UNIVERSITY OF BRISTOL

DEPARTMENT of ECONOMICS

(Agricultural Economics)

THE WINTER FEEDING OF DAIRY COWS

An Economic Study of Eighty-one Herds in the West of England in 1948–49

by

M. B. JAWETZ

Price 5s.

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APPENDICES

Acknowledgements

I should like to thank the British Oil and Cake Mills for their helpful guidance in determining the nutritive composition of compound foods. It must, however, be understood that the figures used in this study have been compiled from other sources, too, and do not, therefore, refer specifically to the nutritive composition of any of the B.O.C.M.'s products.

I am also very grateful for help received, on more than one occasion, from the National Agricultural Advisory Service, South-West Province.

Introduction

The cost of foods is the largest cost item incurred in the management of a dairy herd. In the Bristol I Province it amounted to 53 per cent. of the total annual net cost of milk production in a sample of 79 herds during the year 1947–48 and to over 55 per cent. of the net cost of 81 herds in 1948–49. The increase in the proportion of total costs attributable to foods in the latter year was largely due to a reduction in the subsidy on feeding stuffs, which resulted in a rise in the cost of purchased concentrates. However, this price increase came into effect in the spring of 1949 and did not affect the period with which this study is concerned. The full impact of the increase will only be felt in 1950–51 when the cost of foods will account for a still higher proportion of the total cost of producing milk.

One cannot foresee, with any degree of certainty, the future trend of prices of feeding stuffs in the world markets. For various reasons it is improbable to suppose that sufficient quantities will be available in the world markets, at least in our lifetime, to create anything like the glut of the inter-war years. The standard of living has risen in many countries which, in the past, were traditional exporters of feeding stuffs and which now use more concentrates for their own domestic economies. For example, India's role as an exporter of feeding stuffs has dwindled, and it may well be that her own needs in this respect will offset the gradual reappearance of Indonesia in the world exchanges. It has been estimated that the world's population has risen by over 200 million since 1939, a fact which tends to enhance the demand for food for man and animal alike. Food supplies accumulated in the U.S.A., large though they may appear, may easily be absorbed by the American market with its large potentialities for animal produce, if an adjustment in farm policy brings the produce within reach of the consumers' pockets. Furthermore, the unusually prolonged " wet cycle " in the dustbowl-states is likely to give place to a series of drought years, which might easily do away with the surplus.

The difficulties encountered in Africa by the " Groundnut Scheme " are a spectacular proof that the extension of the world acreages to marginal lands, for lack of better areas under gentler skies, is a costly and painfully slow task. Last but not least, this country's "dollar gap", while influencing world prices, makes the extent to which imported feeding stuffs will be available to the British farmer a matter of speculation.

All these factors make it imperative that the farming industry, dependent as it is on the availability and prices of feeding stuffs, be "food conscious" in an ever increasing degree.

The winter period, with its heavy hand-feeding, is the time when most of the annual cost of feeding dairy cows is incurred. It is the aim of this study to analyse the practice of feeding cows for milk during one winter, to show the cost of that feeding, how it was incurred and the results it produced. The information on which it is based has been collected during the course of the Investigation into the Economics of Milk Production.

Data relating to 81 dairy farms situated in the counties of Somerset, Gloucester, Worcester and Wiltshire have been obtained for the period October 1st, 1948, to March 31st, 1949. The weekly records kept by the co-operating farmers give the quantities of purchased and home-grown foods fed to dairy cows as well as the prices of the former. Numbers of cows in milk, suckling and dry are also recorded, together with the total quantities of milk produced including that fed to livestock.

Actual costs of production for about 50 per cent. of the home-grown foods produced on the 81 farms were obtained in the course of the Milk Cost Investigation and representative average costs of production for hay, oats, dredge corn, mangolds, kale, silage and straw were therefore available for this study. For all other home-grown foods, which are of minor importance and for which cost of production data were not ascertained, feeding values calculated according to the standard formula have been used:

Feeding value per ton = Protein Equivalent × Unit Value for D.P.E.

Plus Starch Equivalent minus 0·94 of Protein Equivalent × Unit Value for N.P.S.E.

The unit values applicable to the winter 1948–49 were:

N.P.S.E. = £0·2169214 = £0 4*s.* 4*d.*

D.P.E. = £0·1146600 = £0 2*s.* 3½*d.*

A complete list of costs of home-grown foods is given in Appendix I.

The composition and nutritive values of straight feeding stuffs have mostly been taken from the tables of the Ministry of Agriculture's Bulletin No. 48, "Rations for Livestock" by

Professor Woodman, and supplemented from other sources. The composition of compound feeding stuffs, including the National Cattle Foods, had to be ascertained and the nutritive values calculated. The latter are shown in Appendix II.

The period dealt with in this study extending from October 1st, 1948, to March 31st, 1949, has been divided into an autumn and a winter quarter covering the months of October, November and December, and January, February and March respectively. Strictly speaking, winter feeding only takes place during the latter quarter. The autumn quarter provides a good deal of productive grazing. It is one of the objects of this study to find out how much of the feeding requirements of dairy cows was supplied by autumn, and how much by winter grazing, and with what result.

The cost of grazing for the period covered by this study has been estimated at one-fifth of the total annual grazing cost as ascertained for the year 1948–49.

The break-down of the feeding period into an autumn and a winter quarter necessitated an apportionment of the winter grazing cost between the two quarters. A clue to the subdivision of the grazing cost was found in J. R. Currie's paper "The Economics of Grassland Management"*. In it the author described a method of weighting seasonal values of pasture based on 15 years of research in South Devon. Briefly, he claims that the different grazing values due to seasonal causes are the inverse of the seasonal supplementary feed requirements. Conditions in South Devon being more favourable to winter grazing than in the counties under review, Currie's weighted assessment working out at 66 per cent. of grazing value in the autumn and 34 per cent. in the winter quarter, could not be applied to this province. By substituting estimated figures, an assessment of 75 per cent. grazing value for the autumn and 25 per cent. for the winter was arrived at for this area, and this proportion adopted in apportioning the cost of grazing in this study between autumn and winter.

Although included in the total cost, grazing has not been shown in the quantity figures. The quantity of food derived from grazing has been estimated from the amount of hand-feeding supplied to the cows so as to balance their theoretical feeding requirements.

* *Journal of the Proceedings of the Agricultural Economics Society*, Vol. VIII, No. 2, April 1949, pp. 124 and 125.

The Number of Cows

The numbers of cows in the sample during the autumn and winter quarters and the quantity of milk they produced is shown in Table 1.

TABLE 1

Aggregate Average Quarterly Number of Cows in Herds and Production of Milk per Cow in Herd 1948–49

Period	Aggregate Average No. of Cows in Herds	Aggregate Production	Average Production per Cow in Herd	Average Production per Cow per Day
	No.	galls.	galls.	galls.
Autumn . .	2,704	438,660	162	1·78
Winter . . .	2,731	457,720	168	1·85

The aggregate average number of cows in the herds was nearly equal in both quarters. The fact that production per cow in herd increased slightly in the winter quarter is due to a higher proportion of cows in milk in winter. This is illustrated by Table 2, from which it will be seen that in the winter quarter, production per cow in milk was a fraction smaller than that in the autumn.

TABLE 2

Aggregate Average Quarterly Production per Cow in Milk* 1948–49

Period	Aggregate Average of Cows in Milk	Average Production per Cow in Milk	Average Daily Production per Cow in Milk
	No.	galls.	galls.
Autumn	2,130	206	2·26
Winter	2,242	204	2·24

* Including on average 14 suckling cows in the autumn and 68 in the winter.

A comparison of the numbers of cows in herds with those of cows in milk suggests that in the sample as a whole the stress was on level milk production during the summer and winter half years. Cows in milk were on average, 79 per cent. of the number of cows in herd in the autumn and 82 per cent. in the winter. This makes an average of 80·5 per cent. for the winter half year. Had the stress been on summer milk production, the percentage of cows in milk in the winter six months would have been nearer 70.

The average size of a herd in the sample was 33 cows in the autumn quarter and 34 cows in the winter quarter, whilst the average number of cows in milk in the herds was 26 and 28 respectively.

The Quantities of Foods

The feeding stuffs fed have been divided into three groups: concentrates, hay and straw, and succulents. A detailed list of the aggregate quantities recorded as fed and their cost is given in Appendix III.

The aggregate quarterly and average daily quantities of foods fed, divided into the three groups mentioned above, are shown in Table 3.

TABLE 3

Aggregate Quarterly and Average Daily Quantities of Foods Fed 1948–49

Foods	Aggregate Quantity		Daily Quantities per Cow in Herd	
	Autumn	Winter	Autumn	Winter
	cwt.	cwt.	lb.	lb.
Concentrates* . . .	12,929	16,424	5·9	7·4
Hay and Straw . . .	14,861	35,044	6·9	15·8
Succulents	44,671	69,030	20·3	31·1
Total	73,701	120,498	33·1	54·3

* Including 62 cwt. of condiments and minerals in the autumn quarter and 122 cwt. in the winter quarter.

The quantities of foods fed have been calculated on a per cow in herd basis. It is, of course, realised that dry cows are not fed so heavily as cows in milk, but a calculation giving consideration to an estimated lower ration for dry cows would have made only a negligible difference in average daily input on a per cow in milk basis. It should be noted, however, that the quantities actually fed were, on average, smaller for dry cows and slightly larger for cows in milk and suckling.

A comparison of quantities fed in the autumn quarter with those supplied in the winter quarter shows that the fall in the value of grazing has been made good mainly by increases in the intake of succulents and hay. The quantity of succulents was increased by nearly one-third in the winter and the hay ration was more than doubled. The ration of concentrates was augmented by only slightly over one-seventh. The fact that the concentrates ration was, on average, nearly equal in both quarters, indicates that farmers are well aware of the protein deficiency of autumn grass for dairy cows in production.

An analysis, on a quarterly basis, of the three groups of foods fed, showing also the percentage of the respective foods within each group, is given in Table 4.

In the group of concentrates, compound dairy cakes and meals (mostly of the National Cattle Food No. 1 and 2 types) predominated; they made up well over half the total concentrates ration in the autumn and over half in the winter.

The shortage of high-protein feeding stuffs, and the fact that also supplies of protein from balanced foods were limited, brought about the rather important position gained by dried grass, which was fourth in the list after dairy cakes, dredge corn and oats and before straight cakes. Dredge corn* and oats between them provided well over one-quarter of the concentrates fed in the autumn and nearly one-third in the winter, while all the other grains, seeds and cereal by-products together, only supplied 2·8 per cent. in the autumn and 4·2 per cent in the winter quarter.

Straight cakes and meals constituted only about 3 per cent. of the concentrates rations in both quarters. High protein compound foods accounted for about 2½ per cent. in the autumn and 4 per cent. in the winter, whilst grain balancers represented less than half the " Other Compound Cakes and Meals " shown in Table 4. The shortage of feeding stuffs with a high content of protein does not permit the use of high-protein concentrates by farmers except on a strictly limited scale. Manufacturers of feeding stuffs, anxious as they are to make the largest possible quantities of grains and low protein foods

* On average, containing a proportion of pulses.

TABLE 4

Analysis of Aggregate Quarterly Quantities of Foods Fed 1948–49

Foods	Autumn		Winter	
	Cwt.	Per Cent.	Cwt.	Per Cent.
CONCENTRATES				
Dairy Cakes and Meals .	7,277	56·3	7,834	47·7
High Protein Cakes & Meals	331	2·6	635	3·9
Other Compound Cakes and Meals	209	1·6	330	2·0
Straight Cakes and Meals .	422	3·3	478	2·9
Dredge Corn	1,764	13·6	2,748	16·7
Oats	1,686	13·0	2,282	13·9
Other Grains and Seeds and Cereal by-products . .	357	2·8	690	4·2
Dried Sugar Beet Pulp . .	202	1·6	335	2·0
Other Industrial by-products	57	0·4	99	0·6
Dried Grass	562	4·3	871	5·3
Minerals and Condiments .	62	0·5	122	0·7
Total Concentrates . .	12,929	100·0	16,424	100·0
Percentage of Total Fed in Six Months	44%		56%	

Foods	Autumn		Winter	
	Cwt.	Per Cent.	Cwt.	Per Cent.
HAY AND STRAW				
Hay	14,436	96·8	32,984	94·1
Straw	425	3·2	2,060	5·9
Total Hay and Straw	14,861	100·0	35,044	100·0
Percentage of Total Fed in Six Months .	30%		70%	
SUCCULENTS				
Kale	28,846	64·6	13,198	19·1
Mangolds	805	1·8	21,975	31·8
Swedes	2,125	4·7	4,196	6·1
Cabbage	2,497	5·6	1,644	2·4
Sugar Beet Tops . .	3,649	8·2	—	—
Other Roots and Green Fodder . .	599	1·3	995	1·4
Silage	5,306	11·9	26,398	38·2
Wet Grains . . .	844	1·9	624	0·9
Total Succulents .	44,671	100·0	69,030	100·0
Percentage of Total Fed in Six Months . . .	40%		60%	

into compound cakes and meals, tend to use the largest part of available high-protein foods in the production of balanced concentrates. These are clearly unsuitable for balancing home-grown foods deficient in protein. The existing position does not seriously affect herds with moderately high yields of milk, but penalises those with a high-yielding capacity. The latter can only attain the highest level of economic efficiency if it is possible for them to balance a fair proportion of their home-grown low-protein foods with high-protein concentrates.

In the hay and straw group of foods, straw accounted for just over 3 per cent. in the autumn and rose to nearly 6 per cent. in the winter. This would suggest that, in the winter quarter, some straw was used when hay was running short. However, it also gives another pointer to the farmer's appraisal of the value of autumn grazing. It may well be that, in the autumn farmers prefer making adjustments for bulk in a more concentrated form by adding a little hay when, owing to the limited capacity of the bovine rumen, a larger intake of straw might result in a proportionally smaller intake of grass and still leave a gap in the nutritive requirements that would have to be filled by an addition of concentrates. In winter time generally there is more emphasis on bulk, and the feeding of additional quantities of straw may prove necessary on account of its filling capacity, despite its low nutritive value.

In the succulents group, the pattern of feeding varies widely from autumn to winter. It is ruled by the keeping propensities of the various roots and fodders and, to some extent, by their seasonal availability. Thus, in the sample analysed, kale constituted about two-thirds of the succulents ration in the autumn and dropped to just under one-fifth in the winter. Sugar beet tops averaged 8 per cent. in the autumn and were, naturally absent from the winter diet. The proportion of cabbage fed in the autumn quarter was more than twice that fed in the winter three months–about 5½ and 2½ per cent. respectively of the total ration. Swedes showed a slight increase in the winter quarter, but " Other Roots and Green Fodder ", although a constant percentage of the total in both quarters, were, among themselves, subject to the same variations as the succulents group as a whole, with green maize used before the winter and carrots and potatoes fed in the latter quarter.

While silage held second place after kale up to the new year with nearly 12 per cent. of the aggregate succulents fed, it became the most important single succulent in the winter, accounting for over 38 per cent. of this group. At the same

TABLE 5

Further Analysis of Aggregate Quarterly Quantities of Foods Fed into Purchased and Home-Grown 1948–49

FOODS	AUTUMN				WINTER			
	Purchased		Home-grown		Purchased		Home-grown	
	Cwt.	Per Cent.	Cwt.	Per Cent.	Cwt.	Per Cent.	Cwt.	Per Cent.
CONCENTRATES								
Compound Cakes and Meals . .	7,817	84·7	—	—	8,799	81·9	—	—
Straight Cakes and Meals . . .	422	4·6	—	—	478	4·4	—	—
Grains, Seeds and Cereal by-products. . . .	445	4·8	3,357	90·8	479	4·5	5,241	92·3
Other Concentrates	259	2·8	—	—	434	4·0	—	—
Dried Grass . .	220	2·4	342	9·2	436	4·1	435	7·7
Minerals and Condiments .	62	0·7	—	—	122	1·1	—	—
Total Concentrates	9,225	100·0	3,699	100·0	10,748	100·0	5,676	100·0
Percentage of Total . . .	71·4%		28·6%		65·4%		34·6%	
	Cwt.	Per Cent.	Cwt.	Per Cent.	Cwt.	Per Cent.	Cwt.	Per Cent.
HAY AND STRAW								
Hay	67	100·0	14,369	97·1	270	76·7	32,714	94·3
Straw	—	—	425	2·9	82	23·3	1,978	5·7
Total Hay and Straw . . .	67	100·0	14,794	100·0	352	100·0	34,692	100·0
Percentage of Total . . .	0·8%		99·2%		1·0%		99·0%	
	Cwt.	Per Cent.	Cwt.	Per Cent.	Cwt.	Per Cent.	Cwt.	Per Cent.
SUCCULENTS								
Roots and Green Fodder . . .	120	12·4	38,361	87·8	728	53·8	41,280	61·0
Silage	—	—	5,306	12·2	—	—	26,398	39·0
Wet Grains . .	844	87·6	—	—	624	46·2	—	—
Total Succulents	964	100·0	43,667	100·0	1,352	100·0	67,678	100·0
Percentage of Total . . .	2·2%		97·8%		2·0%		98·0%	

time the consumption of mangolds rose from an insignificant 2 per cent. in the autumn to 32 per cent. in the winter leaving third place with just over 19 per cent. to kale, and swedes far behind with about 6 per cent. of the total winter ration.

A distinction between purchased and home-grown foods has been made in Table 5, giving the aggregate quantities of each food or group of foods, the percentage they each accounted for within their main group, and the proportion of purchased and home-grown foods in the three main groups expressed as a percentage of the total group. The purchased foods were nearly all concentrates. Purchased hay and straw made up only about 1 per cent., by weight, of the total hay and straw fed, both in autumn and winter. The purchased succulents amounted to 2 per cent. of the succulents ration in each of the two quarters; a good deal of them were wet grains. Dried grass accounted for over 9 per cent. of home-grown concentrates in the first quarter and nearly 8 per cent. in the second.

Comparison of Winter Feeding in 1934–35 and 1948–49

It is interesting to compare the ration of a present day cow to the bill of fare of a dairy cow of the mid-'thirties. Data (which have been used in compiling the following comparative tables) are available for a sample of 133 herds in the Bristol I Province for the "winter"* six months 1934–35.† It has not been possible, however, to make the comparison on a quarterly basis.

Table 6 shows average daily quantities of foods fed per cow in herd in the "winter" six months of 1934–35 and 1948–49 respectively.

The daily quantity of concentrates was a fraction larger in the "winter" six months of 1948–49 and so was the hay and straw part of the ration, while the average daily consumption of succulents was more than doubled. The average number of cows in herds in the sample of 1934–35 was 38 as compared with 33·5 in 1948–49. The average daily production of milk per cow in herd was 1·51 gallons in the pre-war, and 1·82 gallons in the post-war "winter" six months. Theoretically a daily increase

* The term "winter" here refers to the sum of the autumn and winter quarters.

† *Winter Feeding for Milk Production*, by C. V. Dawe, M.Com., Ph.D., and J. E. Blundell, M.Com., University of Bristol, 1935.

TABLE 6

Average Daily Quantities of Foods Fed per Cow in Herds

Foods	"Winter" Six Months	
	1934–35	1948–49
	Daily per Cow	Daily per Cow
	lb.	lb.
Concentrates	6·6	6·7
Hay and Straw	11·2	11·4
Succulents	12·2	25·7

of intake by 13·5 lb. of succulents, such as, on average, were fed in 1948–49 together with the slight increase in concentrates, should have supplied sufficient starch equivalent for an additional gallon of milk per cow per day and protein equivalent for half a gallon. The actual increase in the average daily yield in 1948–49 in comparison with 1934–35 was only 0·31 gallons, a result that leads to speculation as to its possible cause. The following suggestions, either singly or in combination, may supply an answer:

(*a*) More grassland was available for cows in 1934–35 than in 1948–49; its productivity per acre may or may not have been higher.

(*b*) A higher proportion of home-grown corn to purchased concentrates in the 1948–49 concentrates ration.

(*c*) The lower feeding value of purchased concentrates in 1948–49.

(*d*) Higher physiological efficiency at lower level of yield.

(*e*) Hay may have been better in 1934–35.

(*f*) Less loss of weight in the 1948–49 sample of cows.

A comparative analysis of the foods fed daily, within each group of foods, in the two "winter" seasons, is given in Table 7.

While the quantities of compound cakes have remained nearly equal in both "winter" six months, over five times as much straight cake was fed in 1934–35 as in 1948–49. Nearly three times as much grains, seeds and cereal by-products, except maize products, have been fed in the post-war winter under analysis as in the pre-war one, but whereas maize

TABLE 7

Comparative Analysis of Foods Fed in 1934–35 and 1948–49 " Winter " Six Months

Foods	" Winter " Six Months 1934–35		" Winter " Six Months 1948–49	
	Per Cow Daily	Per Cent of Total	Per Cow Daily	Per Cent of Total
	lb.	%	lb.	%
A. Concentrates				
Compound Cakes and Meals .	3·6	55	3·9	57
Straight Cakes and Meals . .	1·1	16	0·2	3
Grains, Seeds and Cereal by-products, except Maize and Maize Products	0·8	12	2·1	32
Maize, Flaked, Meal and Gluten.	0·7	11	0·1	1
Dried Sugar Beet Pulp . .	0·3	5	0·1	2
Others: Dried Grains . . .	0·1	1	*	*
Mainly Dried Grass .	nil	nil	0·3	5
Total Concentrates . . .	6·6	100	6·7	100
B. Hay and Straw				
Hay	9·9	88	10·8	95
Straw.	1·3	12	0·6	5
Total Hay and Straw . .	11·2	100	11·4	100
C. Succulents				
Mangolds	5·0	41	5·3	21
Kale	4·4	36	9·1	35
Swedes and Turnips . . .	1·1	9	1·6	6
Cabbage	0·8	7	1·1	4
Sugar Beet Tops	0·4	3	0·8	3
Wet Grains	0·4	3	0·2	1
Other Roots and Green Fodder	0·1	1	0·2	1
Silage	nil	nil	7·3	29
Total Succulents	12·2	100	25·7	100

* Negligible.

products approximated the grains and seeds group in the mid-thirties, making up 11 per cent. of the total concentrates ration, hardly any post-war cow has ever tasted maize at all. Dried sugar beet pulp did not reach half its pre-war importance and was, for milk producers in this province, another of the war's victims.

The drop in straight cakes, maize and maize products and dried sugar beet pulp in the post-war sample, has been made up by a corresponding increase in home-grown grains, seeds and cereal by-products and by the appearance of dried grass. It is clear that concentrates of this kind could not alone make up the gap in protein equivalent resulting from the decrease in the feeding of straight cakes of high-protein content.

Moreover, in the 1934–35 analysis, the average compound cake had been taken to contain 17 per cent. of protein equivalent, whilst the compound cake of 1948–49 had 16 per cent. on average. A calculation of the protein contents of the total concentrates group, fed in the two winters, revealed an average of 16·5 per cent. of protein equivalent in the pre-war group and 14·3 per cent. in the post-war one.

No dried grass was fed to the cows in the " winter " sample of 1934–35. Although dried grass accounted for only 5 per cent. of the aggregate quantity of concentrates fed in the " winter " 1948–49, it was more important than any other group of concentrates, except compound cakes and meals and cereals. In fact, it nearly equalled the quantity of all the concentrates used in that season, barring the latter two groups.

It may be expected that the cessation of feeding stuffs subsidies, and the sharp rise in prices of concentrates as its corollary, will increase the importance of dried grass. There is a line of thought among some farmers that the advent of what they term " normal " supplies of imported feeding stuffs at " normal " prices will spell the doom of the newcomer. This may be true (provided " normal " times materialise) of low-protein dried grass obtained from poor permanent swards cut past their leafy stage. It would seem that fast-growing leys, capable of producing economic quantities of green material with a higher-protein content, will place dried grass favourably in the running. From the dairy farmer's angle, carotene content of dried grass, although indicative of its content of protein may be entirely disregarded. His only important consideration is the protein content of the material and the unit cost of the protein it contains.

The higher proportion of straw fed in 1934–35 may be explained by the fact that, in that year, straw for bedding was not recorded separately. The figure for 1948–49 includes the proportion of straw for feeding only and, therefore, the proportion of hay is higher.

It is in the succulents group that the most spectacular changes have taken place. All the succulents fed, per cow, in the post-war winter show a marked increase over the 1934–35 figures with the exception of mangolds (where the increase *per* *capita* was insignificant) and wet grains which dropped considerably. The largest increase per cow is shown by kale, from 4·4 lb. per day to 9·9 lb., and by silage from nothing in 1934–35 to 7·3 lb. per day in 1948–49. On a percentage basis, the composition of the average succulents ration in the latter " winter " shows an entirely different pattern from the much smaller pre-war one. The main feature of this change is seen in a very marked decline in the relative proportion of mangolds and a still more marked increase in the proportion of silage fed. The average succulent ration in 1948–49 also contains relatively less turnips, swedes and cattle cabbage, but kale has maintained its position.

To those familiar with the production and feeding of the modern varieties of high-content fodder-beet, it is surprising that the excellent feeding qualities of this type of home-grown food (in extensive use on the Continent) have not been brought to the attention of farmers in this country. They should yield a higher amount of starch value per acre than any other known crop likely to be successful in these latitudes. It would seem that, where the maximum yield of energy per acre is the main consideration, it would be advantageous if the type of roots now grown, with the exception of kale, were mostly replaced by high-content fodder-beet, particularly if high-protein concentrates were more plentiful, or in combination with high quality dried grass. On smaller farms, run intensively, a system of management based on high-content fodder-beet for winter and early spring feeding, some kale and short-duration leys, may permit heavier stocking of the available land and be more efficient than any other system.

Silage, as grown in this country, mostly has a nutritive ratio requiring little balancing for milk production. Its keeping propensities far exceed those of roots. These facts alone, at a time of shortage of protein and the high prices resulting from it, would provide sufficient explanation for the important place achieved by silage in post-war feeding practice. However, these advantages would not carry much weight with the advent of cheap imported concentrates and it is sometimes argued that silage-making, as a system of preserving green fodder, will be restricted to the wetter regions of the country when this hope is fulfilled. Silage addicts would rejoin that, even in good weather conditions, losses in nutrients are smaller in silage than in haymaking and the argument is continued over yields, costs of production, unit prices of nutrients and so on. However, this argument misses the main point, which is one of management.

The outstanding advantages of silage are not in its high protein content in comparison with most roots, or in the smaller loss of nutrients incurred than in making hay. Its most important merit lies in the fact that, with the exception of drying, it is the only method known that would permit farmers to intensify production of grass and other green fodder to the highest limits technically achievable without fear of waste or loss. It is cheaper than grass-drying, easier to fit into any system of management, and necessitates little, if any, capital expenditure. Even when drying is practised, advanced ley farming and catch cropping often produce gluts of green material exceeding the combined capacity of both livestock and drier. On a dairy farm, catch cropping on a larger scale can only be applied in combination with silage-making if it is to be economical. The above points suggest that silage-making is a method of management rather than a technique.

The Cost of Feeding

The total cost of feeding the cows in the 1948–49 sample amounted to £20,238·1 in the autumn and to £27,398·5 in the winter quarter. Of this, the estimated cost of grazing was £2,854·3 and £951·5 for the respective quarters. An analysis of the feeding cost is given in Table 8.

The estimated cost of grazing amounted to 15 per cent. of the total feeding cost in the autumn quarter and dropped to 3 per cent. of the total winter quarter cost which, in terms of money, still amounted to 7*s.* per cow and a ½*d.* per gallon of milk produced. Nearly half the total cost of feeding, in both quarters, was incurred on concentrates.

A more detailed analysis of the cost of feeding is given in Table 9 on the basis of a division into purchased and home-grown foods. In the autumn over 36 per cent. of the total feeding cost was incurred on purchased foods and nearly 50 per cent. on home-grown foods, including grazing, while in the winter the percentages were 32½ and 64 per cent. of the total respectively. The cost per cow of purchased foods was only 10*s.* 2½*d.* less in the autumn than in the winter, while the difference in the cost of home-grown foods over the same period was £2 14*s.* 7*d.*, i.e. almost five times as much. The greater part of the gap, created by the lack of sufficiently productive grazing in the winter quarter, was made up by home-grown foods.

TABLE 8

Analysis of the Cost of Foods
1948–49

GROUPS OF FOODS AND GRAZING	AUTUMN QUARTER October–December 1948				WINTER QUARTER January–March 1949			
	Per Cow in Herd	Per Gallon	Aggregate Cost	Per Cent. of Total Cost	Per Cow in Herd	Per Gallon	Aggregate Cost	Per Cent. of Total Cost
	£	*d.*	£	%	£	*d.*	£	%
Concentrates:								
(*a*) Purchased	2·70	3·99	7,283·5	36	3·13	4·49	8,557·5	32
(*b*) Home-grown	0·99	1·46	2,682·8	13	1·52	2·17	4,146·7	15
Total Concentrates . .	3·69	5·45	9,966·3	49	4·65	6·66	12,704·2	47
Hay and Straw	1·23	1·82	3,323·1	16	2·84	4·07	7,757·1	28
Succulents	1·52	2·24	4,094·4	20	2·19	3·14	5,985·7	22
Total Hand-fed Foods .	6·44	9·51	17,383·8	85	9·68	13·87	26,447·0	97
Grazing	1·05	1·56	2,854·3	15	0·35	0·50	951·5	3
Total Foods and Grazing .	7·49	11·07	20,238·1	100	10·03	14·37	27,398·5	100

TABLE 9

Further Analysis of the Cost of Food per Cow into Purchased, Home-Grown and Grazing
1948–49

Foods	Autumn Quarter Per Cow	Autumn Quarter Per Cent of Total Cost	Winter Quarter Per Cow	Winter Quarter Per Cent of Total Cost
	£	%	£	%
PURCHASED				
Concentrates				
Compound Cakes and Meals .	2·31	30·8	2·55	25·4
Straight Cakes and Meals . .	0·11	1·5	0·13	1·3
Grains, Seeds and Cereal by-products	0·12	1·6	0·14	1·4
Other Concentrates. . . .	0·05	0·7	0·07	0·7
Dried Grass	0·09	1·2	0·20	2·0
Minerals and Condiments .	0·01	0·1	0·04	0·4
Total Purchased Concentrates	2·69	35·9	3·13	31·2
Hay	0·01	0·1	0·05	0·5
Straw	—	—	0·01	0·1
Succulents	0·05	0·7	0·07	0·7
Total Purchased Foods . .	2·75	36·7	3·26	32·5
HOME-GROWN				
Concentrates				
Corn	0·92	12·3	1·43	14·3
Dried Grass	0·07	0·9	0·09	0·9
Hay	1·20	16·0	2·69	26·8
Straw	0·02	0·3	0·09	0·9
Succulents				
Kale	1·01	13·5	0·46	4·6
Silage	0·17	2·3	0·82	8·2
Mangolds	0·02	0·3	0·66	6·6
Turnips and Swedes . . .	0·07	0·9	0·11	1·0
Others	0·21	2·8	0·07	0·7
Total Succulents	1·48	19·8	2·12	21·1
Total Home-grown Foods .	3·69	49·3	6·42	64·0
TOTAL HAND-FED FOODS .	6·44	86·0	9·68	96·5
GRAZING	1·05	14·0	0·35	3·5
TOTAL HAND-FED FOODS AND GRAZING	7·49	100·0	10·03	100·0

The estimated cost of grazing was 14*s*. per cow lower in the winter than in the autumn quarter. However, the low nutritive value of grazing in the winter quarter resulted in an increase in hand-feeding which cost, on average, £3 4*s*. 9*d*. for each cow in the sample. The total net increase in the cost of feeding between the autumn and winter periods, occasioned by the necessity for making good the lack of grazing in the latter quarter by hand-fed foods, was therefore £2 10*s*. 9*d*. per cow.

The above figures are impressive and focus attention on the importance of extending productive grazing throughout the autumn quarter and finding means of providing dairy cows with productive grazing in the winter quarter as well. The former objective may be achieved by knowledgeable applications of fertilisers, coupled with adjustments in the management of grassland, earlier in the season. The answer to winter grazing may be found in the new strains of grasses, particularly when drilled in rows, a method of sowing which helps to avoid poaching even on heavy soils. Lucerne, in places where it can be grown, also provides excellent winter grazing; provided it is left alone in September and October, it will take any punishment in the winter.

A Comparison of the Cost of Feeding and of the Quantities Fed, for the " Winter " Six Months 1948–49 and 1949–50*

Before this study could be completed, data pertaining to the " winter " six months of 1949–50 became available. A comparison could, therefore, be made between the costs of feeding and the quantities of foods fed in the winters of 1948–49 and 1949–50. Sixty-seven farms co-operated in the Milk Cost Investigation in both years and the following tables have been based on data relating to these farms only. Lack of time prevented a sub-division into autumn and winter quarters, but a comparison on a six-monthly basis will show the results of the decrease in the feeding stuffs subsidy on both costs and feeding practices.

The average number of cows in the " winter " six months of 1948–49 was 2,221 and the average production per cow was 332 gallons. In the " winter " six months of 1949–50, the

* i.e. from 1st October to 31st March.

average number of cows in the same herds was 2,351 and their average production of milk in that period was 346 gallons per cow.

Table 10 gives the cost of feeding, on a comparative basis, for the two seasons, with a division into purchased and home-grown foods and grazing

TABLE 10

Comparative Analysis of the Feeding Cost on 67 Identical Farms in the " Winter " Six Months of 1948–49 and 1949–50

Foods	67 Identical Farms			
	" Winter " Six Months 1948–49		" Winter " Six Months 1949–50	
	Cost Per Cow	Cost Per Gallon	Cost Per Cow	Cost Per Gallon
	£	*d.*	£	*d.*
Purchased Foods . .	6·0	4·34	10·5	7·28
Home-grown Foods .	10·1	7·30	11·9	8·25
Grazing	1·5	1·08	1·4	0·97
Total Cost . . .	17·6	12·72	23·8	16·50

The average cost of a cwt. of purchased concentrates was 15*s.* 10*d.* in the " winter " six months of 1948–49 and 26*s.* 2*d.* in the same period of 1949–50. The average cost of purchased foods (which for practical purposes may be taken to represent the cost of purchased concentrates) rose by £4 10*s.* 0*d.* per cow and nearly 3*d.* per gallon in the " winter " six months of 1949–50, while the cost of home-grown foods rose by £1 16*s.* 0*d.* per cow and approximately 1*d.* per gallon. The cost of grazing fell by 2*s.* per cow.

In Table 11 the quantities of foods fed per cow and per gallon in the " winter " six months of 1948–9 and 1949–50 have been set out for comparative purposes.

Although the cost per cwt. of purchased concentrates was, on average 39 per cent. higher in the 1949–50 winter, over 1¼ cwt. more were fed per cow in that half year than in the corresponding six months of the previous " winter ". Consumption of home-grown concentrates also increased, though insignificantly. The larger quantity of concentrates fed, on average,

TABLE 11

Comparative Analysis of Quantities of Foods Fed in the "Winter" Six Months of 1948–49 and 1949–50
Same 67 Herds

Foods	"Winter" Six Months 1948–49		"Winter" Six Months 1949–50	
	Per Cow	Per Gallon	Per Cow	Per Gallon
Concentrates:	cwt.	lb.	cwt.	lb.
(*a*) Purchased . .	7·4	2·5	8·6	2·8
(*b*) Home-grown .	3·5	1·2	3·6	1·2
Total Concentrates	10·9	3·7	12·2	4·0
Hay and Straw* . .	18·6	6·3	18·6	6·0
Succulents:				
Silage	11·9	4·0	16·8	5·5
Kale	14·7	5·0	15·4	5·0
Mangolds . . .	8·0	2·7	5·4	1·7
Others	6·2	2·1	3·1	1·0
Total Succulents .	40·8	13·7	40·7	13·2

* The proportion of straw was approximately 5 per cent in both periods.

to every cow in the 67 herds in the winter period of 1949–50 in comparison with the input of the same period of the preceding year did not result in an increase in milk output corresponding to theoretical standards.

The average intake per cow of hay and straw was equal in both six months, but intake per gallon of milk was slightly less in the latter half year, showing a better input-output relationship than the concentrates group. Consideration must, however, be given to the fact that the 1949 hay crop was of a quality markedly above average. Although the 1948 crop was of good quality too, it is conservatively estimated that hay made in 1949 had a nutritive value 20 per cent. higher than hay in the previous year. Furthermore, in the succulent group there was a rise by nearly one-third in the quantity of silage fed per cow in 1949–50 in comparison with 1948–49 and a small increase of kale, accompanied by a corresponding drop in the quantities of mangolds and "other succulents" fed per cow. Thus the nutritive value of succulents was also higher in 1949–50. The nutritive values supplied by the hay and straw group and by the succulents in the "winter" six months of the two years under review are tabulated below on a per cow basis.

TABLE 12

**The Nutritive Values Supplied by Roughages in Two "Winter" Periods and Increment in "Winter" Six Months 1949–50
67 Identical Herds**

Roughages	"Winter" Six Months 1948–49		"Winter" Six Months 1949–59		Increment	
	Starch Equiv. Per Cow	Protein Equiv. Per Cow	Starch Equiv. Per Cow	Protein Equiv. Per Cow	Starch Equiv. Per Cow	Protein Equiv. Per Cow
	lb.	lb.	lb.	lb.	lb.	lb.
Hay	622	90	746*	108*	+ 124*	+ 18*
Straw	21	†	21	†	nil	nil
Total Hay and Straw	643	90	767	108	+ 124	+ 18
Succulents:						
Silage	168	23	237	34	+ 69	+ 11
Kale	165	23	172	25	+ 7	+ 2
Mangolds	54	3	36	2	− 18	− 1
Others	69	7	35	3	− 34	− 4
Total Succulents	456	56	480	64	+ 24	+ 8
Total Roughages	1,099	146	1,247	172	+ 148	+ 26

* Estimated. † Negligible.

On the above estimate roughages supplied on average 148 lb. of starch equivalent more and 26 lb. of protein equivalent more to each cow in the identical 67 herds in the "winter" six months 1949–50 than in the same period of the previous year. According to conventional feeding standards, the above quantity of starch equivalent would be sufficient for the production of 59 gallons of milk while the protein equivalent would suffice for 43 gallons. Moreover, 1·3 cwt. more purchased concentrates were fed per cow in the "winter" six months of 1949–50. Against these largely increased inputs of nutrients there was only an average increment of 14 gallons of milk per cow.

The explanation of this disappointing result will, in the first instance be sought in a comparison of the estimated grazing values in the two periods under investigation. The summer of 1949 brought one of the most severe droughts on record in this generation to this country, with a disastrous effect on summer grazing. However, heavy rainfall during September of that year resulted in vigorous growth of grass in October, so that on some farms autumn grazing was not affected by the summer drought. There is even evidence that on grassland with a high water table there was more and better grazing in the autumn of 1949 than in normal years. On the other hand, there is evidence that on many farms the grazing value in that autumn was below normal. It is estimated that, on average, the grazing value in the " winter " six months of 1949–50 was two thirds of that of the same period in 1948–49.

The theoretical grazing value for the " winter " six months of 1948–49 has been calculated at a later stage in this study and will be found in Table 19. It was, on average, 3·79 lb. of starch equivalent and nearly half a pound of protein equivalent per cow, daily, during the autumn quarter and nil in the winter quarter. That is to say grazing in the " winter " six months 1948–49 supplied on average 345 lb. of starch equivalent and 44 lb. of protein equivalent per cow. If we estimate that the grazing value in the " winter " six months of 1949–50 fell by one-third as against the same period of 1948–49, the nutrients per cow, provided by grazing, in the " winter " six months of 1949–50 would amount to 230 lb. of starch equivalent and 29 lb. of protein equivalent. This would leave a deficiency of 115 lb. of starch equivalent and 15 lb. of protein equivalent per cow to be made up by hand-feeding. It may be seen from Table 12 that the increase of nutrients resulting from the higher nutritive value of the roughages fed in the " winter " six months of 1949–50, not only covered that deficiency, but would in fact have been sufficient to cover a deficiency of roughly two-fifths of the total nutritive value of grazing in the above period.

The question remains as to the reasons for the very modest average result of a 14 gallon increase in output per cow obtained through a net increase of input of 1·3 cwt. of concentrates, i.e. at a ratio of 10·4 lb. per gallon.

It is not suggested that the very high input of over 10 lb. of average concentrates per gallon really represents the quantity of concentrates it would have been necessary to feed to the majority of cows in the sample to obtain an average increase of

14 gallons over the average output of 332 gallons in the " winter " six months of 1948–49. Such a ratio of concentrates for each additional gallon of milk would probably only be necessary to produce an increase above an average six-monthly rate of production of over 400 gallons.* Two explanations, or a combination of them, are possible: that, on average, there was some overfeeding with purchased concentrates, or that the declining physiological efficiency of the dairy cow to utilise increasing quantities of foods for milk production, became apparent at the given average level of production. It is likely that both factors came into play.

From an economic angle, though, the most important consideration is not whether an increased input of feeding stuffs coincides with an increase in output of milk commensurate with theoretical standards, but that the money value of the increased output of milk is greater than the cost of the increased input of feeding stuffs and the additional cost of labour and some overheads resulting from it.

In the sample studied, the average increase in output of milk per cow for the " winter " six months of 1949–50 was as stated, 14 gallons. A simple average of the monthly pool prices for that period gives a price per gallon of just under 3*s.* for non-designated milk and a price for T.T. milk of 3*s.* 4*d.* Assuming for argument's sake that, on average, both non-designated and T.T. herds had an increase of 14 gallons of milk and that both groups fed, on average, 1·3 cwt. more purchased concentrates to achieve such an increase of output, the money obtained for the milk would have been £2 2*s.* 0*d.* for each " non-designated " cow and £2 6*s.* 9*d.* for each T.T. cow. The average cost of purchased concentrates in the 67 herds was 26*s.* 2*d.* per cwt. making a total cost of £1 14*s.* 0*d.* for the additional input. Considering the small quantities involved, the cost of additional labour and overheads would be only negligible and may be disregarded. Thus the margin resulting from the increased input would, on average, have been 8*s.* per " non-designated " cow and 12*s.* 9*d.* for a T.T. cow.

Had the additional food requirements needed to produce the additional 14 gallons of milk been higher, there would still have been room for increasing input economically. Obviously the limit of economic efficiency would have been lower in the case of non-designated cows than in the case of T.T. cows. In the given example this limit would have been reached when

* *Morrison—Feeds and Feeding*, 1949, p. 676. Table " Effect of Adding increasing amounts of concentrates to dairy rations ".

feeding 1·6 cwt. of purchased concentrates per non-designated cow (cost £2 1*s.* 10¼*d.*), while T.T. cows would only have reached it at an input of 1·77 cwt. of such concentrates (cost £2 6*s.* 9*d.*), that is at marginal input levels of 12·8 lb. per gallon for non-designated and 14·16 lb. per gallon for T.T. herds.

The above example shows that as long as the physiological capability of a cow to produce additional milk in response to an additional input of foods exists, such additional inputs at rates greatly exceeding conventional standard rates are economically justified on condition that the money value of the increase in milk produced covers the cost.

It also shows that the wider the margin between the cost of the increased ration and the price received for the milk produced, the more the production ration can be economically increased. This is borne out by a fact revealed by the Milk Cost Investigation, namely, that T.T. milk producers feed a higher production ration per gallon than producers of non-designated milk.

Morris and Jeffery came to similar conclusions* and express a doubt as to " whether the application of the conventional feeding standards for production rations . . . are not more of a hindrance than a help to the producer who seeks intelligently to maximise his profits from milk production ".

Conventional feeding standards, based as they are on the most advantageous quantitative input-output relationship, tend to fix production at the point of greatest output of milk per unit of nutrients fed. This point is not necessarily the point of maximum efficiency. Feeding standards may well be indispensable for determining a basis from which to start exploring the level of the most economic feeding for each individual cow. However, as they do not take into account the relative price levels of the input-output relationship, they cannot, alone, provide the answer to this question.

In a further study of the relationship between food input and milk output, to be undertaken at a later date, it is hoped that it will be possible, by a more detailed analysis of the data provided by this sample, to study the problem of declining physiological efficiency at various levels of milk output, food costs and milk prices, a problem that is of vital importance to the question of the economic level of feeding dairy cows.

A problem of management presents itself at this juncture,

* " The Effect of Feeding and Management on the Economics of Milk Production ", *Journal of the British Dairy Farmers' Association*, War Series, No. 5.

namely, whether the physiological effect of the increased input of feeding stuffs, discussed on pages 206 and 207, could not have been achieved at a lower cost, thus increasing the economic efficiency of the process.

The nutritive value of the 1·3 cwt. of purchased cake involved is estimated at 0·91 cwt. of starch equivalent and 0·19 cwt. of protein equivalent. In Table 13 a few examples are given of possible substitute rations and their cost, the saving they would bring about in comparison with the original ration of cake, and the net increase of dry matter in the ration that would result. The quantities suggested for each food contain not less nutrients than the replaced cake. The daily net increase of dry matter per cow is calculated on the assumption that the feeding of the suggested quantities of foods would be spread over three months.

TABLE 13

Cost of Possible Substitute Rations for 1·3 cwt. of Dairy Cake "Winter" Six Months 1949–50

Foods	Quantity of Food	Cost	Saving in Cost	Total Dry Matter	Total Net Increase Dry Matter	Daily Net Increase Dry Matter Per Cow
	cwt.	s. d.	s. d.	cwt.	cwt.	lb.
Purchased Cake	1·3	34 0	—	1·1	—	—
Silage alone	10·0	20 0	14 0	2·5	1·4	1·7
Silage	7·5	15 0	—	1·8	—	—
High Protein Cake	0·2	6 0	—	0·2	—	—
Total		21 0	13 0	2·0	0·9	1·1
Hay	3·0	12 6	—	2·6	—	—
High Protein Cake	0·34	10 0	—	0·3	—	—
Total		22 6	11 6	2·9	1·8	2·2
Kale	9·0	17 0	—	1·4	—	—
High Protein Cake	0·25	7 6	—	0·2	—	—
Total		24 6	9 6	1·6	0·5	0·6
Hay alone	5·0	25 0	9 0	4·3	3·2	3·9

It may not be possible to substitute any bulky foods for concentrates, in the case of a high yielding cow, if extensive use has already been made of such foods. However, the following table shows that the net increase in dry matter per day is not so great that it could not be consumed by a moderately high yielder of 11 cwt. live weight.

In the given example, the average increase in output of milk, 14 gallons per cow, was worth 22*s*. as ordinary and 26*s*. 9*d*. as T.T. milk. Assuming that it were possible to substitute any of the home-grown, or mainly home-grown, rations shown in Table 13 for the purchased concentrates actually fed, on average, the resulting margin of profit would have amounted to 17*s*. to 22*s*. per cow for ordinary milk and from 21*s*. 9*d*. to 26*s*. 9*d*. per cow for T.T. milk. The margin of profit for the increased input of purchased cake was 8*s*. per cow and 12*s*. 9*d*. per cow for ordinary and T.T. milk respectively. It seems, therefore, that in the given instance, the additional output could have been achieved at a cost sufficiently low to more than double the margin of profit that, on average, was actually obtained.

The Nutritive Value of the Foods Fed
81 Herds 1948–49

Leaving the comparison between 1948–49 and 1949–50 and returning to the original sample of 81 herds, in which the foods fed have already been analysed with regard to their kind, quantity and cost, it is now necessary to do the same with regard to their nutritive values.

The consumption of food by an animal is limited by its digestive capacity, therefore, the ration has to contain the nutrients necessary for maintenance and production in a bulk which the dairy cow is capable of digesting. On the other hand, the bulk must be large enough to give the animal a sense of repletion. It is accepted that a dairy cow of 11 cwt. requires, daily, a quantity of food containing 25 lb. of dry matter, on average, and this is, by conventional feeding standards, the average daily digestive capacity of a cow of that weight.

The aggregate quarterly and average daily quantities of dry matter contained in the foods fed have been set out in Table 14. The bulk of the dry matter fed in the winter quarter was contained in the hay—more than that in concentrates and succulents together. Succulents provided nearly as much dry matter

TABLE 14

Aggregate Quarterly and Average Daily Quantities of Dry Matter Fed 1948–49

Foods	Autumn			Winter		
	Total D.M.	Per Cow Daily	Per Cent. of Total	Total D.M.	Per Cow Daily	Per Cent. of Total
Concentrates:	cwt.	lb.	%	cwt.	lb.	%
(*a*) Purchased . . .	7,432·0	3·40	24	8,664·2	3·90	15
(*b*) Home-grown . .	3,703·8	1·67	12	4,882·1	2·21	9
Total Concentrates .	11,135·8	5·07	36	13,546·3	6·11	24
Hay and Straw . . .	12,636·5	5·75	40	29,807·6	13·43	54
Succulents	7,463·0	3·40	24	12,228·4	5·51	22
Total All Foods . .	31,235·3	14·22	100	55,582·3	25·05	100

as concentrates in that quarter. In the autumn hay and straw supplied only slightly more dry matter than concentrates, while succulents provided roughly one-third less than each of the other two groups.

The average daily quantity of 25 lb. of dry matter fed, per cow, in the winter, was equal to theoretical requirements for a cow of 11 cwt. In the autumn the dry matter provided by hand-feeding was only slightly in excess of half the theoretical requirements, implying that nearly half the dry matter was supplied by grazing in that quarter.

The aggregate quarterly and average daily quantities of starch equivalent fed have been given in Table 15.

In the autumn concentrates supplied nearly half the amount of starch equivalent provided by hand-feeding, while their contribution in the winter fell to slightly over one-third. The quantity of starch equivalent from purchased concentrates was only slightly higher in the winter quarter than in the autumn, but home-grown concentrates supplied one-third more starch equivalent in the winter. Succulents were as important a source of starch as hay and straw in the autumn, the two groups together supplying one-eighth more starch equivalent than the concentrates in that period, whilst their combined contribution rose to almost two-thirds of the ration fed in the winter, hay and straw alone providing more than the concentrates.

The total quantity of starch equivalent contained in the hand-fed foods was 62 per cent. larger in the winter than in the autumn.

TABLE 15

Aggregate Quarterly and Average Daily Quantities of Starch Equivalent Fed 1948–49

Foods	Autumn			Winter		
	Total Starch Equivalent	Per Cow Daily	Per Cent. of Total	Total Starch Equivalent	Per Cow Daily	Per Cent. of Total
Concentrates:	cwt.	lb.	%	cwt.	lb.	%
(*a*) Purchased . . .	5,540·5	2·52	33	6,403·0	2·89	23
(*b*) Home-grown . .	2,299·3	1·05	13	3,569·6	1·60	13
Total Concentrates .	7,839·8	3·57	46	9,972·6	4·49	36
Hay and Straw . . .	4,704·5	2·14	28	10,966·9	4·95	40
Succulents	4,477·5	2·04	26	6,613·3	2·98	24
Total All Foods . .	17,021·8	7·75	100	27,552·8	12·42	100

The protein contents of feeding stuffs are usually expressed as a percentage of digestible crude protein. However, crude (or total) protein comprises nitrogen in the form of pure protein and nitrogenous compounds in the form of amides. As amides are assumed to have half the feeding value of pure protein, foods containing a high percentage of them may have a considerably lower feeding value than foods containing a larger proportion of pure protein, even though the quantity of digestible crude protein may be equal. Ripe fodders and concentrates from ripe grains and seeds contain only a small proportion of amides, but roots, silage and green fodder have a large proportion of their digestible crude protein in amide form. This must be taken into account when computing rations.

The digestible protein has, in this study, been expressed as "Protein Equivalent" defined thus:

$$\text{Protein Equivalent} = \text{digestible true protein} + \frac{\%\text{ of amides}}{2}$$

A few examples of the discrepancy between digestible crude protein contents of foods, and their value in protein equivalents giving a more accurate idea of their feeding values is set out as follows:

Food	Percentage Digestible Crude Protein	Percentage Protein Equivalent	Protein Equivalent as a percentage of Digestible Crude Protein
Grass Silage (good)	2·7	1·8	67
Mangolds . . .	0·7	0·4	57
Swedes	1·1	0·7	64
Kale	1·7	1·4	82
Hay (good) . . .	5·4	4·6	85
Oats	8·0	7·6	95
Undecorticated Groundnut Cake	28·0	27·2	97

Table 16 shows the aggregate quarterly and average daily quantities of protein equivalent fed.

TABLE 16

Aggregate Quarterly and Average Daily Quantities of Protein Equivalent Fed 1948–49

Foods	Autumn			Winter		
	Total Protein Equivalent	Per Cow Daily	Per Cent. of Total	Total Protein Equivalent	Per Cow Daily	Per Cent. of Total
	cwt.	lb.	%	cwt.	lb.	%
Concentrates:						
(*a*) Purchased . . .	1,522·7	0·69	48	1,771·4	0·80	38
(*b*) Home-grown . .	357·6	0·16	11	554·0	0·25	12
Total Concentrates .	1,880·3	0·85	59	2,325·4	1·05	50
Hay and Straw . . .	667·1	0·30	21	1,531·6	0·69	32
Succulents	644·5	0·30	20	841·4	0·38	18
Total All Foods . .	3,191·9	1·45	100	4,698·4	2·12	100

In the autumn concentrates supplied almost 50 per cent. more protein equivalent in the hand-fed ration than hay and succulents, and in the winter the proportion was approximately the same. The total quantity of protein equivalent from concentrates was one-fifth higher in the winter than in the autumn and was made up by increases of one-eighth in purchased and two-fifths in home-grown concentrates.

Hay and straw supplied practically the same amount of protein equivalent, in the autumn, as the succulents group. In the winter protein from hay and straw provided 32 per cent.

of the total protein in hand-fed foods, compared with only 21 per cent. in the autumn, while protein from succulents increased by less than a quarter

In Appendix IV the data set out in Tables 14, 15 and 16 are tabulated for comparative purposes and the succulents group further analysed. A comparison of Appendix IV with Table 3, showing the quantities of foods fed, discloses the fact that the increases in the quantities of concentrates and hay and straw fed in the winter, as against quantities of foods in these groups fed in the autumn, were accompanied by roughly corresponding increases of the amounts of dry matter and nutrients contained in these foods. In the succulents group, however, the quantity fed in the winter was 55 per cent. higher than that fed in the autumn, while dry matter contained in the foods fed in the former quarter was 62 per cent. higher than dry matter in the autumn; the corresponding increases in starch and protein equivalents were only 46 per cent. and 27 per cent. respectively. The nutritive value of the succulents was, therefore, higher in the autumn than in the winter and the nutritive ratio of this group was also better; approximately 7 in the former as against 8 in the latter quarter. The above facts were due to the variations in the composition of the succulents which were fed, according to their seasonal availability and their keeping propensities. The higher nutritive value of the succulents group of foods, as fed in the autumn, was mostly due to kale and to some extent to sugar beet tops and so was the narrower nutritive ratio. The quantitative increases in the succulents ration fed in the winter quarter consisted, to a large extent, of mangolds, which explains both the lower nutritive value of the total succulents in that quarter, as compared with the autumn, and the wider nutritive ratio of that group in the winter.

The Theoretical Feeding Requirements and the Balance of Nutritive Values

Conventional English feeding standards have been applied in the following calculation of the theoretical requirements of nutrients necessary for the maintenance of the cows in the sample and for the production of the milk they yielded. The majority of the cows were commercial Dairy Shorthorns and British Friesians with an estimated average weight of about 11 cwt. and an estimated average of 3·7 per cent. fat in the milk. According to English feeding standards, cows of this type require daily, on average, 7 lb. of starch equivalent and 0·75 lb. of protein equivalent for maintenance and, in addition, 2·5 lb. of starch equivalent and 0·6 lb. protein equivalent for each gallon of milk produced.

The English standards were adopted in 1924,* but in 1929 Halnan, after a critical review of existing literature on the subject, came to the conclusion that these standards are on the generous side, and that 5 lb. of starch equivalent and 0·6 lb. of protein equivalent would be adequate to cover maintenance requirements of a cow of 1,000 lb. For the production of one gallon of 4 per cent. fat milk he suggested 2·5 lb. starch equivalent with 0·57 lb. protein equivalent. Halnan and Garner (1940) suggest that 0·5 lb. of protein equivalent, per gallon of 4 per cent. fat milk, would be nearer the truth. The National Institute of Dairying organised a large-scale experiment, under ordinary practical dairying conditions, where 700 cows were fed on rations containing 0·6 lb. protein equivalent per 10 lb. of milk and another 700 cows received 0·4 lb. protein equivalent per 10 lb. milk of average quality. According to Mackintosh the lower protein ration was as effective as that containing the conventional amount.† In the United States, the latest Morrison standards (1949) recommend for a 1,000 lb. cow, 0·60–0·65 lb. of digestible (crude) protein and 7–7·9 lb. Total Digestible Nutrients for maintenance requirements. Since this standard bases its maintenance ration on roughages, the figure for protein equivalent would be in the region of 0·5 lb. The Total Digestible Nutrients standard accepted by Morrison overvalues practically all foods in relation to the English standard, particularly bulky foods. Therefore, 7–7·9 lb. Total Digestible Nutrients for maintenance would seem to be equivalent to about 5 lb. starch equivalent. (For example lucerne hay has a starch equivalent value of 32, while its Total Digestible Nutrients value is 47.)

It has been considered whether, in the face of the above evidence suggesting nutritive requirements lower than those in the conventional standards, the calculations in this study would have been better had they been based on such recommendations. However, until the experimental evidence available

* They are based on the recommendations of a Departmental Committee on the Rationing of Dairy Cows appointed by the Ministry of Agriculture and Fisheries in that year.

† Quoted by R. G. Linton and G. Williamson *Animal Nutrition and Veterinary Dietetics*, 1943, also by E. T. Halnan and Frank H. Garner *The Principles and Practice of Feeding Farm Animals*, 1947.

has been confirmed by tests, paying more attention to changes in body weight,* it would, perhaps, be unwise to accept these recommendations uncritically. On the other hand, there are two factors that make it inevitable that practical rationing should be at a somewhat higher level than that based upon theoretical standards. Firstly, there is never any waste of feeding stuffs in the type of experiment used to establish feeding standards, so that foods recorded as fed are really consumed; in practice some waste is bound to occur. Secondly, sick cows are eliminated from experiments unless the trouble is of a very temporary nature. In practice, unless cows are fed individually (as they should be), the factor of sickness tends to increase the input of foods in comparison with theoretical requirements.

It was, therefore, thought that the application of conventional standards for maintenance and production, biased, as they appear to be, on the generous side, would narrow the gap between theory and practice, although, in the lack of any data with regard to the quantity of foods wasted, to an unknown extent.

None of the known feeding standards, however, take into account the requirement of nutrients necessary for the formation of the foetus and placenta by cows in-calf. The better known feeding manuals confine themselves to pointing out the necessity of feeding the dry cow well, so as to keep her in good condition for calving and the subsequent lactation. According to Woodman the requirement of nutrients for the formation of the calf is small, except during the last two months of pregnancy, when the cows, in ordinary practice, will have been dried off. Morrison mentions an American experiment where new-born 65 lb. Jersey calves were found to contain about 11·8 lb. protein, 2·5 lb. fat and 2·7 lb. mineral matter; and 80 lb. Hereford calves 14·6 lb. protein, 2·9 lb. fat and 3·6 lb. mineral matter. To these figures must be added the amounts of nutrients contained in the placenta. Maynard† recommends an increase of 17 per cent. in the protein of the mantenance ration, if spread over the whole period of pregnancy of a cow, or 40 per cent. during the closing stages. This indicates a requirement of 36 lb. of protein equivalent. Among progressive farmers it is a practice to supply pregnant dry cows

* For example, it is not known whether the 700 cows in the Reading experiment on the lower protein ration, lost weight as a result of protein deficiency; or, if they did not show a loss, whether the experiment lasted long enough for a loss in body weight to become measurable.

† L. A. Maynard, *Animal Nutrition*, 1937.

with a production ration for one gallon of milk, in addition to the maintenance ration, to cover pregnancy requirements.* On this basis, over a dry period of 60 days, the starch equivalent involved would be 150 lb. and the protein equivalent equal to Maynard's recommendation, i.e. 36 lb., but clearly a large and unneeded surplus of carbohydrates will result.

A review of the scanty evidence available relating to pregnancy requirements, in conjunction with an independent calculation made by the writer, has led to the conclusion that a more appropriate estimation of this requirement would be a figure of 40 lb. starch equivalent and 45 lb. protein equivalent per pregnant cow. These figures have accordingly been applied in the following tables.

Table 17 shows the total nutritive values of foods fed and the average daily quantities fed per cow. It also shows a balance of the nutritive values of foods fed against the theoretical requirements.

The theoretical requirements per cow were nearly equal in both autumn and winter, as the number of cows in the herds and milk production per cow were approximately the same in both quarters. There were, on average, 514 dry cows in the sample in the autumn and 489 in the winter and the difference, although reflected in the total quantities of the pregnancy requirements, was too small to show on a daily basis when spread over all the cows in the herds. While the pregnancy requirements for starch were an insignificant fraction of the total requirements for that nutrient, they represented, on average, nearly 10 per cent. of the production requirements of protein for milk and just over 5 per cent. of all the theoretical requirements for that nutrient.

The nutritive value of the foods fed showed an increase of starch equivalent by 60 per cent. in the winter, whilst protein equivalent increased by only 47 per cent. at the same time. The nutritive ratio of the hand-fed foods was approximately 5·3 in the autumn and widened to 5·9 in the winter. The wider nutritive ratio of autumn grass required a narrower nutrients ratio in the hand-fed foods to bring about a balance. Hand-feeding in the autumn left only a relatively small surplus of nutrients over maintenance requirements, while in the winter it provided, on average, all the nutrient requirements of the cows in the sample.

The balance shows that in the autumn there was a deficiency

* Halnan and Garner estimate these requirements to be at most the nutrients equivalent to those necessary to produce one gallon of milk.

TABLE 17

Balance of Nutritive Values of Foods Fed
1948–49

Total Requirements	Autumn				Winter			
	Starch Equivalent		Protein Equivalent		Starch Equivalent		Protein Equivalent	
	Total	Per Cow Daily	Total	Per Cow Daily	Total	Per Cow Daily	Total	Per Cow Daily
	cwt.	lb.	cwt.	lb.	cwt.	lb.	cwt.	lb.
Nutritive Value of Foods Fed	17,022	7·75	3,174	1·44	27,553	12·42	4,698	2·12
Theoretical Requirements:								
(*a*) Maintenance . . .	15,379	7·00	1,648	0·75	15,553	7·00	1,664	0·75
(*b*) Pregnancy.	207	0·09	229	0·10	196	0·09	218	0·10
(*c*) Production	9,792	4·45	2,350	1·07	10,217	4·57	2,451	1·10
Total Requirements. . . .	25,378	11·54	4,227	1·92	25,966	11·66	4,333	1·95
	Deficiency				*Surplus*			
Balance	8,356	3·79	1,053	0·48	1,587	0·76	365	0·17
	Deficiency as per cent of total theoretical requirement				*Surplus as per cent. of total theoretical requirement*			
	33%		25%		6%		8%	

of one-third starch equivalent and one-quarter protein equivalent according to theoretical requirements. In the winter there was a surplus of 6 and 8 per cent. of starch equivalent and protein equivalent respectively.

Some Aspects of Autumn Grazing

The deficiency of nutrients in the hand-fed foods provided in the autumn represents the approximate net quantity of nutrients supplied by grazing in that period. The quantity actually supplied, i.e. the gross quantity, was larger by the amount necessary to cover the additional requirements of energy expended in grazing. The nutritive contribution of the autumn grazing may have been larger if, as a result of an error a combination of any of the following causes had occurred in the calculation:

(*a*) over-estimating the nutritive values of foods on which the calculations have been based;

(*b*) gross overfeeding in several, or some overfeeding in a large proportion, of the herds in the sample;

(*c*) a substantial wastage of the foods by the cows in the process of feeding;

(*d*) production requirements larger, on average, than conventional requirements, resulting from a certain proportion of the herds in the sample having attained a level of production at which the physiological efficiency of the cows declined quite appreciably.

Furthermore, the possibility cannot be excluded that grazing in the autumn supplied more than the net quantum of nutrients expressed by the deficiency and that, as a result, the cows in the sample put on, on average, some body weight, although this is unlikely. It is assumed that, on average, dairy cows put on flesh in the summer, maintain it through the autumn and lose body weight in the winter, but for the sample under consideration there is no concrete evidence to show to what extent changes in body weight occurred.

Neither can it be ruled out that the net quantity of nutrients provided by autumn grazing was, in fact, smaller than the quantity expressed by the deficiency, if the nutritive values of the hand-fed foods, on which these calculations have been based, were underestimated. It will be noted that, with the last exception, all the possible errors inherent in the adopted method of calculation point towards an underestimation of the nutritive value of autumn grazing.

The data, obtained at this stage of analysis, permitted the calculation of the average unit cost of starch equivâlent derived from autumn grazing. This is shown in Table 18, which also shows the average unit costs of the main home-grown foods, and also what it would have cost to replace the quantity of starch equivalent contributed by grazing, by an equal quantity of energy from these foods. The calculated cost of substitution does not, however, make any allowance for the nutritive ratio of the foods. The difference, though negligible, should be kept in mind when making comparisons between the cost of substituting starch equivalent from one food by that of another with a different nutritive ratio.

TABLE 18

Average Cost of Starch Equivalent in Autumn Grazing, the Main Home-Grown Foods and the Cost of Substitution
1948

Foods	Approx. Nutritive Ratio	Cost of Starch Equivalent per cwt.	Starch Equivalent Cost per Cow in Autumn Grazing and in Substitute Foods	
			Daily	91 Days
		£	*d.*	£
Autumn Grazing .	7·5 (est.)	0·34	2·77	1·05
Silage	5·4	0·68	5·48	2·08
Hay	7·7	0·70	5·70	2·16
Kale	5·5	0·95	8·62	3·27
Dredge Corn . .	5·5 (est.)	1·17	9·50	3·60
Oats	7·0	1·22	9·89	3·75
Mangolds . . .	13·0	1·38	11·23	4·26

The cost of 1 cwt. of starch equivalent from autumn grazing was 6*s.* 8*d.* and the cost of 3·78 lb. of starch equivalent (i.e. the quantity supplied per cow per day by grazing in the autumn) was, therefore, 2¾*d.* It would have required nearly double the cost to substitute that quantity of starch equivalent from silage or hay, three times as much from kale; three and a half times as much if grains had been used and four times as much in the case of mangolds.

In Table 19 it can be seen how the average substitution costs (for the given home-grown foods) could differ with varying levels of daily starch equivalent inputs supplied by grazing.

TABLE 19

Cost per Cow of Substitution of Foods for Autumn Grazing at Various Levels of Starch Equivalent Supplied by Grazing 1948

Starch Equivalent in Autumn Grazing per Cow per day	Cost of Substitution per Cow of:									
	Silage		Hay		Kale		Dredge Corn		Oats	
	per day	per 91 days	per day	per 91 days	per day	per 91 days	per day	per 91 days	per day	per 91 days
lb.	*d.*	£	*d.*	£	*d.*	£	*d.*	£	*d.*	£
2·5	3·61	1·37	3·76	1·43	5·69	2·16	6·26	2·38	6·52	2·47
3·0	4·33	1·64	4·55	1·65	6·83	2·59	7·52	2·85	7·83	2·97
3·79*	5·48	2·08	5·70	2·16	8·62	3·27	9·50	3·60	9·89	3·75
4·0	5·78	2·19	6·02	2·28	9·10	3·45	10·02	3·80	10·44	3·96
4·5	6·50	2·47	6·77	2·57	10·24	3·88	11·28	4·28	11·74	4·45
5·0	7·22	2·74	7·52	2·85	11·38	4·31	12·53	4·75	13·04	4·95
6·0	8·67	3·29	9·02	3·42	13·65	5·18	15·03	5·70	15·65	5·94

* Actual average of starch equivalent from autumn grazing in the sample.

Assuming that the cost of autumn grazing remains unaltered, grazing would have been a cheaper source of energy than any of the hand-fed foods which could have taken its place, even at levels of input considerably lower than 3·79 lb. of starch equivalent (which was the calculated average of starch equivalent from autumn grazing in this study).

It can be assumed that, on average, the grazing available to cows in this sample was of a quality that usually results from a somewhat inadequate standard of grassland management.* It can be safely asserted that grassland of this type is capable of yielding increasing returns, at lower costs per unit of nutrient produced, for a considerably higher level of input of fertiliser, etc., than it receives under existing management.

Moreover, Table 19 shows that it would have paid to increase the nutritive value of the autumn grazing, even if a higher cost *per unit* of nutrient had resulted in a higher cost of grazing *per cow*. It also shows the economic limit of an increase in the grazing cost per cow, at various levels of

* *The Cost of Grassland in the West of England* by V. H. Beynon and M. B. Jawetz, University of Bristol, Department of Economics, 1949.

substitution, against an equal quantity of starch equivalent supplied by the main home-grown foods.

Some general remarks have been made on page 202 in respect of management for more and better autumn grazing, but two definite recommendations are made, at this juncture, for consideration:

(i) Maiden grass contains a much greater amount of nutrient, in the year of seeding, than is " normal " for the species concerned. This phenomenon is no less remarkable in the autumn, particularly in respect of protein. On a sample of 75 farms in the West of England in 1947–48, only 6 per cent. grazing, and under 9 per cent. grassland cut for hay and silage, consisted of first year leys. Leys, for grazing in their first year, were established on only 26 per cent. of the farms, while one-third of the farmers established new leys for hay and silage.* However, a proportion of these first year leys were undersown with corn in the previous year and, therefore, were not " maiden grass " in 1947–48. The establishing of new leys *every* year, especially by direct seeding, would result in the availability of excellent autumn grazing, which should be reserved for cows in milk.

(ii) Catch-crops for autumn grazing may be cheaper supplies of nutrients than hand-fed foods, with the additional advantage of releasing such foods for use during the winter. Among the cheapest and most suitable for undersowing, Italian Rye-Grass and Timothy may be mentioned; as a catch-crop after corn, mustard seed and rape would seem to be useful, though attention should be paid to a certain danger of tainting. A seed-bed for the cruciferae can be easily and cheaply obtained from the stubble, but the adage that " one week in August is worth four in September " should be borne in mind.

The Possibility of a Negative Nutritive Net Value of Winter Grazing for Dairy Cows

The average surplus of nutrients fed, over theoretical requirements in the winter quarter, suggests that no contribution was made by grazing towards the nutrient of the cows

* *The Cost of Grassland in the West of England* by V. H. Beynon and M. B. Jawetz, University of Bristol, Department of Economics, 1949.

in the sample. The amount of this surplus is subject to error resulting, *mutatis mutandis*, from causes outlined on page 219 of this study, in connection with the nutritive value of autumn grazing. Although all but one possible cause for error pointed towards an underestimation of the calculated nutritive value of autumn grazing, there is one important factor that offsets this tendency where winter grazing is concerned: namely, the fact that, generally speaking, cows lose some body weight in the winter quarter.

If, for any reason, the nutritive value of the foods fed by hand during the winter quarter was, in reality, lower than the calculated one, the resulting deficiency could only be covered by the cows' body tissue, or by a net nutritive contribution from winter grazing, or a combination of both. It may be assumed that, although no data were available with regard to an average loss of body weight by the cows in the sample, such a loss took place. This assumption does not, however, agree with the existence of a positive balance of nutrients fed over theoretical requirements. A possible explanation of this circumstance may lie in the existence of a negative nutritive net value of winter grazing.

At the beginning of this study, it was estimated that the nutritive value of winter grazing in the Bristol I Province, was $33\frac{1}{3}\%$ of autumn grazing. The energy value of autumn grazing was later calculated and amounted to 3·79 lb. starch equivalent daily, per cow in the sample. On this basis, the energy value of winter grazing would, therefore, have been 3·79 lb. $\times \frac{33 \cdot 3}{100}$ = 1·26 lb. starch equivalent. If this figure were true, there would be no explanation for the generally observed fact that, on average, dairy cows lose some body weight during the winter months. Neither would there be a reason for the belief held by a large majority of farmers, that grazing in the winter quarter has no feeding value for dairy cows.

Up to this juncture all references to the amount of nutrients supplied by grazing have been in terms of net quantities, i.e. the quantities that are available for maintenance and production, derived by the grazing of animals from pasture; but no account has been taken of the fact that a certain amount of energy is expended by the grazing animal in searching for its food. It is implicit in all discussions of, or calculations involving, the nutritive value of grazing that the amount of nutrients necessary for this activity is supplied by the grazing in addition to any contribution that grazing may make to the other nutritive requirements of the animal. Obviously, during the grazing season proper, the gross amount of nutrients provided by the grassland is greatly in excess of this " grazing activity requirement " leaving a large net balance for maintenance and for production requirements. During the winter quarter, however, the gross quantity of nutrients derived from grazing by dairy cows may be insufficient to cover this " grazing activity requirement ", leaving a negative nutritive net value of winter grazing for that class of stock. Conventional standard requirements are based on tests carried out on tied animals and, therefore, do not take into account the amount of energy spent by the animals in the process of grazing. No accurate data exist with regard to the amounts of energy thus spent, but it is usually accepted that the requirements of a cow for this purpose are 1 lb. of starch equivalent per day when grazing on good fattening pasture, 2 lb. starch equivalent on good pasture and 3 lb. starch equivalent if grazing on poor pasture.*

The problem looks entirely different when account is taken of the grazing activity requirements of the cows. Taking autumn grazing to represent good pasture, the gross quantity of starch equivalent it supplied daily, per cow, would have been 3·79 lb. + 2 lb. (grazing activity requirement) = 5·79 lb. and the calculated gross quantity of starch equivalent from winter grazing 5·79 lb. $\times \frac{33\cdot3}{100} =$ 1·93 lb. starch equivalent. Assuming winter grazing to represent poor pasture entailing a grazing activity requirement of 3 lb. starch equivalent per day for each grazing cow, a daily deficiency of 1·07 lb. starch equivalent per cow would have resulted. That means that 1·07 lb. starch equivalent per day would have had to be supplied, on average, to each cow out on winter grass, to make up the net loss of energy caused by its movement in search of that grass; or, alternatively that the cows made up that net loss from their body tissue and lost some body weight as a result.

It may be suggested, therefore, that, on average, winter grazing in the Bristol I Province, has a negative nutritive net value to dairy cows.

It is possible that a proportion of, or all the surplus of nutrients hand-fed over theoretical requirements, in the winter resulted from the necessity to make up the negative net nutritive value of winter grazing, and that the lack of such a surplus

* E. T. Halnan and Frank H. Garner, *The Principles and Practice of Feeding Farm Animals*, 1947.

would have resulted in a larger average loss of body weight of the cows in the sample. The surplus was too small, however, to make up the full deficiency in the grazing activity requirement. It is also possible that a surplus of nutrients hand-fed over theoretical requirements existed concurrently with a loss of body weight resulting from the negative net nutritive value of winter grazing.

It appears, from the above discussion, that the practice of keeping dairy cows on grass in the winter quarter results in a loss of body weight, unless the necessity to supplement the deficiency in what was termed, the grazing activity requirement, is observed. This requirement was found to have amounted to 1·07 lb. starch equivalent daily, per cow, under the set of circumstances given in this study. The mean of the cost of starch equivalent from the main home-grown foods tabulated in Tables 17 and 18 amounted to 1¾*d.* per lb. and on that basis it would have cost, on average, 13*s.* 7*d.* per cow to cover the deficiency in grazing activity requirement over 91 days of winter grazing. It is generally held that cows are healthier for the exercise obtained during grazing, however, high-yielding cows are usually housed in the winter, and there is no convincing evidence that such a practice has a deleterious effect on their health.

It does not seem, though, that the loss of body weight of the cows that probably resulted from the negative net nutritive value of winter grazing was, on average, serious, or that it had a noticeably ill effect on milk production. However, it is probable that, among the herds with under average milk yields there was a more serious loss of body weight as a consequence of a greater dependence on winter grazing, and that the low yields were partly caused by such a loss.

The Balance of Bulky Foods for Maintenance Requirements

It is usual to associate the feeding of bulky foods with the maintenance requirements of dairy cows, while the ration of concentrates is associated with their production requirements. The following table shows the balance of bulky foods fed against the theoretical maintenance requirements.

TABLE 20

Balance of Bulky Foods for Maintenance Requirements 1948–49

Foods	Aggregate Quantities							
	Autumn				Winter			
	Starch Equivalent		Protein Equivalent		Starch Equivalent		Protein Equivalent	
	Total	Per Cow Daily	Total	Per Cow Daily	Total	Per Cow Daily	Total	Per Cow Daily
	cwt.	lb.	cwt.	lb.	cwt.	lb.	cwt.	lb.
Maintenance Requirements .	15,379	7·00	1,648	0·75	15,553	7·00	1,664	0·75
Hay and Straw Fed . . .	4,705	2·14	667	0·30	10,967	4·95	1,532	0·69
Succulents Fed	4,477	2·04	645	0·30	6,613	2·98	841	0·38
Total Bulky Foods. . .	9,182	4·18	1,312	0·60	17,580	7·93	2,373	1·07
		Deficiency				*Surplus*		
Balance	6,197	2·82	336	0·15	2,027	0·93	709	0·32
	Deficiency as percentage of total theoretical requirements				*Surplus as percentage of total theoretical requirements*			
	40·3%		20·0%		13%		42·7%	

In the autumn bulky foods supplied, on average, approximately 60 per cent. of the maintenance requirements for starch an 80 per cent. for protein. In the winter all the theoretical maintenance requirements were supplied by the bulky foods, leaving a surplus of starch equivalent sufficient for the production of approximately 3 pints of milk and a surplus of protein equivalent for just over 4 pints daily for each cow in the sample.

The Balance of Concentrates for Production Requirements

In Table 21 the balance of concentrates has been drawn against theoretical requirements for milk production and pregnancy.

On average, concentrates provided roughly three-quarters of the total nutrients required for the production ration in the autumn. The quantities of starch equivalent from concentrates were sufficient to cover 79 per cent. of the production and pregnancy requirements, while protein equivalent from concentrates made up 72 per cent. of the total production and pregnancy requirements for that nutrient. In the winter, production and pregnancy requirements for starch were, in 96 per cent of cases, satisfied by the quantity of concentrates fed, whilst protein equivalent from that source provided 88 per cent. of the total requirements.

TABLE 21

Balance of Concentrates for Production Requirements including Pregnancy Requirements 1948–49

Foods	Aggregate Quantities							
	Autumn				Winter			
	Starch Equivalent		Protein Equivalent		Starch Equivalent		Protein Equivalent	
	Total	Per Cow Daily	Total	Per Cow Daily	Total	Per Cow Daily	Total	Per Cow Daily
	cwt.	lb.	cwt.	lb.	cwt.	lb.	cwt.	lb.
Production Requirements .	9,999	4·54	2,579	1·17	10,413	4·66	2,669	1·20
Concentrates fed:								
(*a*) Purchased	5,541	2·52	1,523	0·69	6,403	2·89	1,771	0·80
(*b*) Home-grown . . .	2,299	1·05	339	0·15	3,570	1·60	554	0·25
Total Concentrates . .	7,840	3·57	1,862	0·84	9,973	4·49	2,325	1·05
Balance: Deficiency . . .	–2,159	–0·97	–717	–0·33	–440	–0·17	–344	–0·15
Deficiency as percentage of Theoretical Production Requirements	21·5%		28·2%		3·6%		12·5%	

It is generally assumed that, under present economic conditions, home-grown foods should provide for maintenance requirements and the production of the first gallon of milk in the winter. In Table 22 the relevant data have been set out to illustrate the average position in the given sample from this angle.

The table reveals that the above assumption, on average, has not been fully borne out. In the autumn quarter, quantities of both starch and protein equivalents from home-grown foods and grazing were, on average, sufficient to cover maintenance requirements and the production of four-fifths of a gallon of milk per cow per day. In the winter quarter, the daily amount of starch equivalent supplied by home-grown foods was sufficient to cover requirements for the production of two-fifths of a gallon of milk per cow, in addition to maintenance requirements, while the daily quantity of protein equivalent supplied to each cow practically sufficed for both maintenance and production requirements for one gallon of milk.

TABLE 22

Balance of Nutritive Values of Home-Grown Foods and Grazing for Maintenance and Production Requirements for 1 Gallon of Milk

Foods	Autumn		Winter	
	Per Cow Daily		Per Cow Daily	
	Starch Equivalent	Protein Equivalent	Starch Equivalent	Protein Equivalent
	lb.	lb.	lb.	lb.
Requirements for Maintenance and Production of 1 Gallon of Milk . .	9·50	1·35	9·50	1·35
Home-grown Concentrates .	1·05	0·15	1·60	0·25
Bulky Foods	4·18	0·60	7·93	1·07
Total Home-grown Foods .	5·23	0·75	8·53	1·32
Grazing (Calculated) . .	3·79	0·48	—	—
Total Nutrients . . .	9·02	1·23	8·53	1·32
Balance: Deficiency . .	0·48	0·12	0·97	0·03

Conclusion

On average, the cows in the sample obtained sufficient nutriment, by conventional standards of feeding, to cover the requirements necessary for their existence and for the production of their calves and milk—and rather more. The available evidence, however, suggests that a higher level of feeding would, on average, have resulted in a higher output of milk accompanied by a higher economic efficiency of the herds involved.

Apart from the more fundamental question of input–output relationships there remains the more practical question of whether the economic results actually achieved by this sample of herds could not have been improved upon in other directions. Even a cursory glance at Tables 11, 17 and 18 in this study will give evidence of economic possibilities in substituting cheaper foods for more expensive ones; cheaper foods being those with a lower cost per unit of nutrient. Moreover, what has been said in this respect in connection with autumn grazing applies, *mutatis mutandis*, to home-grown foods; there are great possibilities in feeding dairy cows at a lower cost by lowering the unit cost of production of these foods. The dairy farmer's economic success depends not less on his skill and foresight in the field than in his knack of balancing rations and handling dairy cows. A bag of fertiliser may save one bag of expensive concentrate and a good deal more.

In a further study, now in preparation, it is proposed to investigate these two aspects of the problem of winter feeding in greater detail. In particular it is hoped that, after the examination of the data available for this sample of farms from the point of view of the deviations from the average input–output relationships, it may be possible to establish what are the economic implications of declining physiological efficiency for milk production at various levels of yield.

Appendices

APPENDIX I

Average Production Costs of Home-Grown Foods in the Sample. 1948–49

Food	*Per Cwt.* s.	d.
Oats	14	6
Dredge Corn	15	3
Hay	4	6
Straw	2	5
Silage	1	8
Kale	1	11
Mangolds	1	7

Feeding Value Costs of Home-Grown Foods for which no Production Costs are Available

Foods	*Per Cwt.* s.	d.	*Foods*	*Per Cwt.* s.	d.
Barley	14	10	Cabbage	1	8
Beans	12	11	Rape	1	4
Peas	13	8	Parsnips	2	3
Linseed	15	9	Carrots	1	10
Dried Grass	11	0	Maize (Green)	1	10
Turnips		11	Sugar Beet Tops	1	9
Swedes	1	6	Sugar Beet Pulp (Wet)	3	3

APPENDIX II

Calculated Nutritive Values of Compound Cakes

Foods	*Dry Matter*	*Starch Equivalent*	*Protein Equivalent*
National Cattle Food No. 1 and 2*	86	59·5	16
National Cattle Food No. 3, Calf Nuts	88	68	20
National Cattle Food No. 4, Calver Nuts	86	60	14
Grain Balancer Foods	88	60	22
High Protein Foods	89	63	31·5

*Including foods listed as "Dairy Cakes, Nuts and Meals" and "Mixed Dairy Foods".

APPENDIX III

Aggregate Quantities and Cost of Foods Recorded as Fed

Foods	1948 Autumn October–December: Purchased		Home-grown		Total		1949 Winter January–March: Purchased		Home-grown		Total	
	cwt.	£	cwt.	£	cwt.	£	cwt.	£	cwt.	£	cwt.	£
Compounds Cakes and Meals												
Nat. Cattle Food Nos. 1 and 2, Dairy Cakes, Nuts and Meals	7,277	5,818·0	—	—	7,277	5,818·0	7,834	6,197·6	—	—	7,834	6,197·6
Nat. Cattle Food No. 3, Calf Nuts	6	6·2	—	—	6	6·2	4	3·8	—	—	4	3·8
Nat. Cattle Food No. 4, Calver Nuts	165	133·5	—	—	165	133·5	198	159·8	—	—	198	159·8
Grain Balancer Meal and Nuts	38	29·6	—	—	38	29·6	128	103·8	—	—	128	103·8
High Protein Cake, Meal and Nuts	331	265·0	—	—	331	265·0	635	524·3	—	—	635	524·3
Total	7,817	6,252·3	—	—	7,817	6,252·3	8,799	6,989·3	—	—	8,799	6,989·3
Straight Cakes and Meals												
Undecorticated Ground Nut Cake	6	3·5	—	—	6	3·5	2	1·6	—	—	2	1·6
Decorticated Ground Nut Cake	124	79·4	—	—	124	79·4	89	57·3	—	—	89	57·3
Decorticated Ground Nut Meal	5½	4·5	—	—	5½	4·5	12½	8·0	—	—	12½	8·0
Coconut Cake	14	9·6	—	—	14	9·6	15½	10·5	—	—	15½	10·5
Cotton Cake	—	—	—	—	—	—	7	4·2	—	—	7	4·2
Sunflower Cake	44	26·6	—	—	44	26·6	41½	23·8	—	—	41½	23·8
Linseed Cake	106	77·5	—	—	106	77·5	149	112·1	—	—	149	112·1
Palm Kernel Cake	95	57·5	—	—	95	57·5	120	71·2	—	—	120	71·2
White Fishmeal	27	37·8	—	—	27	37·8	41½	60·2	—	—	41½	60·2
Blood Nitrogen	¼	0·5	—	—	¼	0·5	—	—	—	—	—	—
Total	422	296·9	—	—	422	296·9	478	348·9	—	—	478	348·9
Other Concentrates												
Dried Grains	30	20·3	—	—	30	20·3	3½	2·3	—	—	3½	2·3
Dried Sugar Beet Pulp	202	82·1	—	—	202	82·1	335	141·8	—	—	335	141·8
Brown Molasses, Molassine Meal, Molassed Palm Kernel, Treacle	27	15·3	—	—	27	15·3	93	54·4	—	—	93	54·4
Malt Coombs	—	—	—	—	—	—	2	1·1	—	—	2	1·1
Total	259	117·7	—	—	259	117·7	434	198·6	—	—	434	198·6
Grains, Seeds and Cereal By-Products												
Oats	—	—	1,686	1,222·4	1,686	1,222·4	—	—	2,282	1,654·5	2,282	1,654·5
Dredge Corn	111	83·3	1,653	1,256·1	1,764	1,339·4	112	84·0	2,636	2,004·1	2,748	2,088·1
Barley	2	2·1	23	16·5	25	18·6	2	2·1	263	207·5	265	209·6
Beans	—	—	—	—	—	—	—	—	21	13·6	21	13·6
Peas	26	39·0	—	—	26	39·0	32½	48·8	21	14·4	53½	63·2
Linseed	20	14·8	—	—	20	14·8	26	19·2	18	13·8	44	33·0
Linseed Meal	25	20·5	—	—	25	20·5	9	6·4	—	—	9	6·4
Flaked Maize	98	75·5	—	—	98	75·5	175	137·0	—	—	175	137·0
Maize Gluten	3	2·1	—	—	3	2·1	—	—	—	—	—	—
Wheatings	91	49·5	—	—	91	49·5	92	53·4	—	—	92	53·4
Bran	57	34·1	—	—	57	34·1	18	10·2	—	—	18	10·2
Oatfeed	12	8·7	—	—	12	8·7	12½	16·5	—	—	12½	16·5
Total	445	329·6	3,362	2,495·0	3,807	2,824·6	479	377·6	5,241	3,907·9	5,720	4,285·5
Dried Grass	220	248·0	342	187·8	562	435·8	436	543·4	435	238·8	871	782·2
Minerals and Condiments	62	39·0	—	—	62	39·0	122	99·7	—	—	122	99·7
Hay and Straw												
Hay	67	39·1	14,369	3,233·0	14,436	3,272·1	270	138·7	32,714	7,360·7	32,984	7,499·3
Straw	—	—	425	51·0	425	51·0	82	20·3	1,978	237·4	2,060	257·8
Total	67	39·1	14,794	3,284·0	14,861	3,323·1	352	159·0	34,692	7,598·1	35,044	7,757·1
Succulents												
Silage	—	—	5,306	451·0	5,306	451·0	—	—	26,398	2,243·8	26,398	2,243·8
Kale	—	—	28,846	2,740·4	28,846	2,740·4	—	—	13,198	1,253·8	13,198	1,253·8
Mangolds	—	—	805	66·8	805	66·8	285	44·9	21,690	1,800·3	21,875	1,832·3
Turnips	—	—	350	15·8	350	15·8	—	—	133	6·0	133	6·0
Swedes	—	—	2,125	157·3	2,125	157·3	110	26·4	4,086	302·4	4,156	319·8
Cabbage	—	—	2,497	207·3	2,497	207·3	—	—	1,644	136·5	1,644	136·5
Rape	—	—	—	—	—	—	—	—	211	13·9	211	13·9
Parsnips	—	—	5	0·6	5	0·6	—	—	185	20·5	185	20·5
Carrots	—	—	19	1·8	19	1·8	103	12·2	133	12·4	236	24·6
Maize (Green)	—	—	80	7·6	80	7·6	—	—	—	—	—	—
Potatoes	120	30·0	20	8·3	140	38·3	230	57·3	—	—	230	57·3
Sugar Beet Tops	—	—	3,649	321·1	3,649	321·1	—	—	—	—	—	—
Sugar Beet Pulp (Wet)	—	—	5	0·8	5	0·8	—	—	—	—	—	—
Wet Grains	844	85·9	—	—	844	85·9	624	55·3	—	—	624	55·3
Total	964	115·9	43,707	3,978·5	44,671	4,094·4	1,352	196·1	67,678	5,789·6	69,030	5,985·7
Total Foods	10,256	7,438·5	62,205	9,945·3	72,461	17,383·8	12,452	8,912·6	108,046	17,534·4	120,498	26,447·0

APPENDIX IV

Summary of Average Daily Quantities of Dry Matter and Nutrients Fed per Cow

Foods	Autumn—1948 October–December						Winter—1949 January–March					
	Dry Matter	Per Cent. of Total	Starch Equiv-alent	Per Cent. of Total	Protein Equiv-alent	Per Cent. of Total	Dry Matter	Per Cent. of Total	Starch Equiv-alent	Per Cent. of Total	Protein Equiv-alent	Per Cent. of Total
	lb.	%	lb.	%	lb.	%	lb.	%	lb.	%	lb.	%
Concentrates:												
(*a*) Purchased	3·40	24	2·52	33	0·69	48	3·90	15	2·89	23	0·80	38
(*b*) Home-grown . . .	1·67	12	1·05	13	0·16	11	2·21	9	1·60	13	0·25	12
Total Concentrates . .	5·07	36	3·57	46	0·85	59	6·11	24	4·49	36	1·05	50
Hay	5·57	39	2·10	27	0·30	21	12·65	51	4·76	38	0·68	32
Straw	0·18	1	0·04	1	‡	‡	0·78	3	0·19	2	0·01	‡
Total Hay and Straw .	5·75	40	2·14	28	0·30	21	13·43	54	4·95	40	0·69	32
Succulents:												
Kale	2·07	15	1·31	17	0·18	12	0·86	3	0·59	5	0·08	4
Silage	0·60	4	0·30	4	0·04	3	2·91	12	1·52	12	0·22	10
Mangolds	0·04	‡	0·02	‡	‡	‡	1·19	5	0·59	5	0·04	2
Swedes and Turnips . .	0·12	1	0·08	1	0·01	1	0·20	1	0·14	1	0·01	1
Others	0·57*	4	0·33*	4	0·07†	4	0·35†	1	0·14†	1	0·03†	1
Total Succulents . . .	3·40	24	2·04	26	0·30	20	5·51	22	2·98	24	0·38	18
Total Foods	14·22	100	7·75	100	1·45	100	25·05	100	12·42	100	2·12	100

* Sugar Beet Tops and Cabbage mostly. † Cabbage and Wet Grains mostly. ‡ Negligible.