

SUNLIGHT IN OKLAHOMA AS AN IMPORTANT FACTOR IN THE PREVENTION OF RICKETS AND THE MAINTENANCE OF NORMAL CALCIUM AND PHOSPHORUS METABOLISM

WILLIS D. GALLUP AND A. H. KUHLMAN

Oklahoma A. and M. College, Stillwater

INTRODUCTION

The prevention of rickets and the maintenance of a normal calcium and phosphorus metabolism in animals and human beings is a problem of major importance. The two processes are closely related and both depend upon an adequate intake of vitamin D, or its equivalent in exposure to ultraviolet rays.

Glisson (1650) is given credit by most writers as having first identified rickets as a definite disease. Palm (1890), following a study of the geographic distribution of disease in the British Isles and the Orient, came to the conclusion, the correctness of which has been amply confirmed in recent years, that rickets is associated with lack of sunshine. He pointed out that rickets was more common in thickly populated than in rural areas and advocated the systematic use of sun baths and the removal of rachitic children from crowded cities to sunny localities.

Credit for discovery of the curative action of ultraviolet rays is usually given to Huldchinsky (1919), who treated four cases of advanced rickets in children with ultraviolet rays from a mercury vapor lamp and demonstrated that calcium salts were deposited in the ends of the long bones as a result of this treatment. Shortly thereafter, Hess and Unger (1921) and others proved that sunlight likewise had curative properties and would prevent rickets in experimental animals. Further research revealed that the effective rays of the sun were in the ultraviolet region of from 296 to 310 millimicrons.

During the time these studies were in progress, other investigators followed the theory that rickets resulted from a dietary deficiency. The experiments of Mellanby (1919), with puppies made rachitic on a restricted diet or kept healthy by the addition of certain foods, although open to criticism, paved the way for the establishment of a relationship between rickets and a dietary deficiency. Mellanby found cod liver oil to be far superior to other oils and fats for the prevention of rickets. It remained for McCollum and his associates (1922) in this country to present direct proof of the curative properties of cod liver oil and show that the curative substance was other than vitamin A. The antirachitic substance was given the name vitamin D.

Exponents of the theory that rickets is due to lack of sunshine and those who held to the idea that rickets is due to a dietary deficiency were confused by these seemingly conflicting reports. Subsequent research with more refined techniques clarified the situation. The discovery was made that after exposure to ultraviolet light ordinary fats and oils and a variety

of foods possess the antirachitic properties of cod liver oil. The substance in these materials which is activated by ultraviolet and solar radiation, and present in an activated form in cod liver oil, was found to be a sterol. Likewise, it was found that the sterols in or on the skin, fur, wool and feathers of animals become antirachitic upon ultraviolet irradiation. Ingestion of these materials, as is the habit of animals, or absorption of irradiated derivatives through the skin, affords protection against rickets. Thus, the relationship between ultraviolet radiation and cod liver oil in the prevention of rickets became evident.

Little is known about the origin of the antirachitic sterols in cod and other fish liver oils. The sterol of yeast, ergosterol, after irradiation and purification has become known as calciferol, vitamin D₂. Viosterol in oil is such a compound. The sterol of the higher plants and animals which becomes antirachitic upon irradiation is 7-dehydrocholesterol, and is thereafter called vitamin D₃. Other sterols of lesser importance, some of which can be activated and others that can not, have been discovered from time to time. Irradiated yeast has been placed on the market as a supplemental feed for animals, particularly for dairy cows as a means of increasing the vitamin D content of milk.

Soon after the discovery of vitamin D, experiments were conducted to determine the minimum amount of vitamin D required to prevent rickets in animals of different species under varied experimental conditions. From the results of this work, it appears that vitamin D requirements are dependent upon such factors as the size of the animal, its rate of growth, stage of life, productive capacity, etc. These might be termed "internal factors." It is also dependent upon dietary factors, especially the amount of available calcium and phosphorus in the diet and the ratio that exists between these amounts. These dietary factors might be considered "external factors." When the absolute amounts of calcium and phosphorus in the diet are large, the relative amount, i. e., the calcium: phosphorus ratio, becomes less important. When the absolute amounts are small, the ratio is of first importance. A ratio of about 1.5 parts of calcium to 1 part of phosphorus is close to the optimum for the prevention of rickets. With this ratio in the diet, vitamin D requirements are at a minimum. Dietary substances that form insoluble compounds with either calcium or phosphorus, thereby interfering with their absorption from the intestinal tract, increase vitamin D requirements and may produce rickets. In contrast to this is the effect of certain organic acids and their sodium salts which, when present in the diet, apparently favor the absorption of calcium and phosphorus and decrease vitamin D requirements. Further, it has been found that the form in which vitamin D is supplied is not without influence. Irradiated ergosterol, for example, is less effective than irradiated 7-dehydrocholesterol in supplying the vitamin D requirements of chicks.

These facts have been briefly mentioned here since they bear upon the problem of supplying vitamin D in an economical manner to animals under practical conditions. The addition of vitamin D supplements to rations for farm animals has been advocated in recent years and has become a regular practice in some localities. The possibility that sunlight would furnish an adequate amount of vitamin D for animals in Oklahoma suggested itself during a study of the vitamin A requirements of dairy cattle.

EXPERIMENTAL

A large number of Jersey calves were raised from birth in individual pens in a wing of the dairy barn which had windows on the east, south and west. When the weather permitted, these windows and large double doors on the south were kept open. Ample light and circulation of outside air were thus available. The calves were given a basal ration which was devoid of vitamin D, being composed of cottonseed meal, beet pulp and bone meal. During the first 6 weeks, however, the calves were given whole milk which carried with it a variable amount of vitamin D. After this 6-week period, skim milk was fed until the calves were 6 months old. Carotene supplements were fed as necessary to supply vitamin A. The ration supplied liberal amounts of calcium and phosphorus in a ratio somewhat greater than 1:1. Other groups of calves were raised under identical conditions but were supplied with variable amounts of vitamin D by replacing a part or all of the beet pulp in the basal ration with sun-cured prairie hay. Other calves were given a vitamin D concentrate in addition to the basal ration and still others were allowed outside exposure as a source of vitamin D. The calves were weighed at regular intervals and examined for gross symptoms of rickets. Determinations of the total calcium and inorganic phosphorus of the blood plasma were made, usually at 10-day intervals. When these values indicated the onset of rickets, the calves were either turned outside daily or supplied with dietary sources of vitamin D. The experiments were continued through several seasons in different years.

RESULTS AND DISCUSSION

Important results obtained in this study are summarized in table I. The ages and dates given in this table correspond with the times at which vitamin D supplements were given. The figures given for the calcium and phosphorus content of the blood plasma are the results of single determinations and are representative of the values obtained for several weeks preceding and several months following the addition of vitamin D to the ration.

In general, vitamin D deficiency symptoms appeared when the calves were about three months old. Rickets was well established before the calves were six months old. The antirachitic value of sunlight, even during the winter months, is demonstrated by the increase in blood calcium of all calves after they were turned outside. This change was usually brought about within ten days after the animals were turned out, during which time and after which the condition of the animals steadily improved. Changes in blood phosphorus were small and irregular. The performances of two calves not shown in table I confirm and extend the above results. These two animals, 1604 and 2604, were raised on the basal ration of beet pulp, cottonseed meal and bone meal plus daily supplements of carotene. After being bred at the age of about 18 months, both heifers completed their gestation periods in good condition and produced normal calves. One has completed her first lactation period. During all this time, vitamin D requirements have been met entirely by solar radiation.

The antirachitic value of sun-cured prairie hay is shown in the blood calcium and phosphorus values of calves 2224 and 2138. Blood calcium never reached a low level in these animals and was increased only slightly when they were allowed outside exposure. A full hay ration (see record

TABLE I
Effect of vitamin D supplements on the Ca and P content of blood plasma of calves
 (Summary of records of representative animals)

Calf No.	Age	Date	Roughage in basal ration	Ave. daily intake		Daily vitamin D supplement	Ca and inorganic P in blood plasma			
				Ca	P		before vitamin D supplement	after vitamin D supplement		
							Ca	P	Ca	P
							mg percent	mg percent	mg percent	mg percent
169	158	July	Beet pulp	24	20	Sunlight	7.30	7.20	11.10	6.00
514	168	Sept.	Beet pulp	17	14	Sunlight	9.15	4.38	14.52	5.16
174	131	Nov.	Beet pulp	22	16	Sunlight	8.18	7.44	11.39	6.69
2224	181	May	Beet pulp and hay ¹			Sunlight	10.75	7.75	13.79	6.67
2138	191	June	Beet pulp and hay ¹			Sunlight	11.70	7.12	13.56	7.38
412	120	Jan.	Beet pulp	16	14	30 ml aerated cod liver oil	7.97	6.45	13.50	5.76
176	79	Feb.	Beet pulp	14	10	1 ml viosterol	10.04	6.48	11.90	8.10
337	126	Nov.	Hay ¹			None	12.24	6.90		

¹The amount of hay fed to No. 2224 was restricted to approximately 25 percent of a normal hay allowance; No. 2138 received double this amount, and No. 337 received a full hay allowance.

of calf 337) provided sufficient vitamin D to prevent rickets and maintain normal calcium and phosphorus values in calves raised under the experimental conditions described. Had the calcium and phosphorus content of the ration been lower, or had the animals been housed in semi-darkness as sometimes occurs under practical conditions, less favorable results might have been obtained with the hay rations. Viosterol and cod liver oil which had been aerated to destroy vitamin A were effective in preventing and curing rickets in the calves. Both of these supplements supplied vitamin D in amounts considerably above the minimum requirement, 300 units per day per 100 pounds live weight, found by Bechdel, et al. (1938).

Coons, et al. (1935), after comparing the calcium and phosphorus retention of expectant mothers living in Chicago with that of a similar group living in Stillwater, expressed the opinion that the higher retention of the latter group was due to the increased vitamin D they received through sunlight. The results obtained in the present study lend support to this contention. The total number of hours of sunshine throughout the year in Oklahoma is high, Oklahoma City ranking fourth in this respect among thirty leading cities in various parts of the nation.

SUMMARY

Calves kept in a well lighted and ventilated barn and fed rations lacking in vitamin D but containing adequate amounts of calcium and phosphorus in a ratio slightly greater than 1:1 developed rickets when they were between three and six months old. The calcium content of the blood plasma decreased from about 12 mg per 100 ml to less than 9 mg; the changes in blood phosphorus were irregular. Sun-cured prairie hay and vitamin D concentrates protected the animals against rickets. Rachitic calves recovered and blood calcium and phosphorus returned to the normal level when the animals were allowed outside exposure during several seasons of the year. The results indicate that solar radiation in Oklahoma is sufficiently antirachitic to protect calves against rickets, providing the animals receive sufficient amounts of calcium and phosphorus in their ration. Calves in confinement require additional vitamin D.

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