IMPORTANCE OF VITAMIN D IN FEEDING LIVE STOCK

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H. A. L.

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INTRODUCTION

The writer attempts in this discussion of "The Importance of Vitamin D in Feeding Live Stock" to review in part results obtained from experiments by various investigators and research workers. Most of the research work has been done with dairy cattle, poultry, and swine. Very little work has been done with beef cattle and sheep with reference to feeding vitamin D so far as the writer of this manuscript was able to discover.

DEFINITION

The term "vitamin" is a group name of substances other than proteins, fats, carbohydrates and salts which occur in minute quantities in natural food mateerials. They have been found to be essential for normal nutrition and to be responsible for the prevention of various pathological conditions known collectively as "deficiency diseases". At present there are six independent vitamins, the existence of which have been definitely established. (1)

HISTORY

Very little was known about vitamin D until twelve or fifteen years ago, although about 1910 Schaumann and Funk, (2), had decided that rickets was in the category of deficiency diseases. Their conclusions were made from analogy.

Glisson, (3) 1923, a teacher at Cambridge, in the seventeenth century, published a story on rickets, the first full description of the disease. At the present time rickets is known on the continent as "die-englishche-Krankheit," and is common in most of northern Europe, especially in districts of industrial activity. In southern Europe and in the tropics it is fairly rare.

Mellanby, (4) 1918, discovered that in diets consisting of cereals and small quantities of milk which are now known as deficient in vitamin D, that puppies developed soft bones, weak legs, and other difficulties found in rachitic animals. Examination of the bones chemically showed shortage of Ca. Mellanby found the same ration with an addition of cod liver oil, did not develop rickets although other oils failed to remedy the condition. Therefore, the evidence offered by Mellanby shows definitely that the difficulty is one pertaining to the diet.

Huldschinsky, (5) 1924, a German physician, proved that the ultra-violet ray constituted a cure for rickets during the World War. At this same time, and for the following four or five years, scientists disagreed on two discoveries, namely, the anirachitic actions of ultra-violet ray and the specific antirachitic factor in food. Hess, of New York and Steenbock

of Wisconsin, (6) 1924, discovered that antirachitic potency could be developed in a number of different biological materials by the rays of a mercury vapor quartz lamp.

Further investigation showed that a substance in the blood or other material which was activated by ultra-violet radiation was not a fat but a substance associated with fats, an obscure chemical compound called ergosterol.

Heuster and Horth, (7) 1932, recovered one and two-tenths milligrams of ergosterol from a liter of steer blood and Henschel and Schindel, (8) 1932, reported that sterols taken from human adult skin contained .42 per cent ergosterol, while that from infant skin contained 15.15 per cent.

Experiments by Hess and Unger, (9) 1921, showed that exposure to sunlight was helpful in treating animals having rachitic diseases. Hess and Park at the same station obtained the same results.

McCollum, (10) 1937, and other research workers, at Johns Hopkins University, demonstrated that the fat soluable vitamin contained two definite dietary factors. Shortly after this time Hess and Weinstock, (11) 1924, working together, and Steenbock and Black, (12), another pair of research workers proved that food materials containing cholesteral and allied substances were

made rich in vitamin D by exposure to ultra-violet rays. The process, perfected by Steenbock, patent No. 16,808,187 U. S., is the property of Wisconsin University Alumnae Association.

Recently German and English research workers in Europe have made pure vitamin D in crystalline form from irradiated ergosterol. It was the first vitamin to be isolated and handled.

The discovery of vitamins was not the result of an accident, but was a gradual process continuing over a period of many years. It is not the result of sudden discovery by some research workers, but is the combining of information from four or five outstanding scientists.

The steps in isolating pure vitamin D, itself, from irradiated ergosterol were a great deal harder than one may imagine and were not accomplished for more than four or five years. The chief difficulty in the isolation was that when ergosterol was irradiated several other similar substances were formed together. They are distinguished and separated from each other with extreme difficulty. All are said to have the same formula when analyzed, $C_{28}H_{44}O_1$ and to have almost identical structure.

Steinbock, (13) 1930, discovered that it was the fatty ingredients in the diet which were capable of acting. He also found that it is the portion which was in

the non-saponifiable fraction of the fats and oils. He found this to be consistent with the presence of vitamins A and D in the non-saponifiable fractions of cod liver oil. It indicated to him that some of these fractions, when treated with ultra-violet radiation changed into a substance which resembled vitamin D a great deal. Steinbock and a large number of scientists all over the world joined in the research. Cholesterol is found distributed in fats and oils and is present in non-saponifiable fraction. It is important as a compound in the animal body. Cholesterol was treated by irradiation, whereby it became so active that a small amount (fraction of a milligram) added to the daily diet of rachitic rations rapidly healed the rickets. Many inconsistencies were found in the behavior of cholesterol and demanded further investigation.

Windaus, Rosenheim, and Webster, (14) 1934, devoted much time to the study of sterols, and discovered that cholesterol invariably contained a small amount of ergosterol. Ergosterol was found by these men to have a great amount of antirachitic potency. Its power was found to be large enough to account for the irradiated cholesterol containing it.

By repeated boilings of cholesterol with potassium permanganate in an ascetone solution, Steinbock succeeded in separating ergosterol and obtaining a pure

cholesterol which could not be activated by ultra-violet irradiation.

Neilson, working with ergosterol, (15) 1935, thought it to be the only substance which can be converted into vitamin D. It is inactive itself but when irradiated it becomes 1,000,000 times as potent an antirachitic as cod liver oil. A daily dose of 1/10,000 of a milligram of irradiated ergosterol fed to rats with severe rickets caused advanced healing in one week. One ounce of irradiated ergosterol is equal to from three to five tons of cod liver oil in terms of vitamin D potency.

Ergosterol is unstable. It turns yellow on standing and is best kept in an ice box. It is difficult, indeed, to obtain ergosterol free from other sterols associated with it in nature, such as cholesterol in animals, phytosterol in plants, and zymosterol in yeast. The small amount of fat in human skin contains, according to Neilson, ten to twenty per cent cholesterol and probably less than .01 per cent of ergosterol.

The great potency of pure vitamin D for the extremely small quantities of it present in foods may be judged from the fact that it is no less than 1,000,000 times more active than cod liver oil. In other words, a tablespoon full of cod liver oil contains about one-millionth of an ounce of pure vitamin D itself.

Ergosterol was first prepared about 1890 from ergot from which it derives its name. It is represented by the formula C_{27} H_{42} O_1. Its exact structure is not known. The melting point for almost pure ergosterol is 190 C. It is a small white crystalline substance, odorless and tasteless, soluable in 506 parts of alcohol, 112 parts of ether, 20 parts of chloroform. It is also soluable in acetone, benzol, ether and other organic solvents and it is precipitated from a solvent by degetonin. Only specific kinds of ultra-violet rays dissociated the electtrons in the compound causing them to give up their negative charge.

When ergosterol is irradiated, vitamin D begins to form. This change continues to a certain point after which a destruction of vitamin D begins to take place at about the same rate as the original conversion. When all the ergosterol has been converted, most of it has, at the same time, been decomposed, and if the change is continued all of the vitamin D will finally be destroyed.

SOURCES AND IMPORTANCE OF VITAMIN D

Sunshine is the chief source of vitamin D for the benefit of the animals. Modern methods of living have placed obstacles in the way of enjoying the benefits of sunshine to its just extent. Dirt particles hanging over every square mile of our large cities reduces the transmission of the effective ultra-violet rays

from sunlight. Shadows cast by buildings also diminish the benefits of sunlight; moreoverm more of the world's work is done indoors than ever before, where window glass, which is impervious to ultra-violet rays,deprives office and factory workers of this source of vitamin D. Experiments on protective clothing demonstrate that even in the sunlight man gets little good from the ultra-violet ray if present. Experiments by Tisdall and Brown, (16) 1932, as well as some other research workers, proved winter sunshine to be only one-eighth as potent as summer sunshine. They also proved that country sunshine is effective only between the hours of 10:00 a. m. and 2:00 p. m. because, according to the authors, the sun rays must pass through a great deal more of the atmosphere before or after these hours.

Most of the known vitamins are rather widely distributed among foods with the exception of vitamin D. Egg yolk is very rich in vitamin D when eggs are from hens that have received plenty of vitamin D in their feed or have an abundance of sunlight. Legume hay, butter and milk, including breast milk, contain only small amounts, and all other foods contain very little, if any, vitamin D. Among the drugs or medicines four sources of vitamin D are available. They are cod liver oil, blue finn tuna liver oil, halibut liver oil, the latter coming into prominence within the past three or

RAT UNIT EQUIVALENTS

	International Units	USP Units	Steenbock Units	Amer. Med. Ass. Units	Amer. Drug Mfrs. Assn. Units	One D Unit	Oslo Units
1 Inter. unit equals		1.00	.37	.37	3.25-3.70	.028	1.67
1 USP unit equals	1.0		.37	.37	3.25-3.70	.028	1.67
1 Steenbock unit equals	2.70	2.70		1.00	10.00	.075	4.50
1 Amer. Med. Assn. unit equals	2.70	2.70	1.00		10.00	.075	4.50
1 D unit equals	36.00	36.00	13.33	13.33	13.30		60.00
1 Oslo unit equals	.60	.60	.22	.22	2.22	.017	
1 Am. Drug Mfrs. Assn. unit equals	.27	.27	.27	.10		.008	.45

Vitamin D's descriptive terms are not generally understood by the public and the comparative explanation is shown above. Some of the equivalents for the common rat units are calculated in the above table. This table is copied from "Antirachitic Activity of Vitamin D Suppliments for Poultry." Drs. Hazel E. Munsell and E. M. Nelson, both of the USDA and Professor E. Poulson of Statens Vitamin Institute of Oslo, Norway, contributed a great deal of information about differences and relationships of the various vitamin D units. (17)

four years, and irradiated ergosterol in corn oil or some other vegetable oil solution, marketed as Viosterol. Cod liver oil fortified by the addition of enough irradiated ergosterol to place the vitamin D potency up to ten times that standard cod liver oil, has been used a great deal. Tuna liver oil has been used only the last two or three years and is reported to be very potent.

Nature, apparently, intended animals to synthesize this substance rather than get it from food. The skin contains a small quantity of ergosterol that is changed into vitamin D when it is exposed to the proper kind of sunlight or artificial ultra-violet ray.

In addition to being an antirachitic agent vitamin D is also an important factor in osteoporsis.

Pure vitamin D substances are also known as calciferal and were isolated to a more or less degree of perfection by Windauss, (18) 1931, and his co-workers in the years 1931-1932. Work done on vitamin D of a recent date shows also that there are several forms of vitamin D.

Comparative concentration of vitamin D sources

Egg yolk	13-16	IU
Cod liver oil	100	IU
Halibut liver oil	1,200	IU
Blue finn tuna liver oil	40,000	IU

IU--International units per gram of substance

VITAMIN D FED TO CATTLE

In research work done with reference to dairy cattle at the Ohio Experiment Station, (19) 1936, it was found

that the function of vitamin D is to help in the assimilation of Ca and P, the two elements necessary for the proper growth of the skeleton. Despite the availability of the reliable sources of vitamin D rickets and dental caries resulting from malnutrition are still common. In view of this a great deal of work has been done by research workers to increase the vitamin D content of some of the common foods such as milk.

The successful developments of several of these methods for increasing vitamin D content of milk has created many differences as to the best methods to use.

There are at the present time several methods of producing vitamin D milk. (a) By feeding irradiated yeast to cows, (b) By adding cod liver, halibut liver oil, and blue finn tuna liver oil to rations, and, (c) By irradiated milk. The use of cholesterol at the present time is too costly to feed to dairy cows on a commercial basis. This, however, has been done by research workers at some few experiment stations, but at the present time the cost is prohibitive for live stock. Standard Brands, Incorporated, (20) 1936, of New York, has cooperated with many research workers in supplying irradiated yeast which was used to increase the vitamin D content of milk.

McCollum, (21) 1937, in a letter dated January 4, 1937, states that in his opinion much is to be learned

about feeding vitamin D foods such as yeast and cod liver oil, as well as other fish liver oils to cattle. McCollum also states in his letter that exposure of cows to sunlight is in his opinion, rather doubtful in the production of vitamin-D-ized milk. Irradiation of cows by ultra-violet rays has produced milk of higher vitamin D content than ordinary milk, but the cost is prohibitive.

Hart, (22) 1937, states that cows do not absorb cod liver oil and fish liver oils very readily and, therefore, do not put much vitamin D into their milk from such food. The best results obtained were those experiments from feeding irradiated yeast. This method of feeding yeast is used by certified milk producers in various parts of the country.

Webb and other research workers, (23) 1934, found that in feeding yeast and irradiated ergosterol in the production of vitamin D milk, an increase in the amount of potency of the milk, in terms of vitamin D, was obtained in both products but less than two parts of the units of the antirachitic factor which was fed to the cattle.

Irradiated yeast produced the following results: Production of vitamin D milk by this method is done by feeding irradiated yeast to the cows. The amount of yeast fed in the rations is based on the quantity of milk the cow produces. Milk from cows fed the correct amount of

irradiated yeast contains about 160 Steenbock rat units (see table on page 9) of vitamin D per quart of four per cent butter fat milk. The advantage of this system of vitamin-D-izing milk is that milk contains the correct amount of vitamin D and requires no further increase in the potency of the D content. As stated before, the cost of this method of producing vitamin-D-ized milk by the average dairy is high and cannot be used commercially until the price of irradiated yeast is lowered or price of milk raised.

Russell and Wilcox, (24) 1933, fed cod liver oil to six Holstein cows after a preparatory period of 17 days. Vitex made from cod liver oil by the National Oil Products Company of Harrison, New Jersey, supplied the vitamin D in the rations. Milk from these cows was carefully tested for butter fat before the experiment with Vitex began and the vitamin D content noted. After carefully checking the results it was found that the vitamin D content changed from 2.76 Steenbock units (see table on page 9) per quart to 30.35 or about eleven times as great. Again the cost of production of vitamin-D-ized milk by this method renders it useless as a commercial commodity.

The same research workers found that a cow receiving ten ounces of 30 International Units (see table on page 9) of D yeast daily in three equal samples of milk and

blood collected during the following four hours increased D content very little. Chemical tests showed that practically all of vitamin D given was absorbed into the blood stream within four hours from which it disappeared rapidly. The rate of disappearance increased with the concentration of the blood. The concentration of vitamin D in the milk was directly proportional to that of the plasma.

Huffman, Duncan, and Lightfoot, (25) 1936, in another experiment found that it required more than ten times the rat equivalent amount of vitamin D in metabolized yeast than in irradiated milk to produce the same antirachitic effect. The data indicated that the vitamin D in milk resulting from the feeding of irradiated yeast to the cow is in the same biological form as that fed to the other animals.

A monthly assay of milk fat from several sources over a period of two years showed that milk may vary as much as 200 per cent in antirachitic potency, the highest value in July, August and September; the lowest in February. Vitamin D value ranges from 418 to 43.8 U. S. P. units (see table on page 9) per quart of milk were observed in the case of the Guernsey milk and for Holstein were 3.1 to 27.7 units per quart. The correlation between the antirachitic potency of milk and the available sunshine indicated that the exposure of the cow to sunlight

is the major factor contributing to the vitamin D content of milk. The cow has little or no chance to store vitamin D during lactation.

EFFECT OF SEASON OF YEAR ON VITAMIN D CONTENT OF MILK

Date	Daily Hours of Sunshine	Vitamin D per Quart Station Herd	Creamery
1933			
July	12.8	17.3	8.7
August	10.8	17.3	6.7
September	7.1	20.7	9.7
October	6.0	12.5	4.9
November	2.0	10.6	2.9
December	1.4	8.7	4.2
1934			
January	2.3	7.5	3.4
February	5.9	8.3	4.2
March	5.0	7.5	
April	6.0	13.9	4.2
May	11.3		

Thomas and McCloud, (26) 1931, found that by feeding cows irradiated yeast and ergosterol it was possible to increase vitamin D content of butter fat of milk as much as sixteen times. Yeast was more effective than ergosterol. Roemmele and Stohr, (27) 1932, found that vitamin D feeds in rations for cows produced no benefit and irradiation of cows increased the antirachitic value of milk.

Bethke and Krauss, (28) 1933, stated that 10 cc of milk from cows receiving either a high or low protein ration when fed to rats increased the ash content of the rat femur above that produced by rickets-producing ration.

The milk produced on the low protein ration caused the greater deposition of Ca. in the femurs. Butter fat from cows receiving one kilogram of irradiated dried brewer's yeast daily for three weeks showed a five-fold increase in the vitamin D content.

In an experiment carried on by Bethke and Krauss, (29) 1936, with more than one hundred calves with low vitamin D rations the following results were obtained. Holstein calves weighing from 151 to 539 pounds were used. In this experiment the decrease in the concentration of Ca and P in the blood was the first sign of low vitamin D rickets. The post-mortem findings were those which accompanied the blood changes and which occurred in the bones. The skeleton changes were weakening of the legs, both front and hind, enlargement of end joints, straightening of pasterns, and humping of back. Symptoms observed other than those mentioned, were stiffness of gait, dragging of feet, irritability, tetany, fast breathing, weakness, and inability to stand for any length of time and the secession of the increase in body weight.

Examinations of the rachitic calves upon the post-mortem showed that the main changes were confined to the skeleton. From this experiment the research workers concluded that low vitamin D rickets in dairy calves is characterized by changes in the bones. Slow calcification

of cartilage appears to be the fundamental change in rickets. Growth is a modified factor in rickets; in other words the more severe rickets occurs in the more rapidly growing dairy calves. Age also is a factor in the development of rickets.

Smith and Briggs, (30) 1933, found alfalfa hay, when sun-cured and fed as a supplement to calves at the rate of two and one-half pounds daily, showed no rickets, whereas dehydrated alfalfa hay resulted in the development of mild rickets.

Hess and associates (31) 1934, reported that green plants stored in the dark were devoid of antirachitic properties but by irradiation with ultra-violet ray made rachitic. Experimentors reported that prairie hay may carry an appreciable amount of vitamin D and that cured alfalfa hay fed as an experiment to calves at the 2.5 per cent daily level showed no rickets, whereas dehydrated alfalfa hay results in the developing of mild rickets.

VITAMIN D FED TO SWINE

Golding and his associates (32) 1925, in an experiment with pigs at Cornell, showed that twenty-three cases of stiffness were produced by a lack of vitamin D and therefore, a shortage of Ca and P. Vitamin D was not mentioned in this experiment, however, but that it played an important part in overcoming the stiffness was evident

even though not recognized by scientists during the experiment. Pathological studies involved thirty-eight animals, including twenty-three cases of stiffness.

Lesions were found in the long bones. These findings were based on a comparative study of the bones of eighteen stiff pigs and eleven normal pigs. Difficulties such as imperfect calcification, tranulation, granulation of tissues, degenerated areas of cartilages and joints and hemorrhage were noted. Routine examination of blood of the stiff pigs showed no leucocytosis and no anemia. The chemical analysis of the femurs of the pigs showed a marked lowering of content of the Ca and P.

In two out of three cases tried, the stiffness was not relieved by the addition of bone meal and Ca and P feeds.

In the trial in which the chemical examinations were made, marked relationships were demonstrated by the Ca content of the ration and the state of the calcification of bones.

In the same experiment,even though the experimentors were unaware of the vitamin D and its work, the use of Ca and P with the aid of vitamin D supplied in the fish oil, gave evidence that it was of great value.

Horn (33) 1934, fed pigs a diet of barley, and fish meal and meat meal showed definitely the beneficiary effect and increased weight rapidly with the vitamin D-containing food.

A ration consisting of barley, soy beans, fish meal, potatoes, and lime was fed with and without the additional preparations (Vigantal) a vitamin D-containing compound. This was done in 1935 by Kronacher and his associates and had no effect on the pigs. (34)

Loeffel and associates, 1931, (34x), carried on an experiment with swine, using (a) sunlight and cod liver oil, (b) sunlight as a preventive by itself, (c) cod liver oil without sunlight.

In trial (a) it was found that sunlight and one per cent of cod liver oil added to the basal ration prevented rickets in pigs fed a ration deficient in vitamin D. Similarly the same antirachitic substances induced healing in pigs suffering from a severe form of rickets. In trial (b) it was found that direct sunlight prevented rickets in pigs fed a ration deficient in vitamin D, while another group of similar pigs on the same ration but denied exposure to direct sunlight developed severe rickets. In trial (c) it was found that cod liver oil fed at the rate of 0.75 per cent of the basal mixture did not prevent mild rickets in pigs fed indoors on a ration deficient in vitamin D. When the cod liver oil was increased to one per cent of the basal mixture recovery of those pigs already affected took place and further trouble from rickets was prevented. Severe rickets developed in another group of similar pigs receiving the same ration but denied both direct sunlight and cod liver oils.

The ration used in this experiment consisted of:

	Pounds
Yellow corn	73.5
Soybean oil meal	15.5
Blood meal	4.5
Dried skim milk	5.5
Sodium chloride	1.0
	100.0

In the three different trials all animals received the same feed except where cod liver oil was added as an antirachitic substance. These animals were hand fed twice daily, morning and evening. In all the trials the daily record of the feed used was kept. Each lot received as much feed mixture as they would consume in two hours without waste. A check was made of all animals at feeding time and variation in appetite was noted. Water was available at all times in troughs.

VITAMIN D FED TO POULTRY

The presence of vitamin D in egg yolk was first demonstrated by Mellanby (3), 1923, when he cured a dog of rickets by adding it to the dog's ration. Hueser and Norris (35), 1933, pointed out that egg yolk was one of the first foods which possessed definite prophylactic and collective properties against rickets.

Hart and associates (36), 1930, stated that the vitamin D potency of egg holk from hens exposed daily to the radiations of quartz lamps was approximately ten times that of an egg yolk from non-irradiated birds.

Recent investigation shows that the antirachitic content of an egg is dependent upon the amount of vitamin D fed to the laying birds. At the same time it was found that the vitamin D of cod liver oil is more efficiently stored in the egg than in the equivalent amount of irradiated ergosterol (viosterol). In 1936 it was reported that the vitamin D potency of egg yolk from yearling hens nearing the end of the period of egg production was greater than the vitamin D content of the egg from pullets at the beginning of their first period of production. The same investigators stated that hens on a ration supplemented with 25 Steenbock units of vitamin D produced eggs which contained 7.2 Steenbock units per egg yolk. The relation between vitamin D and the Ca and P metabolism caused some investigators to study the effect of the antirachitic factor on the Ca and P content of eggs and the 21-day-old embryo. It was discovered at an earlier date that irradiation of hens with ultra-violet light increased markedly the amount of the lime in the egg shell as compared with the eggs from the non-irradiated hens, but that the light treatment did not change the Ca and P present in the white and egg yolk. This work was done by Berthke, Kennard, Kick, and Zanazalian, (37), 1936.

In the experiment carried on by Rankin, (38) 1933, with reference to feeding cod liver oil to chicks from

sixteen to twenty-four weeks old without sunshine, required a minimum of about eight U. S. P. (see table on page 9) units of vitamin D per hundred grams of ration. It was found that for the first sixteen weeks there was apparently an insufficient amount of sunshine to supply these pullets the necessary amount of vitamin D for satisfactory bone formation. With the same conditions it appeared that ultra-violet irradiation from sunshine would supply satisfactory calcification for the summer months, May to September.

When sufficient amounts of vitamin D from cod liver oil were present in a ration it seemed that the sunshine did not increase or retard growth.

Pullets proved to have the ability to store vitamin D during the growing period, which apparently was not exhausted until after three months of egg production. Insufficient amounts of vitamin D from the cod liver oil or ultra-violet irradiation from sunshine retarded egg production.

When a supply of vitamin D from cod liver oil or ultra-violet irradiation from sunshine was available the eggs of the various chickens were of average weight, but with a shortage in the supply of vitamin D the weight was greatly reduced.

These egg studies indicate that when insufficient amount of vitamin D is supplied that the eggs produced were of small size and inferior quality.

Carver and co-workers (39) 1933, in treating chicks by ultra-violet lamp radiation, proved to be proficient; however, commercially speaking, it is not considered worthwhile.

Edison (40), 1931, in an experiment where Ca and P requirements were being studied for growing chicks, found that an addition of cod liver oil to the ration greatly improved the utilization of Ca and P in bone building.

Vitamin D was proved to be an important factor in hatchability and egg production in some work carried on by research done in Ontario Agriculture colleges (41) 1930. Viosterol (irradiated ergosterol) was found to be less valuable than cod liver oil in egg production and hatchability. Hens showed in this same experiment a high resistence to overdosage with vitamin D.

Work done by Insko and Nelson, U. S. D.A. research workers, (42) 1933, showed the relative efficiency of different quantities of cod liver oil and viosterol in the diet of the hen for vitamin D storage varied a great deal from November through July. At the same time it was discovered that cod liver oil is more efficient in storing vitamin D in the egg yolk than in an equivalent amount of viosterol. Antirachitic values of egg yolks varied with the potency of the viosterol in the hens' diet. Hens subjected to fifteen minutes of irradiation with a carbon arc lamp had the same effect on vitamin

D storage as one per cent of cod liver oil in the diet.

An experiment carried on in the South, reported by "Poultry Science" (43) 1932, showed consequently that leg weakness of chicks improved a great deal upon exposure to sunshine. Variations with seasons in effectiveness of sunshine varied a great deal on latitude and on the altitude of the sun. A wide variation as to the amount of exposure given to the chickens showed, conclusively, that the best time for sunshine is in the summer months.

At the Wisconsin Station, an experiment carried on by Halpin, Holmes and Hart (44) 1931, with chicks suffering from rickets proved that ultra-violet ray and cod liver oil were of use in overcoming this condition.

Data used in the statements below are from work done by Holmes, Piggot, and Menard (45) 1932. The storage of vitamin D in day old chicks is dependent upon the intake of the hens. Ergosterol was proved to be more efficient than cod liver oil. Another interesting fact discovered in this experiment showed that the egg contained the same biological amount of vitamin D as was in the hens.

DISCUSSION

Data in this manuscript show that vitamin D produced by ultra-violet rays from sunshine is nature's method of preventing rickets in live stock. The fact that rickets is almost unknown in the tropics and that the disease increases in the temperate and frigid zone is conclusive evidence that sunshine is antirachitic in its action.

Much work has been done in feeding vitamin D to live stock and a great deal is being carried on at the present time. However, the general use of vitamin D from commercial sources is not recommended due to cost and lack of knowledge. The relation of vitamin D to Ca and P in the metabolism of the skeleton is of great importance and should be handled by trained investigators.

The data also indicate that two methods of producing vitamin-D-ized milk have been proved successful, namely: (a) feeding irradiated yeast to cows and (b) the exposure of dairy animals to sunshine. Feeding irradiated alfalfa to cows is worth consideration, but treatment by ultra-violet rays from arc lights and the use of cod liver oil are not worthwhile according to the best authorities. Rickets, which is a common disease among young animals, can also occur in adults. Supplementing feed with cod liver oil and other fish liver oil containing vitamin D is the best method of

combating this difficulty where sunshine is insufficient. Commercial feeds of many kinds now contain vitamin D. Cod liver oil, which does not have the potency that halibut and blue finn tuna liver oils contain, is used more commonly because it is cheaper. However, the latter two compounds are becoming more and more common.

Cod liver oil, when fed in overdoses,may damage the heart and in extreme cases cause a calcification to take place in the blood vessels.

Quality of milk may be improved by feeding vitamin D feeds to cattle, but the quantity is not affected. Feeding cod liver oil to hens increases egg production as well as the hatchability of the egg. Feeding cod liver oil to swine improves the quality of the bones and prevents or cures rickets in young pigs.

SUMMARY

Data presented in this manuscript point out conclusively that vitamin D is of great importance in feeding dairy cows:

1. The amount of vitamin D found in milk may be increased by feeding irradiated yeast to dairy cows. This method is the best way of producing vitamin D milk, according to such authorities as McCollum, Krauss, Steenbock and others.
2. Irradiation of cattle is classed by most investigators as a less valuable method of producing vitamin D in milk. However, due to the fact that sufficient amounts of sunshine are available only during the summer months, it follows that unsatisfactory results are obtained.
3. Ultra violet treatment to dairy cows increases the vitamin D content in milk but is considered impracticable.
4. Cod liver oil, according to McCollum, is not handled very well by the dairy cow's digestive system. Other fish liver oils such as halibut and blue finn tuna cannot be used for the same reason.

5. Feeding irradiated alfalfa and other roughages to cows has not proved to be of much value since vitamin D is an unstable compound.

Feeding cod liver oil to poultry at various experiment stations show that in practically every instance the following results were obtained:

1. The quality of the egg was improved.
2. The vitamin D content was increased.
3. The hatchability was improved.

Feeding cod liver oil to swine was found to be of much value as shown by results obtained from several experiments carried on at different stations. Investigation with a combination of cod liver oil together with plenty of sunshine gave the best results with swine. Sunshine and cod liver oil, when used separately, did not prove satisfactory. However, the cod liver oil was found to be superior.

The use of vitamin D in combating rickets is known to be very valuable as brought out in this manuscript, but is recommended to be used by the more experienced poultrymen, dairymen and swine producers. The supply of vitamin D from sunshine is the best method of combating rickets, especially when supplemented by cod liver oil fed by experienced individuals.

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