DROUGHT FEEDING STUDIES WITH CATTLE

5. The Use of Sorghum Grain as a Drought Fodder for Non-pregnant Heifers

By J. W. RYLEY, B.V.Sc.,* R. J. W. GARTNER, B.Sc.,† and J. G. MORRIS, Ph.D., M.Agr.Sc., B.Sc.‡

SUMMARY

Four groups of 10 maiden Hereford heifers, approximately 16 months of age, were group-fed in bare yards for 26 weeks. All groups received crushed sorghum grain, supplemented with 1 per cent. ground limestone, at the rate of 3 lb per head per day. Daily feeding with and without a supplement of 0.5 per cent. sodium chloride added to the grain was compared with twice-weekly and weekly feeding without added salt.

Two heifers died during the feeding period.

At the commencement of all-grain feeding the heifers averaged 462 lb body-weight. During the period of grain feeding the animals lost weight rapidly during the initial stages, but thereafter the rate of loss declined. After 26 weeks heifers fed daily lost an average of 105 lb, those fed twice-weekly 98 lb, and those fed weekly 129 lb. Although animals receiving 0.5 per cent. sodium chloride in the grain lost an average of only 83 lb, subcutaneous oedema of the submandibular space occurred in six animals in this group. All groups rapidly regained their lost weight when returned to pasture.

The incidence of geophagia was high in all groups, appearing to be more common in the daily-fed groups. Rumination ceased within two weeks of all-grain feeding, but resumed in all animals within 48 hours of either being returned to pasture or fed lucerne chaff. At the conclusion of grain feeding, animals from the two intermittently fed groups had a better general appearance and were more active than animals fed daily.

After 26 weeks of all-grain feeding the haemoglobin, packed cell volume and red cell count of animals in the two intermittently-fed groups were comparable with initial values, whereas these values were significantly lower than initial values in animals from the groups fed daily. In a comparison of the two groups of intermittently-fed animals, those fed twice-weekly had a significantly higher haemoglobin concentration, packed cell volume and red cell count. Animals from this group also had higher blood and plasma volumes than those from the other three groups.

There was a decline in serum protein level due largely to a decrease of serum albumin. Lowest levels were recorded in animals fed 0.5 per cent. sodium chloride daily, but the results did not indicate that oedema was the result of a deficiency in circulating protein.

Although there were statistically significant differences at different sampling periods within groups, and between groups at 26 weeks in levels for prothrombin time; blood inorganic phosphate; serum calcium and magnesium; plasma chloride, sodium and potassium, these levels did not indicate a pathological change at any sampling period.

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* Director of Husbandry Research, Animal Research Institute, Yeerongpilly.

† Chemist, Animal Research Institute, Yeerongpilly.

‡ Husbandry Officer, Animal Research Institute, Yeerongpilly.

The mean liver vitamin A reserves declined in all groups, but there was no clinical evidence of night blindness in heifers after 26 weeks on a ration containing negligible carotenoids.

Under the conditions of this experiment, twice-weekly feeding of restricted sorghum grain for survival appeared more satisfactory than either daily or weekly feeding. The inclusion of sodium chloride with the grain was not beneficial.

I. INTRODUCTION

In introducing this series of papers, Morris (1958*a*) made reference to grains as one of the classes of feedstuffs available in Queensland for the drought feeding of cattle. It was considered that of the grains, sorghum grain probably had the greatest potential for production and storage on beef cattle properties. In another paper of the series, Morris (1958*b*) reported a preliminary experiment in which eight beef-type maiden heifers were individually fed 3 lb of crushed sorghum grain per head per day for a period of 27 weeks.

The drought feeding experiment reported in this paper was designed to study the effects on beef cattle of restricted feeding of crushed sorghum grain under group feeding conditions, to compare daily with intermittent feeding, and to evaluate supplementation of the grain with 0·5 per cent. sodium chloride. Data were obtained on changes in body-weight and body measurements, feed consumption time, and animal behaviour. Determinations were made on prothrombin time; blood haemoglobin, packed cell volume, red cell count, and inorganic phosphate; serum calcium, magnesium, total protein, albumin and globulin; plasma chloride, sodium and potassium; liver vitamin A; plasma volume and extracellular fluid volume.

II. MATERIALS

Experimental Yards and Facilities.—The experiment was conducted in four adjacent open yards (each 40 ft x 48 ft) of identical design. The yards and an area of approximately 2 ft around the perimeter of the unit were maintained bare of vegetation by mechanical means.

Each yard was provided with a feed trough, 28 ft in length, protected from the weather by a hip roof 12 ft wide. Water was available *ad lib.*, one water trough in the dividing fence serving two yards.

Experimental Animals.—Forty-eight dehorned maiden Hereford heifers, approximately 16 months of age and in store condition, were selected on a beef cattle property in the Burnett district of Queensland. The selection was made on the basis of uniformity of body-weight and conformation. They were transported to the Animal Husbandry Research Farm, Rocklea, Brisbane. During the next four weeks these animals grazed predominantly *Paspalum dilatatum* pastures.

All animals were tested and inoculated as described by Morris (1958*a*) and drenched with phenothiazine. All gave negative results to the single intradermal test for tuberculosis and to serological tests for brucellosis, contagious bovine pleuropneumonia, *Leptospira pomona* and *L. hyos.*

Sorghum Grain.—A single consignment of *Sorghum vulgare* L. grain (Alpha variety) was purchased at the commencement of the experiment. It was stored in bags in a closed shed during the experimental period. The grain was crushed in two portions, each of approximately 5 tons. The first portion was crushed immediately prior to the commencement of the experiment, the remaining 5 tons when the first portion had been almost consumed.

Water.—The source of water for the cattle was the Brisbane City supply.

III. METHODS

Body-weight.—Individual animals were weighed on a cattle weighing scale with an accuracy of $\pm$ 2 lb.

Body Measurements.—The height of the withers at their highest point was measured by the technique illustrated by Brody (1945). The heart girth was measured by the technique used by Brody (1945), with the modification that a constant tension of 7 lb was exerted on the steel tape by a spring balance. All readings were done in triplicate.

Sampling and Analysis of Grain.—A seed trier was used to obtain grain samples from both crushings. After each crushing, samples from three sites in each bag were taken from a random selection of approximately one-fifth of the bags and bulked for analysis. Proximate analysis of feed was determined by the method described by the Association of Official Agricultural Chemists (1955). Grain particle size was determined by using a Greebrun laboratory sieve.

Sampling and Analysis of Water.—Equal aliquots of water were obtained at weekly intervals from the point of supply and bulked in a polythene container for analysis. Chloride was determined by electrometric titration against a silver nitrate solution. Sodium and potassium were determined using an Eel flame photometer.

Examination of Faecal Samples.—The method for worm egg counts was that described by Roberts and O'Sullivan (1950).

Meterological Data.—Daily rainfall and maximum and minimum tempera- were recorded at a site approximately 500 ft from the experimental yards.

Prothrombin Time.—Prothrombin time was determined, using oxalated blood, by the technique of Quick (1938).*

Haemoglobin.—Heparinized blood was used for the determination of haemoglobin by the method of Donaldson *et al.* (1951).

Packed Cell Volume (P.C.V.).—Essentially the method of Wintrobe (1947) was used, employing heparinized blood and a relative centrifugal force of approximately 2067 *g*.

Red Cell Count (R.C.C.).—Heparinized blood was taken for R.C.C. The bulk dilution technique (Dacie 1956), using Vallerino's diluting solution, was followed.

Blood Inorganic Phosphate.—The method of Moir (1945) was used for this determination.

Serum Calcium.—Serum calcium was determined by a modification of the method of Clark and Collip (1925).

Serum Magnesium.—Serum magnesium was determined by a modification of the method of Holzapfel (1934).

Serum Total Protein, Albumin and Globulin.—Serum proteins were determined by the method of Gornall, Bardawill and David (1949).

Plasma Chloride, Sodium and Potassium.—Samples were obtained and analysed for plasma electrolytes as described by Morris (1958*b*).

Liver Vitamin A.—Liver samples were obtained by the aspiration biopsy technique of Loosemore and Allcroft (1951), using the instruments described by Dick (1952). Liver cores were expelled into 2 per cent. aqueous hydroquinone and washed free from blood and adhering tissue. Extraneous fluid was removed on filter paper and the core transferred to stoppered, tared flasks containing 12·5 ml of 1 per cent. alcoholic potassium hydroxide. The flasks were re-weighed and 0·4 ml of 10 per cent. hydroquinone in alcohol (96 per cent.) was added as an antioxidant. The contents were then saponified and in the course of saponification the cores were broken up, using a glass rod. The extraction and determination of liver vitamin A was as described by Gartner and Ryley (1956). Extraction was commenced approximately 90 min after the samples were obtained.

Plasma Volume, Blood Volume and Extracellular Fluid Volume (E.C.F.V.).—A sample blank of heparinized blood was withdrawn from the jugular vein. Through the same needle 20 ml of 0·5 per cent. Evans Blue

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* Thromboplastin was prepared from desiccated rabbit brains by the Commonwealth Serum Laboratories, Melbourne.

(T-1824) solution was injected, followed by 50 ml of 10 per cent. sodium thiocyanate solution. At 20 min after injection a sample was taken from the opposite jugular vein and Evans Blue was determined in plasma by the method of Gregersen (1944). At approximately two, three and four hours after injection samples were taken and thiocyanate estimated by the method of Bowler (1944). In the computation of E.C.F.V. a correction was made on the basis of a 7 per cent. protein content in plasma. All measurements were made using a Hilger spectrophotometer. Blood volume was calculated as the product of

$$\frac{\text{plasma volume} \times 100.}{\text{P.C.V.}}$$

IV. EXPERIMENTAL

(a) Design

Forty heifers were retained after elimination of eight animals, which were extremes in body-weight. These were arranged in descending order of weight and formed into 10 blocks (1-10), each block consisting of four animals of comparable weight. One animal in each block was allotted at random to each of four groups.

The animals were removed from pasture, transferred to yards in their respective groups, and changed to the all-grain ration over a period of three weeks according to the following schedule:—

Days	Ration (lb/head/day) Fed Daily	
	Sorghum Grain	Lucerne Chaff
1–4	2·0	4·0
5–8	2·5	3·0
9–12	2·5	2·0
13–17	2·75	1·25
18–21	3·0	0·5

At the conclusion of this period, the groups were fed their experimental rations. The group and experimental treatments were as follows:—

Group	Ration (3 lb/head/day)	Frequency of Feeding
I	Sorghum grain + 1 per cent. limestone	Daily
II	Sorghum grain + 1 per cent. limestone + 0·5 per cent. sodium chloride	Daily
III	Sorghum grain + 1 per cent. limestone	Twice weekly
IV	Sorghum grain + 1 per cent. limestone	Weekly

The feed was distributed evenly along the 28 ft of troughing at each feeding. Animals were fed between 9 a.m. and 10 a.m. Group III received 9 lb per head each Monday morning and 12 lb per head each Thursday morning, while Group IV received 21 lb per head each Monday morning.

The all-grain feeding continued for 26 weeks. At the conclusion of this period, five animals from each Group (Blocks 1, 2, 6, 9 and 10) were turned out on predominantly *Paspalum dilatatum* pastures. The remainder were retained in the yards and fed lucerne chaff *ad lib.* for one week, in order to determine their average daily intakes of dry matter. They were then turned out on the same pasture. Observations on these animals continued for a further eight weeks.

(b) Observations and Recordings

Body-weights were obtained at weekly intervals throughout the whole period. Weighings were made between 7 a.m. and 8 a.m. each Monday morning. Water was available prior to weighing, but the animals had not been fed.

Body measurements were made during the last week on pasture prior to grain feeding and on the last day of the grain-feeding period.

Prothrombin time; blood haemoglobin, P.C.V., R.C.C., inorganic phosphate; serum calcium, magnesium, total protein, albumin and globulin; and plasma chloride, sodium and potassium were determined on samples from all animals on three occasions during the experiment. Initial determinations were made during the last week the animals were grazing, i.e. three weeks before they were on all-grain rations. Subsequent analyses were made at 12 and 26 weeks of all-grain feeding. Further determinations of blood haemoglobin and P.C.V. were done on all animals after six weeks on pasture following the period of all-grain feeding.

Initial determinations of plasma volume, blood volume, E.C.F.V. and liver vitamin A were made on five animals in each group during the last week on pasture and repeated at 26 weeks of all-grain feeding. The animals used were from Blocks 1, 2, 6, 9 and 10. One of these animals in Group I died and for the final determination was replaced by the animal from the same group that was closest to it in weight at the beginning of the experiment.

The animals were observed feeding on five days each week to obtain grain consumption times and to observe animal behaviour. They were observed for three other periods, of approximately 15 min each, during the daylight hours of these five days for evidence of geophagia, wood-chewing, coat-licking and rumination, and to obtain grain consumption times for Group IV.

Faecal samples were obtained at intervals of four weeks from five animals selected at random from each group. Egg counts were made to indicate whether further anthelmintic treatment against internal parasitism was necessary.

V. RESULTS

(a) Analyses of Grain and Water

The proximate analysis of the grain expressed in percentages was as follows:—

Moisture	Protein	Fat	Fibre	N.F.E.	Ash	Ca	P	Cl	Na	K
12·2 ..	12·3	1·3	2·2	70·7	1·3	0·04	0·24	<0·001	0·02	0·38

Examination for particle size of the crushed grain showed that 86 per cent. of the particles were between 0·24 and 0·10 cm in diameter.

The composite water sample obtained during the experimental period had the following concentration of ions in m-equiv./l: chloride 2·45, sodium 1·45 and potassium 0·05.

(b) Mortality

Two heifers died during the period of grain feeding. One, initially the lightest in Group I, died during the 12th week. It became progressively weaker and at the time of death had lost 80 lb in body-weight compared with the group mean loss of 68 lb. The animal was recumbent on the day prior to death and bloating became marked. The significant autopsy findings were emaciation and distension of the rumen with an estimated 8-10 gal of gruel-like liquid. Little fat was present in the carcass.

One animal in Group III died overnight during the 16th week. It had not shown any marked symptoms and its weight at the previous weighing was slightly higher than the mean of the group. It was in poor condition, but at autopsy fat was still present in the subcutis and abdominal depots. The rumen contents weighed 46 lb. They were very fluid and contained grain, soil and approximately 70 hair-balls varying from 1 to 5 cm in diameter. One hair-ball was present in the abomasum and another in the duodenum. There was little ingesta distal to the site of the hair-ball in the duodenum, but the hair-ball was freely movable and appeared unlikely to have caused complete obstruction. Ash analyses indicated that approximately 30 per cent. of the dry-matter content of the rumen was soil.

(c) Body-weight

The group mean body-weight determined at weekly intervals during the periods of grain feeding and recovery is shown in Figure 1. The group mean body-weight at five periods—at the commencement of yard feeding, at the commencement of all-grain feeding, after 12 and 26 weeks of all-grain feeding, and after a recovery period of 9 weeks on pasture—is shown in Table 1. During the initial stages of grain feeding animals lost body-weight rapidly, but thereafter the rate of loss declined. After 12 weeks and also at the end of grain feeding, Group IV had lost significantly more weight than Group II ($P < 0 \cdot 001$) and Group III ($P < 0 \cdot 005$). No other weight differences were significant.

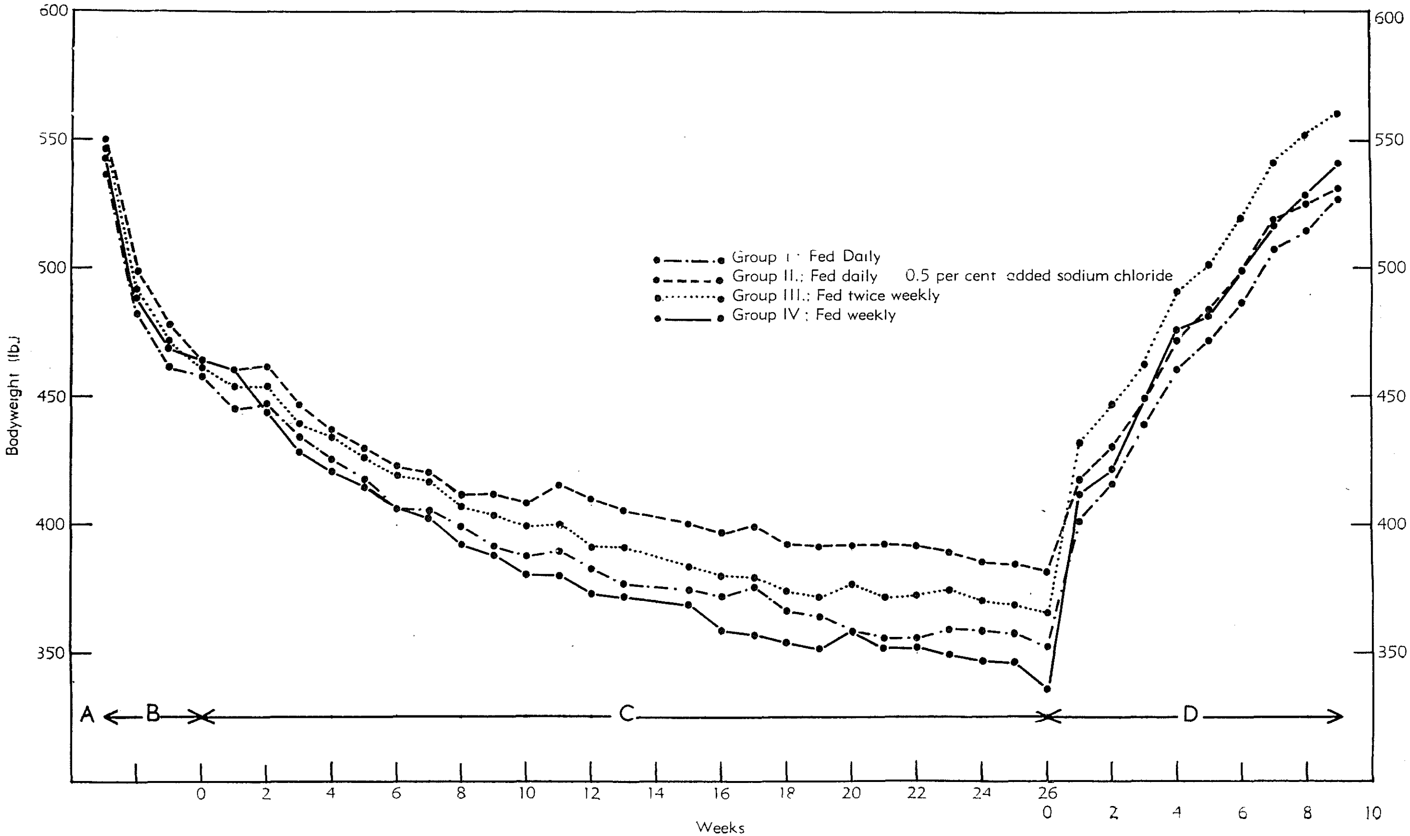

Fig. 1.—Weekly body-weights of heifers prior to, during and after feeding 3 lb crushed sorghum grain per head per day. A, pasture. B, grain/lucerne chaff mixture. C, all-grain. D, recovery on pasture.

TABLE 1

Group Mean Body-weight of Heifers Fed 3 lb Crushed Sorghum Grain per Head per Day

Date	Period	Group Mean Body-weight (lb)			
		I	II	III	IV
19–v–58	Commencement of yard feeding (from pasture)	536	550	547	542
9–vi–58	Commencement of all-grain feeding	457	464	462	464
1–ix–58	After 12 weeks of all-grain feeding	384	409	391	373
8–xii–58	After 26 weeks of all-grain feeding	352	381	364	335
10–ii–59	After 9 weeks' recovery on pasture	520	530	560	540

During the first week of the recovery period the animals fed lucerne chaff showed no statistical differences in body-weight compared with the animals on pasture. Therefore all animals have been used for the assessment of weight gain after grain feeding. During the period of 9 weeks Group IV gained more weight than Group I ($P < 0 \cdot 001$) and Group II ($P < 0 \cdot 01$); Group III gained more weight than Group I ($P < 0 \cdot 05$) and Group II ($P < 0 \cdot 001$). The rapid loss in weight during the introduction to all-grain feeding and the rapid gain during the first week of recovery on pasture are partly due to changes in gastro-intestinal fill.

There were no significant differences in body-weight between groups when initial weights obtained on pasture just prior to the commencement of yard feeding (May 19, 1958) were compared with those obtained after 9 weeks' recovery from grain feeding (February 10, 1959).

(d) Body Measurement

The group means of the height at withers (height) and heart girth of heifers at the time of confinement to yards and also at the conclusion of grain feeding are shown in Table 2. The height increased slightly in all groups, the increase being significant ($P < 0 \cdot 01$) in Groups III and IV. The heart girth decreased significantly ($P < 0 \cdot 001$) in all groups. There was no significant difference between groups in any of these measurements.

TABLE 2

Body Measurements of Heifers Fed 3 lb Crushed Sorghum Grain per Head per Day

Group	Height (cm)		Heart Girth (cm)	
	Initial*	Final†	Initial*	Final†
I	104·5	105·4	142·7	133·2
II	105·9	106·1	142·1	135·2
III	104·5	106·5	141·6	133·2
IV	105·2	106·8	142·2	131·2

*Initial measurements were made during the last week on pasture, prior to grain feeding.

†Final measurements were made on the last day of the 26 weeks' grain-feeding period.

(e) Grain Consumption Time

Animals in Groups I, II and III remained at the trough until all their food was consumed. The average grain consumption times for these groups were as follows:—Group I, 17 min; Group II, 15 min; Group III (Mondays, 9 lb), 53 min; and Group III (Thursdays, 12 lb), 74 min. The rate of grain consumption of these groups was therefore similar, being 1 lb per 5-6 min. There was little change in the rate of consumption as the experiment progressed.

The time required for Group IV to consume their weekly feed was variable. When presented with their first weekly feed, the animals consumed more than 99 per cent. of their ration within 5·3 hr. Thereafter, it required between 48 and 100 hr (average 65 hr) for the animals to consume all their weekly feed.

(f) Animal Behaviour

Geophagia commenced in some animals during the second week of all-grain feeding. There was an increasing incidence of earth-eating until the 12th week, after which it remained relatively constant. During the whole period of grain feeding, earth-eating appeared to be more common in the daily-fed groups. The incidence relative to Group I based on the number of animals observed eating earth during the daily observation periods was as follows:—Group II, 119 per cent.; Group III, 46 per cent.; and Group IV, 55 per cent.

Attempts to chew the wood on the troughs and the rails of the yards were noted during the first few weeks of grain feeding, but thereafter they were seen infrequently. Animals in all groups were frequently observed to lick the coats of other animals in the group.

No animal was observed ruminating after two weeks on all-grain feeding, but "pseudo-rumination" (chewing without a bolus being regurgitated) was observed occasionally during the remainder of the period. After the conclusion of grain feeding, one animal was observed to begin ruminating within 30 min of eating lucerne chaff, and all animals, whether fed lucerne chaff or grazing, were seen ruminating within 48 hr.

The observations made at feeding indicated that, although there was a sporadic incidence of heifers being prevented by others from obtaining a fair share of the ration, no one animal was consistently in this category. One animal in Group I, which died during the 12th week of grain feeding, was tardy in approaching the trough at feeding and did not always remain at the trough until all feed was consumed.

Animals in Group IV were lethargic after they had consumed their first weekly feed. They showed inappetence at the next feed, and one animal was not observed to eat for two weeks after the initial weekly feed.

As the experiment progressed, the animals in all groups became more dejected and lethargic. At the termination of all-grain feeding, Groups III and IV were noticeably more active than Groups I and II. The coats of animals in Groups III and IV did not appear to contain as much debris and soil as those in Groups I and II. At the conclusion of grain feeding, Group III, as assessed by a number of independent observers, had a better general appearance than Group IV, which in turn was better than the other two groups.

During the last few weeks of grain feeding, some of the animals in Group II developed slight subcutaneous oedema of the submandibular space. At the conclusion of grain feeding, six animals in Group II were affected. Oedema was not apparent in any animals in the other groups.

(g) Examination of Faecal Samples

The faeces of the animals in all groups varied in consistency from very firm to semi-liquid. As voided, they always contained visible particles of grain, and had an odour similar to faeces from pigs fed on rations containing a high proportion of cereal grains.

Faecal samples obtained from a random sample of five animals per group at intervals of four weeks showed that 95 per cent. of the samples had less than 100 eggs per gram (e.p.g.), and all except one had less than 200 e.p.g. This sample had 420 e.p.g. All eggs were of *Cooperia* spp. These results, particularly when considered in relation to the low faecal output of these animals, would indicate that internal parasites were not a complicating factor in the experiment.

(h) Feed Intake During the Week after Cessation of Grain Feeding

The *ad lib.* daily mean lucerne chaff consumption, on a dry-matter basis, during the week after cessation of grain feeding is shown in Table 3. During the first few days, the daily dry-matter consumption of Groups I and II was similar to their previous daily intake of grain, and much less than that of Groups III and IV. The daily intakes of the two former groups gradually increased during the week, and at the end of the week approached those of Groups III and IV.

TABLE 3

Mean Daily Consumption of Lucerne Chaff after Cessation of the Grain-feeding Period

Day	Mean Dry-matter Consumption per Head per Day (lb)			
	Group I	Group II	Group III	Group IV
1	3·4	4·8	7·2	7·4
2	2·5	2·4	8·0	6·4
3	3·8	3·7	6·2	7·0
4	5·3	4·5	7·6	6·6
5	4·3	4·6	8·0	6·1
6	7·3	6·3	9·5	7·7
7	4·8	8·6	8·4	9·1

(i) Meteorological Data

The mean daily maximum and minimum temperatures for the grain-feeding period were 75·0°F (range 58-106°F) and 47·7°F (range 30-78°F) respectively. Little rain fell after the first week of the grain-feeding period until the beginning of the 26th week (5·7 in. in 24 weeks). During the last week 1·9 in. fell over three successive days and 16·4 in. fell during the 9 weeks' recovery period.

(j) Blood and Serum Analyses, Body Fluids and Liver Vitamin A.

Biochemical data for blood and serum analyses, body fluids and liver vitamin A are recorded as group means in Table 4. Differences between groups in final determinations are shown in Table 5.

There was a general tendency in all groups for the mean haemoglobin, P.C.V. and R.C.C. to be elevated above the initial group values at 12 weeks of all-grain feeding. At 26 weeks the blood from animals in Groups I and II exhibited a marked fall in haemoglobin, P.C.V. and R.C.C. levels as compared with their initial values, whereas the haematological values of Groups III and IV tended to approach the initial levels. The lowest individual values in Groups I and II at 26 weeks were haemoglobin 6·9 and 6·6 g/100 ml; P.C.V. 20·2 and 18·8 per cent.; and R.C.C. 4·0 and 4·3 million respectively. The lowest individual values in Groups III and IV were haemoglobin 10·8 and 9·7 g/100 ml; P.C.V. 32·5 and 28·3 per cent.; and R.C.C. 6·8 and 5·8 million respectively.

Group means, standard errors and significant differences of haemoglobin and P.C.V. of the animals after 6 weeks' recovery on pasture following 26 weeks of grain feeding are recorded in Table 6. Anomalous results of two animals from Group I decreased the group average for haemoglobin and P.C.V. These two animals, although apparently normal in appearance, had blood haemoglobin levels of 5·9 and and 7·3 g/100 ml and P.C.V. levels of 19·1 and 21·3 per cent. respectively. Apart from these two animals, blood haemoglobin and P.C.V. levels previously depressed in animals from the daily fed Groups I and II had returned to the pre-experimental levels of the groups.

The group mean serum protein level of all animals exhibited a significant decline at 12 weeks and, with the exception of Group I, a significant decline at 26 weeks. This decline in total serum protein level was largely due to the decrease of serum albumin. The mean serum albumin values decreased in Groups I and II to 2·9 and 2·7 g/100 ml at 26 weeks from initial levels of 3·5 and 3·6 g/100 ml. Individual values declined to as low as 2·2 and 2·0 g/100 ml respectively. The lowest individual values obtained in Groups III and IV were 2·9 and 2·6 g/100 ml respectively at the same sampling period.

TABLE 4

Group Means for Blood and Serum Analyses, Body Fluids and Liver Vitamin A of Heifers Fed 3 lb Crushed Sorghum Grain per Head per Day

Group	I†			II			III†			IV		
Period	Initial	At 12 weeks	At 26 weeks	Initial	At 12 weeks	At 26 weeks	Initial	At 12 weeks	At 26 weeks	Initial	At 12 weeks	At 26 weeks
Prothrombin time (sec)	26	28*	20***	26	24	20***	25	25	18***	26	22**	21***
Blood haemoglobin (g/100 ml)	12·1	12·8	9·4***	11·8	13·0*	8·3***	12·8	13·9**	13·3	11·7	12·8*	11·2
P. C. V. (%)	35·9	39·4*	28·7**	34·7	42·9***	24·8***	36·6	45·0***	39·9	34·8	39·3**	33·0
R. C. C. (millions)	7·6	7·4	6·2**	7·6	8·2	5·5***	7·7	8·7**	7·9	7·3	7·8	6·8
Blood inorganic P (mg/100 ml)	5·9	6·0	6·4	5·4	6·1	7·4***	5·4	6·2*	4·9	6·0	6·2	5·4*
Serum Ca (mg/100 ml)	10·1	8·6***	9·3*	10·3	9·2**	9·3**	9·6	9·0	10·4*	9·8	9·6	10·6*
Serum Mg (mg/100 ml)	2·5	2·4	2·5	2·7	2·5	2·7	2·6	2·7	3·0*	2·4	2·4	2·2
Total serum protein (g/100 ml)	7·2	6·4**	6·8	7·3	6·1***	6·2***	7·1	6·1***	6·5**	7·1	6·5**	6·7*
Serum albumin (g/100 ml)	3·5	2·7***	2·9***	3·6	2·8***	2·7***	3·5	3·0***	3·3	3·6	3·1***	3·1***
Serum globulin (g/100 ml)	3·6	3·6	3·9	3·7	3·3	3·6	3·6	3·1	3·2*	3·5	3·4	3·6
Plasma Cl (m–equiv./l.)	102	97***	104	103	99**	107·5**	102	100*	104	102	97***	103
Plasma Na (m–equiv./l.)	144	155***	139*	144	148	139*	142	147	138*	143	153***	135***
Plasma K (m–equiv./l.)	5·5	4·9**	5·0*	5·1	4·9	5·4	4·9	4·8	4·5	5·1	4·4**	4·5**
Liver vitamin A (μg/g)	140	..	56***	176	..	95**	135	..	68**	184	..	113***
Plasma volume (l.)	11·3	..	8·2*	12·9	..	9·2**	11·8	..	10·3	13·3	..	8·4***
Plasma volume (ml/kg)	47·9	..	51·1	53·9	..	54·3	49·3	..	64·9**	56·2	..	56·2
			(45·8)			(48·8)			(55·7)			(46·7*)
Blood volume (l.)	17·4	..	10·9***	19·2	..	12·1***	18·4	..	16·8	19·9	..	12·3***
Blood volume (ml/kg)	73·6	..	68·2	80·3	..	71·5	77·4	..	105·7***	84·4	..	82·5
			(61·0)			(64·2*)			(90·8*)			(68·6*)
Extracellular fluid volume (l.)	104	..	58**	101	..	61***	110	..	53***	105	..	58***
Extracellular fluid volume (l./100 kg)	43·6	..	34·6***	41·4	..	35·3***	46·4	..	32·1***	45·5	..	38·7***
			(30·8***)			(31·6***)			(28·0***)			(32·2***)

† In Groups I and III one animal died and adjustments were made by missing plot technique.
* Significantly lower or higher than initial value at 5% probability level.
** Significantly lower or higher than initial value at 1% probability level.
*** Significantly lower or higher than initial value at 0·1% probability level.

Figures in parentheses are calculated on the basis of body-weights of the animals after the first week on pasture following 26 weeks on restricted grain feeding. This may partially eliminate differences in gastro-intestinal fill.

TABLE 5

Group Means, Standard Errors of Means and Significant Differences for Blood and Serum Analyses, Body Fluids and Liver Vitamin A Obtained at 26 Weeks from Heifers Fed 3 lb Crushed Sorghum Grain per Head per Day

Determination	Means and Standard Errors of Groups				Significant Differences at		
	I†	II	III†	IV	5% level	1% level	0·1% level
Prothrombin time (sec)	20·3 ± 0·4	20·0 ± 0·4	18·3 ± 0·4	21·3 ± 0·4	IV > II	I, II > III	IV > III
Blood haemoglobin (g/100 ml)	9·4 ± 0·6	8·3 ± 0·5	13·3 ± 0·6	11·2 ± 0·5	III > IV IV > I		III > I, II IV > II
P. C. V. (%)	28·7 ± 1·8	24·8 ± 1·7	39·9 ± 1·8	33·0 ± 1·7		III > IV IV > II	III > I, II
R. C. C. (millions)	6·2 ± 0·3	5·5 ± 0·3	7·9 ± 0·3	6·8 ± 0·3	III > IV	IV > II	III > I, II
Blood inorganic P (mg/100 ml)	6·4 ± 0·3	7·4 ± 0·2	4·9 ± 0·3	5·4 ± 0·2		II > I I > IV	II > IV, III I > II
Serum Ca (mg/100 ml)	9·3 ± 0·3	9·3 ± 0·3	10·5 ± 0·3	10·6 ± 0·3		IV, III > II, I	
Serum Mg (mg/100 ml)	2·5 ± 0·1	2·7 ± 0·1	3·0 ± 0·1	2·2 ± 0·1		III > I II > IV	III > IV
Total serum protein (g/100 ml)*	6·8 ± 0·2	6·2 ± 0·2	6·5 ± 0·2	6·7 ± 0·2	I, IV > II		
Serum albumin (g/100 ml)	2·9 ± 0·1	2·7 ± 0·1	3·3 ± 0·1	3·1 ± 0·1	III > I	IV > II	III > II
Serum globulin (g/100 ml)*	3·9 ± 0·1	3·5 ± 0·1	3·2 ± 0·1	3·6 ± 0·1	I > II IV, II > III		I > III
Plasma Cl (m–equiv./l.)	104·1 ± 1·1	107·5 ± 1·0	103·9 ± 1·1	103·2 ± 1·0	II > I, III	II > IV	
Plasma Na (m–equiv./l.)	139·2 ± 1·2	138·6 ± 1·2	138·2 ± 1·2	134·5 ± 1·2	I, II, III > IV		
Plasma K (m–equiv./l.)	5·0 ± 0·2	5·4 ± 0·2	4·5 ± 0·2	4·3 ± 0·2		II > III I > IV	II > IV
Liver vitamin A (μg/g)*	67·6 ± 16·5	84·5 ± 18·2	82·8 ± 16·8	97·8 ± 16·9			
Plasma volume (l.)	8·2 ± 0·6	9·2 ± 0·5	10·3 ± 0·5	8·4 ± 0·5	III > IV, I		
Plasma volume (ml/kg)	51·1 ± 3·0 (45·8 ± 2·6)	54·3 ± 2·7 (48·8 ± 2·3)	64·9 ± 2·7 (55·7 ± 2·3)	56·2 ± 2·7 (46·7 ± 2·3)	III > IV, II (III > II, IV, I)	III > I	
Blood volume (l.)	10·9 ± 0·9	12·1 ± 0·9	16·8 ± 0·9	12·3 ± 0·9		III > IV, II	III > I
Blood volume (ml/kg)	68·2 ± 4·3 (61·0 ± 4·0)	71·5 ± 3·8 (64·2 ± 3·5)	105·7 ± 3·8 (90·8 ± 3·5)	82·5 ± 3·8 (68·6 ± 3·5)	IV > I	III > IV	III > II, I (III > IV, II, I)
Extracelluiar fluid volume (l.)	57·5 ± 3·8	60·6 ± 3·3	52·9 ± 3·3	57·8 ± 3·3			
Extracellular fluid volume (1./100 kg)	34·6 ± 1·9 (30·8 ± 1·6)	35·3 ± 1·7 (31·6 ± 1·6)	32·1 ± 1·7 (28·0 ± 1·6)	38·7 ± 1·7 (32·2 ± 1·6)			

† In Groups I and III one animal died and adjustments were made by missing plot technique.
* In the case of these variates, final values were significantly dependent on initial values and adjustments made by co-variance analysis.
Figures in parentheses are calculated on the basis of body-weights of the animals after the first week on pasture following 26 weeks on restricted grain feeding.

Although there were statistical differences within groups at different sampling periods and between groups at 26 weeks in levels for prothrombin time, blood inorganic phosphate, serum calcium and magnesium, plasma chloride, sodium and potassium, these levels did not indicate a pathological change at any sampling period and their implications at this stage are not known.

There was a decrease in liver vitamin A reserves in all groups at 26 weeks. Although final group means were significantly dependent on initial group means, individual animals showed considerable variation in the degree of depletion. The lowest level recorded in any animal at 26 weeks was $1 \cdot 5$ μg/g liver in a heifer from Group III. It had an initial level of 112 μg/g liver. Another animal from the same group had an initial level of 198 μg/g liver, which only decreased to a level of 130 μg/g. During the 26th week of grain feeding, the animals were individually driven through a maze at dusk in an endeavour to test for any possible night blindness. All animals negotiated the race successfully.

TABLE 6

Group Means, Standard Errors of Means and Significant Differences of Haemoglobin and P.C.V. of Heifers after Six Weeks' Recovery on Pasture

Determination	Means and Standard Errors of Groups			
	I	II	III	IV
Haemoglobin (g/100 ml)* ..	$10{\cdot}4 \pm 0{\cdot}2$**	$12{\cdot}0 \pm 0{\cdot}3$	$12{\cdot}3 \pm 0{\cdot}3$	$12{\cdot}6 \pm 0{\cdot}2$
P.C.V. (%)	$30{\cdot}7 \pm 1{\cdot}4$**	$34{\cdot}8 \pm 1{\cdot}3$	$37{\cdot}2 \pm 1{\cdot}4$	$35{\cdot}6 \pm 1{\cdot}4$

* Values adjusted for regression on initial values.

** Significantly lower at 1% probability level than initial values (due to anomalous results of two animals in this group).

Values for blood volume, plasma volume, and E.C.F.V. are expressed as total volume and as a function of total body-weight. Initial body-weight of the animals from pasture would include a greater gastro-intestinal fill than the weight after 26 weeks of grain feeding. Due to this difference, strict comparisons related to body-weight cannot be made between initial values for body fluids and values at 26 weeks. In view of this discrepancy, the body fluid data at 26 weeks have been expressed as a function of the body-weight both at the time of determination and after one week on pasture.

At the end of the grain-feeding period, animals in Group III had a significantly greater blood and plasma volume when compared with animals in the other three groups. There were no significant between-group differences in E.C.F.V. at this time.

VI. DISCUSSION

This experiment has indicated that 3 lb crushed sorghum grain supplemented with 1 per cent. limestone is a satisfactory drought fodder for maiden heifers confined in small yards. These findings are in agreement with the preliminary data of Morris (1958*b*) and the results obtained by Southcott (1959) with crushed and whole wheat. Mortality under our conditions was low (5 per cent.) and occurred only during the first 16 weeks of all-grain feeding.

Although the animals lost considerable weight during the grain-feeding period of 26 weeks, the rate of weight loss declined as the experiment progressed. During the last 14 weeks, the maximum weight lost in any group was only 2·7 lb per head per week, compared with 7·6 lb per head per week for the first 12 weeks. All groups rapidly regained their lost weight when returned to pasture. The ability of young cattle to gain weight rapidly following transfer from sub-maintenance to productive rations is in agreement with results obtained by other workers (Waters 1908; Winchester and Howe 1955; Morris 1958*b*; Pope 1959).

There were no significant differences between groups in the body measurements after 26 weeks of grain feeding. Height at withers, the more reliable of the measurements for skeletal change used, showed that animals increased slightly in height during the experiment despite a marked loss in body-weight. Although no comparisons were made between the experimental animals and comparable cattle on a high plane of nutrition, the data on increase in wither height with age quoted by Brody (1945) for Jersey and Holstein cattle would suggest that there had been some retardation in skeletal growth. Statistical analyses indicate that chest girth and body-weight in cattle are particularly well correlated (Brody 1945) and our findings of a significant decrease in heart girth, a measurement similar to chest girth, are therefore to be expected.

Franklin and Sutton (1952) and Franklin, McClymont, Briggs, and Campbell (1955) reported that weekly feeding of groups of Merino sheep at levels sufficient for survival was more satisfactory than daily feeding at the same level. Under the conditions of this experiment, twice-weekly feeding of heifers appeared better than either daily or weekly feeding at the rate of 3 lb crushed sorghum grain per head per day. The superiority of the animals fed twice weekly was evident in their general appearance and activity at the conclusion of grain feeding. These animals also had higher body-weights (not significant) at the conclusion of grain feeding and after 9 weeks on pasture.

There was a marked lowering in blood haemoglobin concentration, P.C.V., R.C.C., and serum albumin in the daily-fed groups at 26 weeks. This did not occur in the intermittently-fed groups, although some fall in serum albumin was evident. These markedly lower values in the daily-fed groups are probably a consequence of the greater stress imposed by this system of drought feeding.

In a comparison of the two groups of intermittently-fed animals, those fed twice-weekly had a significantly higher haemoglobin concentration, P.C.V. and R.C.C. at the conclusion of grain feeding. This group also had the greatest total blood volume as determined by the Evans Blue technique.

No apparent metabolic disturbances occurred when animals were introduced to either daily or twice-weekly feeding. However, after the first feed the weekly-fed animals exhibited lethargy and inappetence at the next feed. Probably this would not have occurred with a more gradual introduction to weekly feeding.

After the first week of the experiment, a comparison of the time required for all the feed to be consumed under the different systems of feeding indicated that animals fed weekly had a better opportunity to obtain an equal share of the ration than those fed daily. For this reason, weekly feeding may have greater superiority over daily feeding either when animals vary greatly in age and weight or when there is a shortage of trough space.

In comparing intermittent with daily feeding of groups of sheep under simulated drought-feeding conditions, Franklin and Sutton (1952) and Franklin *et al.* (1955) noted a greater distribution in the body-weight change, expressed as percentage of initial body-weight, of sheep fed daily than of those fed weekly. A similar difference was not observed in this experiment with cattle. The smaller numbers per group, low incidence of "shy" feeders, adequate trough space and uniformity of the animals may have accounted for the smaller distribution in body-weight change.

In practice, twice-weekly feeding would require less labour than daily feeding, and because the feed is consumed immediately it would not be available to predators such as birds and rodents. This is likely to occur with weekly feeding, where uneaten grain would be exposed for 3-4 days each week.

Franklin *et al.* (1955) reported that supplementation of an all-wheat maintenance ration with 0·5 per cent. sodium chloride did not affect body-weight changes or eventual losses in weaner Merino sheep. In this experiment with cattle, there was no advantage in including 0·5 per cent. sodium chloride in the sub-maintenance ration, despite the low levels of sodium and chloride in the sorghum grain. Animals fed daily on this ration lost less weight during the grain-feeding period than animals fed either daily or intermittently without additional salt, but the presence of oedema in six of these animals, together with their slower subsequent rate of weight gain on pasture, could indicate that a greater E.C.F.V. may have been responsible for the difference in body-weights. Although the absolute amount of E.C.F.V. as determined by the thiocyanate technique was greatest in this group, the differences between groups did not reach significance. Meyer (1954) showed an increased E.C.F.V. in growing rats fed diets low in protein and containing very high levels of sodium chloride. The influence of sodium chloride on cattle on a low plane of nutrition is being investigated further, because underground waters in many areas in Queensland contain appreciable levels of total solids, which may be increased during drought times by evaporation.

The mean serum total protein and albumin level was lowest in animals fed 0·5 per cent. sodium chloride daily. This was the only group of animals showing slight subcutaneous oedema of the submandibular space during the last few weeks of grain feeding. The animal with the lowest serum albumin level (2·0 g/100 ml) in the salt-fed group had the most marked oedema. Another animal in this group with a serum albumin level of 2·9 g/100 ml showed slight oedema. However, there were other animals with serum albumin levels of this order or less in which no oedema was detected, viz. three animals in the salt-fed, five in the daily-fed, one in the twice-weekly fed, and three in the weekly-fed group. The product of plasma volume and total serum protein concentration and also of plasma volume and serum albumin did not indicate that oedema was the result of a deficiency of circulating protein. It is possible that the additional dietary sodium intake of animals in Group II allowed increase of the extracellular fluid and resulted in reduction in protein concentration.

The high incidence of geophagia, as judged by observation of the animals and analysis of the rumen content of one of the animals that died, probably resulted in re-ingestion of much of the undigested grain present in the faeces. Although boredom may have been a factor in the high consumption of earth, the apparent lower incidence in the groups fed intermittently would indicate that other factors are involved. No clinical abnormalities in the animals could be attributed to the high consumption of earth.

The presence of numerous hair-balls in one of the animals that died may indicate that fatal intestinal obstruction could occur with restricted feeding of a ration of grain alone. The occurrence of a large number of hair-balls may be associated with the lack of rumination. Hutyra, Marek, and Manninger (1946) reported their occurrence in cattle, particularly during the suckling period, presumably before rumination commences, and also when cattle are on soft feed. However, limited numbers of hair-balls are sometimes found at autopsy in the rumen of cattle fed rations containing high proportions of roughage.

The facilities used in this experiment did not permit the measurement of water consumption of the individual groups. However, in subsequent studies (unpublished) under comparable temperature conditions, heifers housed in stalls, with *ad lib.* water supply and fed at the same rate of sorghum grain daily, consumed an average of less than 1 gal of water per head per day. This low water consumption is in agreement with the general statement that restriction of feed intake in cattle decreases water consumption (Leitch and Thomson 1944).

It is not possible in drought-feeding experiments of this nature to simulate the environmental conditions pertaining to droughts. The grain feeding commenced in early winter and continued until early summer. In Queensland, with a predominantly summer rainfall, this is the most likely period of nutritional stress in grazing animals. Rain, the necessary factor for termination of a drought, fell in moderate amounts (1·9 in.) during the last week of grain feeding, when it could be expected that the experimental heifers would be weakest and therefore most susceptible to environmental changes. However, this amount of rain, which fell over three successive days, did not appear to have any adverse effect on the animals.

The trends in many of the biochemical values as judged by comparison of initial values with those at 12 weeks of grain feeding were not maintained at 26 weeks. Blood haemoglobin, P.C.V., R.C.C., and plasma sodium levels at 12 weeks were higher than initial values, but this trend was not maintained at 26 weeks. Plasma chloride levels at 12 weeks were lower than initial values; however, the highest levels were recorded at 26 weeks. The reasons are not readily apparent, especially when considering the possible inter-relationships of the components analysed. However, the findings indicate that in this type of experiment such values are dependent on the duration of the experiment and possibly on seasonal variations.

At the conclusion of grain feeding, blood inorganic phosphate levels were lowest in animals fed twice weekly, followed by animals fed weekly, daily, and daily with 0·5 per cent. sodium chloride. There was also an inverse relationship between blood inorganic phosphate and P.C.V. levels. As inorganic phosphate was determined on whole blood, differences between groups might be related to differences in P.C.V. K. W. Moir (personal communication) found that for dairy heifers inorganic phosphate levels in whole blood were consistently lower than levels in plasma, but differences ranged only from 0·5 to 1·0 mg P/100 ml. As these differences are small, it is considered that the appreciable difference in blood inorganic phosphate levels between groups at the conclusion of grain feeding cannot be entirely due to a decrease in P.C.V.

Page, Erwin, Varnell, and Roubicek (1958) fed four groups of yearling heifers an essentially carotene-free ration. Liver samples obtained by biopsy at 33 and 61 days showed that, within groups, the magnitude of hepatic vitamin A expenditure was directly related to the initial amount of vitamin A in the liver (170-50 μg/g). Our results show that after 25 weeks on a ration containing negligible carotenoids, final group means of liver vitamin A (133-56 μg/g) were significantly dependent on initial group means (184-135 μg/g). However, individual animals showed considerable variation in the degree of depletion, and of the 20 animals selected for sampling one had a low (0-2 μg/g) and two others a marginal (2-10 μg/g) liver vitamin A reserve. The levels of these two animals at 26 weeks were not dependent on initial levels. From the absence of night blindness, it is apparent that clinical vitamin A deficiency did not occur in these cattle. In general, the need for vitamin A supplementation will be related to the class of cattle, initial reserves, and the duration of feeding rations containing negligible amounts of carotenoids.

Plasma volume was estimated by determining the optical density of a single sample of plasma taken 20 min after injection of Evans Blue. Subsequent studies of this method were applied to cattle of comparable weight. The rate of disappearance of the dye was plotted by taking readings at approximately 10, 15, 20 and 25 min after injection. Extrapolation of the disappearance curve to zero time indicates that the 20 min reading gave results on the average 11·3 per cent.

too high. However, as the value obtained for the 20 min reading falls on the linear range of the curve, results may be taken as sufficiently comparative for the purpose of this paper.

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