METABOLISM EXPERIMENTS -- THEIR TECHNIQUE AND VALUE IN ASSESSING THE NUTRITIONAL VALUE OF PASTURE.

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I, INTRODUCTION.

Common methods adopted to ascertain the nutritional value or quantity and quality of grass and other foodstuffs include changes in live weight, improvement in health and production, chemical analyses - naked eye responses to fertilisers, tons per acre, and so on. Each of these methods has its limitations. Within recent years, however, more attention has been devoted to bridging the gap between the actual production of a foodstuff and its utilisation by the animal which, after all, is the final test of its suitability for particular functions. For that reason matabolism studies must now be recognised as part of any scheme designed to improve pasture or feed production. The purpose of this paper is to discuss the value of digestibility work in relation to grassland research and nutritional problems peculiar to New Zealand conditions.

Support for the views just expressed will be given by a brief discussion of some of the results obtained by Dr. H.E. Woodman in his pasture investigations at the Nutrition Institute Cambridge University. In this work Dr. Woodman has not only estimated total yields and the chemical composition in his pasture research, but has added considerably to the value of his results by digestibility trials thus obtaining data on quantities of the different constituents actually available to the animal. It should be obvious to all that figures for gross production are of much greater value when the percentage availability (and this includes the percentage of the food the animal is able to utilise for production of energy, heat, fat, flesh, milk, etc.) of the individual food constituents is also known,

II. TECHNIQUE OF METABOLISM EXPERIMENTS:

Before dealing with Dr. Woodman's results a brief review of the technique of digestibility trials may be of interest. Some will already be familiar with the details. Actually the procedure is relatively simple, and merely consists in feeding to the animal in a suitable metabolism cage a definite quantity of food, of which the chemical analysis is known, and the collection and analysis of the solid excreta. Every care must be taken to ensure representative sampling and the greatest accuracy in the analytical work, but there should be no necessity to dwell on such obvious details in addressing an audience composed mainly of chemists,

The type of metabolism cage is, in many cases, really a matter of personal choice, and, of course, dependent upon the type of animal with which one is dealing. During the last three years eight or nine different types of metabolism cages have been inspected by the speaker. With the exception of two all were designed for use with the male animal. This is frequently a disadvantage and at the Canterbury Agricultural College we have recently designed a type, really a modification of those used at the Nutrition Institute in Adelaide, which it is hoped will prove equally adaptable for either ewes or wethers, In metabolism trials the urine is also often analysed. This will, of course, consist of material which has been digested by the animal and does not enter into digestibility trials but is of considerable value in finding the quantity of any constituent, either organic or inorganic, which is being retained or lost. For example where one is following, say, the storage of lime or phosphate by the animal both faecal and urinary excretion must be taken into consideration.

CHOICE OF ANIMALS:

Occasionally difficulty may be experienced in obtaining animal which settle down readily to metabolism cage conditions. Where the animal does not take kindly to such experiments, either showing excessive restlessness, large fluctuations in its daily food consumption, or some other abnormal behaviour, it must be rejected. for the results obtained would be of very doubtful value. With care in handling the animals and experience such cases, however, should be rare.

Further, the previous history of the animal must be more fully taken into account than is done by some at the present time. In the case of mineral metabolism studies failure to do so may quite easily lead to erroneous conclusions. The following two cases will illustrate this point.

Mr. A, Leslie, head of the Veterinary Department, at Canterbury Agricultural College, has obtained some particularly in&resting results. on cases of dental attrition in two-tooth ewe's on the College experimental farm at Ashley Dene. Two-tooth ewes bought at the Addington saleyards and drawn from different parts of Canterbury are now, as two-year olds and due to have their first lamb, showing in an exceptionally large percentage of cases signs of dental attrition. College ewes of the same age and which have been kept under similar conditions, in fact in the same mob, during the last twelve months, but which prior to that were reared under good feeding conditions on the College farm, are not showing the same trouble. It is believed that this may indicate that faulty mineral nutrition may be present in some of our Canterbury flocks. It would be reasonable to expect such animals to react differently, in regard to their utilisation of minerals, from others which had been reared in their young growing period on a higher plane of nutrition.

The second example is drawn from my own work at Cambridge University on data obtained during an investigation into the nutritional and biochemical effects of a very low calcium diet on ewes and wethers. The following are some of the results obtained with ore of the animals.

CHEVIOT LAMB--LIME BALANCES.

Period	DATE	Food Intake g.	Faecal Excretion g.	Av. daily Balance (Urine Incl.) g.	Serum Ca Mg. per 100 c.c.
1	Dec. 3- 17 1931	23.859	32.119	- 0.650	11.02 (Dec.9)
2	Dec.17- 31 "	25.104	28.410	- 0.274	11.67 (Dec.30)
3	Dec.31- Jan14 1932	24.960	26.280	- 0.147	11.00 (Jan.13)
4	Jan 14- 28 "	15.397	17,752	- 0.213	10.48 (Jan.28)
5	Jan 28- Feb.11 "	18.231	17.172	+ 0.046	10.49 (Feb. 4)
6	Feb 11- 25 "	4.757	9.137	- 0.351	10.49 (Feb.?0)
7	Apr 7- 21 "	7.067	7,036	- 0.034	9.29 (Apr.20)
8	Apr 21- May 5 "	8.650	9.707	- 0.088	8.96 (May 4)
9	May 19- June 2 "	7.308	14.160	- 0.517	9.29 (May 19)
0	June 2- 16 "	17.143	24.480	- 0.603	9.93 (June 6)
1	June16- 30 "	12.319	20.960	- 0.672	9.89 (June27)
					10.13 (July11)
					10.49 (July25)

The results in the above table show the difference between the faecal excretion and food intake from the commencement of the experiment on 3rd December 1931 until 5th May 1932. After this period, however, a large change took place in the calcium metabolism of the animal and faecal excretion showed a marked increase over the food intake, an imbalance which was not rectified by an increase in the quantity of dietary lime of the wether. This physiological upset in the animal was also reflected in the lever of calcium in the blood. On the low calcium diet it showed a falling tendency until 4th May but with the increase in the withdrawal from the bones due, probably, to excessive activity of the parathyroid glands, the serum calcium level rose to more or less normal values. Obviously such an animal could not have been taken from this experiment and used for the investigation of the normal reaction of the sheep to changes in the mineral content of its diet.

The following tables illustrating-

(a) a digestibility trial
and (b) a nitrogen and mineral balance trial may help to explain further the procedure adopted in such experiments.

DIGESTIBILITY COEFFICIENTS.

PERIOD I (14 days)	CRUDE PROTEIN g.	ETHER EXTRACT g.	CRUDE FIBRE g.	N-FREE EXTRACT g.	ORGANI MATTER g.	TOTAL ASH, g.
Food supply	799.50	178.07	897.43	5425.00	7301.00	274.83
Food residue	36.22	10.27	102.80	263.10	412.40	20.94
Net Consumption	736.28	167.80	794.63	5161.90	6888.60	253.89
Voided	243.00	56.54	506.90	678.50	1485.00	161.90
Digested	520.28	111.26	287.73	4483.40	5403.60	91.99
Digestibility Coefficients %	68.17	66.27	36.21	86.86	8 . 43	36 . 23

NITROGEN AND MINERAL BALANCES.

PERIOD I (14 days)	NITROGEN g.	CaO g.	P_2O_5 g.	K_2O g.	Na_2O g.	Cl_2 g.
Food supply	127.90	27.79	38.36	63.46	5.73	19.04
Food residue	5.80	2.41	1.44	5.75	0.47	1.51
Net Consumption	122.10	25.38	36.92	57.71	5.26	17.53
Voided in faeces	38.87	29.88	32.56	8.88	0.39	0.75
Voided in urine	21.26	0.55	0.17	22.28	1.25	9.97
Total excretion	60.13	30.43	32.73	31.16	1.64	10.72
Period balance	61.97	-5.05	4.19	26.55	3.62	6.81
Mean daily Balance	+4.43	-0.36	+0.30	+1.90	+0.26	+0.49

The futility of short period experiments, in work of this nature, cannot be emphasized too strongly. Results obtained on one, two, three, four or five day trials are little more than useless. Frequently they may lead one to an entirely erroneous conclusion. Further, attention must be paid to the pre-experimental period which one should give an animal in a metabolism trial and also on the diet, before being placed in the cage,

FOOD UNITS;

It is not the object of this paper to deal with the different food units used by nutrition workers or how these are arrived at, Consequently only the briefest mention can be made:. to them here. The Starch Equivalent (1 lb. S.E.) and Digestibily Protein (1 lb, Dig.Prot.) are universally used in England and these will be employed here;, From the results of digestibility experiments all foodstuffs can be reduced to a common basis of starch equivalent and digestible protein units and their relative food values readily compared, or the data so obtained used in compiling rations suitable for meat or milk production or for the demands of pregnancy.

III, THE APPLICATION OF DIGESTIBILITY TRIALS TO THE FOOD VALUE OF PASTURES. .

(a) UNDER DIFFERENT TYPES OF GRAZING: This has been shown very well by Woodman (1932) in his work at Cambridge in which he has'investigated the three types of grazing:-

(i) Non-rotational close grazing.
(ii) Rotational close' grazing.
(iii) Extensive grazing.,

Using the data which he has obtained in'his Cambridge experiments he then traces out the relative amounts of food units supplied by such pastures and the production levels one could hope to get from them, A 9 cwt. dairy cow is used as the basis for his arguments. Such an animal can consume approximately 30 lbs. of dry matter daily, and will require for her maintenance requirements 7.5 lbs. of starch equivalent including 0.7 lb. of digestible protein, Further , for milk production she would require for each gallon (assuming a butterfat content of 3.7 per cent) 2.5 lbs. of starch equivalent including 0.6 lb. of digestible protein,

Using the data obtained by Woo&man in his pasture investfgations it then becomes a relatively simple matter to compare the production levels of the different types' of pasture,

(i) Non-Rotational Close Grazing: .

30 lbs. of dry matter from such pasture supply 21 lbs, S.E. including 6 lbs. digestible protein, The maintenance requirement of the animal is 7.5 lbs. S.E. including 0.7 lbs. of digestible protein, thus leaving for production:---

13.5 lbs of S.E. including 5.3 lbs. of digestible protein. Thus there is sufficient starch equivalent to provide for the production of nearly 5.5 gallons of milk and enough digestible protein for 9 gallons. From such pasture one could expect an animal to be able to produce 5 to 6 gallons of milk without any necessity for supplementary feeding. Production above this level, unless accompanied 'by suitable concentrate feeding would result in a drain on the animal's own reserves.

(ii) Rotational Close grazing:

This will, of course, vary with the intensity of the grazing, If a monthly rotational system is adopted the nutritive value of the pasture can be divided into two stages,

(1) Fore-flush period: During the period of early spring growth the food value has been shown to approximate very closely to that of non-rotational closely grazed pasture

30 lbs. of dry matter containing 21 lbs. of starch equivalent, including 6 lbs. of digestible protein so that the same production could be expected as that given in the section above.

(2) Mid December Onwards: Monthly grazed pasture will now show a slight falling off in food value 100 lbs. of dry matter containing 66⅔ lbs. of S.E. including 13 lbs. of digestible protein. 30 lbs. of such dry matter would, therefore, provide 20 lbs. of S.E., including 3.9 lbs. of digestible protein. Again deducting for maintenance 7.5 lbs. of S.E. including 0.7 lbs. of digestible protein there is left for production:-

12.5 lbs. of S.E. including 3.2 lbs. digestible protein. This is a perfectly balanced diet both as regards starch equivalent and digestible protein for a cow of 9 cwt. live weight producing 5 gallons of milk.

(iii) Extensive Grazing:

Extensively grazed pasture has a lower food value than either of the above types. Under Cambridge conditions Woodman has found that during the spring gronth 100 lbs. of dry matter contain 56 lbs. of S.E. including 12.5 lbs. of digestible protein. 30 lbs. of dry matter would, therefore, contain 16.8 lbs. of S.E. including 3.75 lbs of digestible protein. Again, deducting the cow's maintenance ration, of 7.5 lbs. S.E. including 0.7 lbs. of digestible protein there is left for production:---

9.3 lbs of S.E. including 3.05 lbs. of digestible protein. which is sufficient starch equivalent to provide for 3.7 gallons and sufficient digestible protein for 5 gallons of milk. Such a ration could maintain a 9 cwt. con in good condition and supply the extra food necessary for a milk production of approximately 4 gallons per day.

As the season progresses extensively grazad pasture becomes little better than good hay 100 lbs. of dry matter non supplying 43.2 lbs. of S.E. including 6.3 lbs. of digestible protein. 30 lbs. of dry matter mould, therefore, supply only 12.9 lbs. of S.E. including 1.9 lbs. of digestible protein. Again deducting the maintenance ration of the cow there would be left for production:---

5.4 lbs. of S.E. including 1.2 lbs. of digestible protein. This would suffice for the production of 2 gallons of milk. Higher producing cows on such feed, unsupplemented by other rations, would adapt themselves to it either by a rapid falling off in production or else by a heavy drain on their own body reserves.

The following table summarises the above findings with a 9 cwt. cow grazing under the pasture conditions at the Nutrition Institute, Cambridge University:-

TYPE OF GRAZING	100 lbs. of dry matter contains-		30 lbs. of dry matter contains		Available for production		In gallons of milk,	
	S.E. Lbs.	D.P. Lbs.	S.E. Lbs.	D.P. Lbs'	S.E. Lbs.	D.P. Lbs,	S.E. Gal,	D. Gal.
(i) Non-rotational close grazing	70	26	21	6	13.5	5.3	5.5	9
(ii) Rotational close grazing								
(1) Fore-flush period	70	20	21	6	13.5	5.3	5.5	9
(2) Mid-Dec. onwards	66 2/3	13	20	3.9	12.5	3.2	5.0	5
(iii) Extensive grazing'*.								
(1) Spring growth	56	12.5	16.8	3.75	9.3	3.05	3.7	5
(2) As season progresses	43.2	6.3	12.9	1.9	5.4	1.2	2.0	2

The above data shows most strikingly the varying production levels of different types of pasture. The point which it is the object of this paper to emphasize is that such information could not have been obtained without the results of digestibility experiments. When such data has been applied to the requirements of the animal, making use of maintenance and production tables which have been worked out already and are universally applicable, 'there can be no doubt that such information is much more valuable than gross yields of dry matter' and their composition can ever hope to be,

(b) DISTRIBUTION OF FOOD REQUIREMENTS: A greater use of food untis in the interpretation of some of our nutritional problems could also provide useful information regarding the distribution of food requirements, The following hypothetical case of the annual food requirements of a ewe and her lamb should make this clearer.

FOOD REQUIREMENTS IN POUNDS OF STARCH EQUIVALENT IN EACH MONTH FOR EWES PRODUCING SINGLE LAMBS, (FAT OFF THEIR MOTHERS AT FOUR MONTHS OLD.)

(1) MONTH,	(2) Av. weight of ewe in each month - lb.-	(3) Maintenance reqd. of ewe per month in lbs. of S.E.	(4) lbs. of S.E. reqd. for changes of body weight,	(5) .·. Net maintenance Columns (3) and (4) lbs. of S.E.	(6) Estimated milk production. - gallons-,	(7) Feed reqd. for this milk production-4 lbs S.E. reqd per 1 gall milk. - lbs. S,E.-	(8) Total feed reqd. for ewes only in lbs.S.E.	(9) Growth rate of lamb in lbs.L.W.I. Birth wt. = 10 lbs.	(10) Production req. to give this increase. - lbs. S.E. -	(11) Maint.req.based on mean L.W.of lamb in each month-lbs.S.E.-	(12) Maint. and prod. req. for lamb -lbs. S.E.	(13) Feed reqd. supplied by ewe's milk - 3.60 lbs S.E. per gallon of milk.	(14) Excess above milk prod. which must be supplied by grass,	(15) .·. total reqd. of ewe and lamb in lbs. S.E. per month,
Sept.	110	40.7	Nil	40.7	8.0	32.0	72.7	16	16	12.9	28.9	28.8	0.1	72.8
Oct.	115	43.2	+11.8	55.0	9.7	38.8	93.8	17	19	19.3	38.3	34.9	3.4	97.2
Nov.	120	42.8	+12.5	55.3	7.2	28.8	84.1	18	24	23.6	47.6	25.9	21.7	105.8
Dec.	120	42.8	Nil	42.8	5.4	21.6	64.4	18	27	31.0	58.0	19.4	38.6	103.0
Jan.	125	45.3	+13.1	58.4	--	--	58.4	Lambs sold fat at four months old						58.4
Feb.	120	40.0	- 7.0	33.0	--	--	33.0	--	--	--	--	--	--	33.0
Mar.	125	45.3	+13.1	58.4	--	--	58.4	--	--	--	--	--	--	58.4
Apr.	130	44.9	+13.7	58.6	--	--	58.6	--	--	--	--	--	--	58.6
May	130	46.4	Nil	46.4	--	--	46.4	--	--	--	--	--	--	46.4
June	125	43.8	- 7.0	36.8	--	--	36.8	--	--	--	--	--	--	36.8
July	125	45.3	Nil	45.3	--	--	45.3	--	--	--	--	--	--	45.3
Aug.	125	45.3	Nil	45.3	--	--	45.3	--	--	--	--	--	--	45.3
													Total	761.0

Column 15 in the above table sets out, the total food requirements for a ewe and her lamb (assuming that she has reared only one lamb) and shows how the food distribution should be planned over a twelve month period,

By a combination of farm survey work and metabolism experiments such figures could be placed on a very sound basis. The farm survey work would require for any particular area the collection of data on carrying capacities, average monthly live weights, in the case of sheep, percentage lambings and live weight increases (obtainable from killing weights), milk production, types of food available at different seasons of the year, and so on, Knowledge of starch equivalent and digestible protein values for the types cf foodstuffs available would be necessary for the matabolism work,, At present such data has to be taken from results obtained in other countries and probably frequently for material grown under entirely different soil and climatic conditions and with different methods of husbandry,

III SCOPE OF THE WORK.

Although this paper has been directed primarily to a discussion of metabolism work in relation to grassland research it should be obvious that the work has an unlimited scope. Since the quantities of foodstuffs recommended for a particular purpose by the animal are based primarily on a knowledge of their digestibility and suitability it is -apparent that metabolism work on food peculiar to New Zealand: conditions should receive first consideration,

With hay, for example, time of cutting, methods of drying and harvesting are known in a general way, to affect the food value, Silage, also, will show large variations in feeding value according to the ingredientsused and its method of preparation.

The problem of lucerne growing also requires further investigation in view of the popular belief among the farming community that it yields a greater proportion of food units per acre than pasture grass. From data on total yields and digestibility experiments Woodman (1933, 1934) has shown that this is a fallacy. His results have shown conclusively that, under Cambridge conditions--

" Lucerne, both in bud and in flower is very distinctly inferior in digestibility and nutritive value to pasture herbage submitted to systems of cutting at intervals of one to five weeks, On account of its high content of indigestible fibre and its relatively low content of digestible organic matter and starch equivalent the dry matter of lucerne, in bud or in flower, is comparable in nutritive properties to a superior coarse fodder rather than to the pasture cuts, the dry matter of which has the character of a concentrate, "

The following table summarises a few of Woodman's findings.

COMPARISON OF NUTRITIVE VALUES OF LUCERNE; PASTURE HERBAGE, AND MEADOW HAY (DRY MATTER BASIS)

	MEADOW HAY		LUCERNE		PASTURE HERBAGE (Mean values for season)	
	Very good qual-ity %	Med-ium qual ity %	In bud %	In flow -er %	Fort-nightly cuts %	Monthly cuts %
Crude fibre	25.8	34.1	23.9	29.7	15.9	21 c.2
Digestion coefficient						
Organic matter	64.6	51.9	65.7	60.4	78.0-82.3	76.7-83.4
Crude fibre	63.0	52.4				78.6-84.9
Digestible protein	8.7	5.4	45.3	43.6	80.3-18.8	14.7
" Organic matter	59.3	48.7	58.6	53.4	7202	72.5
Starch Equivalent	4502	29.2	50.8	42.4	69.9	67.1

Also differences between first and second growth rape, lupins, various other green fodder crops, roots and concentrates are some of the problems which require further investigation in New Zealand.

Matabolism studies also have their place in the investigation of many of the so-called deficiency diseases. Particularly is this so in New Zealand where many stock ailments are of a nutritional origin,

IV CONCLUSION:

The educational value alone of such work would justify any research scheme which included metabolism investigations. The accumulation and dissemination of data along the lines suggested by this paper.: would, over the course of a number of years not only provide much valuable data for research workers in animal nutrition in this country, but also, what is of far greater importance, should provide information which interpreted into popular terms, would increase a knowledge of the scientific principles of stock feeding among the farming community of New Zealand,

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