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A. B. CONNER, DIRECTOR
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DIVISION OF DAIRY HUSBANDRY

Sorghum Silage as a Source of Vitamin A for Dairy Cows

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Butter fat from a cow fed only cottonseed meal and hulls over a long period of time contained only about 2½ units of vitamin A to the gram. Cows restricted to cottonseed meal and hulls suffered from night blindness and become very sick; two of them died, two were cured by administration of cod liver oil, and one by fresh green grass. The low vitamin A content of the butter fat, the cure of the cows by cod liver oil, and the symptoms of the diseases show that these cows did not receive enough vitamin A. Cows fed sorghum silage in addition to the cottonseed meal and hulls produced butter fat low in vitamin A and variable in that constituent. The cows showed symptoms of night blindness and one of them had symptoms typical of deficiency of vitamin A. The sorghum silage fed in large quantity did not furnish enough vitamin A to produce butter fat of high potency and apparently furnished not quite enough vitamin A for maintenance and good health. Cows receiving pasture in addition to the cottonseed meal, hulls, and sorghum silage produced butter fat high in vitamin A and containing about 9 times as much per day per cow as that from the cow fed sorghum silage. A tentative estimate that the cow received 106,000 units a day in vitamin A but produced only 1960 units a day in the butter, indicated that the dairy cow has a high requirement for vitamin A, either on account of destruction during the process of digestion or high maintenance requirements during lactation or both.

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SORGHUM SILAGE AS A SOURCE OF VITAMIN A FOR DAIRY COWS

O. C. COPELAND AND G. S. FRAPS

Silage is fed to milk cows quite extensively throughout the leading dairy sections of the United States and is recognized as one of the cheapest and most satisfactory succulent feeds available in large quantities. Silage is usually fed during that part of the year when pasturage is poor or unavailable; however, some dairymen feed silage the entire year to cows which have access to good pastures at least a part of the year.

Dairy cows have the capacity for storing large quantities of vitamin A (11) so that the large reserve of this vitamin stored up in their bodies during the pasturing season in addition to that furnished in the hay, silage, and other feeds will usually carry them through the dry-lot feeding period to the next pasturing season without any noticeable effects of an undersupply of vitamin A on the health of the animal.

Since silage is prepared from green feeds, it would be natural to assume it to be high in vitamin A. Very little definite information is available concerning the vitamin A content of silage. Scheunert (8) lists silage made from green fodder along with green feeds, hay, and sugar-beet leaves as a good source of vitamin A. He states that "ensiled green feeds contain vitamin A at the most, in slightly smaller amounts, if any, than the green feeds not ensiled," and "that the source of vitamin A for our animals are green feeds and silage made therefrom and hay." Henry and Morrison (6) list corn silage as a good source of vitamin A. Halverson and Sherwood (4) found that rations of cottonseed meal and corn silage did not maintain good health and normal reproduction in dairy cows. They state that "the necessary nutritive factors for supplementing this deficient ration, both for maintenance and normal reproduction, are carried in butter fat or cod liver oil and in calcium carbonate or steamed bone meal. The data of reproduction indicate a lack of fat-soluble A in the ration." Corn stover, timothy hay, and even alfalfa hay in moderate amounts also did not seem to supply sufficient vitamin A.

The original object of this investigation was to ascertain if cottonseed meal fed in combination with other feeds for long periods of time in large quantity to dairy cows, would have a deleterious effect upon their health or production of milk due to any toxic effect of the gossypol present or to any other possible injurious constituent. It became evident during the progress of the experiment that the disturbances of health of the animals receiving cottonseed meal and hulls were chiefly due to deficiency of vitamin A, and that some of the animals receiving the ration containing sorghum silage did not get enough vitamin A for best results.. This showed that in this ration the cottonseed meal and hulls as well as the sorghum silage did not provide sufficient vitamin A. Since the sorghum silage was a feed which was naturally expected to furnish sufficient quantities of vitamin A but which was found to be deficient, most importance was attached to its deficiency.

Plan of Experiment

In the original plan of the experiment three groups of cows were used. One group was fed on cottonseed meal and hulls in a dry lot, without access to green feed or silage.. Another group was fed on cottonseed meal, cottonseed hulls, and sorghum silage and had access to pasture. The third group was fed cottonseed meal, cottonseed hulls, and sorghum silage. As this group was the one in which the silage was fed, it is the one especially significant in this work.

This group consisted of four pure-bred Jerseys and one grade Jersey. Three of them were mature cows, one was four years old, and one slightly over two years old, milking with her first calf. On December 20, 1929, these five cows were placed in a lot free from all vegetation and fed sorghum silage, cottonseed hulls, and cottonseed meal. An addition of 2½% of ground limestone and 1% of salt was made to the cottonseed meal. As there is not sufficient lime in either sorghum silage or cottonseed hulls to balance the 2½ to 3 per cent of phosphoric acid in the cottonseed meal, the limestone was used to prevent a large excess of phosphoric acid. The cottonseed meal was fed at the rate of one pound for every 2¼ pounds of milk produced per day during the lactation period and 4 pounds per cow per day during the dry period. Fresh water, block salt, and shelter were available at all times. Records were kept of the exact amount of feed fed to each group of cows, but as this information is not essential to the present discussion, it is omitted.

Description of Silage

The silage fed during this investigation consisted mainly of sorghum silage, although a small amount of corn silage was fed from August 1930 to the latter part of December, 1930. The silage fed during the first three months of the experiment had been in the silo slightly over two years. The remainder of the silage used in the investigation was 3 weeks to 14 months old. The silage used was produced during the years 1927, 1929, 1930, and 1931. Two silos were used with intervals of about two weeks between filling. The silage was harvested when most of the grain was in the hard dough stage. All of the silage fed apparently had become well fermented, as judged by the color and odor of the silage.

Effect on Vitamin A Content of Butter Fat

Samples of the butter fat from one of the cows fed on cottonseed meal, cottonseed hulls, and silage were secured on April 13, 1931, after the cows had been on experiment 479 days. Samples from one cow of each of the other groups of cows were also taken. Additional samples were taken on other dates as shown in Table 1. The vitamin A content of the butter fat was determined by Mr. Ray Treichler, of the Division of Chemistry (3) using the Sherman-Munsell method (9), as modified by this station (2). The results are expressed in units of vitamin A, a unit being the amount

Table 1—Quantitative tests for vitamin A in butter fat and in sorghum silage

Laboratory number	Date received and description	Grams fed daily	Number of rats at beginning	Number of rats at end	Average gain 8 weeks gm.	Grains butter fat to 1 unit vitamin A	Units vitamin A to 1 gram butter fat
34127	Butter, April 13, 1931—Cottonseed meal, hulls, and silage group	.3	6	4	25	.3	3.3
	Butter, April 13, 1931—Cottonseed meal, hulls, and silage group	.4	6	6	50		
34155	Butter, April 23, 1931—Cottonseed meal, hulls, and silage group	.2	6	4	37	.17	6
35707	Butter, Nov. 12, 1931—Cottonseed meal, hulls, and silage group	.2	6	6	68		
	Butter, Nov. 12, 1931—Cottonseed meal, hulls, and silage group	.083	6	4	20	.08	12
34016	Butter, March 17, 1931—Cottonseed meal and hulls group	.05	6	1	—1		
	Butter, March 17, 1931—Cottonseed meal and hulls group	.1	6	4	—2		
	Butter, March 17, 1931—Cottonseed meal and hulls group	.2	6	4	4	.4	2.5
34128	Butter, April 13, 1931—Cottonseed meal and hulls group	.2	6	4	13	.3	2.5
34156	Butter, April 25, 1931—Cottonseed meal and hulls group	.4	6	6	21	.4	2.5
34017	Butter, March 17, 1931—Cottonseed meal, hulls, silage, and pasture group	.03	6	4	27	.03	33
	Butter, March 17, 1931—Cottonseed meal, hulls, silage, and pasture group	.05	6	6	69		
34126	Butter, April 13, 1931—Cottonseed meal, hulls, silage, and pasture group	.03	6	3	25	.03	33
35831	Sorghum silage, Dec. 30, 1931	.1	6	0	---		
	Sorghum silage, Dec. 30, 1931	.2	6	3	40		
	Sorghum silage, Dec. 30, 1931	.4	6	6	55	.2	5

Table 2—Effect of feed of cows on vitamin A content of butter fat and daily production of vitamin A in butter

Laboratory number	Feed	Date of sample 1931	Units per gram	Units per pound	Pounds butter fat per day	Units per cow per day
34016	Cottonseed meal and hulls, cow No. 44, begun Dec. 20, 1929	March 17	2.5	1130	.40	450
34128	Cottonseed meal and hulls	April 13	2.5	1130	.25	280
34156	Cottonseed meal and hulls	April 25	2.5	1130	.25	280
	Average					340
34015	Cottonseed meal, hulls, and silage, cow No. 42, begun Jan. 17, 1930	March 17	2.0	907	1.09	980
34127	Cottonseed meal, hulls, and silage	April 13	3.3	1500	1.16	1750
34155	Cottonseed meal, hulls, and silage	April 25	6.0	2700	1.16	3150
	Average					1960
35707	Cottonseed meal, hulls, and silage, cow No. 182	Nov. 12	12.0			
34017	Cottonseed meal, hulls, silage, and pasture, begun Dec 20, 1929	March 17	33.0	14970	1.23	18400
34126	Cottonseed meal, hulls, silage, and pasture	April 13	33.0	14970	1.08	16170
	Average					17280

required to produce an average gain of three grams a week for 8 weeks on rats previously depleted of the vitamin.

As shown in Table 1 the butter fat produced by the cows fed on the cottonseed meal, cottonseed hulls, and silage contained much less vitamin A than the butter fat produced by the cows which received pasture in addition to the feed mentioned above. The quantity of vitamin A varied from one-tenth to a little more than one-third of the vitamin A in a normal butter fat. The cows fed on cottonseed meal and cottonseed hulls without the silage produced butter fat very low in vitamin A. The addition of silage increased the vitamin A in the butter fat of the cows, but the amount was still very much lower than that contained in normal butter fat.

The above data show that the amounts of vitamin A provided by cottonseed meal and hulls to dairy cows are sufficient to place only low quantities of vitamin A in the butter fat. The sorghum silage also furnishes insufficient vitamin A for the butter fat. That is to say, the sorghum silage cannot be relied upon to provide the quantity of vitamin A necessary to produce butter high in vitamin A or of normal potency in vitamin A. The vitamin A stored in the bodies of the cows at the beginning of the experiment had no doubt been depleted, and the sorghum silage, cottonseed meal, and cottonseed hulls furnished insufficient amounts.

Relation to Quantity of Vitamin A fed to that Produced Daily in Butter Fat

The quantity of vitamin A produced in the butter fat can be estimated from the data secured regarding the number of units in the butter fat and the quantity of butter fat produced at the time the samples were taken. These results are given in Table 2. The cow fed cottonseed meal and hulls produced daily butter fat containing 340 units of vitamin A. The one receiving cottonseed meal, cottonseed hulls, and silage produced 1960 units a day, and the one receiving pasture in addition to the cottonseed meal, hulls, and silage produced 17,240 units per day. It has already been pointed out that vitamin A in the butter of the cow receiving silage varied considerably, as is evident from both Tables 1 and 2. On an average the addition of silage to the meal and hulls increased the output of vitamin A in the butter fat 1,620 units per day, while silage and pasture together increased it 16,940 units a day. The addition of the pasture to the ration of cottonseed meal, cottonseed hulls, and silage on an average increased the vitamin A output 15,320 units a day, a very high increase.

It seems reasonable to conclude that cottonseed meal, cottonseed hulls, and sorghum silage do not furnish sufficient vitamin A to produce butter of high potency if they are fed for long periods of time without access to pasture.

Vitamin A Content of the Sorghum Silage and of the Feed Eaten by the Cow

Since the experiment was not planned as a study of vitamins and the silage was expected to furnish sufficient amounts of vitamin A, no estimation was made of the vitamin A content of the silage during the first

part of the experiment. After it was discovered that the ration was deficient in vitamin A, a sample of the silage was secured and tested by the Sherman-Munsell rat method already mentioned. This sorghum silage in the original moist condition was found to contain 5 units of vitamin A per gram, which is about 15 units per gram of dry matter. Although the data are insufficient for exact estimates, we believe that we are justified in discussing the data and drawing tentative conclusions. An average of 52.3 pounds of sorghum silage per cow was given to the silage group daily. It is estimated that 10 per cent was wasted, which would leave 47 pounds consumed daily per cow. With 5 units of vitamin A to the gram of silage, the total consumption would be 106,000 units of vitamin A a day. The cow from which the butter was secured weighed 750 pounds.

Silage is well known to be variable in composition according to the variety of the plant, stage of growth at which cut, manner of handling in the silo, and other factors, and no doubt varies in content of vitamin A. It is probable that some of the vitamin A in the green feed is destroyed during the fermentation which forms the silage, after which the vitamin A is lost more slowly. A decrease during storage we have found to occur with dried foods, such as corn, dried milk, and alfalfa. The portions of the silage referred to were taken beginning December 30, 1931 and may have contained more vitamin A than older silage. Definite information regarding this point is desirable.

The estimated consumption of 106,000 units of vitamin A a day in addition to that in the cottonseed meal and hulls was accompanied by the production in the butter of only 1,620 units a day, as an average, which may be compared with 15,320 units a day assigned to pasture. This apparently low utilization of vitamin A of the sorghum silage might be due to several causes. The estimate of the quantities of vitamin A, based upon a very small amount of data, may be too high. However, even if the consumption were only one-third of the estimate, the percentage utilized would still be very low. It is possible that the fermentation in the digestion of the silage destroys part of the vitamin A. This seems a possible hypothesis. According to Hauge and Aitkenhead (5), enzymes are the important factor in the destruction of vitamin A in the field curing the alfalfa. The enzymes might destroy the vitamin A during the fermentation which occurs when silage is formed. A third hypothesis is that the cow has a high requirement for vitamin A to maintain the body. While this enters into the matter, it is questionable if the maintenance requirements are sufficiently high to account entirely for the low utilization of the vitamin A. The subject clearly requires more study, which we have under way.

Effect on Health of Animals

All five of the animals fed on cottonseed meal, hulls, and silage had disturbances of health, which might be ascribed to a deficiency of vitamin A. After having been in dry-lot feeding for about five months, some of them showed signs of hemeralopia, or night blindness. This trouble was intermittent among all of the animals on experiment; at times the vision was

apparently normal and at other times they appeared very blind after dark. McCollum (7) is of the opinion that this eye trouble frequently occurs as the result of a deficiency of vitamin A in the ration. Converse and Meigs (1) found calves fed on over-ripe timothy hay were weak and often blind.

After having been on experiment for about four months all the cows fed silage were extremely nervous and excitable when handled outside of their lot or milking barn. Slight nasal discharges were observed in all of the animals; however, this condition was also intermittent, lasting only for a day or two at a time. Cow No. 42 apparently "broke down," as she showed symptoms typical of vitamin A deficiency such as swollen legs, loss of appetite, hemeralopia, loss in body weight, and skin lesions. Sherman and Smith (10) report evidences of cutaneous malnutrition in rats deprived of vitamin A, as shown by scabbiness of the tail or ears, sores on the nose, thin bushy hair, and sore feet. This cow showed all of these symptoms. Figure 1 shows a picture of this animal taken on April 30, 1932. On the 374th day of the experiment, she fell to her knees three or four times, trembling markedly; her condition was very critical for about 2 weeks, when she began to improve although she remained on the same ration. Traces of her present symptoms first became noticeable after she had been on experiment about two years; her condition gradually became worse and she finally died. After about the fifth month of dry-lot feeding all these animals were observed licking the dirt, showing signs of craving something not present in their ration. Except for cow No. 42, the other cows on the silage ration were in a high degree of flesh and showed no loss of appetite, swollen legs, lameness, or scabbiness, although all had night blindness as mentioned above.

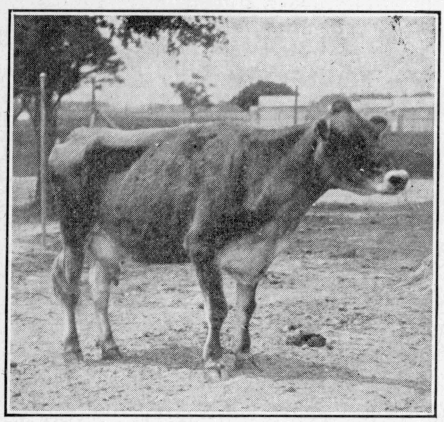

Fig. 1. This cow had been fed in dry-lot on a ration of cottonseed meal, hulls, and sorghum silage for 833 days at the time this picture was taken. Note the unthrifty condition and swollen legs.

The disturbances mentioned above might, to some extent, be ascribed to an insufficient quantity of vitamin A in the ration. However, the symptoms are by no means conclusive. It might be thought that it is due to the gossypol. The evidence is rendered more satisfactory by comparison with the animals fed cottonseed meal, and cottonseed hulls without silage or green feed. All of these cows became weak, some so weak that they were unable to stand. Two of them died. One was fed daily 2½ pounds of fresh green grass, and after complete recovery the fresh green grass was omitted from her ration and she again became sick and died. The two others were fed cod liver oil, one at the rate of 250cc. a day and the other 125cc. a day; both recovered rapidly. The cod liver oil made the change

for the better in a markedly short time of one or two days and caused complete recovery in a month. Cod liver oil supplies both vitamin A and vitamin D, but the cows all had an abundance of bright Texas sunshine and as sunshine is the equivalent of vitamin D, they probably received sufficient vitamin D for maintenance. Since the animals were cured by cod liver oil or green grass containing vitamin A, it thus is positively established that the cows fed cottonseed meal and hulls suffered from a deficiency of vitamin A. The night blindness and other disturbances of health of the cows fed sorghum silage in addition to the cottonseed meal and hulls would indicate that the amount of vitamin A they received was at times sufficient for maintenance, but at other times fell slightly below maintenance requirements. Halverson and Sherwood (4) in the extensive work already referred to, concluded that a ration of cottonseed meal and hulls was deficient in vitamin A and in other respects, and that corn stover, corn silage, and possibly timothy hay supplied vitamin A on the border line for maintenance for dairy cows. These conclusions are similar to those reached above.

SUMMARY

Five Jersey cows were fed in dry-lot on a ration of cottonseed meal containing 2½ per cent of limestone, 1 per cent of salt, and sorghum silage and cottonseed hulls ad libitum. The silage contained approximately 5 units of vitamin A per gram and was the chief source of vitamin A. Other groups of cows were fed cottonseed meal and hulls only, while another group received pasture in addition to cottonseed meal, hulls, and silage.

The butter fat from one of the cows fed cottonseed meal and hulls averaged 2.5 units of vitamin A per gram. The butter fat from one of the cows fed silage in addition to cottonseed meal and hulls contained only 2 to 12 units of vitamin A, while that from cows on pasture contained as much as 33 units.

The cow on cottonseed meal and hulls, on each of the days the samples were taken, produced fat containing, on an average, 340 units; that receiving silage in addition produced 1960 units a day; that on pasture produced 17,280 units a day.

Sorghum silage, cottonseed meal, and cottonseed hulls did not furnish enough vitamin A to produce butter fat of high potency in vitamin A. Pasture supplied sufficient vitamin A to produce butter fat of high potency in vitamin A.

The cows after prolonged feeding on cottonseed meal and hulls became very weak; two of them were cured by administration of cod liver oil and one by feeding fresh green grass. As cod liver oil is a carrier of vitamins A and D, and as vitamin D was supplied in abundance by sunshine, it is evident the cows were suffering from a deficiency of vitamin A and that the cottonseed meal and hulls did not supply sufficient vitamin A for maintenance of the cows.

The cows that received sorghum silage in addition to cottonseed meal and hulls exhibited symptoms of night blindness and other disorders, which indicated that the ration might not quite supply sufficient vitamin A for good health.

Based upon the available data, an estimate is made that the cow receiving sorghum silage consumed about 106,000 units a day of vitamin A, although it produced only about 1960 units a day in butter, which was low in vitamin A. While more data are needed, the results indicate that the dairy cow has a high daily requirement for vitamin A, either on account of destruction of vitamin A during the process of digestion or high maintenance requirements during lactation, or both.

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