2-1-1946

Vitamin D Defficiency in Dairy Cows

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Bulletin 372, Revised February, 1946

VITAMIN-D DEFICIENCY in DAIRY COWS

Symptoms, Causes, and Treatment

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How much vitamin-D deficiency there is in dairy cattle in South Dakota is not known. Work at this Station suggests an intake of 12,000 to 15,000 International Units of vitamin D daily as a possible minimum feeding guide for dairy cows. Where cows are exposed to sunshine while on pasture and are fed during the winter on sun-cured roughages high in vitamin D, they probably receive an amount of vitamin D equivalent to the suggested minimum intake. However, even then milk production, calving performance, and general health might be improved by supplying additional vitamin D, since the optimum requirement for nutrients is often higher than the minimum.

On the other hand, there are undoubtedly many times when roughages low in vitamin D are fed. Then when spring comes, cases of mild vitamin-D deficiency and lowered general health and producing ability may occur.

Further information is needed to determine the vitamin-D content of various roughages, the effectiveness of sunshine as a source of vitamin D, and the degree of deficiency that may exist in dairy cows. Until this information is available, a farmer will do well to be sure that his cattle get as much sun-cured hay and sunshine exposure as is consistent with good management. It would seem that providing each cow an additional 10,000 to 15,000 units of vitamin D daily as a supplement might be desirable for improving the health and producing ability of the dairy herd, especially when cows are fed on roughages which would be expected to be low in vitamin D, or when they are heavy producers and are confined in the barn for a long period of time.

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Symptoms, Causes, and Treatment

By G. C. Wallis, Associate Dairy Husbandman

Farmers are making greater profits as they use new information from studies on how to feed and care for farm animals more efficiently. Experiments recently completed at the South Dakota Station show that dairy cows as well as calves need a certain amount of vitamin D in order to keep healthy and to produce efficiently. Vitamin D helps calcium and phosphorus to build and maintain strong bones and sound teeth, and in sufficient quantities it prevents rickets in young animals.

This bulletin gives information on the symptoms of a Vitamin-D deficiency, the conditions under which it is likely to occur, the sources of vitamin D for dairy cows and young stock, and the approximate amounts of it that they need.

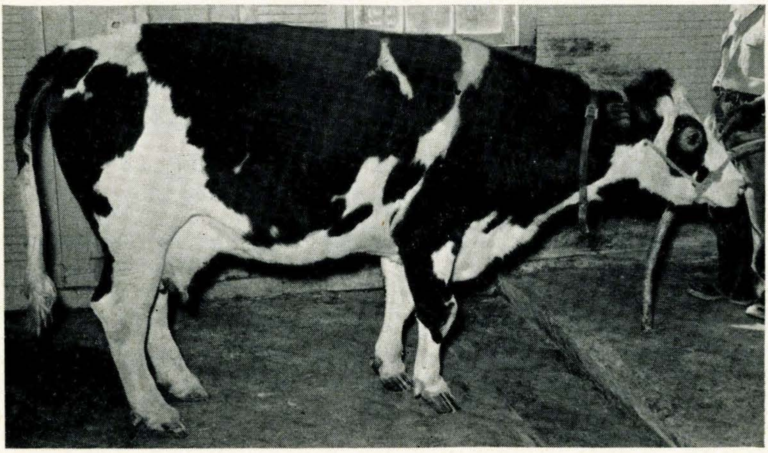
Symptoms of Vitamin-D Deficiency

Dairy farmers and others interested in the practical value of this study should keep in mind that the symptoms reported here are from a part of the experiment in which the vitamin-D content of the feeds was limited to as little as possible. Of course the greater the deficiency is, the more obvious the effect will be. It is improbable that so little vitamin D is found under farm conditions, and so a deficiency on the farm would not show up so strikingly as in this experiment. However, similar effects are likely to occur when animals on the farm are not receiving enough vitamin D.

Fourteen grade Holstein cows were used in determining the symptoms of vitamin-D deficiency. The ration fed contained as little vitamin D as possible, and the cows were kept out of direct sunshine, which provides vitamin D. The more milk a cow gave the sooner a deficiency of this vitamin was noticed, for a considerable part of the outgo of vitamin D from a dairy cow is in the butterfat produced. Definite symptoms of a deficiency usually occurred within 6 to 10 months.

Results Observable on the Farm

Lameness in legs and back. The visible symptoms of a vitamin-D deficiency in dairy cows are similar to those of rickets in calves. The animals begin to show stiffness in their limbs and joints which makes it difficult for them to walk or lie down and get up. The knees, hocks,



Symptoms of severe vitamin-D Deficiency are shown in this cow, which collapsed about a week after this picture was taken. Note rigid position, swollen joints, knees springing forward, and elevation of back.

and pastern joints usually become swollen, tender, and stiff. The knees often spring forward, the pastern joints straighten, and the animal is tilted forward on its toes. The hair becomes coarse and rough, and there is an overall appearance of unthriftiness.

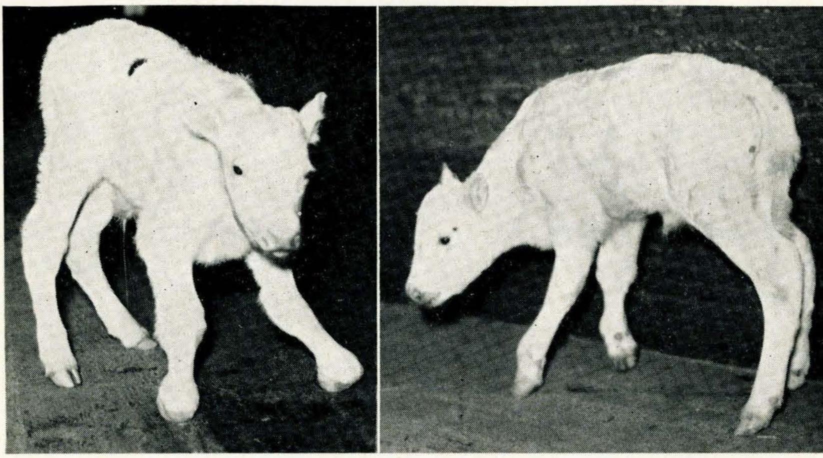
As the deficiency becomes more severe, the back often becomes stiff and humped and is bent or flexed as little as possible when the animal walks or moves. In severe cases cows need assistance in getting up and occasionally even with assistance they are unable to rise or stand.

Calves likely to be weak. About half of the calves born to animals having various degrees of vitamin-D deficiency during the gestation period were born dead or very weak, even though most of them were carried full term. A decrease in the percentage of calcium, phosphorus, and ash in the skeleton of these calves at birth was the most pronounced characteristic observed.[1] Because of this lack of minerals in the bones,

[1]The percentage of ash in the sixth rib was lowered from about 25 percent for normal calves to about 14 percent for calves from vitamin-D-deficient cows.

the legs of the calf were usually crooked, giving the appearance of rickets. However, a careful study (by Dr. J. B. Taylor, Station Veterinarian) of the bones of two of these calves revealed no malformation of the internal structure such as is typical of calves having rickets.

The effects of a vitamin-D deficiency on reproduction indicate that a much smaller number of calves are born where a deficiency exists and



Calves dropped by vitamin-D-deficient cows were usually weak, and the legs of many were crooked because of lack of minerals in the bones. The calf shown above died within a week after it was born.

that some of these calves will probably be dead and others so lacking in vitality that they are hard to raise. To what extent a mild deficiency of vitamin D would affect reproduction in farm herds is difficult to say. But it is quite likely that some interference with reproduction would result.

Milk flow lowered. As the deficiency of vitamin D became more acute, the cows in this experiment nearly always went off feed. Then there was loss in weight and evidence of generally poor physical condition. There was also a rapid decrease in the amount of milk produced. It is interesting to note that whatever milk was produced, even under extreme vitamin-D deficiency, was entirely normal in its content of calcium and phosphorus. The milk was low in vitamin D, however, and sometimes had such a small amount that it was not even measurable. Normal summer milk may have 35 to 40 International Units of vitamin D per quart, and winter milk, 8 to 10.

Heat periods less frequent. The reproductive efficiency of dairy cows suffering from lack of enough vitamin D was greatly decreased. Heat periods seldom occurred. In some cases in this experiment no heat periods were observed until the vitamin-D deficiency had been corrected.

Results Observable in the Laboratory

In addition to the effects on cattle of vitamin-D deficiency which can be seen on the farm, there are other far-reaching effects that can be determined in the laboratory. Since vitamin D is concerned with the proper utilization of calcium and phosphorus in the body, particularly in the building of strong bones and sound teeth, laboratory studies were made to show the effects of a vitamin-D deficiency on calcium and phosphorus utilization.

Balance trials. Studies were made to find out how much of the calcium and phosphorus present in the feed of the cow was retained for use in meeting the animal's need for these minerals. Such an experiment is called a balance trial. A record was kept of all the calcium and phosphorus consumed by a cow over a given period of time, usually 10 days. The total outgo of these minerals from the animal's body in the milk, urine, and manure was determined for the same period of time. If there is continuously a larger loss of calcium and phosphorus from the body than is contained in the feed consumed, sooner or later the health of the animal will be impaired.

Many balance trials were run in the course of this experiment. It was found that cows suffering from a deficiency of vitamin D were not able to retain and utilize the normal amount of calcium and phosphorus. In fact, when the vitamin-D deficiency was pronounced, dairy cows were almost always losing calcium and phosphorus from their bodies in abnormal amounts. The losses tended to be greater in cows with higher milk production, although some cows that were dry also showed a loss of minerals when they were deficient in vitamin D.

Bones weakened by mineral loss. The losses in calcium and phosphorus must come from the mineral reserves which, for these two minerals, are stored largely in the bones of the animal's body. If mineral losses continue too long, it is possible that the strength and soundness of the bones may be affected enough so that the bones can be more easily broken.

In one case in this experiment the large bone in each thigh was found broken in a post-mortem examination of a cow that died from a severe vitamin-D deficiency. An examination of another animal that died from the same cause revealed that the surfaces where the bones

came together in the hip, stifle, and other joints were no longer smooth and firm. They were inflamed and rough, with open sores and eroded areas on the surface of the joint. There was also a large amount of inflammation, pus, and rotting tissue around the hip joints.

Calcium and phosphorus in blood plasma. In studying vitamin-D deficiency and rickets, it has been customary for some time to determine the level of calcium and phosphorus in the blood. The importance of such observations can be readily understood when it is realized that the calcium and phosphorus of the feed are carried by means of the blood stream from the digestive tract for utilization in other parts of the body. In normal dairy cows the total calcium in the blood plasma amounts to 10 or 12 milligrams per 100 cubic centimeters. The inorganic phosphorus ranges around 5 to 6 milligrams per 100 cubic centimeters.

A large number of determinations were made of calcium and phosphorus in the blood plasma of the cows used in this experiment. One of the first signs of the onset of a vitamin-D deficiency was a decrease in the level of calcium and phosphorus in the blood plasma. This usually preceded any indication of stiffness or other visible evidence of a vitamin-D deficiency in dairy cows. In severe cases of vitamin-D deficiency the level of calcium in the blood plasma was only one half that of normal cows. The phosphorus declined to one fifth of the normal amount. The small amount of calcium in the blood was often accompanied by tetany, muscle twitchings, and convulsions. Determinations of the level of magnesium in the blood plasma showed no variations from essentially normal concentrations even with severe vitamin-D deficiency.

Blood-phosphatase values. The activity of the blood-phosphatase enzyme is concerned with the proper utilization of calcium and phosphorus in the building of bones. With calves and the young of some other species, higher phosphatase values as determined in the laboratory constitute one of the earliest evidences of rickets.

For dairy cows, normal phosphatase values were found to vary from 3 to 5 Units. In the work at this Station with dairy cows, values as high as 22.62 Units were observed but only after a very severe vitamin-D deficiency had developed. In other words the phosphatase values were found to increase with cows under vitamin-D-deficient conditions the same as with calves. But for cows they were not one of the first symptoms.

Blood as index to vitamin D. One other laboratory test was made which is of considerable interest. Work at other experiment stations

has shown that as animals become depleted of vitamin D, the blood and liver are among the last places in the animal's body where the vitamin may still be found. Since this is true, the level of vitamin D in the blood becomes an important index of the amount of this vitamin which the animal still has in its body.

Normal cows under summer conditions, when the vitamin-D reserves are at their highest, were found to have 5 to 6 International Units per cubic centimeter of blood plasma. A few figures available for cows under usual early winter conditions varied from about 1 International Unit to more than 4 Units of vitamin D per cubic centimeter of blood plasma. Cows having 0.20 to 0.25 International Unit of vitamin D per cubic centimeter were usually about on the borderline where other evidences of a vitamin-D deficiency might develop.

Studies with the vitamin-D-deficient cows showed that when there were other symptoms of a mild deficiency, the blood plasma had about a 0.15 to 0.20 International Unit of vitamin D per cubic centimeter. When the vitamin D reached a level of 0.15 International Unit or less per cubic centimeter of blood plasma, other symptoms of the deficiency became increasingly severe. In a few cases the vitamin-D potency of the blood plasma was so low that it could not be measured.

Conditions Resulting in a Deficiency

A deficiency of vitamin D is most likely to occur when the vitamin D available to the cow is at a low level and when the demands on her reserves are the greatest. The main sources of this vitamin for dairy cows are (1) sunshine and (2) the feed and vitamin-D supplements fed. One function which tends to use up the available vitamin D more rapidly is high milk production, which removes considerable vitamin D from the body in the butterfat. Another is the demand of the developing fetus, especially during the last few months before calving.

Deficiency Likely in Winter

Vitamin D in sunshine. A deficiency of vitamin D is most likely to occur in late winter. The amount of vitamin D received from sunshine during the winter is small because in many regions the weather is so severe that cows are not turned out where they are exposed to direct sunshine. Furthermore, in northern regions, sunshine is not very effective as a source of vitamin D in winter because of the relatively small amount of ultraviolet light it supplies.

To be effective the direct rays of the sun must reach the animal. Sunshine which passes through ordinary window glass has most of the

portion of it removed which is capable of producing vitamin D in the animal's body.

Vitamin D in feeds. The only other source of vitamin D available to the cow in late winter is the feed. Of the more common feeds, only the roughages contain significant amounts of vitamin D. Farm grains and their byproducts contain little, if any.

Not too much is known about the vitamin-D content of different kinds of roughages or the curing and handling conditions which will give the highest vitamin-D content (see page 11). If the roughage available for winter feeding is of poor quality and low in vitamin D, there is a time during the winter when the main source of vitamin D for dairy cows is the limited amount which they stored in their bodies during the previous summer. Under usual circumstances dairy cows will gradually lose during the winter a portion of the vitamin-D stores which were built up during the previous summer. The more vitamin D available in the feed and from sunshine exposure during the winter season, the longer the reserves of the previous summer will last.

Demands for Vitamin D

Production of milk. The amount of milk produced is undoubtedly a more important drain on the vitamin-D supply than is the growth of the fetus. The butterfat produced by a dairy cow contains more or less vitamin D, roughly in proportion to the amount of vitamin D available to the cow. It is a drain on the available supply. When a cow in heavy milk flow receives only small amounts of vitamin D from outside sources (as is usual during the winter in northern regions), the butterfat that she produces draws heavily on the vitamin-D reserves stored in her body.

When rations were used which had as little vitamin D as possible but were otherwise complete, cows giving up to 60 or 65 pounds of milk daily were so depleted of vitamin D that they showed definite symptoms of a vitamin-D deficiency in about 4 months. The length of time depends also upon the amount of vitamin D stored in the animal's body at the start. Cows giving 25 to 40 pounds usually became depleted of vitamin D in 6 to 8 months when no outside source of vitamin D was available to them. In one case a cow was kept dry and fed under vitamin-D-deficient conditions for 20 months before mild symptoms of a vitamin-D deficiency were evident.

Under farm conditions where ordinarily some vitamin D would be available to the cow in the feed and sunshine even during the winter,

the time it would take for a severe deficiency to develop would probably be somewhat longer than under the experimental conditions here.

Development of the fetus. A second measurable demand on the vitamin D available to the animal is the development of the unborn calf, particularly during the last 2 or 3 months before calving, when the greatest development of the fetus takes place. Just how much this added demand amounts to is difficult to specify.

In this experiment, on several occasions the deficiency symptoms became rather severe quite suddenly as calving time approached. On one or two occasions the effects of vitamin-D deficiency became so severe that cows which were held to a very low intake of this vitamin died shortly after calving. Death would undoubtedly not have occurred with cows that had reasonable amounts of vitamin D available, either in the feed or as body reserves.

High demand and low intake. From this discussion it can be seen that a cow that has freshened in the late fall and is giving a large flow of milk during the winter will be drawing heavily on available vitamin-D supplies. If the roughage is low in vitamin D and little or no sunshine is available, the cow's reserves of this vitamin are likely to be depleted. Symptoms of a deficiency may be in evidence by late winter or early spring. Of course these are not the only conditions under which a deficiency might occur. But they undoubtedly are the most likely circumstances.

This information does not mean that advantage should not be taken of fall freshening for economical production or to equalize production throughout the year. It simply indicates that under these conditions added care shoud be taken to avoid a vitamin-D deficiency. Examples of helpful practices are feeding vitamin-D supplements and sun-cured roughage high in vitamin D.

Minerals Cannot Be Substituted

Even though there may be a lack of vitamin D in the rations of some species of animals, rickets and other symptoms of a deficiency do not develop when the ration contains calcium and phosphorus in the right proportions and in large enough amounts. However, this experiment indicates that dairy cows need vitamin D even though calcium and phosphorus are fed in abundant amounts and in the favorable ratio of about two parts of calcium to one of phosphorus.

In this experiment one vitamin-D-deficient animal was fed over twice the requirement of calcium and phosphorus and in the favorable ratio of two parts of calcium to one part of phosphorus. The animal showed no improvement and continued to get worse for nearly a

month. By this time the effects of vitamin-D deficiency had become so severe that she died shortly after giving birth to a premature dead calf.

Two other cows were put under vitamin-D-deficient conditions but were given twice the required amount of calcium and phosphorus. These cows developed severe cases of vitamin-D deficiency in about the same length of time as the cows that had not been given additional calcium and phosphorus.

A deficiency of calcium and phosphorus in the ration would likely express itself either as a straight mineral deficiency or tend to shorten the time when a combined deficiency of minerals and vitamin D would develop.

Curing a Vitamin-D Deficiency

Facts for the Dairyman

Various sources of vitamin D can be used to cure or prevent a vitamin-D deficiency. Animals suffering from a severe deficiency should be given 50,000 to 100,000 International Units of vitamin D daily for a few days to a week or so and then given somewhat smaller amounts until they recover.

Cod-liver oil and yeast. The amount of vitamin-D supplement needed to supply the amount of this vitamin recommended above depends on the supplement used. One-fourth to one-half pint of a good grade of cod-liver oil or a teaspoonful of irradiated yeast is about the right amount for 50,000 to 100,000 Units of vitamin D.

Cod-liver oil should not be fed to dairy cows in large amounts over too long a period as it tends to lower the butterfat test of the milk.

Vitamin D in roughages. Roughages furnish the main natural feed source of vitamin D for dairy cows during the winter. There is considerable variation not only in different kinds of hay or other roughage, but also in different lots of the same kind of roughage. For instance, samples of alfalfa hay analyzed in the South Dakota laboratory were found to vary from 300 International Units of vitamin D per pound to as high as 2,762 International Units. A sample of prairie hay had 250 International Units per pound and one of oat straw had 748. Only a comparatively few samples have been run so they cannot be used to indicate the average amount of vitamin D in different roughages. They are quoted only to give some idea of the amount of variation present. Much further study is needed to provide definite information as to the exact causes of these variations and to show what conditions of handling and curing must be used to insure a hay or other roughage of high vitamin-D content.

Effect of sunshine on hay. In general, the more sunshine that hay receives during curing the higher will be its vitamin-D content. But exposure to sunshine explains only a part of the variations found in alfalfa hay. For example, one sample of third-cutting alfalfa exposed for 3 days in the swath and windrow to September sunshine developed a potency of 1,950 International Units of vitamin D per pound. But another sample of second-cutting alfalfa cured in a comparable way in July sunshine had only 385 International Units. Even after 9 days of sunshine exposure in the swath, it had only 1,243 Units of vitamin D per pound. Another sample was cut after dark and dried artificially in a dehydrating machine so that it was not exposed to any sunshine. It had 812 Units per pound.

It can readily be seen that sunshine exposure during the curing process is far from being the only factor concerned in determining the amount of vitamin D in a roughage such as alfalfa hay. But it undoubtedly is one of the important factors.

Effect of sunshine on cows. Some observations were made on the antirachitic effectiveness of sunshine at different seasons of the year. Two cows showing pronounced vitamin-D deficiency were turned out into summer sunshine starting in April and June, respectively, but were continued on the experimental ration low in vitamin D. Their condition showed improvement quite promptly and followed about the pattern described on page 13.

However, their body stores of vitamin D were not built up to the level found in other dairy cows kept under usual summer conditions. For instance, the vitamin D in the blood plasma of these cows never got above 0.31 International Unit per cubic centimeter, whereas 5 to 6 Units were found for dairy cows under usual summer conditions. These observations raise some question about the direct action of sunshine on the cow being the main influence in building up her vitamin-D stores and providing for the higher vitamin-D potency of summer butterfat.

Three other vitamin-D-deficient cows were turned out to sunshine exposure in late August, October, and mid-November, respectively. All showed improvement but, in general, it was somewhat slower with fall sunshine as the source of vitamin D. In the case of the mid-November exposure, the degree of recovery was not as great. Deficiency symptoms soon developed again as the weather made further sunshine exposure impossible. These observations indicate that even late fall and winter sunshine in South Dakota will furnish a limited amount of vitamin D to dairy cows when they are exposed to it.

Experimental Methods and Results

Cures used. In these experiments, viosterol, cod-liver oil, cod-liver-oil concentrates, alfalfa hay, and sunshine were all used effectively in curing or preventing a vitamin-D deficiency. The sequence of events during recovery was the same for these other sources of vitamin D as is described below for viosterol. Where smaller amounts of vitamin D were supplied, the recovery was slower and in some cases was not complete because the amount of vitamin D supplied was too small.

Studies were made of the healing and recovery responses of the animal to the various amounts and kinds of vitamin D used. In the early studies it was desirable to feed what seemed to be a large dose of vitamin D that was comparatively free of other materials in order to make sure that vitamin D alone would cure the animals. By so doing any recoveries would be additional proof that a vitamin-D deficiency and not some other deficiency had existed. A concentrated form of vitamin D known as viosterol was used. Five cubic centimeters, about 50,000 International Units of vitamin D, were given daily during the period of recovery.

Recoveries rapid. When enough vitamin D in viosterol was given to cows suffering from a severe deficiency, the recovery was quite rapid. Within a week or so the stiffness and swelling of the joints began to subside and within a month or two the animal was usually moving around in a normal manner. The swelling of the joints decreased but in severe cases did not entirely disappear. The appetite improved almost immediately and the cow soon gained weight, developed a smoother coat of hair, and often produced more milk. When the cow recovered enough to be in good condition, heat periods that had been irregular or missing usually began again. Other phases of the reproductive process also proceeded in the normal way.

Laboratory analyses at this time showed that the calcium of the blood had returned to normal in 1 or 2 weeks, and the inorganic phosphorus in about 2 or 3 weeks. Within a month or two the phosphatase values returned to normal. The cows were then able to make use of the calcium and phosphorus in the feed to meet body requirements. A balance trial at this time showed that the outgo of minerals from the body was much less than the intake. This meant that the animal was storing large quantities of calcium and phosphorus to replace the losses caused by the vitamin-D deficiency. Cows were found to store as much as ½ pound of calcium and ¼ pound of phosphorus in a 10-day period. The vitamin D present in the blood plasma and in the butterfat increased as the amount of this vitamin fed to the animal increased.

Vitamin-D Needs for Normal Health

It is impossible with information available now to give the exact amount of vitamin D necessary to maintain the health of a dairy cow. Enough work has been done, however, as a part of this experiment to give a general idea.

Cows that showed the first symptoms of a deficiency of vitamin D were fed this vitamin during 1942-43 in amounts varying from 1,000 to 6,000 International Units daily. Alfalfa hay of known vitamin-D potency was fed. These experiments were not continued long enough to determine definitely whether these levels would provide enough vitamin D to maintain normal health, reproduction, and good milk production year after year.

1,000 Units not enough. It seems clear that 1,000 International Units of vitamin D daily is not enough. Two vitamin-D-deficient cows started on this amount improved only slightly and then got much worse until given larger doses. Indications are that a cow on 2,000 International Units daily was still not receiving quite enough.

Another cow that calved in July showed definite signs of a vitamin-D deficiency by September and was then started on 3,000 International Units of vitamin D daily. Gross evidences of a deficiency largely disappeared and she gave a fair flow of milk during the year. This level of vitamin-D feeding also proved sufficient to build her up so that heat periods were reestablished the following April. It appears that 3,000 International Units of vitamin D daily may be close to the physiological minimum level for a dairy cow. Whether this would prove sufficient for a period of several years is a question which cannot as yet be answered.

Estimated minimum amounts. Still another cow was fed 6,000 International Units of vitamin D daily for about 9 months. On the whole, the record for this cow is somewhat better than for the one getting only 3,000 Units daily. There is no sharp line of demarcation where it can be said that one animal is well and another is not. There is a gradual change from one condition to the other. For that reason it is not safe to figure too closely in stating minimum requirements.

With the evidence now at hand, it seems safer to suggest that 5,000 to 6,000 International Units of vitamin D daily represents what may be considered a minimum amount to maintain a reasonable degree of health, milk-producing ability, and reproductive efficiency. Ordinarily, two or three times the minimum figure is recommended for general feeding practice. On that basis 12,000 to 15,000 International Units of vitamin D daily would be indicated as a minimum feeding guide.

Assuming a 1 percent recovery, this amount would provide for only the low winter levels of vitamin D in the milk. More work is needed to determine whether such amounts are sufficient for best year-after-year performance.

In practice, direct sunshine would provide a part of the vitamin D for the cow. The amount contributed during the different seasons cannot be definitely stated, but the results of this study raise some question as to whether sunshine is as uniformly effective as has been commonly supposed.

Breed Differences in Using Vitamin D

Some studies were made to find out the differences, if any, in the amount of vitamin D in the butterfat and milk produced where animals of different breeds were fed the same vitamin-D intake. Jersey cows giving a smaller amount of high-testing milk were compared with Holstein cows giving a larger amount of milk with a lower test. Three pairs of cows were used.

Only a comparatively small proportion of the 19,000 Units of vitamin D fed daily was recovered in the milk produced by one pair of cows. The total amount recovered in the milk was practically the same for both cows. The Holstein gave more milk but the Jersey's milk had a higher content of vitamin D per quart. For both cows the amount of vitamin D in the milk represented about 1.50 to 1.75 percent of the amount of vitamin D fed them during the first of the lactation. This

VITAMIN-D CONTENT OF BUTTERFAT AND MILK FROM A JERSEY AND A HOLSTEIN
(19,000 International Units of vitamin D fed daily in alfalfa hay)

	Jersey Cow				Holstein Cow			
Month of lactation	Milk given daily	Butterfat	Vitamin D per gram of butterfat	Vitamin D per quart of milk	Milk given daily	Butterfat	Vitamin D per gram of butterfat	Vitamin D per quart of milk
	lb.	*perct.*	*I.U.**	*I.U.*	*lb.*	*perct.*	*I.U.*	*I.U.*
1	17.0	5.81	0.28	15.9	45.6	3.85	0.31	11.6
2	16.04	6.09	0.53	31.6	55.5	3.82	0.37	13.8
3	16.8	5.40	0.61	32.3	58.0	3.17	0.40	12.3
4	15.6	5.19	0.63	31.8	54.7	2.81	0.43	11.8
5	15.3	5.45	0.63	33.3	41.9	2.06	0.45	9.0
6	13.3	6.11	0.42	24.9	32.2	3.77	0.29	10.6
7	12.9	6.40	0.43	27.0	32.4	3.60	0.25	8.8
8	12.1	6.60	0.49	31.3	32.4	3.30	0.25	8.0
9	7.8	7.20	0.48	33.6	32.1	3.35	0.27	8.8
10	7.38	7.10	0.44	30.3	35.4	3.20	0.23	7.2
11	6.28	8.00	0.43	33.6	33.7	3.49	0.27	9.2
12	----	----	----	----	28.2	3.95	0.26	10.0
13	----	----	----	----	15.5	4.27	0.30	12.5

*I. U.—International Unit of vitamin D

percentage declined to about 0.50 to 0.75 toward the end of lactation. The recovery of vitamin D in the milk was therefore more efficient at higher levels of production.

The general relationships were the same for the other two pairs of cows, although there is naturally some variation in the exact figures.

Holstein limited in roughage. The relationships found exist only where conditions like those of this experiment prevail. To assist in arriving at basic principles, the cows of the two breeds were adjusted to the same vitamin-D intake by limiting the roughage for the Holstein to what the Jersey would eat. Under practical conditions the Holstein would eat more roughage than she was allowed in this experiment, thus getting more vitamin D, so the potency of her milk and butterfat would undoubtedly be more nearly that of the Jersey. It would take more study to find out the exact relationships under these conditions and also to find out what changes would be made by exposing the cows to sunshine as an added source of vitamin D.

In each case the cows were given the same amount of vitamin D in alfalfa hay of known vitamin-D potency. The vitamin-D intake was kept at a constant level throughout the entire lactation period. The vitamin-D potency and the percentage of butterfat in the milk were determined monthly on 3-day composite samples. Feed and milk production records were kept on a daily basis. The cows were kept out of direct sunshine so there was no other source of vitamin D available except the feed.

As has been stated, the results were in general agreement from all three pairs of cows. Some figures from the first pair are shown in the table on page 15. They are typical of the information obtained.

Jersey milk high in vitamin D. The Holstein produced about three times as much milk as the Jersey, but the percentage of butterfat was about half as high. Even though the cows received the same vitamin-D intake, 19,000 International Units daily, the vitamin-D content of the butterfat from the Jersey was about 50 percent higher than the vitamin-D content of the butterfat from the Holstein. This higher vitamin-D potency of the Jersey butterfat combined with the higher percent of butterfat of Jersey milk made the vitamin-D content of a quart of Jersey milk about 30 International Units on the average. The Holstein milk contained about 10 Units per quart. For both cows the vitamin-D potency of the butterfat decreased toward the end of the lactation, but the percentage of butterfat in the milk increased in about the same proportion, so the vitamin-D content per quart of milk remained at about the same level throughout the lactation period.

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