filled periodically.

The management of marker bulls is fairly complex and must be modified in accordance to the herd management system. The following suggestions, based primarily on New Zealand experiences may be helpful.

1. Under seasonal breeding, as widely practiced in New Zealand, one marker bull is recommended for every 50 cows in the herd during the breeding season. If the breeding schedule is distributed throughout the year, one bull for every 100 to 150 cows may be adequate, depending on the ratio of pregnant to open cows in that particular lot. An equal number of bulls should be resting.

2. A minimum of two bulls per lot is usually advisable.

3. Active bulls will make a surprising number of mounts daily and may suffer a reduction in efficiency within a week. Rotating bulls every 3 to 5 days, allowing an equal period for rest, is recommended.

4. Cows determined to be in estrus should be isolated so that the bulls will be encouraged to seek more agressively other cows in heat.

5. Chin-ball marks on bred cows should be cancelled so newly marked cows can be easily distinguished from their recently inseminated herdmates. A spray of a different color will simplify this problem.

6. Performance of bulls should be checked periodically to make certain they are working. The chin-ball apparatus also should be checked to assure the ink supply is adequate and that the marker is working properly.

7. The use of marker bulls can be modified in several ways which will extend their use:

   a. Some may choose to rely on visual observation by day and turn the marker bulls in with the cows only at night.

   b. Others may find it more feasible to turn the bulls in with the cows only for an hour or so, preferably twice daily and at 12-hour intervals.

   c. A dairyman might choose to use surgically altered bulls only to check doubtful cows to improve heat detection accuracy. This use requires good judgement because a few cows may stand to be mounted during proestrus and others have short heat periods. A cow in heat at night, for example, may no longer stand for the bull by morning.

These suggestions should be considered only preliminary. It is likely that experience will dictate further modification. It is my reserved opinion that marker bulls may not be worth their cost and nuisance in well managed herds. But, if heat detection cannot be done satisfactorily in any other way, marker bulls may provide an answer.

Group Behavior of Sexually Active Cows

Both heat detection efficiency and accuracy can be improved by making maximum use of the behavior of cows in sexually active groups. Such groups are made predominantly of cows coming in heat, in heat, or going out of heat (proestrus, estrus, metestrus).

Sexually active groups are not difficult to find because the cows involved are closely grouped and are likely to be active while other cows are complacent or resting.

In a project at the University of Guelph,[3] groups of 12 Holstein cows from 3 to 9 years old were continuously monitored by television for a period of 9 weeks. The data following include three replications. Some interesting relationships in the determination of mounting partnerships were observed within sexually active groups.

Table 4. EFFECT OF ESTROUS SYNCHRONIZATION

	Interactions			Mounting-Mounted Ratio		
Cows in Estrus	Mean	Median	Range	Mean	Median	Range
1	11.2	10.5	1-30	.37	.35	0-2.00
2	36.6	17.0	1-179	.88	.60	0-10.50
3	52.6	20.5	1-173	.83	.60	0-7.28
4 or more	49.8	20.0	1-130	1.02	.65	0-14.66

It was evident that the frequency of mounting was much higher if the peaks of estrus in two or more cows were closely synchronized. A large individual variability of this trait was found. Heavier and older cows took part in fewer interactions, with body weight causing more individual variation than age.

With this much "average activity" it is difficult to understand how cows in heat can escape detection. But all cows are not average. In a 6-hour period (9:45 p.m. to 3:45 a.m.) one cow was mounted 104 times by the same partner whom she mounted 28 times. This was no "silent heat." The influence of such cows on the average performance would indicate that some cows fell considerably below the average.

The ratio of mounting to mounted also points out some interesting data. Cows not in heat are less likely to get involved in sexually active groups but they are more likely to mount other cows than to stand to be mounted by other cows.

Occasionally, we still hear the old adage that the cow being mounted is the one in heat and the cow doing the mounting is not. Don't you believe it! Table 4 provides ample evidence to scuttle this theory.

We also hear it recommended frequently that cows in heat should be isolated so they won't bother the remainder of the herd. The advocates of this recommendation maintain that the nuisance cows in heat create reduces milk production of the other cows and contributes to the incidence of broken udders. LEST WE FORGET--long calving intervals also reduce milk production. California culling studies indicated that approximately 34 percent of the cows culled are culled because of breeding problems in contrast to only 5 percent because of broken udders--and there are other reasons for broken udders, primarily genetic reasons.

I contend that we need these sexually active cows to help us spot other cows in heat. We need all the help we can get. In light of the Guelph data cited in table 4:

1. Isn't it likely the isolation of cows in heat would greatly reduce the activity among the sexually active groups?
2. Isn't it likely that more "hard to catch" cows might remain undetected?
3. Isn't it also possible that cows in heat might stimulate these "hard to catch" cows (silent heat) into greater sexual activity and facilitate their detection?

Cow Groups

A few of our dairymen group open cows together to facilitate heat detection and breeding. The practical aspect of this practice has not been clearly defined because there are other reasons for grouping cows--mastitis control, age, and milker supervision are but a few. Some dairy nutritionists are advocating the segregation of cows on the basis of production level to facilitate group feeding. This practice is quite compatible with managing for optimum breeding efficiency. In general, cows in the high-producing group are in early lactation so this group is made up predominantly of open cows, cows in early stages of service, or early pregnancy--the critical periods from a breeding standpoint. Consequently, the cows that demand critical attention are conveniently grouped together. Most of the sexually active cows are likely to be in this group to aid with heat detection as previously described. Seldom do management practices allow "killing two birds with one stone" as does grouping cows for feeding and breeding; more often than not, the dairy manager finds himself choosing between the lesser of two evils.

Influence of Retained Placentas

Several herds in the California study had a high incidence of retained placentas but reliable records of this condition were maintained in only two Holstein herds. These herds provided a unique opportunity to study the influence of retained placentas on breeding efficiency.

Table 5. INFLUENCE OF RETAINED PLACENTAS (RP) ON SUBSEQUENT FERTILITY

	Herd H		Herd B		Total	
Item	RP	Normal	RP	Normal	RP	Normal
1st services	181	687	116	1,767	297	2,454
Conception, 1st service	57	349	31	670	88	1,019
Conception, 1st service (%)	31.5	50.8	26.7	37.9	29.7	41.5
Services	451	1,339	356	4,475	807	5,814
Conceptions	145	625	90	1,507	235	2,132
Services per conception	3.11	2.13	3.96	2.97	3.43	2.73

Table 5 shows the relationship of retained placentas to subsequent breeding efficiency. This relationship was highly significant statistically ($p<.001$). This does not mean that retained placentas were the direct cause of low breeding efficiency. It is more likely that retained placentas were only a predisposing factor and that metritis, vaginitis, and other abnormal conditions were the immediate causes of reduced fertility. Nevertheless, it is rather evident that if the incidence of retained placentas can be reduced by better post-calving care, breeding efficiency is likely to be improved. Prompt and effective treatment for retained placentas may reduce the incidence of secondary conditions and enhance breeding efficiency.

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Nutrition and Reproduction in Dairy Cows

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Ideally, a dairy cow should calve normally every 12 months, produce a large volume of milk and have a productive life of 10 years or more. In practice, only a very small minority of cows are able to reach this goal. In herds where reproduction is at a satisfactory level, it is generally accepted that they will have a non-return percentage that is 75% or higher when bred between 60 and 90 days; to put it another way, we would expect to have 1.6 or less services per conception. Most dairy farmers have some cows which are problems, but these values provide ground rules that can be used to give a quantitative value for the seriousness of the reproductive problem.

The causes of low herd fertility may be classed under the headings of disease, management, heredity and nutrition. Thus, nutrient deficiencies are not likely to be responsible for all problems in any situation. Some of the nutritional factors known to be serious problems are discussed briefly. Keep in mind that a severe deficiency of any required nutrient is likely to cause reproductive problems; fortunately, only a few nutrients are usually likely to cause problems.

Underfeeding

In many cases the cows may have sufficient feed available, but it may be deficient in one or more nutrients. Underfeeding of cows is seldom done knowingly by dairymen. However, it may be done unknowingly for several reasons. These would include over estimation of the feeding value of feeds used, especially roughages; over estimation of feed intake with self-feeding systems; and failure to appreciate the reduction of forage intake caused by high concentrate intake.

The nutrient content of feedstuffs varies widely depending on soil fertility, fertilization practices, type of forage, harvesting practices, weather damage and so on. Consequently, using average book values for nutrient content may lead to gross errors. The only remedy for this is to resort to feed analyses; unfortunately, complete nutrient analyses are expensive and are only rarely done. However, as information is built up on likely deficiencies in different areas as related to fertilization and soil types, it is to be hoped that this type of data will be useful in suggesting likely nutrient problems in the future.

Depending on the quality and type of feed and how it is processed, we may expect lactating cows to consume about 2.5% of her body weight (as dry matter in the feed) during her lactation. A good eating cow should be eating 3% of body weight by 2-4 weeks after calving and 3.25-3.4% by 6-8 weeks. Some may go as high as 4%. On the other hand, some may never reach 3%, particularly cows with narrow, shallow bodies. Also, nervous, timid cows are not likely to get their share. In addition, feed intake is likely to be depressed when cows are subjected to heat stress and feed intake will normally increase (if available) when the weather is very cold.

It is well established that fertility in dairy cows is negatively related to milk or butterfat production and to loss of body weight during lactation. Most high producing cows are not able to eat enough to maintain body weight during the period of peak milk flow. If any nutrient is critical at this time (normally desired breeding time and peak milk flow will coincide--i.e., 60-90 days after calving), then reproduction is more apt to suffer than is milk flow. The result is that the number of services per conception tend to climb as the milk production increases.

Energy

Excellent pasture may allow milk production of about 40 lb./day. In order to get much more milk than this, we must feed energy sources such as the cereal grains or other comparable feedstuffs. Generally, if we feed an excellent quality roughage, the average cow can obtain a maximum intake of energy with about 40-50% of her ration as concentrates. a few cows may require more than this, but an energy level of about 68-70% TDN should allow maximal consumption. If energy intake is not adequate, then weight losses will be greater than normal and estrus and ovulation and, eventually, ovarian activity are inhibited. A dietary deficiency of energy linked with declining weight and milk yield is a relatively common cause of reduced fertility in dairy cows. British studies show that energy deficient herds usually have lower blood glucose values than those receiving adequate diets. Cows, as with sheep, generally are more fertile when they are gaining weight, but it is practically impossible to have a cow gaining weight at 60-90 days postpartum. Overly fat cows generally have more problems with fertility, also.

To remedy an energy problem, it may be necessary to alter the ration, to feed a higher quality of forage, or to feed more frequently. Recent data show that consumption is apt to be increased when complete diets are fed rather than feeding concentrates and roughages at separate times.

Protein

Protein is a critical nutrient for high producing cows. Current standards suggest 16% (% of ration dry matter) for cows giving 65 pounds of milk or more per day. Some cows may need a little more than this, however. Studies with beef cattle show that underfeeding on protein may lead to low birth weights and a relatively high incidence of dead or weak calves. Protein deficiencies may lead to an increased interval from calving to first postpartum estrus by quite a period of time. Clinically, blood samples show a reduced level of blood albumin when protein is deficient.

On the other hand, cows may get an excess of protein when receiving high quality spring pasture (or green chop) and a concentrate with the usual level of protein (15-16%) used during the winter months. Great excesses of protein may result in ketosis, but this is not believed to be much of a problem in typical cases of ketosis.

Non-protein nitrogen supplements, primarily urea, may inhibit intake in some rations if used in rations over 1-1.5% of the mix for high producing cows consuming large amounts of feed. However, Michigan DHIA data do not indicate that urea feeding was related to reproductive problems in that state. When urea is used, more attention must be paid to the sulfur content of the ration as sulfur is a normal constituent of plant and animal proteins and is required by rumen micro-organisms to synthesize microbial proteins from urea.

Minerals

Deficiencies of several minerals (calcium, phosphorus, manganese, iodine, zinc) have been linked with reproductive problems in cattle. Of these, the most common problem is probably with phosphorus, but attention should be paid to the others, depending on local soil types and fertilization practices.

Calcium has not been directly linked with reproductive problems, but it is an indirect factor since excess amounts reduce the uptake and interfere with the metabolism of phosphorus, particularly, as well as several other mineral nutrients. Generally, a Ca:P ratio of 1.5:1 is appropriate for lactating cows (a lower ratio such as 0.5:1 is better during the dry period). If expressed on a percentage basis, calcium should be about 0.6-0.7% and phosphorus 0.4-0.5% of the total ration.

When phosphorus is deficient, we may expect a prolonged interval between calving and first estrus and a reduction in feed intake. German data suggest that the phosphorus and potassium intake may need to be increased when heavy applications of nitrogen are used on forages. This may also apply to a number of the trace minerals (copper, manganese, cobalt, zinc).

Manganese has been implicated as a factor in fertility. Research studies have shown that a deficiency will result in suppressed estrus. Field studies have shown that excessive calcium will reduce utilization of manganese and that, with sheep, reproduction was much improved when deficient animals were supplemented with manganese. German data suggest that manganese is a much more common problem than zinc with respect to reproduction.

With respect to zinc, several field studies have shown improved conception with both sheep and cattle when supplemental zinc was given. Excess calcium interferes with zinc utilization, so we might anticipate some problem where legume hays with a very high calcium content are fed for a long period of time if soil content of zinc is low.

Iodine is the other mineral element likely to be a problem in many areas. Field data show that the conception rate of repeat breeder cows may be improved substantially by treating with organic iodine for 8-12 days before the onset of estrus. Other reports suggest that the number of retained placentas was greatly reduced after administration of iodine. If cows are very deficient, calves will be born with goiters. Some common feedstuffs, such as soybean meal, have goitrogenic compounds present in them. If these are used, the amount of iodine in the ration needs to be increased.

Vitamins

Vitamin A is the vitamin most likely to be a problem, although studies with beef cattle suggest that cows must be quite deficient before conception is prevented. Deficient animals may have silent estrus and deficient calves are, of course, more subject to diarrhea and secondary infections. Recent data suggest that 50,000 international units of added vitamin A are probably sufficient for dairy cows.

Vitamin E deficiency may be a problem in producing viable young animals which may develop nutritional muscular dystrophy. However, there is little or no evidence to indicate that it is a critical nutrient with respect to other reproductive processes. There is recent evidence, however, to suggest that treatment with vitamin E and selenium may reduce the incidence of retained placentas.

Vitamin D may, at times, be deficient for cows receiving forage which has not been suncured and when cows are maintained in covered lots. Some evidence suggests that feeding vitamin D will improve fertility, presumably because of its known relationship with respect to phosphorus metabolism.

Improvement of Reproductive Efficiency in Dairy Cattle

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Improved reproductive efficiency offers dairymen an opportunity to increase the productivity of their dairy herds. It is well to remember that a cow producing 13000 lb. per lactation with a 12 month calving interval is just as valuable as her herdmate which is producing 17500 lb. per lactation with a 16 month calving interval - they are both producing an average of 36 lb. milk/day for every day of their calving interval or 13140 lb. per year(7). But why not have 17000 lb. cows with a 12 1/2 month calving interval?

It is usually accepted that high producing cows are harder to breed-they do not begin to cycle as soon after calving, they are harder to detect in heat, they take more services per conception, etc. But is this really true? A survey of dairy herds in the New York area indicated that conception decreased markedly with increased production(15). Cows producing 2000 lb. milk or more per lactation above herdmates were 20.5 percentage units lower in first service conception rate than cows which were producing 2000 lb. milk or more per lactation below herdmates.

On the other hand, a recent survey of California herds revealed the opposite results(10). Daily milk production during the first four DHI test periods (time of peak milk production) had no effect on breeding efficiency of the cows.

These studies are surveys across many herds. We are currently looking at production records of the OSU dairy to determine if a relationship exists between milk production and fertility on a within herd basis where management should be similar for cows of all production levels.

Accepting that a shorter calving interval will improve milk production in terms of lb. milk/cow/day/year, in what ways can the calving interval be shortened? There are several. One method is to begin breeding sooner after calving. A summary of several studies has indicated that first ovulation occurs 20 to 45 days after calving(5). Many people advocate beginning breeding 40 or 45 days after calving (1). I believe this is a sound practice if, following calving, you are ascertaining by rectal exam that the reproductive tract has returned to normal size and is not infected.

A second means to shorten the calving interval is to improve the conception rate. Although 60 to 90 day non-return rates may indicate a 65 to 75% rate of fertility, most surveys show that it takes about 2 services per calf born.

Conception rate is difficult to improve and a 25 or even a 50% improvement will have only a slight effect on the calving interval. A survey of Ohio DHI herds indicated that Ohio dairymen are losing 15 days due to conception failure and 40 days due to missed heat periods (2). However, it is still important to ensure that cows are bred at the proper time during standing heat or estrus. Optimal conception rate can be obtained by breeding about 14 hr after the onset of standing heat (13). Of course, breeding at the correct time in relationship to standing heat requires frequent observation. Conception rate has always been higher (10 to 20%) in cows observed continuously as compared to cows observed normally (2 or 3 heat checks daily). Breeding at the wrong time not only results in reduced fertilization, but also will cause a higher incidence of early embryonic mortality. This is indicated by long estrous cycles - cows returning to estrus 30 to 50 days after breeding.

Probably the most important factor in improving the calving interval is proper observation for estrus. It has been estimated that dairymen are missing nearly 50% of the heat periods in which they intend to breed their cows. We have ample evidence that cows do cycle. A Minnesota study indicated that 90% of cows said to be anestrus were actually cycling (18). Using a herd of 104 anestrous cows, researchers in Australia detected 92% in heat within a 21-day period when the cows were observed continuously (6). During this same time, routine heat detection by the herdsman resulted in 56% being detected in estrus. And of the cows bred by the herdsman, conception to first service was 48% as opposed to 63% conception in cows bred during continuous observation.

Why do dairymen fail to detect 50% of the cows in heat? Part of the answer has been revealed by continuous observation or TV monitoring. A Canadian study showed that 43% of the mounting activity occurred between midnight and 6 AM - a time when we normally don't observe cows for estrus. And an additional 25% of the activity occurred between 6 PM and midnight. Similarly, a Cornell study revealed that 2/3 of the cows were in estrus in the morning; of these, 45% were no longer in estrus by the evening observation (8). So it is obvious that early morning heat checks are more important than other times of the day.

While the interval from parturition to first ovulation is 20 to 45 days, the interval to first estrus has been reported at 30 to 72 days (5). The first ovulation is almost always accompanied by silent heat. Although Morrow indicated that the occurrence of standing heat increased with each ovulation following parturition, silent heat was not found to be a problem in cows observed continuously (table 1). The interval from parturition to first estrus was 34.5 days in a group of cows monitored continuously and 56.6 days in a similar group observed normally (11). The postpartum interval to first estrus is longer in high producing cows (5); although breeding efficiency may be equal in high producing cows (10), the problem appears to be a lack of behavioral estrus.

It would appear, then, that the postpartum cow is exhibiting behavioral estrus. Since it is rather impractical to observe cows continuously, how can you, the dairyman, detect heat on a day-to-day basis?

A number of estrus detection aids, such as heat detector patches and marker bulls have become available in the past few years. Estrous synchronizing compounds have been available for a number of years, but, as reported at the 1974 OSU Dairy Day, they have had two major faults. First, fertility is lowered significantly at the synchronized estrus, and secondly, the compounds have not synchronized estrus closely enough to eliminate the necessity of estrous detection. Thus the same opportunity for management failure exists.

More recently, hormones have become available which have the ability to synchronize estrus precisely enough to eliminate the need for estrous detection. One of these is prostaglandin. This is a hormone which, upon injection, causes rapid degeneration of the yellow body (corpus luteum). This removes progesterone from the circulation, permitting follicles to develop which secrete estrogen which then causes behavioral estrus and ovulation. At least two major field studies have been concluded which illustrates the precision with which prostaglandins will synchronize estrus. The first field study involved beef and dairy heifers at 4 locations (table 2). The heifers were divided into 3 groups. The control group was observed for estrus twice daily and the heifers were bred about 12 hr after the onset of estrus. The second and third groups received prostaglandin - heifers in the second group were observed for estrus and bred 12 hr after the onset of estrus while the third group was bred at 72 hr and 90 hr after the prostaglandin injection without regard to the time of estrus. As noted in table 2, fertility was similar in all groups. Fertility was equal in the group bred without regard to estrus because prostaglandin uniformly causes estrus at 72 hr and ovulation at 95 hr after treatment. In this study, 88% of the heifers were in heat on days 2, 3 and 4 after the prostaglandin injection.

A second major experiment involving prostaglandin was recently completed in England (9). This field study involved 1,352 heifers and lactating cows in commercial herds. The cattle were given two injections of prostaglandin 10 to 12 days apart because prostaglandin is not effective from about 3 days before to 4 or 5 days after estrus. Thus, prostaglandin would not be effective in about 35% of a random group of cattle at the first injection, but all the cattle should be in the luteal phase during the second injection. Of the prostaglandin-treated cattle, about half were inseminated twice (at 70 and 88 hr) and the remainder were inseminated once at 80 hr after the second injection of prostaglandin without regard to estrus. Two conclusions are evident from the data in table 3. First, fertility in the prostaglandin-treated cattle was equal to that of control cattle inseminated normally at estrus without treatment. And secondly, a single insemination at 80 hr yielded a conception rate similar to that from two inseminations at 70 and 88 hr following prostaglandin treatment. Consequently, these authors feel prostaglandin warrants commercial application. In fact, an English Company, Imperial Chemicals Industries (ICI), is now licensed to market this hormone in the United Kingdom; milk does not need to be withheld from lactating cows. Obviously, this has tremendous implications in the use of AI for dairy heifers and beef cattle. But it also can eliminate much of management error in estrous detection by applying its use to lactating dairy cattle.

More recent experiments with progestogens suggests that they too may be useful in estrous synchronization. For example, Roche (14) observed fertility of heifers to be normal when inseminated after an initial injection of progesterone and estrogen succeeded by a progesterone implant for 9 or 12 days. Most heifers were in estrus on the second day after implant removal. Wishart and Young (17), using a similar synchronization sequence, obtained significantly improved fertility in heifers inseminated twice at 48 and 60 hr after implant removal as compared to heifers inseminated 48 hr after implant removal or untreated heifers inseminated at estrus (table 4). Thus, it is evident that this treatment regime is also successful in precisely synchronizing estrus. Prostaglandin treatment was successful using a single insemination whereas the progestogen-estrogen treatment needed two inseminations; both treatments would involve handling the cattle twice prior to insemination.

However, these treatments do not induce estrus in anestrous cattle. Consequently, for such treatments to be successful in high-producing postpartum cows, a means must be found to decrease the incidence of anestrus. Bear in mind that much of this anestrous condition is due to management failure to detect estrus.

At least two treatments have been used in an attempt to bring cows out of anestrus. One of these involved GnRH, a synthetic hormone which can indirectly induce ovulation (4). Lactating cows given GnRH on day 14 postpartum ovulated the following day. But the time interval from parturition to first observed estrus was unchanged. A second treatment involved the use of MGA, an early estrous synchronizing compound (3). Lactating cows were given MGA for 14 days beginning about 21 days postpartum; average days open was reduced from 153 days in untreated cows to 83 days in MGA-treated cows.

Perhaps, with further study, these or similar treatments may be used to successfully treat anestrous cows or heifers. Certainly it would be an improvement to induce these cattle to exhibit estrous cycles. Thatcher and Wilcox (16) reported that services per conception decreased on subsequent breedings as the number of estrous periods observed prior to the beginning of breeding at 60 days postpartum increased.

In conclusion, management is responsible for most of the missed heat periods in dairy cattle. Researchers are striving to develop treatments which will induce anestrous cows to cycle. And successful estrous synchronization treatments have been developed which can obviate the need to observe for estrus. These treatments may become commercially available; if so, they have the potential to dramatically improve reproductive efficiency in dairy cattle.

Table 1. Percentage of reproductively normal cows detected in estrus at the first, second and third ovulation when maintained under different systems of observation[1]

Observation system[2]	Ovulation		
	First	Second	Third
Continuous	50	94	100
Normal[3]	20	44	64

[1]From King, Hurnik and Robertson(11).

[2]Differences between observation systems was significant at all ovulations, P<.01.

[3]Cows were checked 2 or 3 times daily.

Table 2. Fertility of heifers following prostaglandin treatment[1]

Treatment	No. Heifers	Fertility
I-Control, AI at 12 hr[2]	122	53.3 %
II-Prostaglandin, AI at 12 hr[2]	69	52.2 %
III-Prostaglandin, AI at 72 & 90 hr[3]	86	55.8 %

[1]From Lauderdale _et al._ (12)

[2]Heifers inseminated 12 hr after the onset of estrus.

[3]Heifers inseminated at 72 and 90 hr after prostaglandin injection.

Table 3. Fertility of heifers and lactating cows inseminated without regard to estrus following prostaglandin treatment[1,2]

Treatment	No. Cattle	Pregnancy Rate
Control[3]	479	53%
Prostaglandin-AI at 70 & 88 hr	393	61%
Prostaglandin-AI at 80 hr	480	60%

[1]From Hafs et al. (9).

[2]Prostaglandin was injected twice, 10 to 12 days apart. Cattle were inseminated after the second injection.

[3]Control cattle received no treatment and were inseminated during estrus.

Table 4. Fertility of heifers inseminated without regard to estrus following estrogen-progestogen treatment[1,2]

Treatment	No. Heifers	Pregnancy Rate
Control[3]	53	51%
Estrogen-Progestogen, AI at 48 hr	51	41%
Estrogen-Progestogen, AI at 48 & 60 hr	46	65%

[1]From Wishart and Young(17).

[2]Initial estrogen-progestogen injection, followed by progestogen implant for 9 days.

[3]Control heifers received no treatment and were inseminated during estrus.

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