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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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Distr.
LIMITED

ID/WG.171/19
3 May 1974

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

International Consultation on
Agro-Industrial Development

Belgrade, Yugoslavia, 13-18 May, 1974

AGRO-INDUSTRY AND FEEDSTUFFS PRODUCTION[1]

A.W.A. Burt*

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* Managing Director, Burt Research Ltd., Kimbolton, Huntington, PE18 OHU., U.K.

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INTRODUCTION.

Feed is the largest single cost factor in most animal production systems. Compound feed manufacture has reached an advanced stage of development in some of the developed countries, where its function is to integrate variable supplies of many different feed raw materials into a steady supply of supplements or complete balanced feeds.

Feed must be a major factor in any agro-industrial development of animal production. The aim of this paper is to try to bring together some aspects of the management of mixed feed production, avoiding exessive technical detail.

In advanced feed production systems, the use of computers for least cost formulation will continue to become more closely linked, back to buying and stock control on the one hand, and forward to the practical management of the livestock receiving the feed, on the other, since it is increasingly recognized that the animal has not one optimum nutrient requirement, but responds to a range of nutrient intake.

Nutritional expertise is likely to become increasingly important to dealing with the accurate assessment of the available nutrients in raw materials and with the assessment of animal responses leading to effective product specification. This trend will be enhanced by the increasing necessity to find substitutes for what were once feed ingredients in ample supply.

1. REQUIREMENTS FOR ANIMAL FEEDSTUFFS PRODUCTION.

A. Animal production requirements.

It is not the purpose of this paper to discuss or to assess the needs of the worlds population for increased supplies of animal products. This need arises both from the need to improve the nutritional adequacy of many human diets, as illustrated by the extremely wide differences now existing between the protein intakes of the population in different areas of the world. The fact that the population of some developed countries consume not only twice the total protein, but also ten times as much animal protein/head as the population of some developing countries, has been well documented and discussed.

For animal production to be reasonably efficient, feed supplies must be sufficiently consistent to maintain reasonable rates of growth, milk output, egg output etc., in the livestock population. In any system of animal production of reasonable intensity, feed is the major technical and economic input of the production system.

B. Agro-industrial requirements.

If feed supply is crucial to animal production in general, it is even more crucial to the vertically integrated enterprise producing animal products, since it represents the major initial input of such enterprises.

Feed supply and animal supply are the prime requirements of animal agro-industry, which is therefore absolutely dependent upon its agricultural base for both of these components. Unless such an adequate base exists any attempt to establish vertically integrated agro-industry is doomed to failure. Not only must the base exist but particularly in the case of feed supply, it will determine to a very large extent the type of animal production unit which can be established. It is salutary to remember that one of the major reasons for past failures in the vertically integrated of agriculturally based product chains has been that the management of such enterprises has been too heavily geared either towards agriculture or towards the relevant industrial activity, resulting in management failure to appreciate crucial situations affecting other parts of the enterprise.

Without adequate feed supplies, any enterprise in animal production is doomed to failure. The situation is particularly critical in vertically integrated enterprises, where the returns from the investments in all the later stages of the production chain depend upon feed supply. Not only must the average feed supply be sufficient, but its reliability is also crucial.

No feed production project, vertically integrated or not, can be considered without thorough survey of the raw material resources at its disposal and the animal population which it seeks to serve. Both these items are affected to a greater or lesser extent by the agricultural base upon which it is proposed to establish such an enterprise.

Just as an industrial organisation would ensure that it had obtained adequate knowledge of the local agricultural and market situation before establishing new feed plants, similar considerations obviously apply to the operations of International Agencies. Success in U.N. backed projects in this field must depend upon adequate collaboration between those agencies concerned with industrial development and those concerned with agriculture.

C. Animal feedstuffs concepts.

The basic concept of animal feed production is that these exists:-

(1) A supply of a range of suitable raw materials for use in feeds.

(2) A processing facility.

(3) A user animal population requiring mixed feeds.

The user animal population might require manufactured feed to meet the whole of its dietary requirements, as in intensive poultry enterprises or manufactured feed as a supplement to forage or cereals etc., produced on the farm, as in feeding dairy or beef cattle, and in some pig production units.

The concept therefore usually excludes the use of herbages, forage and cereals which may be produced on the farm units holding the animal population and which are fed with very little processing, although the distinction is somewhat artificial and may even be irrelevant with increasing technological inputs in feed processing at the site of production. For example, although the total output of green crop drying may be fed to cattle at the site of production, the technological input is substantial.

If we consider animal feedstuff production in terms of the concept of vertically integrated agro-industry outlined in the briefing paper for this consultation, many enterprises already exist in which processed feed production (level 2) is integrated with livestock production (level 4) and rather fewer enterprises in which the integration is carried to the processing of livestock products (level 5) and their distribution and marketing (level 6).

Although such enterprises may often be based upon, or closely related to, substantial crop production, almost invariably feed production in an intensive livestock enterprise involves the purchase of very substantial inputs from outwith the vertically integrated structure. It may often be that these inputs are much more important in technical and economic terms than in terms of gross tonnage of feed. For instance many pig production enterprises are based upon substantial usage of cereals grown on the same farm, supplemented with purchased compound feeds to provide the necessary supplementary protein/vitamins/minerals and some small amounts of specialist products such as creep feed for very young pigs. In this case management has chosen to confine its integrated operation to the simplest processing of the bulk of the material being fed, relying on the feed manufacturer to provide all the necessary dietary knowhow in the form of the supplements and specialist products. Again, intensive poultry enterprises, vertically integrated from chick production to consumer marketing, may choose to purchase the whole of their feed requirements from outside the organisation.

In short, regardless of the intensity of the particular animal enterprise, the degree of backward integration into feed supply is very variable, even when feed manufacture is integrated within the production unit it can range from the purchase and mixing of vitamin and mineral supplements with feeds produced on site, through to a high automated substantial feed production facility.

II. RAW MATERIAL SUPPLY AND VERTICAL INTEGRATION.

A. Raw materials.

Raw materials used in animal feeds can be classified somewhat imprecisely into the following groups:-

(1) Low grade roughagee e.g., etraw.
(2) High grade roughagee e.g., artificially dried forages.
(3) Cereals.
(4) Cereal replacements e.g., cassava.
(5) Cereal and other byproducts - bran, beet pulp, and citrus pulp.
(6) Vegetables proteins (oilseed residues)
(7) Animal proteins.
(8) Fats and oils.
(9) Minerals.
(10) Vitamins.
(11) Medicaments and growth stimulants.

These items are arranged roughly in diminishing order of their likelihood of local availability to the vertically integrated animal enterprise, and also in order of increasing cost/unit weight.

One may distinguish between several types of typical situation in terms of the relationship between the animal enterprise and its feed supply, making generalizations which are somewhat sweeping.

These are:-

(1) Ruminant production is generally based on local and immediate access to all sources of roughage required.

(2) Pig production is largely based on cereal availability,,many enterprises purchasing the remainder of their dietary requirements.

(3) Intensive poultry may be based upon the complete purchase of the entire feed requirement from outside the enterprise either in finished form, or as raw materials for manufacture on site.

These types of enterprises fall into the order of increasing sophistication of nutritional inputs and it is therefore no surprise that this is correlated with an increasing tendency to obtain nutritional expertise from outside the confines of the animal production unit.

However, this relationship is modified by the effects of the other major production factor which is animal supply. The management inputs required to obtain this are relatively less in the case of a well developed poultry industry than for cattle production. This being so, although the degree of technical sophistication required to produce feed is greater for poultry, individual enterprises e.g., in broiler production can more easily reach the scale required to justify their own integrated feed plants, and more readily find the necessary management capability to run them.

The sophisticated feed mill in the developed country usually has access, either locally or through international trade, to all the classifications of raw material mentioned. The local plant in the developing country may on the other hand, have much more restricted access to the general pattern of feed materials. The management approaches appropiate to the operation are therefore entirely different in the two cases.

B. Scale factors.

Unlike many other facets of Agro-Industry, physical size of the operation is not a major factor in the physical efficiency of feed production. Effective feed production does not necessarily depend upon the existence of large technically sophisticated plants with high volume production. This means that, within reason, the size and nature of the feed production unit can be geared to the size and nature of the animal population which it seeks to service, and to the nature of the materials it is called upon to process.

However the managerial aspects of scale of operation are much more important. Smaller feed production units may function efficiently in physical terms, but may be grossly inefficient in terms of the nutritional and technical know-how put into the purchase of raw materials and the formulation and use of feeds, if this is attempted entirely under the direction of local management. Such units may therefore suffer from inefficient use of management resources. This may be overcome by hiring expertise on a part time basis, or by purchasing combined packages of the more sophisticated nutritional components of the ration together with nutritional expertise in feed formulation and feed use.

C. Crucial questions for the establishment of feed production units.

We can now list the questions which have to be faced in the establishment of such units regardless of the degree of vertical integration.

These are:-

(1) Raw material supply.

What are the local availabilities of raw materials, and the reliability of raw material supply ?. If major components are unreliable in supply, what alternative resources are likely to be accessible when this occurs.

(2) Animal population.

What is the nature and size of the animal population that the unit is designed to service and how is it likely to change in the future ?.

(3) Given that certain dietary constituents have to be purchased from outside the enterprise, what alternatives are available ?. For example are these best purchased as individual raw materials or as premixes or concentrates?.

(4) From where and in what form are the relevant inputs of technical expertise to be obtained to allow the unit to function efficiently ?, and how are these related to expertise in animal nutrition and management required in the animal production units which it is to serve.

D. Agro-Industry as a source of raw materials.

Many of the raw materials used in animal feed production are byproducts of other agro-industrial activities. The list is very extensive for it includes cereal byproducts, citrus pulp, sugar beet pulp, oilseed residues, molasses, blood meal, dairy byproducts, brewers grains, meat and bone meal etc. In some cases, exploitation of these as animal feed materials is already highly developed, but in other cases there are many opportunities for improvement particularly but not only in the developing countries (e.g., see Barat (1)). While it is the duty of the managements of feed production units to ensure that they seek out and exploit local byproduct resources, it is also the duty of management of other sectors of agro-industry to ensure that their production of byproducts is properly processed in relation to animal feed production. Very often managements are only interested in rapid disposal of such materials, and have neither the time, interest or knowhow to improve their disposal procedures and thereby enhance the usefulness of such byproducts. Lack of time and knowhow to seek such improvement is not unexpected, and appropiate technical assistance can often bring about substantial improvement in this respect.

III. MANAGEMENT OF MIXED FEED PRODUCTION.

A. General.

Raw materials for feed production vary considerably from time to time in their availability and price. Effective feed production must therefore be based upon,

(a) effective purchase.

(b) effective substitution of one material for another to counter adverse supply and price situations.

(c) maintenance of supply of the appropriate feed to the animal i.e., maintenance of the relevant nutrient inputs.

Obviously all these facets are closely related one with another, for effective purchase depends upon detailed knowledge of effective substitution rates, while the latter depends upon detailed knowledge of animal response.

Specialized feed production units justify their economic existence by their ability to solve the problems of integrative management involved in this series of operations. It is the purpose of this chapter to put into perspective one or two of the more recent developments in this field.

B. Effective purchase.

Those responsible for the acquisition of raw materials must integrate their purchases with the requirements for the manufacture and disposal of product, taking into account the market situation and the substitutions which are possible i.e., the relative price/effectiveness of the materials available for purchase.

This situation reaches the extreme of complication in large feed mills in developed countries. These may have access to locally produced raw materials, and be able to buy on world markets, while they have to supply varying proportions of a free market for feed for substantial numbers of the different animal species. Some of the techniques described below relate to the operation of such units and may have very little relevance to smaller local plants with a limited spectrum of raw material supply.

Decisions made in buying are crucial to the success of any feed production operation, because the further technical processing operations to convert raw materials into product are fairly fixed in any particular enterprise, in terms of their nature and operating cost. Unless the acquisition of raw materials is carried out efficiently therefore, the resultant production cannot result in an economically optimum product.

C. Least cost formulation.

Least cost formulation using analogue or digital computers has become widely used in the manufactured feed industry over the last decade. It is important to understand the information required for least cost formulation and the output which is generated, before one can consider possible extensions back into buying or forward into animal production.

Least cost formulation requires two types of information (a) costs of, and nutritive values (i.e., contents of energy, protein, amino acids, minerals etc) assigned to a series of raw materials (b) a product specification which sets out the minimum or maximum levels of nutrients required in the particular feed being formulated, together with any minimum or maximum inclusions of individual raw materials. The latter may arise from nutritional or non nutritional considerations. Examples of these are given in Table 1.

Using an analogue or digital computer the least cost formulation which meets the product specification may then be produced. The results of such a calculation using a remote access digital programme are shown in Tables 2 and 3.

This output shows the least cost solution, although notice that the quantities included require further rounding, before practical application, which can be done using a subprogramme in this particular instance. The results also show the calculated analysis of the product. Economic values are assigned to the individual ingredients in the formulation, showing the value above which their inclusions would be materially altered, unless their inclusion is dictated by the product specifications, and gives economic values at which those ingredients which have been rejected on the grounds of expense, would be included.

The final piece of information is the sensitivity analysis which shows those requirements in the product specification which are proving most expensive to meet, e.g., in the example in Table 3, the energy (SE value) in the specification is costing £2.3/ton to increase from 59 to the value of 63 required by the specification.

D. Multiproduct formulation.

If the production unit were only producing one product, carried no stocks and had no forward purchases of materials, the information produced by such a least cost formulation of the product is obviously of great use as guidance to the acquisition of raw materials in the market place. However, such simplicity is seldom the case. Most feed mills produce varying tonnages of a variety of products and have varying amounts of raw materials in stock or already ordered for delivery. In this situation a number of approaches may be used, although techniques in this are still subject to much further development.

The most obvious approach is to carry out individual least cost formulation of the major products to give guidance as to the relative values of their constituents. This approach has been widely used, but still requires substantial interpretation on the part of the nutritionist and the buyer.

Multiple regression techniques have been used on historical datato attempt to establish relationships between the nutrient content of individual raw materials and their economic value, which are then used to compute the value of raw materials under a given set of market conditions. This is really a more sophisticated example of rule of thumb methods of comparing ingredient values e.g., protein sources in terms of price/unit of protein.

Genuine multiproduct formulation systems are now being developed, which simultaneously formulate a series of products and minimize overall ingredient cost. They may also extend to projecting the forward raw materials position in terms of stock deficiencies and indicate when purchase may be necessary and may therefore be integrated with a stock control programme. An example of the type of information obtained from a fairly simple example is shown in Table 4. This is taken from the paper by Waldroup & Johnson (2) which deals with the practical use of such a system to make most effective use of ingredients in short supply, in formulating a limited number of products for a limited period.

E. Effect of the nutritive values assigned to raw materials.

One of the pieces of information which can be obtained from least cost formulation is the economic value of a particular raw material. However this value is based entirely upon the nutritive values assigned to that particular ingredient and upon the nutritive value and cost of the other ingredients in the matrix and upon the product specification.

It cannot be emphasized too strongly that if the nutrient contents assigned to an ingredient are not correct, then its economic value is not correctly determined and if the error is gross, then the final product may deviate sufficiently from the specified nutrient composition to adversely affect animal performance. It is unfortunate that some of the most important nutrient parameters in economic terms are also those which are most difficult to determine, or to control by analytical procedures. Nevertheless, it is plain that the management of any animal feedstuff operation must be prepared to keep this situation under constant review as part of its quality control function, in order to avoid unnecessary expenditures to acquire nutrients already available in its particular sources of feed, or adverse animal performance due to inadvertent deficiencies.

In this respect the FAO project (3) which is concerned with gathering together feed composition data for feeds available in whole continents may help to provide very useful starting points in planning vertically integrated projects. Like all tables of feed composition however, this is an not effective substitute for actual analysis of the materials being used. The selection and updating of nutrient data on raw material composition is a skilled and vital operation for feed plant management.

F. Parametric linear programming.

Parametric linear programming may be used to generate repeated LP results in which one or more factors are varied in discrete steps(parametricised) while the other factors in the matrix remain constant.

The approach may be of considerable value in studying new ingredients and as a research tool. Davies, Trotter and Burdick (4) quote examples of parametric cost ranging, parametric nutrient ranging and parametric restriction or specification ranging in poultry feeds. Parametric cost ranging refers to ascertaining the effect of variations in the cost of a ingredient upon its inclusion rate in the formulation concerned. Parametric nutrient ranging refers to the effect of the level of a particular nutrient in a raw material upon its economic value, while parametric restriction or specification ranging refers to studying the effect of a specification parameter e.g., minimum lysine content, upon cost of the formulation.

Table 5 illustrates the results of a parametric LP of the effect of variations in cost upon the percentage inclusion of an ingredient in a particular cattle feed formulation. This short summary of information is abstracted from a considerable amount of information about the inclusion of other ingredients, formulation cost etc., which is generated by such procedures.

However, several points should be noted, first, while the technique is useful as a research tool it essentially consists in this instance of repeated least cost formulation. A large computer is needed. In some circumstances, therefore, it may be more convenient to study the matter in question by repeated least cost formulation, varying the quantity to be studied, using either an analogue or a digital facility.

Secondly, while this technique, like other least cost procedures, gives discrete formulation results, they depend absolutely upon the rest of the information in the matrix, which is held constant. In practice, markets do not behave in this manner, for instance, studying effects of variations in the price of a cereal upon its inclusion rate is of little consequence, unless other cereals are considered, because these can be ,,and are, quite freely substituted one for another in the animal feed market, and their price will tend to vary together to a greater or lesser extent. The results also depend upon the product specification used. Davies et al (4) illustrate this by showing substantially different economic value curves for sunflower expeller meal in broiler starter, broiler finisher and layer diets, and the reader is referred to their paper for a clear exposition of the merits and demerits of the feed feed formulation uses of the technique.

It should also be noted that the type of least cost formulation output shown in Tables 2 and 3 in itself gives indicative information about the value of excluded raw materials and about the cost of the most important nutrient constraints in the specification.

IV. ANIMAL RESPONSE AND LEAST COST FORMULATION.

A. Cheapest nutrients formulation.

Up to this point, we have been discussing the situation where each diet is formulated to a minimum specification,i.e., each unit weight of formulation is designed to contain given amounts of energy, protein, specific amino acids, vitamins, minerals etc. This is the usual situation in commercial compound feed mills where products are sold to individual nutrient specifications for each particular product. The corollary is that the user, in theory at least,is purchasing these products to feed in a consistent manner to the same class of animal e.g., formulations for dairy cows, designed to be fed at 4 kg/10 milk, pig fattening diets for feeding on a particular scale of intake etc.

The corresponding restraint imposed on formulation is that the product should always contain e.g., 16% protein, or that 16 parts of protein should always be contained in 100 parts of product. Relaxation of this constraint implies that the amount of feed given to the animal must be altered, so that while such relaxation may cheapen the cost of particular amount of nutrients, this has to be set against the changes necessary in animal management.

In poultry diets, energy input is usually a major cost factor, and it may be appropriate to attempt to minimize the cost/unit energy, bearing in mind that protein and other nutrients must also maintain their appropriate rations to energy value. One way of approaching this is to formulate a series of diets at different energy densities and appropriate specifications. An example of a minimum nutrient cost formulation is shown in Table 6. In this case a dairy cow production ration has been formulated using a blank ingredient with no cost and no nutritive value and with cheap tallow included in the matrix. The results show that the most economic nutrient package contains 8.97% of the blank ingredient. In other words, if the ration is made up in the proportions shown and fed at 100-8.97 = 91.03% of 4 kg/10kg milk, it should not only be nutritionally adequate but be cheaper than a ration formulated from this particular matrix to meet the requirements when fed at 4kg/10kg milk. In this particular case the saving was £0.87/ton compared with the formulation constrained to contain the required nutrients in 100%. This has to be compared with the cost of making appropriate adjustments to the rates of feeding of the raw material in the animal production unit.

B. Description of animal response.

Most of the foregoing discussion assumes that the animal has a specific requirement for nutrients which can be expressed in terms of a specific and detailed product specification. The underlying assumption is that the animal will perform inefficiently unless it is fed at least its somewhat precisely defined minimum requirement for each particular nutrient i.e.,

Nutrient Requirement = Nutrient intake = Concentration of Nutrient in product. X Weight of product fed.

In fact animal responses to alteration in nutrient intake are far from being so simple, for major nutrients, particularly for energy, protein individual amino acids, etc., responses are usually curvilinear. Furthermore, because of between animal variation, the measurement of such responses with a degree of precision necessary to produce reliable data suitable for management control is not easy.

A further problem is the choice of the animal respons parameter. In the pig, for example, the response to changes in nutrient intake of live weight increase may differ substantially from that of lean meat output. (5). Choice of animal response for optimization is therefore crucial.

Such response curves are usually of the diminishing returns type i.e., the marginal increase in animal output diminishes with each sucessive input of the nutrient involved, to a point where the response becomes zero and may become negative. In this situation it is clear that optimization of the economic aspects of animal production depends upon the relationship between the cost of the marginal increment of nutrient input and the value of the associated inrement in animal production. The nutrient intakes required to optimize animal response in economic terms therefore changes with changes in nutrient cost and/or animal product value.

Some of the problems involved in the application of such concepts to the nutrition of the laying hen have been discussed by Filmer (6), while de Groote (7) describes the derivation of a series of least cost laying hen diets with different energy densities based upon a common specification and the results obtained when these were experimentally fed ad libitum to White Leghorn hens.

The problems are:-

(1) Although Fisher, Morris & Jennings (8) present a promising method for the derivation of predictions of response in the laying bird to changes in nutrient intake, the accuracy and the relevance of the predictions used remains crucial to the successful practical application of such systems.

(2) Responses may be modified by breed, stress or environmental effects e.g., temperature, and by the physical form of the diet.

(3) The system of feeding used may profoundly affect the optimum result. For example a diet designed to give optimum economic results when fed <u>ad libitum</u> is likely to be different from one designed to be optimal under a particular system of restricted feeding. The system used may change. For example, <u>ad libitum</u> feeding of laying hens has become much less attractive with the recent substantial rises in feed costs.

(4) More than one animal response parameter may have to be considered e.g in the laying hen, egg number, egg weight and body weight of the birds could all be subject to influence by feeding and all have noticeable effects upon the economic outcome.

This discussion shows that there is indeed a requirement for any animal feed production operation to consider not only the economic optimization of its own operations, but also to give considerable attention to the economic optimization of the operations of the users of its products, whether or not the two operations are vertically integrated. However, it is clear that attempts to reach overall optimum solutions can only come about by very careful consideration of the actual situation and above all by use of reliable data for prediction purposes.

A practical example of the type of data required are the equations quoted by de Groote (7) which, since nutrient density had no significant effect upon egg number in his experiments, relate nutrient density (x) with egg weight, body weight increase and energy intake (Table 7). He suggested that these could be linked with economic data and least cost linear programming to produce overall optimum solutions.

V. PRACTICAL CONSIDERATIONS.

A. Computer application.

It might appear that ultimately the application of a large linear programming excercise would be capable of producing the optimum solution to the inter related activities of raw material acquisition, feed formulation and animal management in any particular situation. We may be reaching this stage, where the structure of such systems is relatively simple, but this is rarely the case in practice. Superficially, it would also appear easier to reach such optimal solutions more readily in a vertically integrated unit.

However, buying, feed production, feed formulation and animal production management are all substantial management tasks, each requiring its own particular skill. Before any integrated unit can hope to derive substantial benefits from integration it must have achieved the relevant level of operating efficiency in all its departments, in addition to effective co-ordination between them. In integrated animal agro-industry the addition of animal product processing and disposal to the areas listed above makes the total management task formidable.

Use of computers and optimizing techniques are obviously of importance to any organisation involved in substantial feed production and/or animal production. However they cannot be used effectively unless the management also has very highly developed management skills in their own fields. Computer output may be as misleading to the unskilled buyer as to the unskilled nutritionist. If such data cannot be controlled, understood and interpreted in the light of the practical day to daysituation by the management concerned, it is of little value.

In some respects the situation is becoming easier with developments in computer use. Remote access terminals, time sharing on large computers and conversational programmes all help to make the computer a more effective tool in the hands of the manager. Easier access and greater comprehension also help to encourage an evolutionary approach to the use of computers.

B. Nutritional and technical knowlegde.

Animal feed production obviously demands nutritional skills of a high order. The economic value of raw materials depends upon correct assessment of their nutrient content. Adequate and properly controlled specifications for products are required. Specifications will only be successful if they take into account knowledge of animal response, management systems and economic circumstances. It is the task of the nutritionist to deal with these crucial questions. Since nutritional science and its applications are changing so rapidly no feed production unit can hope to be successful without adequate access to the flow of nutritional information.

Managements must take positive decisions as to what means they intend to adopt to keep in touch with the main stream of nutritional science. They may choose to rely entirely on nutritional advice purchased with a proportion of their raw materials, or they may purchase raw materials and advise separately, or they may hire their own nutritionist, or they may combine several of these methods. They must also seriously consider the relationships between nutrition in the feed mill and nutrition in the animal production unit, whether or not the two are integrated.

The main requirement is that management should recognise that the nutritional information input of their operation is of fundemental importance to its success, gives positive returns and has a cost. Too often in the past, feeds have been commodities and information just something that happens to arrive from time to time. A practical approach to this problem enables the management of a feed production unit to ensure that its inputs of nutritional information have a source content and cost appropriate to the real requirements of their operation.

VI. FUTURE PROBLEMS.

World population pressures are likely to having an increasing impact upon the future total supply of raw materials for animal feeds. At present substantial quanties of cereals are used in animal feeds, which could be of direct use in human diets. Signs have already appeared of pressure upon this supply, which currently provides much of the available food energy for many of the more highly productive systems of animal production.

Some forward projection (9) have indicated that by the year 2000, the pressure on cereal supplies for human needs might be such, that there could be a substantial shortfall in the amounts of cereals available to maintain global animal production at appropriate levels, even allowing for a persistent and steady increase in total crop production. Since the ruminant animal can make much better use of fibrous byproduct feeds than the monogastric, it is rational to suppose that most of the shortfall would be met by increasing diversion of cereals away from use in feeding ruminants and towards pig and poultry feeding. Indeed Reid (9) calculated that by the end of the century, this could amount to a total absence of cereals for use in beef production and a 50% deficiency in the amount available for milk production (see Table (8)).

However accurate these progratications may be, they point to a continuation of the trend already evident, towards increasing use of previously unconsidered or underutilized materials in the preparation of animal feeds. Such trends may have important consequences for the pattern of feedstuffs production and for the management of existing and new enterprises in this field.

What are the feed resources which are likely to be utilized in such developments ? They would appear to be fibrous byproducts, such as straw and forest products, recycling of animal wastes, and increased utilization of the potential of the humid tropics to produce vegetative resources e.g., (10).

Next, the use of such resources implies technological inputs beyond the normal simple processes commonly used in animal feed manufacture, in order to improve or provide adequate safety of these materials before they are fed. For example, the Comfrith process for derinding sugar cane and the alkaline treatment of fibrous raw materials are both processes which demand more technological input than the normal feed compounding operations of grinding, mixing and possibly, pelleting.

Increased technological input means increased cost, and complex evaluation problems arise concerning process cost and efficiency and animal response. Will rising transport costs make it preferable to locate processing and animal production units at the site of production of such materials and to ship out finished animal products ?.

There are many questions yet to be answered, but the possible future impact of such developments should not be disregared in any planning exercise.

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Table 1. **Examples of raw material data and product specification for least cost formulation.**

```
RAW MATERIAL   1 ON 26.04.74 @ 12.33
***********************************
BARLEY
TYPE 999
COST     55.000 [ON 17.04.74]
QTY.        .000

OIL : 1.500       CP  : 10.000      F     : 4.500

TDN : 71.000      ME  : 1420.00     SE    : 71.000

CA  : .060        P   : .370        NACL: .200

LYS : .300        M+C : .200        LIN : .700



RAW MATERIAL   6 ON 26.04.74 @ 12.34
***********************************
WHEATFEED
TYPE 999
COST     53.000 [ON 17.04.74]
QTY.        .000

OIL : 4.000       CP  : 15.500      F     : 8.000

TDN : 63.000      ME  : 1250.00     SE    : 50.000

CA  : .100        P   : .600        NACL: .050

LYS : .410        M+C : .330        LIN : 1.600



 SPECIFICATION   1 ON 28.04.74 @ 12.39
 ***********************************
 COW
 PRICE       .000 [ON 16.11.73]
 QTY.        .000

 ..........MIN........MAX..    .........MIN.....MAX..
 OIL :      2.500      4.000   RM   1     .000 100.000 BARLEY
 CP  :     16.000 99999.000   RM   2     .000  40.000 WHEAT
 F   :       .000     10.000   RM   3     .000  30.000 MAIZE
 SE  :     63.000 99999.000   RM   5     .000  30.000 SORGHUM
 CA  :      1.000      2.500   CM  10     .000  15.000
 P   :       .500    100.000   RM  14     .000  15.000 EXT RAPE
 NACL:      1.000      2.000   RM  19     .000  10.000 FEATHER MEAL
     :                         RM  20     .000   5.000 MEAT & BONE 50%
     :                         RM  22    5.000  10.000 MOLASSES
     :                         RM  25     .500   1.000 SALT
     :                         RM  29     .000   1.500 UREA
     :                         RM  30     .000   3.000 LIMESTONE
```

Table 2. An example of least cost formulation.

Part 1.

```
SPECIFICATION    1 COW

19 RAW MATERIALS ENTERED
 0 EXCLUDED. TOTAL 19

 0 CRM CONSTRAINTS
10 NUTRIENT CONSTRAINTS
..........10...........20..END


FORMAT RESULTS 22.04.74 @ 17.07
===============================
   OPTIMAL SOLUTION
SPECIFICATION    1 COW
22 MAJOR &  4 MINOR ITERATIONS
COST    53.696
LESS      .000 MANUFACTURING COST
        -------
        53.696
        -------


INGREDIENTS:
...%... ...COST.. ..VALUE..
  5.625    55.000    55.636   1 BARLEY
 23.352    70.000    72.652  11 DFC COTTON 40%
 37.045    46.000    46.341   4 OATS
 21.166    59.000    59.249   3 MAIZE
  2.066     6.000    45.265  30 LIMESTONE
   .726    15.000   157.056  25 SALT
 10.000    37.000    38.511  22 MOLASSES
```

Table 3. An example of least cost formulation.

Part 2.

```
...ANALYSIS...

OIL : 4.000      CP  : 16.000     F   : 7.475

SE  : 63.000     CA  : 1.000      P   : .500

NACL: 1.000


REJECTED:
...COST.. ..VALUE..
   76.000     74.566   12 EXT GROUNDNUT
   61.000     56.762    2 WHEAT
  165.000    140.993   27 TALLOW
   53.000     45.709    6 WHEATFEED
   55.000     47.119    7 BREWERS GRAINS
   65.000     62.345    8 BEANS
   75.000     61.593   14 EXT RAPE
   83.000     72.716   15 EXT SOYABEAN MEAL
  110.000     97.549   19 FEATHER MEAL
   95.000      7.531   26 DICALCIUM PHOSPHATE
   60.000     49.159   23 DRIED GRASS 17%
   83.000     73.668   20 MEAT & BONE 50%


SENSITIVITY:
..S.P.. ..LIMIT.. ..COST..
   .008    15.990      .006 LL CP
   .062  .    .775     .016 LL NACL
   .594    59.092     2.323 LL SE
   .031      .201      .025 LL CA
   .055     4.017      .001 UL OIL
   .015    10.161      .002 UL  22 MOLASSES
```

Table 4. Example of output from multiple product.
Least cost formulation
(from Waldroup and Johnson (2))

Ingredient Analysis

		pounds used		
Ingredient	Diet	Per week	Per ton	% of diet
Corn	A	124,595	1245.95	62.29
Soybean meal	A	39,933	399.33	19.96
Fat	A	8,994	89.94	4.50
Poultry Byproduct	A	20,000	200.00	10.00
Feather meal	A	2,275	22.75	1.14
Limestone	A	934	9.34	0.47
Dicalcium Phosphate	A	1,215	12.15	0.61
Premix	A	2,000	20.00	1.00
Methionine	A	54	0.54	0.03
Corn	B	330.072	1320.30	66.00

Mill Usage per week (lb)

	Opening Stock	Weekly Usage	Closing Stock
Corn	800,000	492.948	307.052
Soybean meal	200,000	159,189	40,811
Fat	60,000	45,378	14,622
Poultry Byproduct	20,000	20,000	
Feather meal	10,000	10,000	
Limestone	16,000	10,108	5,892
Dicalcium Phosphate	22,000	10,316	11,684
Premix	10,000	7,560	2,440
Methionine	1,500	499	1,001

Table 5. Results of Parametric Linear programming of cost of an ingredient v. its inclusion rate in a cattle feed formulation

Cost/Tonne (D.Fl)	% Inclusion
140	37.1
160	36.2
180	35.7
200	32.6
220	32.6
240	32.1
260	12.9
280	8.5
300	8.5

Table 6. Formulation of dairy cow production ration to minimum nutrient cost.

```
FORMAT RESULTS 22.04.74 @ 17.19
==================================
    OPTIMAL SOLUTION
SPECIFICATION   1 COW
10 MAJOR &  3 MINOR ITERATIONS
COST    52.512
LESS       .000 MANUFACTURING COST
        -------
         52.512
        -------


INGREDIENTS:
...%...  ...COST..  ..VALUE..
  1.623    78.000     78.067  12 EXT GROUNDNUT
  1.741   100.000    101.038  27 TALLOW
 56.168    55.000     55.047   1 BARLEY
  6.972      .000       .000  40 X
 23.304    70.000     70.669  11 DEC COTTON 40%
  2.211     6.000      9.748  30 LIMESTONE
   .780    15.000     17.316  25 SALT
  5.000    37.000     36.960  22 MOLASSES


 ...ANALYSIS...

 OIL : 4.000      CP  : 16.000     F    : 5.497

 SE  : 63.000     CA  : 1.000      P    : .500

 NACL: 1.000


 REJECTED:
 ...COST.. ..VALUE..
     61.000    56.753   2 WHEAT
     83.000    77.866  20 MEAT & BONE 50%
     48.000    45.254   4 OATS
     53.000    42.915   6 WHEATFEED
     55.000    43.470   7 BREWERS GRAINS
     65.000    63.530   8 BEANS
     95.000     6.138  26 DICALCIUM PHOSPHATE
     75.000    62.602  14 EXT RAPE
     83.000    75.673  15 EXT SOYABEAN MEAL
     59.000    58.223   3 MAIZE
     60.000    47.629  23 DRIED GRASS 17%
    110.000   104.145  19 FEATHER MEAL
```

Table. 7 Equations relating energy density (x) with egg weight, body weight increase and ME intake in White Leghorn hens fed ad libitum (De Groote (7))

Egg weight (g) $= 0.213\,x + 53.66$ ($r = +0.903$)

Body weight increase (g) $= 38.85\,x - 840.13$ ($r = +0.903$)

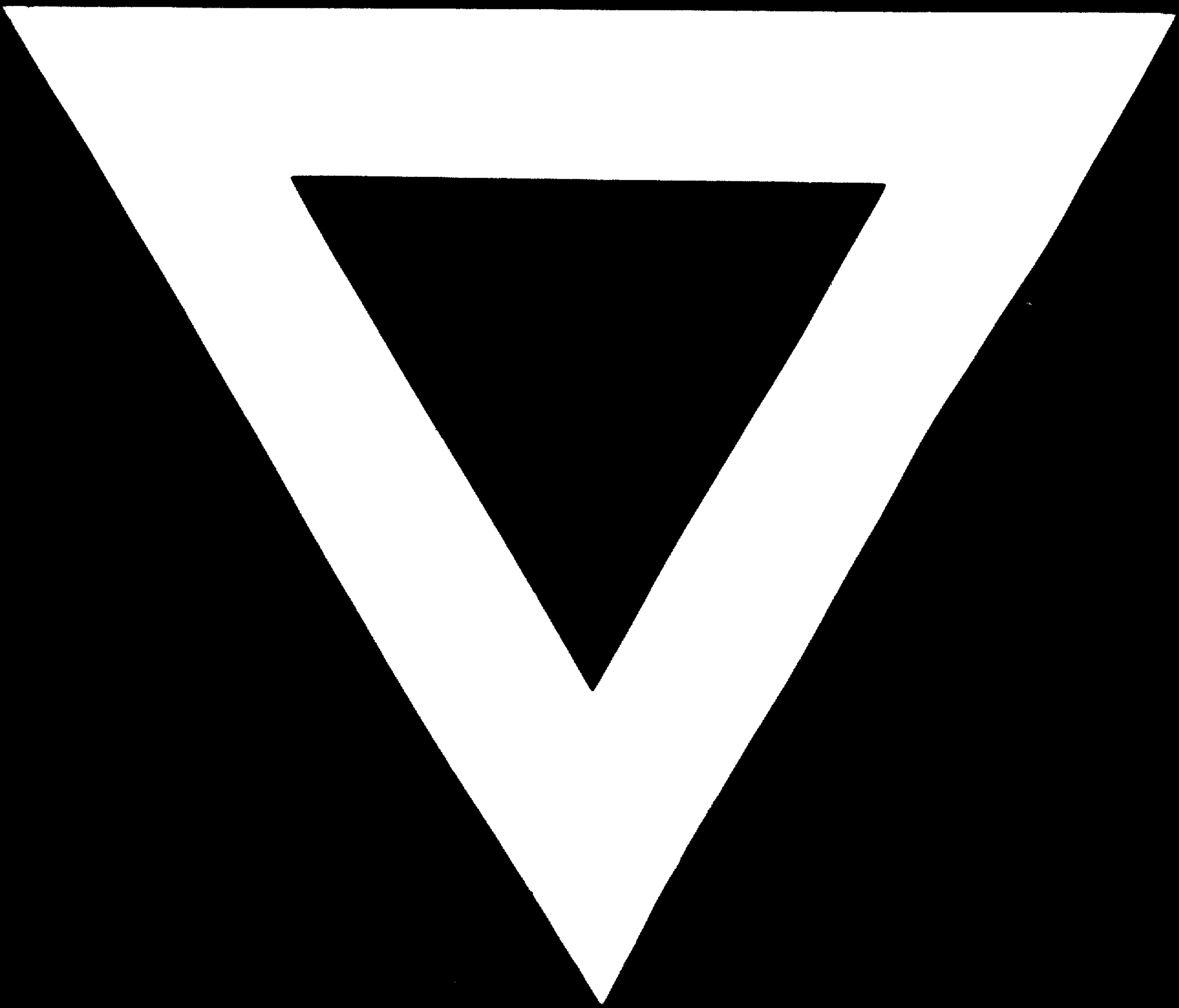
ME intake $= 3.14\,x + 236.53$ ($r = +0.858$)
(Kcal/h/d)

x = M.E. (kcal/kg diet)

Table 8. Approximate projections of cereal supply and requirements for animal production (Reid (9))

		Tonnes x 10^6 1965	1975	1985	2000
Cereal equivalent available for animal production which allows:-		541	540	508	475
Pork, Eggs, Poultry			(Supply = Requirement)		
Milk	**Produced**	373	441	524	301*
	Needed	373	441	524	677
Ruminant	**Produced**	39	46	14*	0*
Meat	**Needed**	39	46	55	71
Cereal Surplus after animal production		98	8	-144	-397

[redacted]



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