RECENT ADVANCES IN PRACTICAL FEED FORMULATION IN THE UNITED KINGDOM

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SUMMARY

Ideas in Nutrition were originally confined to diet formulation or diet nutrient content. This is still the main concept among some nutritionists and most practical farmers.

New ideas in which the daily intake of nutrients is defined by means of a "Nutrient Intake Profile" will soon replace these original ideas. Further sophistication allows Genetic, Environmental and Economic factors to influence and modify the ideal Nutrient Intake Profile for a particular flock or group of animals.

A means of delivering these ideal Nutrient Intake Profiles to individual flocks or groups of animals using automatic computer control to mix two feeds every day to achieve optimal performance is described.

INTRODUCTION

Feed formulation and Animal nutrition have been closely interrelated since the early days of animal husbandry. This must always be so as feed is the vehicle by which nutrients are delivered to the animal. Recently we have begun to untangle and better understand this relationship. Feed formulation can now become more dynamic and take into account Genetic, Environment and Economic factors on a day to day basis using "Real Time" information from individual flocks of birds or groups of animals.

There has been a logical progression in the development of these ideas and it is helpful to trace this evolution under 7 headings. These illustrate the progression of sophistication which spans from the 1940's and will take us into the year 2000 and beyond.

PROGRESSION OF IDEAS AFFECTING FEED FORMULATION

A) Fixed Formulations
B) Fixed Nutrients in the Diet
C) Fixed Daily Nutrient Intakes
D) Economic Daily Nutrient Intakes
E) Nutritional/Genetic Interactions
F) Nutritional/Environment Interactions
G) Reductions in Variability of feed composition

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FIXED FORMULATIONS

Advantages

(i) Simple and easy to understand by all.
(ii) Costs on farm = Sum of RM Costs + Mixing + Transport + Profit.
(iii) RM Costs of product "easy" to forecast and explain to farmers.
(iv) Fixed manufacturing skills.
(v) Shopping list of **RMs** depends just on sales forecasts.

Disadvantages

(i) Reliance on a few RM suppliers.
(ii) Takes no account of RM Quality or price changes.
(iii) Takes no account of different stock, different levels of performance, different management/environments, different performance objectives or economics.
(iv) No progress in nutritional understanding of animal.

Fixed formulations were used for broiler/turkey feeds in the 1950's. Now they are used only for some fish and other specialist feeds where price is less important and nutritional knowledge is scant.

FIXED NUTRIENTS IN THE DIET

This is currently the most common basis for feed formulation in the UK. Nutrients are regarded as the important items that animals need and which the diet must supply. The feed is therefore seen just as a vehicle to supply nutrients. It is the level of nutrients present in the feed that is important, rather than their source (i.e. the Raw Materials). The "Diet Specification" therefore becomes much more important than the formulation.

Assumption – additivity

i.e. that the property of mixtures can be calculated from a knowledge of the properties of their components and the proportions in the mix. Whilst this is true for chemical components such as calcium etc, it is not so true for energy.

Requirements

Detailed tables of composition of all available Raw Materials for all nutrients i.e. a database. "Specifications" for each feed – (Tend to be confused with nutrient requirements).

Advantages

(i) Reduces RM cost compared to fixed formulations
(ii) Flexibility in RM usage gives buyers of ingredients more negotiating opportunities. Can allocate scarce **RMs** via **Multimix** systems.
(iii) Highlights unit costs of critical nutrients in the diet.

(iv) Encourages experimental work to answer "what if" questions.
(v) Leads to ideas on "dose/response" and the development of more efficient cost effective feeds.
(vi) Aids the progress of understanding of Nutrition.
(vii) Diet costs can be expressed as the sum of the level of each nutrient, multiplied by its cost coefficient (Don't forget the bulk cost coefficient!).

Disadvantages

(i) Needs a computer to formulate the diets.
(ii) Can lead to large swings in RM made up for very little saving in RM cost. Therefore the physical appearance and pellet making quality can vary widely from formula to formula.
(iii) On farm animal performance results are not always consistent.
(iv) Some **RMs** appear to give better animal performance results than others. Other **RMs** give poorer results than predicted. This leads to **Min/Max** RM constraints.
(v) Only as good as the relevance and the quality of the RM analyses.
Bear in mind that RM analyses are predicted from historic data in the main, and are rarely based on analyses of materials actually going into particular formulations.
(vi) Leads to simple formulae ie fewer numbers of materials in the formula, some used at high levels, This is because the computer uses a material to the maximum if it is "economic". If it is uneconomic, the computer rejects it or uses it at the minimum level specified.
(vii) The result is an increasein variability of nutrient levels.

Although currently the industry standard, its short comings must be recognized.

FIXED DAILY NUTRIENT INTAKES

Background - a better understanding of Nutrition. Dr Charles Payne at Sutton Bonington showed that environmental temperatures affected layer performance and this was related to the appetite of the birds. Dr David Charles of **ADAS** showed at Gleadethorpe that higher environmental temperatures reduced feed intake and saved feed costs.

Nutrient requirements redefined

It was recognized that "nutrient requirements" should be related to the animal and not the feed. In other words, it is the animals that have daily requirements for nutrients, and the composition of the feed they need to supply these, depends on the quantity of feed that they eat per day. If they eat less feed per day, the composition of that feed has to be higher in nutrient content.

It is the animal that has nutrient requirements not the feed!

The new ARC and NRC tables of requirements are now beginning to recognize this but are still largely setting out animal nutrient requirements in diet composition form. Instead of saying (for example), that the nutrient requirement of a laying hen is (say) 17% protein, one should talk about its requirement in terms of grams of protein per day.

Suppose you decide that the laying hen needs 18 grams a day. Then 100 grams/day (3.5 oz) needs 18% Protein in the feed; but 114 grams/day (4 oz) needs only 15.8% Protein in the feed.

BOTH give the bird 18 grams protein per day.

Factors affecting daily feed intake

(i) Temperature - Animals eat less at higher temperatures.

(ii) Stocking Density - High stocking density reduces feed intake

(iii) Energy in the feed - High energy reduces consumption.

(iv) Protein in the feed - Slight reductions at high levels.

(v) Level of Production - High producers have higher appetites.

(vi) Imposed feed restriction- Under the farmer's control.

So Diet composition has to fit in with appetite to get the Daily Intake of Nutrients right.

Application of daily nutrient intake ideas

(i) Original application - 3.5lb/gallon and 4lb/gallon dairy cakes. (Note lower costs per gallon with 3.5lb cakes)!

(ii) Feeds for breeds eg Diets for laying hens with different appetites.

e.g. Silcocks Millmoor Layers "L" (Low appetites)
Millmoor Layers "M" (Medium appetites)
Millmoor Layers "H" (High appetites)

(iii) Phase feeding of Layers

e.g. Crosfields Goldyolk "R" (Restricted)
- a layers feed for early lay to avoid the "post peak dip"

(iv) Optimum Nutrient Density

Background - Energy in a broiler feed alters appetite of bird so:-

Devise a diet where the on farm delivered cost multiplied by the daily feed intake - gives the minimum daily feed costs. This concept led to big improvements in FCR and profitability.

ECONOMIC DAILY NUTRIENT INTAKE

Background

(i) Dose response work at Reading University by Colin Fisher on response of laying hens to methionine in the diet.
(ii) Peter Pilbrow / Trevor Morris - Response of laying 'hens to daily lysine intake.
(iii) Robert Curnow, Professor of Mathematics Reading University, Formalized the interpretation of dose response experiments.

Animal modelling

The animal is regarded as an input - output model. Output such as daily lean tissue growth (g/day) is related to daily input of lysine (mg/day).

This shows that, above the level needed for maintenance, the daily output is proportional to the daily intake of nutrient. This continues up to the Genetic limit of output, at which point further increases in daily nutrient intake gives no further output response.

This concept is then extended to the population of animals taking the population variation of maintenance needs and of genetic limit into account.

The familiar dose response curve is generated from which economically optimal nutrient intakes for the population can be derived. This depends not only on the genetics of the strain of animal involved, but also on the costs of supplying increasing intakes of nutrients and on the value of the increased output generated.

Summary of economic daily nutrient intake and application

(i) Regard the flock or group as an input-output model
(ii) Select economic optimal
Depends on Flock or group response data of breed or strain.
Costs of Nutrients, ie relative RM costs.
Value of end product (meat, eggs, milk etc) including premiums paid for "Quality".
(iii) Leads to Value for money concepts. i.e. flexible specifications. (nutrient levels in diet may change as costs fluctuate)
(iv) Highly suitable for integrated operators.
(v) Used to develop product and marketing strategies.
(vi) Leads to fully integrated economic models for integrated companies.

NUTRITIONAL/GENETIC INTERACTIONS ,

Genetic improvements in growth rates continue, and can be predicted several years in advance. This lifts the average genetic maximum for growth rate each generation.

There is no evidence that the rate of lean tissue growth per unit of nutrient intake ABOVE maintenance will change. This means that the extra growth potential has to be supported by extra daily nutrient intakes.

In other words the NET efficiency is unchanged (mg lysine needed per gram of lean tissue growth). However the GROSS efficiency IS improved as the unproductive maintenance needs are spread over greater yield outputs. Therefore optimal daily intakes are likely to increase.

At the same appetites this means a higher concentration of THE CRITICAL nutrients will be required in the feeds.

Genetic selection

Currently most breeding stock are selected on commercial feeds. So only animals with high appetites can get enough nutrients to express their genetic superiority. With broilers this has led to birds with big appetites being selected, and this is correlated with fatness!

If birds were selected on a high nutrient feed, then birds with normal (or low appetites) could get enough nutrients to show their genetic superiority for lean tissue growth and could be selected. Under current feeds, such birds would never be selected. Selection under a high nutrient feed could therefore increase the population lean growth potential WITHOUT increasing appetite and fatness.

Growth hormone

Whether administered externally or by selection of animals which produce more growth hormone, it is only the RATE of output such as milk or lean growth (and maximum adult body mass) that is increased. Nutrients required per unit will remain the same - so in an increased growth hormone scenario, more nutrients per day will be needed. The animal can achieve this only by a) eating more b) eating a higher nutrient feed.

Projected growth rates for chicken to the year 2000

From my University notes of 1956, chickens in 1954 took 12 weeks and 131b of feed to grow to 3.25lb LW. In 1965 Dr. Percy Blount of BOCM introduced his "388" broiler feeds. (3lb, 8 weeks, 8lb feed). Currently we can produce 5lb at 6 weeks on 9lb feed. By 2000 I predict we will produce 5lb at 5 weeks on 8lb feed as shown in Table 1.

TABLE 1 Chicken performance - projections to the year 2000

	1954	1965	1989	2000
L. Weight (lb)	3.25	3.00	5.00	5.00
Age (weeks)	12	8	6	5
Feed (lb)	13	8	9	8
FCR	4.00	2.70	1.80	1.60

Implications for animal agriculture

There is a need for a closer liaison between nutritionists and geneticists to ensure that feeds are provided to support the higher potential performance of improved strains as they arise. Animal Modelling can give a good clue as to what these new feeds should be.

NUTRITIONAL/ENVIRONMENT INTERACTIONS

We are now able, not only to monitor, but to control environment in animal (particularly pig and poultry) houses. This refers not only to temperature but to Relative Humidity, Ammonia, CO_2 and O_2. This is done by automatic operation of fans, air inlets and heaters. We also control lighting, stocking density and the timing and frequency of feeding etc.

Optimising nutrition/environment

There are 3 possible methods.

Optimising diets - with environment constant Currently diets are normally developed by experimenting with different nutrient levels and combinations in a fixed conventional environment. Usually this is in experimental facilities. For statistical reasons, large numbers of small pens of animals are needed to cater for randomisation and replication so that results are "statistically significant". This experimental method has led to major improvements in animal performance and is not to be despised.

However there are some major disadvantages :-

(a) In order to ensure that differences in performance are truly related to nutritional treatments, all other factors have to be standardized. Such factors as temperature and stocking density (both of which are known to affect appetite) are therefore fixed.
(b) Small pens cannot accommodate as many birds per square foot as commercial houses because of the "edge effect".
(c) Because of the need for feeding passages, the number of birds per cubic foot of airspace is much smaller than in commercial units.

All this means that conclusions drawn from such experiments, particularly when trying to optimise nutrient levels or feeding programmes, may not reproduce the results in commercial practice as on the experiment farm. Even if . commercial conditions could be reproduced on an experimental farm, only one combination of environmental background would be used. The diets produced would therefore optimise nutrition under a defined environment.

Optimising environment - with nutrition constant On many chicken growing units a standard feed and feed program is used. Growers therefore experiment with temperatures, stocking densities, feeding time table etc, in order to optimise environment under the conditions of the defined feeds and programmes imposed on them.

Optimising the combination of Nutrition and Environment The idea is to have control of diet composition AND environmental factors simultaneously, and take genetic factors such as strain and sex into account as well as economics in order to find a combination that produces the most profitable solution.

For example, higher temperatures reduce feed costs (which saves money) but increase fuel costs and diet formulation costs. The correct combination depends not only on average farm delivered feed costs, but on unit nutrient costs of increasing or decreasing nutrients in the feed and fuel costs of heating the house. The optimal nutrient intake depends on the dose response of output to nutrient intake for the strain and sex as well as the unit costs of nutrients and the relative value of different levels of output.

MODELLING

This is a theoretical method of predicting performance of a single animal when offered feed of a given composition in a defined environment. Gerry Emmans and Colin Whittemore at Edinburgh as well as some notable Australian workers have produced some excellent concepts which have helped nutritionists understand a lot more about nutrition and the growth process. The model for pigs normally works on an assumed feed scale, while the one for broilers assumes ad lib feed intake. The latter has therefore to predict the birds' feed intake also.

The basis is to calculate the daily intake of nutrients for day one. Then to deduct the quantities needed for maintenance (this depends on body weight and composition as well as environment). Having found the nutrients available for growth, to see how much of the genetic potential can be fulfilled or how much nutrient needs to be excreted. The model then adds the calculated lean tissue and fat to the original body composition to arrive at the body composition at the end of day one.

This then becomes the start point for day two - and the calculations are repeated with appetites, diet make up and environment for day two - and so on. Some programmes use sub-divisions of a day for greater accuracy.

All the calculations are of course done by computer. The feed trade and some practical growers have, in the main, used these models to attempt to answer "what if" questions. e.g. what prediction does the model make if I increase the feed scale (or the protein content of the diet) etc. Such models are good examples of the use of computers to assist decision making.

'Commercial application of modelling for profit optimisation

To turn this into a commercial tool for practical use for say Broilers which would produce optimum profit/would require the following procedures:-

Construct a FLOCK Model (not a single bird model), to take into account

(i) Daily intake of nutrients for the flock related to lean tissue gain, lean/fat, total weight gain etc.

(ii) Effects of environment (temperature, RH and stocking density) as well as energy of diet on daily feed intake.

(iii) Incorporate economic data

a) RM Cost

b) Value of Weight produced including lean/fat and other Quality premiums.

c) Chick, litter, building, gas, electricity costs etc.

Then calculate

(i) The value of meat birds at slaughter allowing for different values at different weight bands.

(ii) The total feed costs i.e. Sum of each days feed cost (i.e. on farm delivered cost x daily feed intake).

(iii) Costs of maintaining environment and other costs.

Scan 1 minus (2 plus 3) for all possible combinations

Select and implement optimal strategy.

So far, such an application has not been made. One of the biggest problems is that the predictions of feed intake are not accurate enough. The rest of the model depends critically on this.

Example of a practical nutrition model for broilers / turkeys

Calculate for the Breed / Sex, for each day, the optimal daily intake of nutrients for the flock, using RM costs and meat values.

Calculate the Ideal Diet Composition for each day for different assumed feed intakes.

Construct a series of diets (3-5) with graded levels of key nutrients.

Derive a feed programme to fit the Ideal Diet Composition most nearly.

Measure feed intake daily and use this information to calculate actual nutrient intake compared to target.

Modify the feed programme AND/OR environment during flock's life to keep actual nutrient intakes in line with targets.

FLOCKMAN - a means of implementing nutrition/environment control

This electronic equipment monitors and controls environment and nutrition in intensive poultry houses and was developed at Harper Adams by Chris Belyavin in conjunction with BOCM Silcock and Stonefield Systems (the manufacturers).

It won the best new equipment award at the European Poultry Fair 1986 and has recently been updated to contain a nutritional element to ensure actual daily nutrient intakes are in line with targets. This is done by automatic blending between two feeds at each chicken or animal house to achieve thetarget daily NUTRIENT intake at the observed daily FEED intake. One of the feeds can be a whole cereal.!

One on-farm computer is linked to up to 16 houses and displays details of performance in each house. Each house is monitored and controlled for :-

Temperature	-	Mean, Min and Max including external
Moisture	-	i.e. Relative Humidity, Mean, Min and Max
Ammonia		
Bird Weight daily	-	Mean and SD plus histogram

Daily feed dispensed - to + or - 0.5%
Feeding cycle/timing, waste control
Daily Water Intake
Automatic Fan control including timer for minimum ventilation rate.
Automatic Air inlet controls (where appropriate).
Light control - timing

All data are transferred to the farm computer automatically at midnight. Individual screens for each house show by graphs, how actual performance compares to targets for LW, LWG, FCR, Feed Intake, Water Intake, Temperature, RH and Ammonia.

Alarms are activated if fans, heaters, feed chains etc malfunction. **FLOCKMAN** is currently being sold by Stonefield Systems Plc. to large broiler growers world-wide. It is used in the following sequence :-

(i) Determine and set up local performance targets for the strain/sex.

(ii) Set up the best estimates of the optimal daily environment, Nutrient Intake Profiles and feeds. This is done in conjunction with the producer's feed or supplement supplier.

(iii) Monitor continuously, daily bird weight, feed intake, water intake.

(iv) Compare actual results against targets, daily on coloured graphical displays.

(v) If necessary modify environment and/or feed program or composition, so as to steer birds along the predetermined growth curve.

(vi) All data are archived to memory so that previous crops can be recalled for comparison or for overall economic analyses.

(vii) Monitoring of flocks can be done remotely by modem at head office.

(viii)An advisory service for first flocks via modem is available.

(ix) Pay back period for capital costs is approximately one year.

Implications for animal agriculture of "real time" management systems

(i) They assist nutritionists to devise better feed programs for their existing broiler/turkey/pig feeds.

(ii) They assist nutritionists to devise better feed specifications for animals or birds having lower or higher appetites than usual.

(iii) They offer the opportunity to implement the best on farm mix of two compounds or of one compound and cereal for the finishing stages of broiler/turkey/pig growing. Ideally the mix changes gradually and progressively as the animals grow and this is best achieved by computer control on farm where the daily feed intake and liveweight gain is under automatic control as in the **FLOCKMAN** system.

REDUCTIONS IN VARIABILITY OF FEED COMPOSITION

Linear programming increases the variation of protein and other nutrients in feeds. This is reflected by a lack of consistency of farm performance.

In a standard broiler feed formulated to 20% protein for example. We are likely to find a Standard Deviation of one percentage unit of protein.

so 50% of samples will be below 20% protein
16% of samples will be below 19% protein
2.5% of samples will be below 18% protein

In order to reduce variability perhaps we should specify that no more than 16% of samples should be beneath 19%

Protein? Just to remind you, the standard deviation of a mixture can be calculated from the formula and the SDs of the components as shown in Table 2.

Protein variation in puffin pellets

TABLE 2 Method of calculating standard deviation of protein in a mix

	(A) PROTEIN %	(B) PROTEIN S.D.	(AxB)	$(AxB)^2$	% Total
Barley	40.5	1.5	0.607	0.369	82.9
Wheat	15.0	1.2	0.180	0.032	7.3
WheatFeed	8.4	1.1	0.092	0.008	1.9
Sugar Beet	15.0	0.9	0.135	0.018	4.1
Molasses	7.5	1.0	0.075	0.006	1.3
Soya	10.6	1.0	0.106	0.011	2.5
Oil	3.0	0	0	0	0
	100.0			0.444	100.0

SUM OF $(AxB)^2$ = 0.444

Therefore S.D. of this formula = SQR/ 0.444 = 0.666

A method exists using linear programming to produce a least cost formula such that only 16% (or any other percentage) of the samples fall beneath a given level (13.33% in Table 1). This method produces a different formula with a lower mean and standard deviation but still having only 16% of the samples beneath 13.33% protein. In the example in Table 3, it also saved 40p/tonne!

TABLE 3 Raw material cost of puffin pellets

STANDARD METHOD		NEW METHOD	
i.e. LEAST COST TO 14% CP.		LEAST COST TO GIVE 16% BELOW 13.33% CP	
RM COST = £ 105.26		RM COST = £ 104.87 (Saved 40p/tonne)	
MEAN C.P. =	14.00%	MEAN C.P. =	13.69%
SD of C.P.=	0.67%	SD of C.P.=	0.36%
Therefore 16% of Product below	13.33% C.P.	Therefore 16% of Product below	13.33% C.P.

The Quartile level is often used in quality control assessments as it is more accurately assessed with a small number of samples then say the 2.5% risk level. The Quartile level is that level below which one quarter of samples lie (and above which three quarters lie). Table 4 shows the percent of product falling beneath 18% protein and the Quartile levels for compounds with various mean protein levels and Standard Deviations.

TABLE 4 Interchange of mean and standard deviation

% of **PRODUCT FALLING BENEATH** 18% **PROTEIN**

		Mean level of Protein in Product (%)					
		18.0	18.2	18.4	18.6	18.8	19.0
S.D. of Protein in Product (%)	1.2	50	43	37	31	25	20
	0.9	50	41	33	25	19	13
	0.6	50	37	25	16	9	5
	0.3	50	25	9	2	0.4	0

There is clearly a trade off between Standard Deviation and mean level of protein in the mix to give the same level of risk of falling beneath a given threshold. For example you would have to formulate to 18.8% protein if your SD was 1.2 to give no more than 25% of samples falling below 18%. However you could reduce your formulated levels to 18.4% if you could reduce your SDs to 0.6 - and still have only 25% falling below 18%.

Reducing variability means reducing exceptionally good animal performance results as well as the exceptionally poor. However exceptionally good results only increase farmer's expectations. If you cannot consistently guarantee this, most farmer's would prefer more predictable performances. So the method of formulating to reduce variability has much to commend it and could be used more extensively in the future.