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'ALL FLESH IS GRASS'

Chairman: Professor T. L. BYWATER, *University of Aberdeen*

General Composition of Herbage

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The most noticeable feature of any consideration of the chemical composition of herbage is that no one set of figures can possibly represent a particular plant or association of plants. This is an error into which the early investigators fell and it is common, even to-day, to see, for example, a single set of analytical figures quoted for a specific grass or clover. Most of the early figures of the agricultural chemist were based on single cuts of grasses and clovers, grown separately, and usually cut at a fairly advanced stage of growth.

This may not have been so great a mistake as would appear at first sight, because in some cases the investigators had in mind the use of the plant for hay and not for grazing. The samples were, therefore, cut at about the usual time for hay-making and took no account of the stage of growth of the plant at the time of cutting. In other investigations, however, there is a wide scatter in dates of cutting and the figures are of little value for comparative purposes since some grasses or clovers were cut while young, others at advanced stages of maturity.

Some of the Continental workers appreciated the importance of stage of growth, but the earliest reference in this country is the work of D. Wilson, later Sir David Wilson (1886, 1889), in the west of Scotland.

Main constituents

Before discussing the changes in composition which occur in herbage, it may be as well to refer briefly to the analytical groups into which the agricultural chemist has for many years divided the constituents of herbage. Though the divisions are rough, they have served their purpose tolerably well, so far as classification of the forages is concerned, and have enabled the feeding of farm animals to be conducted with a certain degree of accuracy. By their use the main principles of animal nutrition have been established and they have allowed of the formulation of feeding standards for farm animals, which have been used with every success. The usual methods of foodstuff analysis divide the sample into six main groups.

Moisture. In grassland herbage, moisture or water content is high and may vary from 65 to as much as 85 %; the younger the plant the higher will its moisture content be. The moisture content is one of the most important factors in fixing the value of a foodstuff since it determines the dry-matter intake. The ordinary silo in which young herbage is preserved by a fermentative process can be given as a simple example. The silage at the surface may contain 75 % moisture, and at the bottom up to 80 %. This does not seem a great difference, but the dry-matter intake of the animal which receives 100 lb. of silage would be 25 lb. when feeding on material from the top, and only 20 lb. when feeding on material from the bottom of the silo, a reduction of the order of 20 %, which is appreciable.

Similarly, since the plant tends to have a higher dry-matter content as it matures, any comparisons at different stages in the growth cycle should be made on a basis of the analysis of the dry matter of the herbage, and not of the fresh material.

Minerals. The ash or mineral matter is the second group, and as it does not usually form a large proportion of the dry matter it has received only lately the detailed attention that it deserves.

Nitrogen. The nitrogenous constituents are usually stated in terms of protein, using the factor of 6·25 to transform the value for total nitrogen into that for crude protein. This figure is sometimes further fractionated into 'true' protein, copper-precipitable nitrogen multiplied by 6·25, and a residue with the unwieldy title of non-protein nitrogenous material or sometimes, incorrectly, 'amides'. The crude protein, despite the shortcomings of the conversion factor, is a useful measure of the nitrogenous substances, since, except in the very early stages of growth, a high proportion of the nitrogen exists in complex forms that are readily precipitable by copper.

Fat. The fourth group, the ether extract, is often called crude fat and whilst it includes the true fats, it also includes a number of other constituents of which, for the agriculturist, the most important are undoubtedly the carotenoid pigments. They are the precursors of vitamin A, the accessory factor of greatest importance to the ruminant, the animal most suited to dealing with grassland herbage as its main or sole item of diet, though the horse may also be included in this category.

Fibre. The fifth group is the fibre, and this has a purely empirical value which does, however, give some clue to the relative ease of digestion of the sample and is, therefore, a useful figure.

Nitrogen-free extractives. The last and usually the largest group is that of the nitrogen-free extractives, and the value for it is obtained by difference and hence is a summation of all the errors inherent in the other methods of analysis. Its apparent advantage is enhanced by the fact that, being a difference figure, it means that all analyses of foodstuffs add up to 100 %, correct to as many places of decimals as the analyst may like to use. It is, however, fair to say that, despite their obvious shortcomings, the figures obtained have shown clearly the nature of the differences that exist between different components of the sward and between the different stages of growth within any one species in the herbage.

Changes in composition with growth

Wilson (1886) was the first to show clearly the changes in composition of herbage and to emphasize the fact that stage of growth is the most important factor. In his own words: 'It may be stated generally, that as the grass advances to maturity, the percentage of water in the green grass diminishes greatly. In the dry matter the percentage of albumenoids diminishes greatly; the ash and oil generally diminish, but less regularly and to a less extent. The woody fibre and extractive matter free from nitrogen, on the other hand, increase. The greater the amount of albumenoids they seem to be the more easily digested, so that the digestibility of albumenoids also decreases as the plant grows older.'

Then again: 'Compared with the difference of composition at different stages of growth, the differences between the composition of the various grasses cut at the same stage are small.' This latter point is of paramount importance, and indeed Wilson grouped all his analyses of grasses and of clovers, irrespective of species, under age groups.

The modern work of Fagan and his collaborators at Aberystwyth (Fagan & Jones, 1924; Fagan, 1929; Fagan & Milton, 1931) and of Woodman and his colleagues at Cambridge (Woodman, Blunt & Stewart, 1926, 1927; Woodman, Norman & Bee, 1928, 1929; Woodman, Norman & French, 1931; Woodman & Underwood, 1932) has amply confirmed and extended these findings. This and the work of other investigators has been summarized by Watson (1951). The most recent information is that of Waite & Sastry (1949), working at the Hannah Dairy Research Institute, in which a very complete study has been made of the composition of certain grasses during seasonal growth. The following figures, taken from the work of Fagan (1929), show clearly that the different grasses cut at a young stage are similar in composition. The values are for percentages in the dry matter:

Constituent	Cocksfoot	Yorkshire fog	Bent
Protein	24·3	23·9	18·9
Fibre	22·3	16·1	23·0

At this stage all three grasses, though of very different economic value because of their varying growth characteristics, are high in crude protein and low in fibre. Similar data are available for different clovers cut at equivalent states of maturity. At more advanced stages of growth the analytical values show the same trends.

Turning now to the differences in composition at different stages of growth in any one plant it is interesting to take Fagan's (1929) data for Italian rye grass, a quick-growing grass (Table 1).

The changes are exactly those which Wilson showed in his earlier work. In the ash the calcium is relatively steady throughout, but the phosphorus and potassium follow the nitrogen as it decreases with the age of the plant.

The simplest single figure to follow is the nitrogen, which can be determined with the greatest degree of accuracy and which is a useful guide to the general value of the plant.

The practical application of the changes can be shown most easily from the work of Shutt and his collaborators in Canada (Shutt, Hamilton & Selwyn, 1928, 1930, 1932). They used plots of meadow foxtail cut under different systems, and Table 2 shows the changes in protein content.

Table 1. *Composition of Italian rye grass expressed as percentages of dry matter at different stages of growth (Fagan,* 1929)

Constituent	At 2 weeks	At 6 weeks	At 10 weeks
Ether extract	3·75	2·42	2·10
Crude protein	18·54	12·12	6·90
'True' protein	13·32	7·80	5·47
Non-protein N × 6·25	5·52	4·32	1·43
Fibre	20·45	21·62	25·33
Nitrogen-free extractives	44·36	55·89	60·22
Ash	12·60	7·95	5·45
Calcium (CaO)	0·87	0·91	0·81
Phosphorus (P_2O_5)	0·88	0·45	0·37
Potassium (K_2O)	3·75	3·17	2·20

Table 2. *Crude-protein content of grassland herbage expressed as a percentage of dry matter in different seasons (Shutt, Hamilton & Selwyn,* 1928)

	1927	1928	1929
Cut weekly	21·20	28·95	29·15
Cut fortnightly	18·60	22·54	26·38
Cut every 3rd week	17·17	20·74	22·89
Cut as hay and aftermath	10·16	13·30	11·19

The increase in protein content in the first three plots in the 2nd and 3rd years was due to an incursion of wild white clover, due to the system of cutting, and shows that the leguminous plants show the same general trend, though they are normally higher in protein content than the grasses, especially under more lenient systems of cutting.

Effect of nitrogenous manure

It would seem that the stage of growth is, therefore, the dominant factor in deciding the protein content of grassland herbage and consequently in fixing the feeding value of the sward. Nitrogenous manuring may have an effect, and this is more marked at later stages of growth, apart altogether from its effect on yield of crop. Early American work was followed up in this country by Lewis (1939–40), who applied nitrogen to hay crops shortly before cutting (Table 3).

The protein content was raised by 1·5–3·0 percentage units by this treatment with little increase in yield of dry matter, most of the extra nitrogen being present in a complex form precipitable by copper. At earlier stages in growth, for silage cuts, there was still a response, though it was less marked according to later experiments.

The Aberystwyth work also gives a clue to a simple method of classification of grassland herbage; the proportion of leaf to stem determines to a considerable degree the protein content because of differences in composition of these two fractions. Fagan (1929) gives data (Table 4) for perennial rye grass that make this clear.

Table 3. *Effect on crude-protein content of hay of late applications of nitrogen (Lewis, 1939–40)*

Days before harvest ...	10		20	
Nitrogen applied (lb./acre)	17·4	34·7	17·4	34·7
Crude-protein content (percentage of dry matter) after application of:				
Sulphate of ammonia	10·77	11·84	10·63	11·14
Nitrate of soda	10·11	11·77	10·28	12·38
Nitrochalk	9·96	11·63	10·00	11·16
Mean	10·28	11·74	10·30	11·56
No nitrogen	8·69			

Table 4. *Composition of perennial rye grass, leaf and stem expressed as a percentage of dry matter (Fagan, 1929)*

	Young		Mature	
Constituent	Stem	Green leaf	Stem	Green leaf
Ether extract	2·45	2·45	3·30	3·65
Crude protein	15·50	24·75	10·37	17·68
'True' protein	11·31	20·37	8·75	13·68
Non-protein N × 6·25	4·19	4·38	1·62	4·00
Fibre	26·85	19·73	28·60	20·15
Nitrogen-free extractives	46·33	41·49	47·87	47·02
Ash	8·87	11·58	9·86	11·50

The leaf is richer in protein and ash than the stem, whereas the fibre and the nitrogen-free extractives are highest in the stem. In addition, the proportion of leaf to stem alters with age; the most complete study of this change is that of Waite & Sastry (1949), who show with timothy grass a ratio of 2·5 parts of leaf to 1 of stem in the early part of the season, falling to less than 0·5 part of leaf to 1 of stem as the plant approaches maturity.

Feeding value

The leafiness of pasture grass will, therefore, give a simple and relatively accurate method of forecasting its feeding value. This is shown in Table 5 taken from the work of Watson (1949).

Table 5. *Composition and feeding value of pasture grass (Watson, 1949)*

Stage of growth	Dry matter	Crude protein	Ether extract	N-free extractives	Fibre	Ash	Starch equivalent (S.E.)	Protein equivalent (P.E.)	Ratio: S.E./P.E.
Very leafy	18	4·0	0·6	7·5	3·6	2·3	10·8	2·8	4
Leafy	19	3·3	0·5	8·5	4·5	2·2	11·3	2·2	5
Early flowering stage, little stem	21	3·0	0·7	9·8	5·4	2·1	12·2	1·9	6
Flowering stage, stemmy	23	2·4	0·5	11·7	6·2	2·2	12·7	1·5	9
Full flower, seed stage	25	2·1	0·6	13·1	7·4	1·8	12·8	1·2	10

These values are based on actual digestibility trials and show in general the changes that have already been described. It should be realized that the figures are for the fresh material and if they are compared on a dry-matter basis, as they should be, the

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changes will be accentuated. This shows most clearly for the energy value or starch equivalent of the herbage which seems to increase with age, but on a dry-matter basis the values would be 59·9, 58·9, 58·5, 57·4 and 50·4 for the samples from very leafy to full flower respectively.

Energy and protein value. It is evident that the value of the herbage as regards its energy and protein value is correlated with its age, which in turn is related to the leafiness of the sward. In considering any particular pasture it is necessary to bear in mind its age, and a useful practical guide to its value will be the proportion of leaf to stem. It is not necessary to take into account the actual components of the sward if it is a mixture of grasses with a proportion of clover of the prostrate type. If, however, the herbage is predominantly leguminous, a similar set of figures is available and is again based upon the age of the sward, irrespective of the actual plants of which it is composed.

Minerals. Though the main basis of evaluation of herbage is its content of energy and of digestible protein, other factors must be taken into consideration. The mineral matter is most important, but it will have been evident from the figures already shown that the ash content tends to vary with the nitrogen, this being especially true of the phosphorus and potassium.

Further confirmation of this comes from the work of Elliot, Orr & Wood (1925), who examined typical pastures in England and Scotland. Their classification gave cultivated pastures an average value of 2·83 % nitrogen, 1·00 % calcium and 0·74 % phosphorus (stated as N, CaO and P_2O_5). Good natural pastures gave 2·50, 0·65 and 0·67 % respectively, poor natural pastures (eaten) 2·54, 0·56 and 0·60 %, and poor uneaten, natural pastures contained only 1·82 % nitrogen, 0·30 % calcium stated as the oxide and 0·37 % of phosphorus, stated as phosphorus pentoxide.

The soil status will have a marked effect on the mineral content of the herbage, and in cases of deficiency the stage of growth will afford no clue to the amounts of the various constituents present. This will be most marked in the case of the trace elements where the stage of growth and the relative leafiness have no relation whatsoever to the amounts of the different elements present (Watson, 1951).

Vitamins. As far as vitamins are concerned, vitamin A is the most important factor, and the relation of its precursor, carotene, to the stage of growth is of interest. Waite & Sastry (1949) have made a full study of this and show that the carotene content of the grasses is closely related to the nitrogen content, so that here again relative leafiness is a valuable guide to the amounts of carotene present. This is true of the fresh grass, but when it is cut for haymaking, artificial drying, or ensilage there may be a loss of carotene and this will vary with the time of exposure and with climatic conditions immediately after cutting. These workers found, for example, that in hot sunny weather as much as 50 % could be lost in 24 h and in cases of extreme exposure 80 % could disappear.

Other factors. In conclusion, it should be remembered that other factors must be taken into account in interpreting the feeding value of pasture. The practical man will claim that, despite the analysis, grass in autumn has not the productive value of spring grass. Morris, Wright & Fowler (1936), at the Hannah Dairy Research Institute, suggested that it was due to variations in the biological value of the protein, and more recently the work of Legg, Curnow & Simpson (1950) has focused attention on the oestrogens in grass which they show tend to be higher in spring grass.

Then again there is the marked laxative effect of young grass, particularly for cattle that have just been turned out, a factor which markedly affects its value at that time. Finally, we have troubles such as blowing or bloat in cattle on grass at certain periods of the year when the animals are unable to eliminate the rapidly formed gas from the rumen, and the work of Ferguson (1948) has shown the presence of a compound which affects muscle activity and is present in legumes at certain seasons.

A good deal more information is still needed before a final assessment can be made of the feeding value of grassland, and the animal itself is the only final and accurate yardstick. It is, however, possible to forecast the value for most purposes more accurately to-day than before.

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The Utilization of Herbage Protein by Animals

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Between 80 and 90 % of the nitrogen of herbage is, beyond question, protein. The remainder, the so-called 'non-protein nitrogen', consists mostly of free amino-acids, but also includes nucleic acids, purine and pyrimidine bases, choline and betaines, alkaloids, peptides, ammonia, urea, nitrate and other compounds. Chibnall (1939) and Lugg (1949) have well summarized much of the chemical information available. Most of the protein seems to be in the chloroplasts; the substances of low molecular weight behave as if in solution in the tissue juices.

The usefulness of protein to such animals as the rat, the chicken, the pig and man is understood nowadays to depend chiefly on amino-acid composition and particularly on the content of about ten so-called 'essential' amino-acids. These are not well