STUDIES ON PURIFIED DIETS

FOR BEEF CALVES

By

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INTRODUCTION

The value of the purified diet for experimental feeding is based on the fact that all of the nutrients are supplied in relatively pure form. This makes it possible to include or withdraw a given nutrient with a minimum of disturbance to any of the other nutrient relationships. This technique has led to the discovery of many of our vitamins, differences in protein quality, and other knowledge of nutrition which we have today.

Although the purified diet technique has been used quite extensively and successfully in experiments with simple stomached animals, only a relatively small amount of research has been conducted using this technique with ruminants. Several workers have formulated purified rations which have been used successfully with sheep, but a satisfactory purified ration has not been developed for cattle.

Only limited information is available concerning the quantitative requirements of cattle for trace elements. Although several investigations have shown that most good quality cattle rations are not improved by the addition of trace elements, other studies have indicated the existence of deficiencies in certain areas. Since natural feedstuffs contain many of the trace elements in large amounts, a natural ration would be unsatisfactory for determining requirement levels. A ration essentially void of the element(s) in question would be needed. Such a ration can be obtained only through the use of purified nutrients.

This investigation was designed to develop a purified ration which would: (1) contain a minimum of contaminant minerals, (2) promote appreciable growth when fed to young beef cattle, and (3) maintain the cattle in a normal physiological condition when fed as the only source of nutrients over an extended period.

REVIEW OF LITERATURE

Source of Roughage

Woodward and McCay (1932) were unable to maintain goats upon a synthetic diet using paper as a source of roughage. The animals usually refused the feed entirely after a period of two weeks. However, in further experiments it was observed that goats, rabbits, and rats readily ate a diet containing regenerated wood cellulose as a source of roughage. An adult male goat was maintained upon a synthetic diet of the following composition for a period of 152 days: regenerated wood cellulose (Sylphrap), 30 per cent; corn starch, 30 per cent; casein, 15 per cent; sucrose, 10 per cent; yeast, 5 per cent; salt mixture, 7 per cent; and lard, 3 per cent. This goat was maintained in nitrogen balance and was quite fat when he suddenly died of a kidney infection. Twenty rabbits were fed synthetic diets of similar composition. They consumed the feed readily and young animals continued to grow for about one month. At the end of six weeks these young animals developed a paralysis of the rear legs, and in most instances, died after a short period.

Madsen et al. (1935) in a continuation of the study of Woodward and McCay (1932) found that the paralysis of the legs was due to a degeneration of the skeletal muscles. The heart muscles also were frequently involved, especially in the goats. A fatty liver was a characteristic finding in goats, sheep and rabbits. These abnormalities were first noted with synthetic diets containing cod-liver oil. The substitution of a vitamins

A and D concentrate markedly delayed the onset and lessened the severity of the abnormalities but did not eliminate them.

Johnson et al. (1940) conducted experiments with dairy calves using cellophane as a source of roughage. The growth rates of 15 calves studied were below normal in most cases. Poor feed consumption associated with periodic digestive upsets seemed to be largely responsible for the slow growth.

Loosli et al. (1949) studied the suitability of cellophane as a source of roughage in purified diets for sheep. Three lambs which were fed the ration over a three month period gained an average of .23 pounds per day.

Argrawala et al. (1953) found that calves could not survive on a ration containing: cornstarch, 42 per cent; glucose, 25 per cent; cellophane, 20 per cent; lard, 4 per cent; mineral mixture, 5 per cent; and urea, 4 per cent. There was an absence of rumination and the calves developed anorexia within 9 to 15 days. It was postulated that cellophane is not a suitable substitute for natural roughage because cellulose derivatives, in general, exhibit higher resistance to microbiological degradation than the cellulose molecule itself.

Woods and Tillman (1956) found regenerated wood cellulose (Solka Floc) to be a satisfactory source of roughage in purified diets for lambs. Average daily gains of .14 pound per head were reported.

Byers et al. (1955) conducted digestion studies with eight 400-pound Holstein steers. The steers were fed a purified diet containing wood cellulose (Solka-Floc), cornstarch, sucrose, hydrogenated beef tallow, urea, and a complex mineral mixture. All steers gained weight during the first four weeks on the diet; subsequently nearly all steers lost weight. Abnormal conditions such as unthriftiness, blindness, and enlarged pasterns were observed. In an attempt to eliminate these abnormalities the amount of cellulose in the rations of four of the eight steers was reduced from 55 to 35 per cent. This resulted in an improved physical appearance. Digestion studies indicated that total dry matter digestibility was highest on the low cellulose ration. Nitrogen balance studies showed the steers on the 35 per cent cellulose ration were in positive nitrogen balance whereas those on the 55 per cent ration were in negative balance.

Byers et al. (1956) in further studies reported that steers on the 35 per cent cellulose ration continued to develop enlarged pasterns, swollen knees and hocks, and posture difficulties. When a purified soybean product ("Drackett") was substituted for urea on a protein equivalent basis these symptoms did not develop and gains of 1.5 pounds per day per head were reported.

Gall et al. (1951) conducted two experiments in which sheep were fed a purified diet containing 20 per cent cellophane. Increased growth rates were obtained in two out of three instances when one-half of the cellophane was replaced by wheat straw.

Thomas et al. (1951), studying the utilization of inorganic sulfates and urea nitrogen by lambs, reported that all lambs lost weight when fed a ration containing 20 per cent cellophane. The substitution of wheat straw for one-half of the cellophane resulted in gains by all lambs receiving the dietary sulphur.

Soluble Carbohydrates

Mills et al. (1942) reported that urea was not utilized at a maximum rate and efficiency in the rumen of the cow unless adequate fermentable carbohydrate (starch) was included in the ration. A 1000-pound Holstein heifer with a rumen fistula was used in a series of trials. The fistula was equipped with a removable plug to facilitate sampling. When timothy hay alone was fed both the ammonia-nitrogen and total protein were at low levels, and remained almost constant throughout the trial period. When urea was fed with the hay hydrolysis of the urea to ammonia was delayed, being incomplete at one hour after feeding. Disappearance of the ammonia was also very slow with about one-half remaining in the paunch six hours after feeding. From these results it appeared that no abundant and active flora was operating in the rumen. In contrast, when starch was fed in addition to the timothy hay and urea, microbiological activity was very great. The urea was completely hydrolyzed in less than one hour, and the ammonia thus formed had practically disappeared in six hours. As the ammonia-nitrogen level fell there was a concurrent rise in protein, indicating that the ammonia was being built into protein. The total rise in protein was approximately equivalent to the amount of ammonia disappearing from the paunch in the same period. It was postulated that the soluble carbohydrate functioned to serve as a readily available energy source for the microorganisms. This would enable the microorganisms to build new protoplasm, utilizing the nitrogen from urea.

Mills et al. (1944) in further studies again reported a low utilization of urea when fed alone with timothy hay. The addition of corn molasses provided a suitable substrate for the development of an active flora, and urea was fairly well utilized. The addition of starch to the ration of timothy hay, urea, and corn molasses increased the utilization of urea. Apparently somewhat better utilization was obtained due to the lower solubility of starch as compared to sugar.

Arias et al. (1951) used an artificial rumen to study the energy requirements of rumen microorganisms. Results indicated that rumen microorganisms possess definite energy requirements. Apparently the degree to which these requirements are fulfilled has considerable influence upon the utilization of urea or other ammonia supplying compounds by the microorganisms. Six different sources of energy (dextrose, cane molasses, sucrose, starch, cellulose, and ground corn cobs) were each studied at three different levels. Each source of energy aided urea utilization provided the urea underwent digestion. It was observed that small amounts of a readily available carbohydrate aided cellulose digestion thereby increasing urea utilization. However, large amounts of a readily available carbohydrate tended to inhibit cellulose digestion.

Arias et al. (1951) postulated that there is a specific need for small amounts of readily available energy in rations containing cellulose as the principle source of energy. It was further postulated that rumen microorganisms are unable to obtain energy for their body functions from cellulose until the cellulose molecule is digested or reduced in size to approximately that of dextrose. Immediately following the subjecting of large amounts of cellulose to fermentation there is a time interval required for rumen bacteria to either become attached or arranged in close space relationships to cellulose fibers. During this time interval the supplying of a small amount of supplementary dextrose would be beneficial. It was concluded that the ideal ratio of energy sources would appear to be a medium amount of readily available carbohydrate and a medium amount of fibrous material, or a large amount of fibrous material and a small amount of readily available carbohydrate.

Belasco (1956) also found that urea utilization by rumen microorganisms "in vitro" was dependent on the amount and type of carbohydrate used as the energy source. The extent of urea utilization was slightly greater with starch than with cellulose. Xylan and pectin promoted urea utilization but not to the same extent as starch. High input levels of dextrose when used in combination with cellulose inhibited cellulose digestion markedly.

Source of Nitrogen

A major problem in formulating a purified diet for cattle is a source of purified nitrogen which is non-toxic and promotes satisfactory growth. Thomas et al. (949), Gall et al. (1951), and Woods and Tillman (1956) successfully fed urea as the sole source of nitrogen in purified diets for sheep. However, Byers et al. (1956), using urea as the source of nitrogen in purified diets, reported that dairy steers developed toxicity symptoms within four weeks. When purified soybean protein ("Drackett") replaced urea on a nitrogen equivalent basis, no toxicity symptoms were observed and the steers gained 1.5 pounds per head per day. Protein products purified from natural feeds have, in general, given better results than synthetic non-protein nitrogen products. However, these natural sources of protein contain certain amounts of impurities which are impossible to remove and thus are unsuitable for many studies.

Non-protein nitrogen compounds other than urea have been studied in an attempt to find compounds which produce satisfactory growth without toxicity when fed at high levels. Belasco (1954), using the artificial rumen technique, reported that the amides of monocarboxylic acids, and the salts of guanidine released ammonia at a slower rate than urea. However, these compounds were inferior to urea in digestion of cellulose. Propionamide, creatine, and creatinine appeared to be the most promising of the compounds tested. Repp et al. (1955a) reported that propionamide was non-toxic when administered as a drench to 75-pound lambs. Repp et al. (1955b) reported equal gains by sheep on rations containing propionamide and urea when each supplied 50 per cent of the total protein. Welch et al. (1956) reported that creatine was significantly more effective than urea in enhancing the nitrogen utilization of lambs. Creatine compared favorably with soybean protein ("Drackett") in increasing digestibility of organic matter and protein.

EXPERIMENTAL

Three pairs of identical twin calves weighing an average of 375 pounds were selected as experimental animals. The calves were placed indoors in separate, concrete-floored pens provided with individual feed and water facilities. A ration of cottonseed hulls and cottonseed meal was provided for a preliminary period of approximately three weeks. At the close of this period the assigned experimental rations were substituted for one-fourth of the preliminary ration. The proportion of experimental rations was gradually increased over an 8 day period until the calves were receiving only the experimental rations.

The basal ration (Ration A) used in this experiment was identical to that used by Woods and Tillman (1956) in feeding trials with lambs. The components of the rations are shown in detail in Tables I, II, III, and IV. One calf of each pair of twins received the basal ration while its twin received the basal ration modified by the removal or addition of some ration component(s).

Trial I was designed to study the effect of vitamins (primarily B vitamins) in a purified ration. Two rations were assigned at random to a pair of identical twin, grade Angus heifer calves. Calf No. 2 received the basal ration (Ration A) which contained a vitamin mix and Calf No. 1 received a ration which did not contain a vitamin mix (Ration B).

Trial II was originally designed to study the effect of cobalt in the ration. A pair of identical twin, grade Angus steer calves was used as experimental animals. Two rations were assigned at random with Calf No. 3 receiving the basal ration (Ration A) which contained cobalt, and Calf No. 4 receiving a ration which did not contain cobalt (Ration C).

Trial III was designed to evaluate the desirability of including a small amount of natural feedstuffs in a purified ration. A pair of identical twin, Red Polled heifer calves was assigned rations at random. Calf No. 5 was fed the basal ration (Ration A) which did not contain natural feedstuffs and Calf No. 6 was fed a Ration which contained 10 per cent cottonseed hulls (Ration D).

A concentrate mixture of the experimental rations (Tables I, II, III, and IV) was prepared by mixing all ingredients except cellulose, corn oil, and cottonseed hulls. The concentrates were stored in individual 20-gallon containers provided for each calf. The concentrate mixture, cellulose, corn oil, and hulls were weighed and mixed in individual feed pails at time of feeding. All individual feed containers and feed pails were plainly marked in order to minimize errors and contamination during feeding.

Due to the varied results and lengths of time over which the different experiments were conducted each pair of twins was considered as a separate trial in the recording of results.

Abnormal developments among several of the calves early in the experiment necessitated changes from original treatment plans. The specific changes instituted in the case of each set of twins are outlined in the section on results for each individual trial.

TABLE I. COMPOSITION OF RATIONS

Ingredient	Ration A	Ration B	Ration C	Ration D	Ration E	Ration F	Ration G	Ration H	Ration J
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Starch	22.9	22.9	22.9	22.9	17.9	17.9	17.9	22.9	22.9
Cerelose	23.0	23.0	23.0	23.0	17.8	17.8	17.8	23.0	23.0
Cellulose[1]	40.0	40.0	40.0	30.0	40.0	40.0			38.0
Cottonseed Hulls				10.0			40.0	40.0	2.0
Urea	4.0	4.0	4.0	4.0				4.0	4.0
Drackett[2]					14.2	14.2	14.2		
Corn Oil[3]	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Mineral Mix[4]	5.0	5.0	5.0[7]	5.0	5.0	5.0	5.0	5.0[9]	5.0
Choline Chloride	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Vitamin A and D[5]	----------0.5 gm. per lb. of ration----------								
Vitamin B Complex[6]	Yes	No	Yes[8]	Yes	Yes	No	Yes	Yes[8]	Yes

[1] "Solka Floc"
[2] A purified soybean product.
[3] "Mazola"
[4] Components given in Table II.
[5] Nopco "Quadrex". Vitamin A, 10,000 U.S.P. units per gram; Vitamin D, 1250 U.S.P. units per gram.
[6] Components and amounts given in Table IV.
[7] Cobalt not included.
[8] Vitamin B-12 not included.
[9] Does not include Cobalt, Copper and iron.

TABLE II. COMPOSITION OF MINERAL MIX

Ingredient[1]	Grams
NaCl	2835.0
KH_2PO_4	5010.0
$CaHPO_4 \cdot 2\ H_2O$	5595.0
$MgSO_4$	1552.5
$CaSO_4 \cdot 2\ H_2O$	6562.5
$CaCO_3$	474.5
$FeSO_4$	121.5
KI	12.75
$ZnSO_4$	4.5
$CuSO_4 \cdot 5\ H_2O$	5.25
$CoSO_4 \cdot H_2O$	3.00
CaF	3.75
$MnSO_4 \cdot H_2O$	22.5
NH_4Br	0.0488
$Na_2B_2O_7 \cdot 10\ H_2O$	92.92
MoO_3	0.0488
	22,295.7676

[1]All minerals were of "analytical reagent" quality except $CaHPO_4$, which was U.S.P. grade, and NaCl which was of "common table" quality.

TABLE III. AMOUNT OF ELEMENT SUPPLIED PER POUND OF RATION

Element	Mg. per pound
Na	1162.08
Cl	1730.00
Ca	3065.86
P	2180.00
K	1463.05
S	1662.57
Mg	319.16
Fe	45.43
I	9.91
Mn	7.48
Zn	1.85
Cu	1.36
Co	1.02
F	1.23
Br	0.40
B	5.68
Mo	0.03
	11,657.11

TABLE IV. AMOUNTS OF VITAMINS ADDED PER POUND OF RATION[1]

Vitamin[2]	Mg. per pound
Thiamine HCl	2.27
Riboflavin	3.63
Niacin	18.16
Pyridoxine HCl	2.27
Ca Pantothenate	18.16
Biotin	0.1816
Folic Acid	0.9181
Vitamin B-12	0.0136
Inositol	45.41
PABA	45.41
Menadione	2.27
	138.6933

[1]The actual mix used can be obtained by converting the amounts shown to grams.

[2]All vitamins are "B" vitamins except menadione which is shown here in order to eliminate a separate table.

RESULTS

Trial I.

Changes in body weight and average daily feed intake of the calves are shown in Table V.

Approximately 5 days after the last of the natural feedstuffs was removed from the ration, both Calf No. 1 and Calf No. 2 developed scours which lasted for a period of about one week. After 19 days on the purified ration Calf No. 2 began acting abnormally and also refused the feed offered on that day. The animal appeared highly excited and remained with her head in the feed stanchion for several hours. When forced from the stanchion the animal began walking in rapid continuous circles around the sides of the pen. Although not discovered at this time, examination of other calves developing similar symptoms at later dates showed them to be partially blind. This might account for the aimless walking around the pen. The calf began to consume some feed on the third day after first exhibiting the symptoms and gradually returned to normal in a period of 5 or 6 days.

After 23 days on the purified ration Calf No. 1 developed symptoms similar to those exhibited by Calf No. 2. These symptoms were observed 4 days after their first appearance in Calf No. 2. Calf No. 1, like Calf No. 2, went through a 4 to 5 day period of hyperexcitability and feed refusal before regaining normality. After recovering from the apparent toxicity, the calves approached their previous level of feed

Table V. Total Gains, Average Daily Gains, and Average Daily Feed Intake of Calves
Trial I

Days in Period	Ration Fed: Calf No. 1 ("B" Vitamins)	Ration Fed: Calf No. 2 (No "B" Vitamins)	Total Gain by Periods[1]: Calf No. 1	Total Gain by Periods[1]: Calf No. 2	Av. Daily Gain by Periods: Calf No. 1	Av. Daily Gain by Periods: Calf No. 2	Av. Daily Feed Intake by Periods: Calf No. 1	Av. Daily Feed Intake by Periods: Calf No. 2
			lb.	lb.	lb.	lb.	gm.	gm.
38	B (urea)	A (urea)	3	-14	.08	-.37	2474	2269
57	F (Drackett)	E (Drackett)	20	19	.35	.33	2296	2645
26 [5]	F (" ")	E (" ")	12	5	.48	.20	1829	2096
118 [5]	F (" ")	[2]	55	[2]	.55	[2]	2932	[2]
35 [5]	F (" ")	E (" ")	-15	17	-.43	.49	2405	2371
76	F (" ")	E (" ")	-99	-64	-1.30	-.84	977	1460
88	D (urea) [3]	J (urea) [4]	66	59	.75	.67	3519	3121

[1]Initial weights: Calf No. 1, 360 lb.; Calf No. 2, 389 lb.
[2]Calf No. 2 was removed from the trial during this period.
[3]Ration "D" contained 10 per cent cottonseed hulls.
[4]Ration "J" contained "B" vitamins and 2 per cent cottonseed hulls.
[5]Periods during which calves were housed in dirt-floored pens.

consumption, an average of 2600 grams per day. During the initial 38-day period Calf No. 1, receiving ration "B" which did not contain "B" vitamins, gained 3 pounds in weight. Calf No. 2, receiving the basal ration (Ration A) which contained "B" vitamins, lost 14 pounds in weight.

Since it was deemed inadvisable to allow the animals to remain on the initial rations it was decided to replace the urea in the ration with a natural source of protein. Accordingly on August 10, 1956, the initial rations were modified by replacing the urea with a purified soybean product ("Drackett") on a nitrogen equivalent basis (Rations E and F in Table I). Calf No. 2 received Ration E, which contained "B" vitamins, and Calf No. 1 received Ration F, which did not contain "B" vitamins. Almost immediately following the change in rations the calves began to gain weight and also showed a slight improvement in physical appearance.

On October 6th, the 95th day of the experiment, it was necessary to move the calves into dirt-floored pens for the winter months. Cottonseed hulls were used for bedding in these pens and although they were used sparingly the calves were able to pick up and consume a small quantity, making it impossible to completely control the diet for this period.

On November 1, 51 days after being placed on the "Drackett"-containing ration, Calf No. 2 developed symptoms similar to those observed previously when all nitrogen in the ration was supplied by urea. Although the symptoms were not as severe as those previously observed, the calf was temporarily removed from the trial.

Calf No. 1 was maintained on the "Drackett"-containing ration (Ration F) in the dirt-floored pens from the 6th day of October until the 3rd of April. During this period of 179 days the calf gained an average of .34 pounds per day. The calf appeared normal in all respects with the exception of a rough haircoat.

On February 27 Calf No. 2 was returned to the trial; again receiving ration "E". The calf was maintained on this ration in the dirt-floored pens until April 3rd. During this period of 35 days an average daily gain of .49 pounds per day was recorded. No physical abnormalities were observed with the exception of the development of a rough haircoat during the latter part of the period.

On April 3rd the calves were returned to the original concrete-floored pens. Both calves showed an immediate reduction in feed consumption and consequent loss in weight. During a 76 day period (April 3 to June 18) Calf No. 1 lost 99 pounds in weight while Calf No. 2 lost 64 pounds. Apparently the calves were unable to effectively utilize the rations without the benefit of cottonseed hulls, which they had been able to secure in small amounts while in the dirt-floored pens. It was deemed necessary to change the rations at the end of this period due to the extremely emaciated condition of the calves.

Since cottonseed hulls had also promoted moderate gains in Trial III, when included as 10 or 40 per cent of the ration, it was decided to determine the effect of including cottonseed hulls at a level lower than 10 per cent of the ration. Accordingly on June 18 the calves were assigned rations at random with Calf No. 1 receiving a ration containing 10 per cent cottonseed hulls (Ration D) and Calf No. 2 a ration containing 2 per cent cottonseed hulls (Ration J).

Both calves showed an immediate improvement in physical condition following the change in rations. During an 88 day period ending September 14, Calf No. 1 (10 per cent hulls) gained an average of .75 pounds per day while Calf No. 2 (2 per cent hulls) gained an average of .67 pounds per day. Calf No. 1 consumed a slightly greater amount of feed than Calf No. 2, an average of 3519 grams compared to 3121 grams daily. Although the appearance of the calves was greatly improved at the end of the period they naturally did not appear as sleek and healthy as calves which had received natural rations throughout their lives. Both calves still exhibited rough haircoats and a rather stunted appearance.

Trial II

Changes in body weight and average daily feed intake of the calves are shown in Table VI.

On the 5th day of the trial both calves developed scours which lasted for a period of about one week. On the 26th day of the trial Calf No. 3 developed symptoms similar to, but much more severe than, those observed in Trial I. This animal was highly excitable, refused all feed and water, and either walked in continuous circles around the pen or pushed against the walls of the pen with his head. After a period of 4 or 5 days the calf began to consume a small amount of natural ration but the level of feed consumption did not return to that previously observed.

Approximately five days after the symptoms of abnormality were first observed it was noted that the hind feet of the calf were swollen and the hooves burst. The violent exertions of the calf on the concrete floor may have contributed to this condition. The condition became incurable and it was necessary to destroy the animal. A gross necropsy indicated lesions of the hind feet and fat deposits of the body. Each hind foot contained an extensive infection under the soles and extending

Table VI. Total Gains, Average Daily Gains, and Average Daily Feed Intake of Calves
Trial II

	Ration Fed		Total Gain by Periods[1]		Av. Daily Gain by Periods		Av. Daily Feed Intake by Periods	
Days in Period	Calf No. 3 (Cobalt)	Calf No. 4 (No Cobalt)	Calf No. 3	Calf No. 4	Calf No. 3	Calf No. 4	Calf No. 3	Calf No. 4
			lb.	lb.	lb.	lb.	gm.	gm.
26	A (urea)	C (urea)	-12	-20	-.46	-.77	2317	2546
51	[2]	G (Drackett)[3]	[2]	49	[2]	.96	[2]	5200

[1]Initial weights: Calf No. 3, 374 lb.; Calf No. 4, 391 lb.
[2]Calf No. 3 was removed from the trial at the close of the first period.
[3]Ration "G" contained cobalt and 40 per cent cottonseed hulls.

up toward the fetlock. Calf No. 4 also appeared to be developing symptoms of abnormality and was therefore removed from the experiment at this time.

On October 6 Calf No. 4 was moved into a dirt-floored pen for the winter months. On October 26 Calf No. 4 was returned to the trial. The calf was fed a "Drackett"-containing ration with the cellulose replaced by cottonseed hulls (Ration G). During a period of 51 days the calf gained an average of .96 pounds per day and appeared in excellent physical condition at the close of the trial.

Trial III.

Changes in body weight and average daily feed intake of calves are shown in Table VII.

On the 5th or 6th day of the trial both calves developed scours which lasted for about one week. After apparently adjusting to the ration both calves showed an increased feed consumption and began gaining weight steadily. It was not until September 4, after 63 days on the purified ration, that Calf No. 5 developed symptoms similar to those observed in Trials I and II. On the day following the first appearance of the symptoms the calf apparently became excited and wedged herself in the feed stanchion, becoming completely exhausted before being discovered. The calf appeared to be totally blind for a period of 5 or 6 days; walking in continuous circles around the pen and bumping into the walls at each corner. The calf began to consume a natural ration after 3 or 4 days. The calf did not appear to be completely recovered for about four weeks.

Calf No. 6 did not exhibit any symptoms of abnormality during the trial. On the 48th day of the trial the calf was injured while attempting

Table VII. Total Gains, Average Daily Gains, and Average Daily Feed Intake of Calves
Trial III

Days in Period	Ration Fed: Calf No. 5 (No C.S. Hulls)	Ration Fed: Calf No. 6 (C.S. Hulls)	Total Gain by Periods[1]: Calf No. 5	Total Gain by Periods[1]: Calf No. 6	Av. Daily Gain by Periods: Calf No. 5	Av. Daily Gain by Periods: Calf No. 6	Av. Daily Feed Intake by Periods: Calf No. 5	Av. Daily Feed Intake by Periods: Calf No. 6
63	A (urea)	D (urea)	19	45	.30	.71	3447	3686
32 [3]	( )[2]	D (")	[2]	6	[2]	.19	[2]	3806
48 [3]	( )[2]	D (")	[2]	37	[2]	.77	[2]	3617
131 [3]	H (urea)[4]	D (")	135	58	1.03	.44	4582	3832
62	H (")[4]	D (")	96	72	1.55	1.16	7350	5300

[1]Initial weights: Calf No. 5, 382 lb.; Calf No. 6, 357 lb.
[2]Calf No. 5 was removed from the trial during these periods.
[3]Periods during which calves were housed in dirt-floored pens.
[4]Ration "H" contained 40 per cent cottonseed hulls, but did not contain vitamin B_{12}, cobalt, copper, and iron.

to jump out of the pen, resulting in a temporary loss of weight. However, during the initial 95 day period in the concrete-floored pens the calf gained an average of .54 pounds per day.

On October 6 the calves were moved into dirt-floored pens with cottonseed hulls used for bedding. Since the calves consumed small amounts of these hulls the percentage of hulls in the rations was slightly above the stated amounts for this period. Calf No. 6 appeared in good physical condition throughout the 180 day period in the dirt-floored pens and gained an average of .53 pounds per day.

Due to the moderate gains of Calf No. 6 on a ration containing 10 per cent cottonseed hulls (Ration D) it was decided to determine the effect of a ration containing 40 per cent cottonseed hulls. Cobalt, copper and iron were removed from the ration in order to determine if a deficiency of the elements could be developed in animals receiving a ration containing such a large amount of natural feedstuffs. Accordingly on November 23 Calf No. 5 was returned to the trial and fed a ration which contained 40 per cent cottonseed hulls but did not include cobalt, copper and iron (Ration H, Table I). During the remaining 131 days in the dirt-floored pen the calf gained an average of .99 pounds per day. Blood samples were taken from both calves (Calves 5 and 6) after Calf No. 5 had been receiving the cobalt, copper and iron deficient ration for 129 days. An analysis revealed only slight differences in the blood levels of hemoglobin, red blood cells, and inorganic phosphorus of the two calves.

On April 3 both calves were returned to the original concrete-floored pens. During the remaining 62 days of the trial (April 3 to June 4) Calf No. 5 gained an average of 1.55 pounds per day and Calf No. 6 an average of 1.16 pounds per day. During the entire trial period of 338 days Calf

No. 6 gained an average of .64 pounds per day. During the last two months of the trial Calf No. 5 consumed more than 7000 grams of feed per day. Calf No. 6 consumed over 5000 grams per day for this period. At the close of the trial both calves appeared in excellent physical condition.

DISCUSSION

The basal urea-containing ration (Ration A) did not promote appreciable gains in beef calves. Only slight increases in gains were obtained by replacing the urea in the ration with a purified soybean product ("Drackett") Rations E, F, and G). However, when cottonseed hulls were available to the calves either ration promoted appreciable gains. Moderate gains were made by all calves during the periods they were able to secure cottonseed hulls from the bedding of the dirt-floored pens. When the calves not receiving cottonseed hulls in the ration (Trial I) were moved into concrete-floored pens they began to lose weight rapidly. Calves which were fed a ration containing cottonseed hulls (Trial III) not only continued to gain but actually gained more rapidly after moving into the concrete-floored pens. The increase in gain was possibly due to the warmer weather during this period and also the effect of being housed in individual pens with feed available at all times. While in the dirt-floored pens the calves were housed together and fed individually by being placed in stanchions for 1 to 2 hours twice daily.

The beneficial influence of cottonseed hulls can be explained by assuming that: (1) cottonseed hulls contain (an) essential nutrient(s) necessary for the well being of the calves, and/or (2) cottonseed hulls provide a physical structure which was lacking in the purified rations. Cottonseed hulls were chosen as the natural feed additive in this study due to their relatively low level of digestible protein, vitamins and minerals. Probably the most logical explanation for the beneficial effect of cottonseed hulls is that they supply bulk and increase the palatability of the ration. The natural ruminant ration is normally very bulky due to the large proportion of feedstuffs which tend to maintain their structure and, in general, increase in size for a period of time after entering the digestive tract. In contrast, the purified materials used in this experiment tend to shrink into a doughlike mass immediately upon becoming wet. Maynard and Loosli (1956) state that bulk in the diet is important: (1) to avoid a doughlike mass in the stomach which is not readily digested, and (2) to maintain a certain distention of the digestive tract which is considered desirable for the tract's most effective functioning, particularly in the elimination of feed residues. McCandlish (1923) postulated that lack of bulk in the diet prevented the normal elimination of feed residues from the digestive tract, resulting in the formation of toxic putrefaction products.

In addition to the volume concept associated with bulk, most natural ruminant rations contain an abundance of coarse sharp materials which were entirely lacking in the experimental ration which did not contain cottonseed hulls. Cole (1943) postulated that coarse sharp material in feeds is important in stimulating peristalsis. Cole (1943) reported reduced feed consumption, lack of rumination, and frequent bloat in dairy cows when an alfalfa hay ration was reduced in bulk by fine grinding. Powell (1941) and Balch (1952) found in experiments with dairy cows that the use of rations low in bulk resulted in reduced feed consumption and a lowering of the fat content of the milk.

The purification of feeds, in general, leaves them considerably less palatable than the natural feedstuffs from which they are obtained.

This factor has been a source of trouble in nearly all types of purified diets, especially when fed over an extended period. The presence of cottonseed hulls in certain of the experimental rations probably increased their palatability as shown by the greater feed intake of rations containing hulls. However, palatability could not be considered a factor in those instances in which appreciable gains were obtained apparently due to the availability of cottonseed hulls from the bedding of the calves.

The inclusion of cottonseed hulls at levels of 10 or 40 per cent of the ration was definitely very beneficial. Limited data obtained in Trial I indicated that a much lower level of hulls in a purified ration might be sufficient to maintain weight gains of calves. Calves fed 2 and 10 per cent cottonseed hulls in the ration gained 59 and 66 pounds, respectively, over an 88 day period. This might possibly indicate that cottonseed hulls supplied (a) factor(s) other than bulk and palatability to the ration. Further research would be necessary to clarify this point.

The source of nitrogen in those rations which did not contain cottonseed hulls might also have been a factor contributing to their failure. Repp et al. (1955a) found that the administration of high levels of urea as a drench to lambs was fatal. At certain levels however, toxicity was encountered but the animals recovered. Byers et al. (1955) and Byers et al. (1956) reported that cattle developed abnormal conditions such as blindness and swollen knees and hocks when fed a purified ration very similar to the basal ration (Ration A) used in this experiment. Byers et al. (1956) observed that the symptoms of abnormality were eliminated and gains of 1.5 pounds per head per day obtained when the urea in the ration was replaced by a purified soybean product ("Drackett"). In the research reported here calves did not gain consistently on a "Drackett"-containing ration unless cottonseed hulls were available. None of the protein in cottonseed hulls (3.9 per cent crude protein) is digestible (Morrison, 1956), however it is possible that cottonseed hulls supplied some factor(s) supplementing or enhancing the utilization of the nitrogen present in the purified rations. One of the calves receiving the urea-containing ration (Trial II) developed symptoms similar to those reported by Byers et al.(1956). Whether the swelling of the feet of this calf was due to a toxic substance contained in the ration or was merely an infection of the hooves is not known. Neither can an explanation be given for the failure of this calf to return to normal condition in a few days as did some of the other calves.

Trial II was designed to study the effect of cobalt in the ration, but conditions necessitating removal of one of the calves from the trial after 26 days prevented obtaining any useful information pertaining to a cobalt deficiency. The calf removed from the trial was receiving cobalt in the diet.

The failure to demonstrate differences in performance attributable to cobalt, copper and iron in the ration (Trial III) may have been due to the large amount of cottonseed hulls (40 per cent) contained in the supposedly deficient ration. Although standard analysis data indicated the ration containing 40 per cent hulls did not meet the estimated requirements of the calf for cobalt, copper and iron, the cottonseed hulls used in this study were not analyzed. It is possible that the ration was deficient but the experiment was not of long enough duration to deplete body stores of the minerals. It is also possible that the water supply contained the minerals in amounts sufficient to at least partially meet the requirements of the animals. Other possible sources of minerals were air-borne dust, metal objects in the pens, and additional cottonseed hulls not accounted for but available to the calves from the bedding during most of the experimental period.

The failure to demonstrate differences in performance due to B vitamins in a purified ration is in agreement with numerous B-vitamin studies conducted with ruminants. Kon and Porter (1953) have reviewed the findings of several investigations indicating appreciable B vitamin synthesis in the rumen.

SUMMARY

Feeding trials were conducted with 3 pairs of identical twin calves fed a basal purified ration composed of starch, cerelose, cellulose, urea, corn oil, and complex mineral and vitamin mixtures. During the initial phase of the experiment one calf of each pair of twins received the basal ration while its twin received the basal ration modified by: (a) the removal of "B" vitamins, (b) the removal of cobalt, and (c) the addition of 10 per cent cottonseed hulls in place of an equal amount of cellulose. Results observed during the initial phases of the trial prompted further modifications of the basal ration including: (a) the substitution of a purified soybean product ("Drackett") for urea, (b) the substitution of a purified soybean product for urea plus the removal of "B" vitamins, (c) the substitution of a purified soybean product for urea plus the addition of 40 per cent cottonseed hulls at the expense of cellulose, (d) the removal of cobalt, copper and iron plus the addition of 40 per cent cottonseed hulls at the expense of cellulose, and (e) the addition of 2 per cent cottonseed hulls at the expense of cellulose.

The basal urea-containing ration did not promote appreciable gains in calves. Feeding the basal ration resulted in abnormalities such as loss of appetite and blindness within 4 to 8 weeks. Fatal swelling of the hind feet occurred in one instance but possibly was not a direct result of the ration fed.

Calves made appreciable gains when either 2, 10, or 40 per cent cottonseed hulls were added to the ration in place of an equal amount of cellulose. Only slight increases in gains were obtained by replacing the urea in the ration with a purified soybean product ("Drackett"). Calves gained appreciably when 40 per cent cottonseed hulls were substituted for cellulose in the ration containing the purified soybean product.

No differences in performance were noted which could be attributed to "B" vitamins; cobalt; or cobalt, copper and iron in the ration. It was postulated that the limited length of the experiment and/or the level of cobalt, copper and iron in the purified rations prevented the development of mineral deficiency symptoms.

LITERATURE CITED

Argrawala, I. P., C. W. Duncan and C. F. Huffman. 1953. A quantitative study of rumen synthesis in the bovine on natural and purified rations. I. Protein, dry matter, and non-protein nitrogen. J. Nutr. 49:29.

Arias, Carlos, Wise Burroughs, Paul Gerlaugh and R. M. Bethke. 1951. The influence of different amounts and sources of energy upon "in vitro" utilization by rumen microorganisms. J. Animal Sci. 10:683.

Balch, C. C. 1952. Studies of the secretion of milk of low fat content by cows on diets low in hay and high in concentrates. I. The effect of variations in the amount of hay. J. Dairy Research. 19:39.

Belasco, I. J. 1954. New nitrogen feed compounds for ruminants--A laboratory evaluation. J. Animal Sci. 13:601.

Belasco, I. J. 1956. The role of carbohydrates in urea utilization, cellulose digestion and fatty acid formation. J. Animal Sci. 15:496.

Byers, J. H., J. R. Staubus, W. O. Nelson, R. E. Brown, C. L. Davis and K. E. Gardner. 1955. Studies in ruminant nutrition. I. A purified diet for dairy cattle. J. Animal Sci. 14:1195.

Byers, J. H., J. R. Staubus and K. E. Gardner. 1956. Studies in ruminant nutrition. II. Further studies in the development of a purified diet for dairy cattle. J. Animal Sci. 15:1234.

Cole, H. H. and S. W. Mead. 1943. A physical deficiency in the ration of ruminants. Science 98: No. 2555. 543.

Gall, L. S., W. E. Thomas, J. K. Loosli and C. M. Huhtanen. 1951. The effect of purified diets upon rumen flora. J. Nutr. 44:113.

Johnson, P. E., J. K. Loosli and L. A. Maynard. 1940. Purified diet studies with calves. J. Dairy Sci. 25:553.

Kon, S. K. and J. W. G. Porter. 1953. The vitamin B complex. In: Bourne, G. H. and G. W. Kidder, eds. Biochemistry and Physiology of Nutrition. Vol. I. Academic Press Inc., New York.

Loosli, J. K., H. H. Williams, W. E. Thomas, Fent H. Ferris and L. A. Maynard. 1949. Synthesis of Amino acids in the rumen. Science 110:144.

Madsen, L. L., C. M. McCay, L. A. Maynard, G. K. Davis and J. C. Woodward. 1935. Synthetic diets for herbivora with special reference to toxicity of cod liver oil. N. Y. Agri. Exp. Sta. Mem. 178.

Maynard, L. A. and J. K. Loosli. 1956. Animal Nutrition. Fourth Edition. McGraw-Hill Book Company. New York.

McCandlish, A. C. 1923. Studies in the growth and nutrition of dairy calves. V. Milk as the sole ration for calves. J. Dairy Sci. VI:54.

Mills, R. C., A. N. Booth, G. Bohstedt and E. B. Hart. 1942. The utilization of urea by ruminants as influenced by the presence of starch in the ration. J. Dairy Sci. 25:925.

Mills, R. C., C. C. Lardinois, I. W. Rupel and E. B. Hart. 1944. Utilization of urea and growth of heifer calves with corn molasses or cane molasses as the only readily available carbohydrate in the ration. J. Dairy Sci. 27:571.

Morrison, F. B. 1956. Feeds and Feeding. Twenty-second Edition. Morrison Publishing Co. Ithaca, New York.

Powell, E. B. 1941. Progress report on the relation of the ration to the composition of milk. J. Dairy Sci. 24:504.

Repp, Ward W., W. H. Hale, E. W. Cheng and Wise Burroughs. 1955a. The influence of oral administration of non-protein nitrogen feeding compounds upon blood ammonia and urea levels in lambs. J. Animal Sci. 14:118.

Repp, Ward W., W. H. Hale and Wise Burroughs. 1955b. The value of several non-protein nitrogen compounds as protein substitutes in lamb fattening rations. J. Animal Sci. 14:901.

Thomas, W. E., J. K. Loosli, F. H. Ferris, H. H. Williams and L. A. Maynard. 1949. Synthesis of amino acids in the rumen. Fed. Proc. 8:398.

Thomas, W. E., J. K. Loosli, H. H. Williams and L. A. Maynard. 1951. The utilization of inorganic sulfates and urea nitrogen by lambs. J. Nutr. 43:515.

Welch, J. A., G. A. McLarem, G. S. Smith, C. D. Cambell, D. C. Shelton and G. C. Anderson. 1956. The relative value of biuret, creatine, soybean protein and other nitrogenous materials for lambs in digestion and nitrogen metabolism trials. J. Animal Sci. 15:1265.

Woods, W. R. and A. D. Tillman. 1956. The effect of soybean meal ash or vitamins of the "B" complex group upon the growth of sheep receiving purified diets. J. Animal Sci. 15:1259.

Woodward, J. W. and C. M. McCay. 1932. Synthetic diets for herbivora. Soc. Exp. Biol. and Med. Proc. 30:241.

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