RECENT ADVANCES IN ANIMAL NUTRITION

1985

STUDIES IN THE AGRICULTURAL
AND FOOD SCIENCES

Recent Advances in Animal Nutrition—1985

W. Haresign, PhD
D.J.A. Cole, PhD
University of Nottingham School of Agriculture

BUTTERWORTHS
London Boston Durban Singapore Sydney Toronto Wellington

First published 1985

British Library Cataloguing in Publication Data

Recent advances in animal nutrition.—1985
—(Studies in the agricultural and food sciences)
1. Animal nutrition
I. Haresign, William II. Cole, D.J.A. III. Series
636.08'52 SF95

ISBN 0-407-01161-7

Typeset by Scribe Design, Gillingham, Kent.
Printed in England by Robert Hartnoll Ltd, Bodmin, Cornwall

STUDIES in the AGRICULTURAL and FOOD SCIENCES

A series of high-level monographs which review recent research in various areas of agriculture and food science

Titles in stock:

Recent Advances in Animal Nutrition—1978
Edited by W. Haresign and D. Lewis

Recent Advances in Animal Nutrition—1979
Edited by W. Haresign and D. Lewis

Recent Advances in Animal Nutrition—1980
Edited by W. Haresign

Recent Advances in Animal Nutrition—1981
Edited by W. Haresign

Recent Advances in Animal Nutrition—1982
Edited by W. Haresign

Recent Advances in Animal Nutrition—1983
Edited by W. Haresign

Recent Advances in Animal Nutrition—1984
Edited by W. Haresign and D.J.A. Cole

Plant Breeding for Pest and Disease Resistance
G.E. Russell

The Calf—Fourth edition
J.H.B. Roy

Energy Metabolism
Edited by Lawrence E. Mount

Growth in Animals
Edited by T.L.J. Lawrence

Mineral Nutrition of Animals
V.I. Georgievskii, B.N. Annenkov and V.T. Samokhin

Protein Contribution of Feedstuffs for Ruminants
Edited by E.L. Miller and I.H. Pike in association with A.J.M. van Es

Advances in Agricultural Microbiology
Edited by N.S. Subba Rao

Antimicrobials and Agriculture
Edited by M. Woodbine

PREFACE

This, the proceedings of the Nineteenth Annual Nutrition Conference for Feed Manufacturers, contains chapters on a range of topics related to the nutrition of farm livestock.

The first chapter considers the accuracy of predicting the energy value of pig, poultry and ruminant feedstuffs from chemical measurements, a factor of paramount importance if the declaration of energy values is made compulsory within the EEC.

Following a chapter describing the various definitions of fibre in animal feedstuffs, a series of further chapters consider the importance of fibre in feeds for the different classes of farm livestock. The first of these discusses the influence of fibre on the digestibility of poultry feeds, the second discusses the role of fibre in pig feeds and the final one of the group discusses the effect of fibre level in compound feedstuffs on the performance of dairy cattle.

Three chapters relate to aspects of pig nutrition and production. The first of these attempts to model the relationship between feed inputs and outputs in the breeding animals, with the ultimate objective of assessing the effects of different strategies for sow nutrition on animal performance. Two further chapters relate to meat quality in pigs, the first providing information on how to achieve grading standards by genetic and nutritional means and the second highlighting the consequences of changes in carcass composition on meat quality.

There are two chapters within the general area of poultry nutrition. The first describes recent developments in the use of coccidiostats in broiler diets, highlighting the various types of materials available, the development of resistance to them and how to prevent resistance occurring by alternating the compounds used. A major factor influencing returns from laying poultry is downgrading of eggs because of poor shell quality. One chapter describes the changes in quality that can occur and discusses both the physiological and nutritional reasons for them.

The final group of chapters relate to ruminant nutrition. The first of these describes the extent of natural variation in appetite with season, which occurs independently of diet quality, and the possible mechanisms underlying such changes. One aspect of season which can be readily and cheaply manipulated is daylength, and one chapter describes the beneficial effects that increasing daylength in winter can have on growth rate and milk production in dairy cattle. Since many ruminant production systems revolve around silage as the basal part of the ration, it was particularly opportune to have a further chapter discuss recent developments in our understanding of the factors affecting the nutritive value of silages. The ruminant chapters are completed by a consideration of the amino acid requirement of ruminants and how one might be able to influence amino acid supply to the hind-gut by dietary manipulation.

Each chapter is written in a clear and informative manner, and should be useful to research workers, advisers and students alike.

The organizers and the University of Nottingham are grateful to BP Nutrition (UK) Ltd, for the support they gave in the organization of this conference.

W. Haresign
D.J.A. Cole

CONTENTS

I	**General Nutrition**	1
1	**PREDICTION OF THE ENERGY VALUE OF COMPOUND FEEDS** G. Alderman, *ADAS, London, UK*	3
II	**Fibre in Animal Feeds**	53
2	**DEFINITION OF FIBRE IN ANIMAL FEEDS** P.J. Van Soest, *Cornell University, Ithaca, NY, USA*	55
3	**INFLUENCE OF FIBRE ON DIGESTIBILITY OF POULTRY FEEDS** W.M.M.A. Janssen, *Speiderholt Centre for Poultry Research and Extension, Beekbergen, The Netherlands and* B. Carré, *Station de Recherches Avicoles, INRA, Nouzilly, France*	71
4	**ROLE OF DIETARY FIBRE IN PIG DIETS** A.G. Low, *National Institute for Research in Dairying, Shinfield, Reading, Berks, UK*	87
5	**EFFECT OF FIBRE IN COMPOUND FEEDS ON THE PERFORMANCE OF RUMINANTS** A. Steg, Y. van der Honing and H. de Visser, *Institute for Livestock Feeding and Nutrition Research, Lelystad, The Netherlands*	113
III	**Pig Nutrition**	131
6	**STRATEGIES FOR SOW NUTRITION: PREDICTING THE RESPONSE OF PREGNANT ANIMALS TO PROTEIN AND ENERGY INTAKE** I.H. Williams, W.H. Close, *National Institute for Research in Dairying, Shinfield, Reading, Berks, UK and* D.J.A. Cole, *University of Nottingham School of Agriculture, Sutton Bonington, UK*	133

7 NUTRITIONAL MANIPULATION OF CARCASS QUALITY IN PIGS 149
C.T. Whittemore, *Edinburgh School of Agriculture, Edinburgh, Scotland*

8 CONSEQUENCES OF CHANGES IN CARCASS COMPOSITION ON MEAT QUALITY 157
J.D. Wood, *AFRC Food Research Institute Bristol, Bristol, UK*

IV Poultry Nutrition **167**

9 RECENT DEVELOPMENTS IN THE FIELD OF ANTICOCCIDIAL AGENTS FOR POULTRY 169
A.C. Voeten, *Gezondheidsdienst voor Dieren in Noord-Brabant, Boxtel, The Netherlands*

10 EGGSHELL FORMATION AND QUALITY 181
K.N. Boorman, J.C. Volynchook, *University of Nottingham School of Agriculture, Sutton Bonington, UK and* C.G. Belyavin, *Harper Adams Poultry Husbandry Experimental Unit, Edgmond, Newport, England, UK*

V Ruminant Nutrition **197**

11 SEASONAL VARIATION OF APPETITE IN RUMINANTS 199
R.N.B. Kay, *Physiology Department, Rowett Research Institute, Aberdeen, Scotland*

12 PHOTOPERIODIC INFLUENCES ON MILK PRODUCTION IN DAIRY COWS 211
H.A. Tucker, *Department of Animal Science, Michigan State University, East Lansing, MI, USA*

13 FACTORS AFFECTING THE NUTRITIVE VALUE OF GRASS SILAGES 223
C. Thomas, *Animal and Grassland Research Institute, Hurley, Maidenhead, Berks, UK and* P.C. Thomas, *Hannah Research Institute, Ayr, Scotland*

14 AMINO ACID REQUIREMENTS OF RUMINANTS 257
P.J. Buttery *and* A.N. Foulds, *University of Nottingham School of Agriculture, Sutton Bonington, UK*

LIST OF PARTICIPANTS 273

INDEX 285

I

General Nutrition

1

PREDICTION OF THE ENERGY VALUE OF COMPOUND FEEDS

G. ALDERMAN
ADAS, London, UK

Introduction

Both in the UK and in other member states of the European Community, farmers' organizations have been expressing their concern over the lack of information about the nutritive value of compound feeds conveyed to them as purchasers of the major input into most animal production systems. This concern has intensified as the traditional cereals and protein sources in animal feeds have been replaced by less traditional plant materials and by-products of human food production. Allied to these changes farmers feel that with the general introduction of computer formulation, the feeds they are purchasing are of a more variable ingredient make-up than they used to be. This has resulted in pressure for the full declaration of ingredients.

For its part, the feed industry has pointed out that the increased use of by-products has kept down the price of compound feeds and that it has carried out research and implemented technical developments for the benefit of its customers as well as their companies. They are not willing to make available the results of their researches to their trade rivals, which is what ingredient declaration would mean in their view. A major gap in the information concerned the energy content of compound feeds.

In the UK, the megajoule (MJ) is the agreed metric unit for energy, metabolizable energy (ME) is used for ruminant feeds, apparent metabolizable energy (AME) is used for poultry feeds and digestible energy (DE) for pig feeds. For ruminants the values are expressed per kg dry matter (DM) and for pigs and poultry they are expressed on an as-fed basis. The prediction of such values, for example from chemical analysis, has been of interest to the farmer, adviser, feed compounder and research worker for some time. This chapter gives the approach taken by a joint working party of the United Kingdom Agricultural Supply Trade Association (UKASTA), the Agricultural Development and Advisory Service (ADAS) and the Council of Scottish Agricultural Colleges (COSAC) whose full report is published elsewhere (UKASTA/ADAS/COSAC, 1985). It is based on collaborative research programmes at the Rowett Research Institute (ruminants), the East of Scotland College of Agriculture (pigs) and the Poultry Research Centre. The accuracy of prediction is examined for voluntary use by the member organizations, for possible incorporation into legislation on energy declaration for compound feeds and for reference purposes.

The following is a glossary of the terms and abbreviations used throughout this chapter.

Glossary of terms used and abbreviations

CHEMICAL ANALYSES

Acid detergent fibre	ADF	Goering and Van Soest (1970)
Acid detergent lignin	ADL	Goering and Van Soest (1970)
Available carbohydrate	AV.CHO	Bolton (1962)
Cellulase digestibility	NCD	Dowman and Collins (1977, 1982) (see Appendix II)
Crude fibre	CF	The Feedingstuffs (Sampling and Analysis) Regulations (1982)
Christian lignin	CL	Christian (1971)
Crude protein	CP	The Feedingstuffs (Sampling and Analysis) Regulations (1982)
Dry matter	DM	ADAS RB 427
Ether extract (see also OIL(PT))	EE	The Feedingstuffs (Sampling and Analysis) Regulations (1982)
In vitro digestibility	IVD	Tilley and Terry (1963)
In vitro organic matter digestibility	IVOMD	Tilley and Terry (1963)
Modified acid detergent fibre	MADF	Clancy and Wilson (1966)
Neutral detergent fibre	NDF	Wainman, Dewey and Boyne (1981)
Nitrogen free extractives as %	NFE	100 – (CP + EE + CF + TA)
Oil (acid hydrolysis)	OIL(AH)	B.S. Method No. 4401
Oil (petroleum ether) (see also EE)	OIL(PT)	The Feedingstuffs (Sampling and Analysis) Regulations (1982)
Organic matter	OM	DM—TA
Starch	STA	EC Regulation 72/119/EEC
Sugar	SUG	AOAC 10th Edition (1965) Methods 29.039 and 43.012
Total ash	TA	The Feedingstuffs (Sampling and Analysis) Regulations (1982)
Ratio unsaturated:saturated fatty acids	USR	

DIGESTIBILITY TERMS

Digestible crude fibre	DCF
Digestible crude protein	DCP
Digestible ether extract	DEE
Digestible N free extractives	DNFE
Digestible organic matter in DM	DOMD
Organic matter digestibility	OMD

ENERGY TERMS

Apparent metabolizable energy	AME	
Digestible energy	DE	
Gross energy	GE	
Megajoule, unit of energy	MJ	
Metabolizable energy	ME	
True metabolizable energy	TME	Sibbald (1976)

STATISTICAL TERMS

Analytical tolerance	A
Coefficient of variation, (%)	CV
Repeatability	r
Reproducibility	R
Residual mean square	RMS
Residual standard deviation	S
Prediction error (S modified by R)	S″
Standard deviation	SD
Technical tolerance	T
Reproducibility variance covariance matrix	V

Existing methods for the prediction of ME or DE from chemical composition

Numerous prediction equations have been published for pig and poultry feeds, and have been reviewed recently (Morgan and Whittemore, 1982; Fisher, 1982). A well-known example for poultry feeds is equation (1), from Bolton (1962):

$$\text{ME (kcal/kg)} = 40.8\,[0.87\,\text{CP}\% + 0.87 \times 2.25\,\text{EE}\% + \text{AV.CHO}\% + 4.9] \qquad (1)$$

For pigs, the work of Morgan, Cole and Lewis (1975) gave equation (2)

$$\text{DE (MJ/kg DM)} = 0.479\,\text{CP}\% + 0.472\,\text{EE}\% + 0.375\,\text{NFE}\% - 21.2 \qquad (2)$$

Crude fibre has been found to be less effective as a predictor of DE for pigs than other fibre fractions such as modified acid-detergent fibre (MADF) or acid detergent lignin (ADL). In the main, the published equations were derived for raw materials such as cereals and not for compound feeds.

For ruminants, no suitable equations were available in 1976, when ME was introduced as a practical system in UK, so use was made of an equation (equation (3)) published by workers at the Oskar Kellner Institute in East Germany (DLVB, 1971)

$$\text{ME (MJ/kg)} = 0.0152\,\text{DCP} + 0.0342\,\text{DEE} + 0.0128\,\text{DCF} + 0.0159\,\text{DNFE} \quad \text{(all as g/kg)} \qquad (3)$$

This equation was used to convert existing tables of feed composition from digestibility and starch equivalent to ME. In the case of compound feeds, although digestibility varies depending on the quality of the raw materials used, it was decided to use average digestibility coefficients for each parameter, CP digestibility = 0.8; EE digestibility = 0.9; CF digestibility = 0.4; NFE digestibility = 0.9.

This resulted in equation (4) (Equation (75) of Technical Bulletin 33, MAFF, 1976) in which CP, EE, etc. are as g/kg dry matter and NFE = 1000 − (CP + EE + CF + TA)

$$\text{ME (MJ/kg DM)} = 0.012\,\text{CP} + 0.031\,\text{EE} + 0.005\,\text{CF} + 0.014\,\text{NFE} \quad (4)$$

At the time of its publication, this equation could not be used with the declared analyses, since the presence of the term NFE required the total ash content to be known. Since February, 1983, this deficiency has been remedied in the UK by the coming into force of the Feeding Stuffs (Sampling and Analysis) Regulations 1982.

Ruminant compound feeds

PROCEDURE

A series of 24 compound formulations, based on raw materials used in the UK feed industry for cattle and sheep feeds, was made to meet a number of criteria. Each raw material was limited to inclusion in only a proportion of the feeds, usually six out of 24, except for the cereals, two cereal by-products and rape seed meal which occurred in the majority. The range of chemical composition was specified for ether extract (either 2–3.9% or 5–7% in DM), crude protein (either 12–14.9%, 15–17.9% or 18–20.9% in DM), and crude fibre (either 4–6% or 8–12% in DM). ME values covered the range 9–14 MJ/kg DM, with a good spread over the range.

Each compound was fed to two wether sheep at maintenance in combination with hay or silage in three ratios 25:75, 50:50 and 75:25. All feeds were comprehensively analysed at five collaborating laboratories from ARC, ADAS and UKASTA. The work was carried out at the Rowett Research Institute Feed Evaluation Unit (RRI/FEU) and reported by Wainman, Dewey and Boyne, 1981.

STATISTICAL ANALYSIS

Detailed statistical analysis of the results and regression of the measured ME values on the chemical analyses, resulted in the listing of 73 equations with a residual standard deviation (S) of less than 0.5 MJ of ME/kg DM. The statistical analysis also considered the important question of interlaboratory variation for the methods used. With the exception of GE measurements made with adiabatic bomb calorimeters, significant differences were obtained between all laboratory mean values at the 1 per cent level of probability for EE and ADL, and at the 0.1 per cent level for all other analyses.

A technique was devised to take interlaboratory error into account when ranking prediction equations for application in a multi-laboratory situation. Details of the calculation of S′ are given in the RRI/FEU Report (Wainman, Dewey and Boyne, 1981).

COMPARISON WITH OTHER ESTIMATES OF ME VALUE

The measured ME values of the test feeds were compared with calculated values, using the MAFF Tables of Feed Composition in *Technical Bulletin 33* (MAFF, 1976) (Estimate A), and an agreed set of values from UKASTA (Estimate B), which were typical of those in use to formulate ruminant compound feeds. Estimate A overestimated ME on average by 0.49 MJ/kg DM, and Estimate B by 0.25 MJ/kg DM. It is interesting to note that the residual standard deviations, S, about the means were 0.65 and 0.71 MJ/kg DM for Estimates A and B respectively, greater than the S values for chemical prediction techniques. This indicates a discrepancy between the measured ME using wether sheep at maintenance and the values in the databases used for feed formulation.

ADAS Nutrition Chemists had adopted a prediction equation, based on the use of *in vitro* digestibility (IVD) and equation (3), which uses digestible proximate values. A common digestibility was applied to all the coefficients to give equation (5) where CP, EE, CF and NFE are % in dry matter.

$$\text{ME (MJ/kg DM)} = \frac{\text{IVD}\,[0.152\,\text{CP\%} + 0.342\,\text{EE\%} + 0.128\,\text{CF\%} + 0.159\,\text{NFE\%}]}{[100 - \text{TA\%}]} \qquad (5)$$

This theoretically derived equation was found from the data of Wainman, Dewey and Boyne (1981) to underestimate ME on average by 0.12 MJ/kg DM, and to have an S of 0.48 MJ/kg DM.

Equation 75 of *Technical Bulletin 33* (MAFF, 1976) was similarly examined, and shown seriously to overestimate ME values by 0.73 MJ/kg DM on average, the bias increasing at the lower values. The use of equation 75 has now been discontinued by MAFF.

An alternative approach has been suggested by Morgan and Piggot (1978), which combines an *in vitro* estimate of organic matter digestibility (IVOMD) with an estimate of the GE of the feed, to calculate DE. This was then converted to an estimated ME value by multiplication by a factor of 0.81 to correct for average urine and methane losses, as shown in equation (6). This equation was found to underestimate *in vivo* ME values on average by 0.23 MJ/kg DM, and to have an S of 0.42 MJ/kg DM.

$$\text{ME} = \frac{\text{GE} \times 0.81\ \text{IVOMD}}{100} \qquad (6)$$

Subsequently, Belgian workers at the Institute of Animal Nutrition, Melle, have presented results which confirm those of the RRI/FEU study, although they used a much narrower range of ME values, ingredients and chemical composition.

Poultry compound feeds

PROCEDURE

From a list of 29 raw materials used in the feed industry to manufacture poultry compound feeds, a series of 32 formulations were made to meet a number of criteria. Each raw material was limited in the number of formulations in which it could be included. The range of chemical composition was specified for ether extract (2, 4, 8 or 16% in air-dry feed) and crude protein (either 12 or 25% in air-dry feed). The AME values were 9, 11, 13 or 15 MJ/kg air-dry feed.

This gave 32 possible formulations, but some combinations such as 2% EE and 15 MJ/kg of AME were technically impossible with the ingredients available. The number of diets was reduced to 28, which were to be tested both as meal and as pellets, to give a total of 56 diets in the programme.

The True Metabolizable Energy (TME), of each feed was measured by a modification of the technique of Sibbald (1976), using six mature cockerels for each feed. Feed intakes were fixed at 30 g, and the Apparent Metabolizable Energy (AME), calculated from the TME value. The completed programme was published by Fisher (1982).

STATISTICAL ANALYSIS

Analysis of variance was used to estimate the main effects of the test feeds (formulation × form) and of different laboratories. The feed × laboratory interaction was used as an estimate of error. Regression equations for the AME value on chemical composition were calculated and evaluated both in the conventional way, using laboratory mean values, and also taking into account interlaboratory variation to derive the term S''. For all analyses there were significant differences between laboratories, but none large enough for data to be rejected.

The AME values calculated from TME assays had a standard deviation of 0.372 MJ/kg, and the standard error of the mean of six determinations was 0.152 MJ/kg or 1.15% of the mean, indicating the high precision of this biological assay. The mean values for meals and pellets were 13.185 and 13.155 MJ/kg, a mean difference of −0.03, with a range of +0.465 to −0.996 MJ/kg due to pelleting. The highest negative effects occurred at high fat levels, and a significant correlation ($r = 0.712$), between EE and this difference was found. This suggests that during pelleting there is some loss of the more volatile components of added fat.

A number of two, three and four factor equations were derived, and those with residual standard deviations, S, of less than 0.5 MJ/kg were listed. No two factor equations met this requirement, although of 364 possible three-factor equations, 41 did. A total of 1001 four-factor equations was possible. Of these 329 had S values of less than 0.5 MJ/kg, and 30 were more accurate than the best three-factor equation.

A four-factor equation proposed by Hartel (1979) was also examined. This features CP, EE, STA and SUG, but no measure of fibre in the feed. It is represented by equation (7) and has been recalculated to MJ/kg from kcal/kg. The residual standard deviation, S, takes no account of interlaboratory variation. The bias, however, was large at −1.18 MJ/kg.

$$\text{AME (MJ/kg)} = 0.322\,\text{EE\%} + 0.151\,\text{CP\%} + 0.170\,\text{STA\%} + 0.109\,\text{SUG\%}$$
$$S = 0.31\ \text{MJ} \qquad (7)$$

An equation of the same type (equation (8)) was derived from the PRC set of data. However, the best equation found (equation (9)) included a term for the ratio of unsaturated fat to saturated fat, (USR), as determined by gas chromatography of the anhydrous methyl esters of the EE fraction. Since this equation accounted for 98.5% of the total variation in AME values, it was concluded that 'it seems improbable that the addition of further analytical variables could be more effective, though they might replace those used or be more cost effective' (Fisher, 1982).

$$\text{AME (MJ/kg)} = 0.343\,\text{EE\%} + 0.167\,\text{CP\%} + 0.179\,\text{STA\%} + 0.185\,\text{SUG\%}$$
$$S = 0.31\ \text{MJ/kg} \qquad \textbf{(77)}\ (8)$$

$$\text{AME (MJ/kg)} = 7.42 + 0.262\,\text{EE\%} + 0.079\,\text{CP\%} + 0.098\,\text{STA\%} - 0.093\,\text{NDF\%} + 0.069\,\text{USR}$$
$$S = 0.25\ \text{MJ/kg} \qquad \textbf{(74)}\ (9)$$

Equation numbers in bold type relate to the original reports.

COMPARISON WITH OTHER ESTIMATES OF AME VALUE

The report compared the measured AME values of the test feeds with calculated values, using Tables of Feed Composition given by Bolton and Blair (1974) in MAFF *Bulletin 174*, 'Poultry Nutrition', and with tabulated American, German and Dutch values. As assessed by overall means, all the predictions were below the observed values, although highly correlated with them. The MAFF values were 0.57 MJ/kg and the Dutch 0.22 MJ/kg below. Residual standard deviations about the means were 0.42 and 0.50 MJ/kg respectively.

A number of published prediction equations were also tested on the data, including those of Bolton (1962), and Carpenter and Clegg (1956). Both equations were a good fit to the data, but were for AME values uncorrected for nitrogen retention, whereas all the values in the PRC study were corrected to zero N balance. The agreement is therefore partly fortuitous.

SUBSEQUENT ACTIVITY IN UK AND EEC

It became clear that there was a good deal of additional poultry data available from Germany, Denmark, France and Holland. Dr Fisher was asked to pool the data if possible and to produce an equation of the Hartel type, which used only official EEC analytical methods. The resulting equation (10) was accepted by a European Working Group of poultry nutritionists. The residual standard deviation, S, for this equation is 0.315 MJ/kg, but it is the result of fitting parallel lines to the different data sets, with intercepts ranging from −0.268 to +0.106 MJ/kg.

$$\text{AME (MJ/kg)} = 0.342\,\text{EE\%} + 0.155\,\text{CP\%} + 0.167\,\text{STA\%} + 0.130\,\text{SUG\%} \qquad \textbf{(EEC)}\ (10)$$

Laboratory variability has been reported by Fisher (1983). Large interlaboratory differences were found, but there was high repeatability within laboratories, all nominally using EEC official methods. The equation predicted relative AME values with an S value of 0.51 MJ/kg. The important implication of this work is that it requires declaration of starch (STA) and sugar (SUG) analyses in the UK to be compulsory instead of optional as at present.

Pig compound feeds

PROCEDURE

From 33 raw materials used by the feed industry to manufacture pig compound feeds, a series of 36 diets were formulated to specifications for ether extract (2, 4 or