External Review and Evaluation of Progress of the Livestock Production Programme Project R5180 "Development of Improved Methods for Estimating the Nutritive Value of Tropical Forages"

This project is a continuation of project A0316 which began in April 1992. It will finish on March 31st 1997. The R & D grant application and project memorandum supplied took effect on April 1st 1994 and thus cover the final 3 years of the project. The total budget from April 1992 to 31st March 1997 was £ 1.15 million; from April 1st 1994 to the end of the project, the budget was £ 767,000. The stated aims, objectives, workplan and predicted outputs of the project are summarised below and are adapted from the project memorandum of 1994. These aims are consistent with and developed from those of the earlier project A0136.

Aims

The project set out to address the difficulties of ruminant production in developing countries caused by the scarcity and low quality of feeds. The aim was to formulate improved methods for measuring the nutritive value of forages from pasture, crop residues, agro-industrial by-products and the browse material of shrubs and trees, with particular focus on the presence of toxic and antinutritional plant secondary metabolites in some of these forages. The main beneficiaries envisaged were farmers and others involved in small scale production.

Objectives

Four technical and scientific objectives were defined.

1) To develop and refine analytical methods for measuring the nutritive value of tropical forages.
2) To integrate these methods into a collection of protocols for measuring the nutritive value of tropical feeds.
3) To determine the effectiveness of these protocols using data from animal production studies in the tropics.
4) To decide how the protocols might be best applied to the development of new feeding strategies.

Workplan

These objectives were to be achieved by a workplan involving ten activities.

1) Measurement of short-term intake.
2) Measurement of gas production upon incubation with rumen microorganisms in vitro.
3) Analysis of nutrients (crude protein, fibre etc.).
4) Analysis of feedstuffs for the presence of tannins.
5) Feeding studies in vivo.
6) Comparison of the results obtained in vitro and in vivo, especially comparison of rankings. of feeds.
7) Improving the methods used.
8) Retesting the techniques against a broad range of feeds and locations.
9) Developing recommendations on new feeding strategies, especially involving mixed feeds.

10) Preparing technical literature for use by extension workers and others.

Outputs

The outputs of the project were designed to be used by animal scientists, educational institutions and extension services. They were as follows.

1) Methods for measuring feed components that affect the nutritive value of tropical feeds and their mixtures.
2) Protocols consisting of a suite of methods for measuring the nutritive value of such feeds.
3) A demonstration that the gas production technique can predict animal performance better than existing techniques.
4) Recommendations on possible feeding strategies.

Dissemination was intended to involve Government and non - Government organisations, extension services in less-developed countries, supplemented by the following.

Overseas assignments and demonstrations, and transfer of the techniques used to less developed countries.
Publication in scientific journals and elsewhere.
Correspondence with contacts in developing countries.
Contact with trainees and visiting workers from overseas.
Provision of information through non-Government organisations.

The criteria used to measure output were publication in scientific journals, the extent of technology transfer (i.e. uptake and application of the methods) and the promotion of the new technologies by extension services. The first and last of these is in line with the "how to assess" indicators listed in the framework scheme for project A0136 (file ref. RAF9294 630/514/001A)

The review

The project review was carried out between November 1st and 30th 1996 by Drs. C.S. Stewart (Rowett Research Institute, Aberdeen, N. Jessop (Dept. Agriculture, University of Edinburgh) and T. Acamovic (Scottish Agricultural College, Aberdeen). The group composition was agreed by Dr. J. Wadsworth prior to his departure from NRI.

We first reviewed the R & D grant proposal, scientific papers, theses (Honours BSc, Masters and PhD) and other documents sent for our inspection as part of the output. A list of the main documents seen is appended (Appendix 1). The review group met in Perth on November 13th to discuss their initial reactions to examination of the grant application, the outputs (particularly scientific papers) and the objectives of the review. Some further information was sought from NRI (quarterly and annual reports, additional scientific papers), which was supplied promptly. A short statement on how the project leader Dr C.D. Wood and his colleagues saw the outcome of the project was requested and received in the form of a first draft of the Final Technical Report.

The group travelled to NRI Chatham on 24 November and spent the following 2 days discussing the project. The program in Chatham for November 25th was organised by Dr. A. Frost, and after a short tour of laboratory facilities, opening discussions were held with Prof. M. Gill and Dr. R. Matthewman. In particular it was clear that the research strategy of the ODA had changed during the lifetime of this project, and that there has been a shift

in research emphasis from strategic to more applied farmer participatory work. In measuring the outcome of the project, it seemed appropriate to bear in mind that there was an element of "moving goalposts" to consider. There were also changes in management, notably the increasing level of managerial seniority of Professor Gill and the departure of Dr. Wadsworth whose successor will arrive in 1997. Dr. Matthewman carries line management responsibility for the project meantime.

The remainder of the working day was spent with Dr. C.D. Wood. He began by describing the projects and its achievements as he saw them. The group spent the afternoon with Dr. Wood discussing various points relevant to the objectives of the review.

On November 26th we visited Wye College and discussed the gas production technique and its deployment further with Dr. Wood and with Ms Anna Murray, who impressed us as being able, energetic and committed. We also discussed aspects of the studies with plant proteins with Dr. J. Rossiter of Wye College. Other relevant aspects of chemical analysis of tannins were also discussed. It was clear that Wye College contains a high level of valuable facilities, including facilities for laboratory analysis, animal facilities and a modern library. The group left Wye in the early afternoon and returned to Gatwick for a final discussion and summing-up before their departure.

At our request, Dr Wood later sent more information on students, visitors and visiting workers attracted to Chatham by the project. One of us (CSS) has also discussed the possibilities, problems and pitfalls of the gas production technique with Dr. M.K. Theodorou at IGER by telephone. Our views on the achievements and the uptake of the work carried out in this project are summarised below.

Main Findings of the Review Group.

The main findings are listed in order of the objectives of the review defined by NRI

1) The extent to which the project is on target to meet its original objectives and projected outputs.

It was obvious that the original targets and outputs are defined more broadly and generically than would be acceptable in 1997. This has advantages and disadvantages for assessing progress and achievements, because very broadly-defined objectives can seem over-ambitious to reviewers, who by the nature and timing of events have the advantage of hindsight. On the other hand the lack of specificity can be advantageous in allowing operational flexibility, but may obscure woolly thinking. We bore such points in mind during our assessment. We consider this first objective further under 4 sub-headings below.

1.1). To develop and refine analytical methods for measuring nutritive value

A number of analytical methods have been used throughout the project, including routine chemical analyses of fibre, crude protein and other feed components as well as several assays for phenolic compounds and for tannins in particular. A substantial amount of information has ben provided and included in the papers listed in the Appendix, and more papers will be forthcoming. However, reading these papers suggested that the methods used were mainly standard methods which were not significantly modified, except for the gas production technique, where progress has been made in relation to requirements for nitrogen.

Comparison of gas production data using buffers with or without sources of nitrogen utilizable by microorganisms has led to the development of a nitrogen deficiency assay which is likely to prove particulary useful for poorly degradable fodders which may require a supplementary source of nitrogen to achieve optimal rumen degradation. We believe this to be an important first step in development of this technique to address the problem of supplementation of poor quality feeds, but further and substantial development is still required. A vital party of this would be in vitro / in vivo / in sacco comparisons. This aspect is considered below.

1.2). To integrate these methods into a suite of protocols

We took "suite" to imply a high degree of matching and complementarity in a collection of methods. A range of chemical analyses of nutrients and antinutrients, together with the microbiological gas production assay probably could be realistically considered as a suite of methods only if they were deployed in a genuinely integrated way. Although a number of valid tests have been performed, all with some value, there is still a need to define what the final suite is and indicate the relationships between the methods. Furthermore, the gas production method still requires substantial development.

In some cases, such as the relationships between the assays for total phenols and tannins, some attempt has been made to consider what these different tests measure and how they are related, but the potential for gaining greater insight through more informative test methods has not been taken. For example, HPLC and other chemical methods could have helped characterize the tannins present in some of the feeds under study. The gas production method as it has been deployed in most of the work described is little or no more informative than a simple "Tilley and Terry" (in vitro incubation with buffered rumen liquor, measuring dry matter loss of the substrate over 48 h) test might have been. We were not convinced that a genuine suite of methods had been obtained because, for the most part, the aims of the different measurements were diffuse rather than focused, and little indication was given that the methods had been chosen for their complementarity. For example, gas production reflects the extent and rate of fermentability of the substrate. Other measurements which are likely to influence intake and retention time within the rumen (and hence nutritive value) such as comminution rate and water holding capacity have not been considered. We believe that the study falls short of this objective.

1.3). Evaluation of methods using animals production data from the tropics.

It was disappointing to find that the project has concentrated mainly on in vitro methodology and had provided no new data on animal production in the tropics, although some in vivo information obtained in other projects has been used. Use of these data to evaluate in vitro methods appeared to be based on derivation of empirical relationships through use of multiple regressions. The potential problems of this approach need to be recognised and we would recommend consideration of a more mechanistic approach. The in vivo experiments done in the UK at Wye and ADAS are valid tests of principles but they support our suggestion of a need for more work in the target countries: given the strong links between NRI and laboratories abroad we believe that more relevant work could have been done, especially in India, Nepal and Zimbabwe where good facilities and expertise exist and where the cost of such work would be lower than in the UK. An opportunity existed to do a substantial

number of in vivo studies on freshly harvested materials for comparison with the results from the gas production test and with the chemical characteristics of the feeds.

1.4). To decide how the protocols might best be applied to the development of new feeding strategies. It would be possible for NRI to make preliminary recommendations about possible levels of supplementation of forages by different tree leaves and browse material, but these recommendations would need to be tested by feeding. Given the sparsity of in vivo data, it is difficult to see how firm recommendations about new feeding strategies (i.e. strategies not already in use) can be said to arise from this study.

2). Adequacy of the research hypothesis, approach, experimental designs and scientific quality of the research conducted in achieving the stated objectives.

Intake studies were the first element of the 1994 workplan, but these studies have not been performed within the present project. This was a surprising omission, and the lack of other relevant data obtained in vivo in the target countries in the present project is to our mind a major drawback of this project. In this respect, we feel that the actual research hypothesis and approach as carried out are inadequate and don't seem to match the original plans. At times, the work seems to have been driven by a retro-active opportunistic approach, rather than by pro-active design. We accept that in this area, in which opportunities may well arise fortuitously, there is definite merit in taking advantage of opportunities, but our impression is that the original workplan has been largely obscured and diverted.

Despite these reservations, some worthwhile work has been done and a number of scientific papers have been accepted for publication in recognised journals, indicating generally competent standards. However, there is little that is really novel or outstanding.

Regarding the gas production technique, the work of M. Rosales (PhD thesis) has produced useful information on the changes occurring in the substrate during the incubations. This helps to explain what components may be limiting at different stages during the fermentations. Further work along these lines with different forages should be very informative; in any event, such findings would underpin greater understanding of the gas production technique and its application. The work on N deficiency mentioned above also indicates scope for further advances, and it is disappointing that more use was not made of these findings within the project. For example, the N deficiency assay could have been deployed much more systematically to address the specific issue of whether certain tree leaves provided a suitable supplementary N source for poor quality fodders. Despite these advances, some misunderstandings about the gas production method seem to remain. If the dynamic nature of the technique is to be exploited (and if not, then a Tilley and Terry approach is simpler), it should be borne in mind that many models used to interpret the data assume first order kinetics where the characteristics of the feed limit the rate of gas production. Reduction of the fermentable N level will cause microbial activity to limit the rate of fermentation. In these circumstances, the microbial activity of the inoculum will significantly influence the pattern of gas production observed and such microbial activity is likely to differ widely between donor animals fed on a high quality ration in the UK and ruminants fed on poor quality forages in target countries. It is also necessary to determine whether the partitioning of carbohydrate between microbial matter and volatile fatty acids changes as the substrate mixture is varied, since this will influence the pattern of gas

production.

The farmer-participatory work in Nepal seems to offer opportunities for the future, but we did not see plans to follow it up, and thought that this should be done.

We believe that the project would have benefitted considerably from more contact and discussion with other experts, particularly at NRI Chatham and perhaps at other UK centres. NRI is a unique and important resource that houses many outstanding UK scientists, several and perhaps many of whom would probably have been able to offer critical assessment, help and guidance in different aspects of the work. It was not clear whether the research approach etc. have been the topic for critical discussion within NRI.

3. Assessment in terms of uptake, application and impact in livestock research institutions, especially overseas.

The aims, objectives and workplan of the project as originally designed seem very worthwhile. Changes in the workplan, notably the reduced in vivo research, have markedly reduced the potential impact of the project.

The gas production method is now about 15 years old; the 1994 Theodorou modification used here is a technical adaptation which makes the method more convenient and probably cheaper to operate on a large scale. It is difficult to ascertain how much of the interest in the gas production method overseas should be directly attributed to this project. Professor Gill made the relevant point that the gas production method is a good educational tool; it makes people think. This can itself be an important objective for aid to less developed countries which in the final analysis will probably have to solve their own problems with some guidance and help from us. One drawback of the method is that it may if anything be a little too convenient for generating large amounts of in vitro data of dubious relevance. There is thus a danger that interest in the method from some groups overseas is based more on a desire to collect publishable data using a recently devised method, than to contribute to problem-solving.

We believe that the uptake, application and impact of this project would have been greatly enhanced had good in vitro-in vivo comparisons been carried out overseas in at least one of the target countries. Apart from enabling the purchase of gas production equipment at ILRI, we think that there has been insufficient technology transfer to target countries, several of which could clearly have coped with carrying out both in vitro and in vivo experiments with the feeds and feed mixtures of direct interest, i.e. in particular, tropical forages supplemented with tropical browses. We have to disagree with Dr. Wood's belief that the gas production technique is not ready for use overseas. We think that good laboratories in the target countries could have carried out such work at less cost than is required for similar work in the UK, and that the purchase cost of at least some of the equipment could have been offset by this consideration. An important aspect is that the equipment could have been provided (as was the case with ILRI) and with the support, guidance and supervision of the knowledgeable and motivated staff from NRI the method could have been employed in work extremely useful for the project. As noted in section 2 para. 3 above, the characteristics of the rumen microbial populations from the animals in the UK might differ substantially from animals in the target countries, but the latter would be much more relevant to the project in hand.

4. Effectiveness of methods to promote uptake.

A recent review commissioned by the Programme Management of the Livestock Production Programme at NRI has addressed the question of dissemination pathways of NRI's work overseas (J. Morton, September 1996). The comments in Morton's review are favourable about the efforts made to disseminate information during this project and we accept them.

A list was provided of some of the principal students and visitors to NRI who either worked directly on this project or took interest in it. The major users from target countries have been the following.

Drs K T Sampath and C S Prasad, National Institute of Animal Nutrition and Physiology, Bangalore, India

Mr D Daalkhaijav, Research Institute of Animal Husbandry, Mongolia

Mr F Cadario (MSc student at Reading University), Bolivia.

Dr M Rosales and Mr J Vargas, CIPAV, Cali, Colombia.

Mr I Armendariz (PhD student, Wye College), Mexico.

Mr D Subba, Pakhribas Agricultural Centre, Nepal.

Mr F Avornyo (MSc student, Wye College), Ghana

Mr R Pulido (PhD student, Wye College), Chile.

Dr O Parra, Central University, Venezuela.

In addition, Morton mentions a successful presentation of the gas production technique to a group of visitors from four Central Asian Republics, The technique has also been introduced to the National Dairy Research Institute from India via trainees funded by the Netherlands Government. Many others have passed through for a quick demonstration of the method, and there have been about ten UK/European students/visiting workers with some hands-on experience.

The workshop in Pakhribas, Nepal held in March 1986, has given farmers in that country the opportunity to learn about the work. The farmer-participatory work in that country has also been a means of promoting uptake, and could be the basis for more work in the future.

A significant number of papers have been published in scientific journals. There are longer-term plans eventually to produce "glossy brochure" for free distribution, but further progress to validate the use of the gas production technique in the context of the specific issues addressed here is required before such publications can be produced. Such a brochure would increase promotion of the results of this project.

5. Use made of analyses of samples submitted by other projects

We were not able to fully explain the origin of all of the samples used in this project. Its very broad and generic nature allowed the project leader to take advantage of opportunities that arose during the lifetime of the project. We believe that the samples from Nepal can realistically be described as being clearly related primarily to this project; the other samples probably all derive to some extent from other projects. The samples from India were analyzed with a view to a future project, and the fodders from Bolivia were of interest to a forestry project involving NRI. The samples from Mongolia appear to have been partly submitted through another project, and partly through this project.

We thought it reasonable that the opportunity had been taken to obtain samples through any feasible route, and a degree of opportunism was probably necessary and useful. Our one reservation would be that time spent analyzing a wide range of samples may have detracted from carrying out more detailed investigations on any one class of samples, or on any one technique, blunting the impact of the work and detracting from the opportunity to spend time on more original work.

6. Impact. Uptake of the methods in developing countries.

We felt strongly that it would have been appropriate within this project to help set up the gas production method in particular in the developing countries, despite the view expressed to us that perhaps only a small number of samples needed to be processed and that this could be done more readily in NRI. Our opinion is that creating conditions in which as much as possible of the routine work is done abroad is highly desirable. This would not only eventually give many more people that can ever visit Chatham the opportunity to get hands-on experience and begin to think about the issues involved, but it would also free the relevant NRI staff from the drudgery of carrying out routine work that demands considerably less expertise and skill than can reasonably be expected of established UK scientists. It could also enable work to be done on a wider range of samples at varying stages of maturity without the necessity of drying, which may cause some adverse effects. We think that in future, appropriate steps should be taken to transfer the gas production technique and as much as possible of the routine chemical analysis to laboratories in the target countries. If necessary, modern computerised analyses of the data could be completed at NRI in close collaboration with the providing centres.

Publication in scientific journals is highly desirable and an important indicator of scientific performance, but it is not appropriate to rely too heavily on this route for uptake in less developed countries, as these journals are not always available in places where the knowledge is most needed. More direct methods, like on-the-spot training have an irreplaceable role in uptake.

Another means of ensuring uptake could be by the arrangements of practical workshops held in the target country of interest. The success of the Pakhribas workshop suggest that this type of meeting would be well-attended if it was accompanied by practical demonstrations and the opportunity to get some hands on experience.

6. Uptake. Prospects for future work.

We do not believe that the research group, as presently constituted, has the necessary depth of knowledge and critical awareness of the scientific issues and techniques being used to further this programme of work significantly. It is our view that closer collaboration with

scientists both within and external to NRI is an essential pre-requisite to the future success of this group. We have commented on some related issues pertaining to management of this group in an accompanying letter.

One of us (CSS) has had sight of a future project for India which I believe will be jointly led by Dr. Matthewman and which is due to start in 1997. This project involves in vivo work to be carried out in India and its' budget is about 10% of that of project R5180. This involves gas production work also; as much as possible the gas production work should be done in India and should include at least checks on the relationship between gas and VFA production which we know can be done readily.

7. Recommendations for the future direction of the research in the context of the overall theme of the livestock production programme.

Apart from proposed work in India, there seem to be good prospects for further work in Nepal to capitalise on the work so far. Performing chemical analyses in Nepal, if it were possible, would avoid problems resulting from changes in the samples such as oxidation, polymerization or irreversible binding of constituents such as tannins. Further development and use of the gas production method could be applied to the forages and tree leaves of interest, and the scene seems to be set for good farmer participatory research.

Apart from following up the use of browse species as supplements for poor quality forages, there is scope for studies on changes in the effects of growing season and local environment on feed quality. In vivo work would be required, and in view of the findings from Zimbabwe that feeding mixtures might influence rate of passage, there would be scope for work on passage using alkanes as intake and digestibility markers, and in particular, scope for use of different marker alkanes for different feed components.

Tannins are a diverse and reactive set of compounds in plants but the routine chemical detection of tannins seems ripe and perhaps overdue for transfer to laboratories in target countries. In the UK, the analysis of tannins by HPLC and other methods should become a priority within the time which can be devoted to in vitro methodology. Dr. Rossiter of Wye seems willing and able to help and if Dr. Wood had less routine analysis to perform, he might find it useful and rewarding to spend time developing his own expertise in this direction; we note that he has HPLC equipment at his disposal.

Although the existing project has been concerned entirely with tannins, little has been done in the project to elucidate the type of tannins present and their mechanisms of action in vitro and in vivo. There is considerable scope for work in this area, and it should not be forgotten that low levels of tannins can have beneficial effects in animal diets and may also act as anthelminthics. There is also scope for interest in plant compounds other than tannins. The hypothesis that polyphenolics are the only important antinutrients in the feeds of interest should be tested.

One aspect of the gas production technique that has not been explored is the nature of the microbial population which survives in this system in the longer term. These incubations favour the bacterial component of the rumen population and in that the system provides an acute test which allows for little or no microbial adaptation, there seems a strong possibility that the microbial populations in these incubations is substantially different from the population in the rumen of animals fed the relevant diets. If this were so, one has to question the interpretation of the correlations with nutritive value which have sometimes been

made. A microbiological investigation to properly characterise the microbiological characteristics of the gas production method would involve the kind of molecular approach which has been developed by Dr. H.J. Flint of RRI.

We believe that serious consideration should be given to the use of simulation modelling, at a mechanistic level, as a complementary activity running alongside such a project. It may be possible to use the gas production method as a way of determining the potential degradability of a forage and use a simulation model to predict responses to variation in fermentable N supply and antinutrient level.

Summary.

The project has provided some interesting and worthwhile information but had very ambitious aims which were always likely to be very difficult to achieve. The work was strategic in nature and judged against current guidelines is not significantly targeted or applied. Too little work has been done in vivo in the target countries, and even in vitro, the experiments have not been focused enough on forages of interest to those countries. We thought that a less empirical and more mechanistic investigation would have been appropriate, with as much of the more routine work being done in the target countries, thus facilitating technology transfer and allowing time for NRI staff to pursue more innovative work. In the longer term, this will be advantageous both for the target countries and for the future career development of the NRI staff concerned.

Appendix 1.
Major documents reviewed

Wood C D, Tiwari B N, Plumb V E, Powell C J, Roberts B T and Gill M (1993). Interspecies differences in tannin activity of leaves from 13 species of Nepalese browse trees p212-213. In Animal production in developing countries. An occasional publication of the British Society of Animal Production, No 16 Editors Gill M, Owen E, Pollott G E and Lawrence T L J.

Wood C D, Johnson J and Powell C (1993). Evaluation of Bolivian tree leaves as fodders by an *in vitro* fermentation technique Agroforestry Forum **4**(3) 28-34.

Prasad C S, Wood C D and Sampath K T (1994). Use of *in vitro* gas production to evaluate rumen fermentation of untreated and urea treated finger millet straw (*Eleusine coracana*) supplemented with different levels of concentrate. Journal of the Science of Food and Agriculture **65** 457-464.

Sampath K T, Wood C D and Prasad C S (1995). Effect of urea and by-products on the *in vitro* fermentation of untreated and 5% urea treated finger millet (*Eleusine coracana*) straw. Journal of the Science of Food and Agriculture **67** 323-328.

Wood C D, Tiwari B N, Plumb V E, Powell C J, Roberts B T and Gill M (1995). Differences in protein precipitation activity of extractable tannins, crude protein and ash contents of leaf samples from Nepalese fodder trees. Tropical Science **35** 376-385.

Wood C D, Tiwari B N, Plumb V E, Powell C J, Roberts B T, Sirimane V D, Rossiter J T and Gill M (1994). Interspecies differences and variability with time of protein precipitation activity of extractable tannins, crude protein, ash and dry matter contents of leaves from 13 species of Nepalese fodder trees. J Chemical Ecology **20**(12) 3149-3162.

Sampath K T, Wood C D and Prasad C S. Effect of sources and levels of nitrogen supplements on *in vitro* fermentation of untreated and 5% urea treated finger millet straw (*Eleusine coracana*). Proc. VI Anim Nutr Res Workers' Conf, Bhubaneswar (1993) Abstract No 309 p151-152.

Prasad C S, Sampath K T and C D Wood (1993). Evaluation of untreated and urea treated finger millet straw (*Eleusine coracana*) at different levels of concentrate supplementation using *in vitro* gas production techniques. Proc. VI Anim Nutr Res Workers' Conf, Bhubaneswar (1993) Abstract No. 310 p152.

Wood C D and Plumb V E (1994). Total phenols and protein precipitation assays as indicators of the inhibitory effects of phenols on rumen micro-organisms Paper No. 75, presented at British Society of Animal Production Jubilee Winter Meeting, Scarborough, UK, March 1994.

Wood C D and Plumb V E (1994). Total phenols and protein precipitation assay as indicators of the inhibitory effects of phenols on rumen micro-organisms. Proceedings of the 109th meeting of the British Society of Animal Production, Abstract No 75. Animal Production **58** 445 (and summary).

Wood C D (1995). Feed Evaluation: Recent developments. Summary of presentation given to LSAAC, Feb. 1995.

Wood C D, Grillet C, Rosales M and Green S (1995). Relationships between *in vitro* gas production characteristics and composition of tree leaf fodders from Bolivia, West Africa and Colombia. Abstract Animal Science **60** 541 (and summary).

Wood C D and Plumb V E (1995). Evaluation of assays for phenolic compounds on the basis on *in vitro* gas production by rumen micro-organisms. Animal Feed Science and Technology **56** 195-206.

Poster "Use of an *in vitro* gas production method to investigate interactions between veld hay and napier hay or groundnut hay supplements - by C D Wood and B Manyuchi" presented at a conference on Evaluation of Forages for Ruminants in the Tropics held Zimbabwe.

Poster "Nitrogen mineralisation in soils and *in vitro* rumen fermentation parameters as affected by chemical composition of tree fodders - by I R Armendariz, G Cadish, K E Giller and C D Wood" presented at a conference " Driven by Nature" held Wye College, UK.

Panigrahi S, Bestwick L A, Davis R and Wood C D (1996). The nutritive value of stackburned yellow maize for livestock: tests *in vitro* and in broiler chicks British Journal of Nutrition **76** 97-108. (Not A0316 funded, but illustrates use of gas prodn method).

Murray A H, Daalkhaijav D and Wood C D (1996). Rumen degradability of Mongolian pastures: a comparison of *in situ* and *in vitro* gas production techniques. Abstract, summary and poster presented at the British Society of Animal Science Winter Meeting (1996). Animal Science **62** (3) 684.

Gill M, Bennison J and Wood C D (1996). The selection of trees for fodder. Advances in Agroforestry. Proceedings of a British Council Short Course, University of Wales, Bangor 29 March - 10 April 1992. Pub. The British Council. p65-73.

Papers submitted and under review

Wood C D and Manyuchi B, under review, (now accepted subject to moderate revision). Use of an *in vitro* gas production method to investigate interactions between veld hay and Napier hay or groundnut hay supplements.

Papers in preparation

Thorne P J, Subba D B, Walker D H, Thapa B, Wood C D and Sinclair F L (in preparation). Indigenous and laboratory assessment of the nutritive value of tree fodder. Part 1: Discrimination amongst and within species.

Walker D H, Thapa B, Thorne P, Sinclair F L, Wood C D and Subba D B (in preparation). Indigenous and laboratory assessment of the nutritive value of tree fodder. Part 2: Comparison of farmer and laboratory assessment.

Whetton M, Rossiter J T and Wood C D (in preparation). Protein degradation of two fodder tree leaf species (*Gliricidia sepium* and *Calliandra calothyrsus*) in an *in vitro* model of ruminant digestion (now submitted)

Dryhurst N and Wood C D (in preparation). The effect of nitrogen source and concentration on *in vitro* gas production using rumen micro-organisms.

Wood C D, Stewart J L and Vargas J E (in preparation). The evaluation of gliricidia varieties by an *in vitro* gas production technique.

Murray A H, Daalkhjaijav D and Wood C D (in preparation). The rumen degradability of Mongolian pastures measured by *in sacco* and *in vitro* gas production techniques.

Unpublished reports, reviews, theses etc.

Powell C. To determine the effect of supplementation of barley straw with lucerne hay, meadow hay, rye hay and timothy hay on gas production during *in vitro* fermentation.

Powell C. To determine the effect of the *in vitro* fermentation technique on the fibre fraction of five samples of temperate hay and straw.

Wood C D. Effects of tannins in ruminant nutrition.

Use of the gas production technique for determining the fermentation characteristics of animal feeds - extracts from meeting at ADAS Bridgets Dairy Research Centre, July 1994.

Use of the gas production technique for determining the fermentation characteristics of animal feeds: 2 - extracts from meeting at University of Reading, February 1995.

Techniques for evaluating ruminat feeds in less developed countries, with particular refernce to the potential use of in vitro gas production methods.

Contract report XOACH/A (ADAS, 13/3/96)

On-going studies

An evaluation of the gas production technique for identifying digestive interactions between forages and supplements - protocol for *in vivo/in vitro* comparisons.

Related work and other projects

The effect of cyanide containing forages on rumen function (project IOi46)

Morton, J. (1996) A review of dissemination pathways within the ODA livestock production programme

Others

File note on Meeting of Collaborations on nutritive value assessment. NRI, Chatham, 15 April 1994.

Feed samples from NW India: Report on initial evaluation. Wood C D and Matherman R W.

Note on a workshop held at Pakhribas Agric. Centre, Napal, 25-29 March 1990.

Theses etc.

Caderio F (MSc Thesis, Reading). Use of *in vitro* gas production technique for predicting *in vivo* apparent digestibility and voluntary intake of feedstuffs for sheep.

Rosales M (1996). PhD thesis, Oxford. *In vitro* assessment of the nutritive value of mixtures of leaves from tropical fodder trees.

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NRI Quarterly and annual reports

A set of reports covering the period from 1992 to present

Draft version of the final technical report Development of imprtoved methods for estimating the nutritive value of tropical forages

Back to office reports on visits to Nepal and Zimbabwe

R & D funding application and project memorandum forms

(Equivalent) Project A0316 frmaework document 29 October 1992

Project R5180 April 1994

Effect of harvest and post-harvest prasctises on the production nutritive value and safety of rice straw in Bangladesh (we understand this will not now be funded and we are not

suggesting that it should be reconsidered).

Correspondence

Comments of a reviewer on the use of gas production for feed mixtures
Reply regarding these comments from C. Wood to R. Mathewman, 20/11/96