

ECONOMIC AND LEGAL ASPECTS RELATED TO THE UTILIZATION OF CERTAIN BY-PRODUCTS IN THE ANIMAL FEED INDUSTRY

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(Key words: *Economics, Legislation, By-products, Feed Industry*)
(Sleutelwoorde: *Ekonomie, Wetgewing, Neweprodukte, Voerindustrie*)

Mendoza (1972) states that the nutritional value of a feed depends not only on its intrinsic quality but also on the use the animal can make of it. The most important function of the feed manufacturer is to process different natural or synthetic ingredients in such a way as to change the potential nutritional level to actual nutritional value. This is in order to maximise the return of their nutritional elements and to satisfy the nutritional requirements of animals.

Most raw materials used by the feed industry can in essence be considered by-products with perhaps the exception of the energy feeds such as maize and grain sorghum where the whole grain is used in the production of animal feeds.

Many workers, notably Cloete (1978) and Griesel (1979) have warned that an acute protein shortage can be expected in the Republic in the foreseeable future. It would therefore seem that much emphasis should be placed on the most efficient utilisation of available raw materials.

The value of raw materials for animal feed depends on:

- 1) Nutritional elements present.
- 2) The presence or absence of any toxic materials in the ingredient.
- 3) The availability of the nutritional elements to the animal.
- 4) The palatability or acceptability of the ingredient to the animal.

The manufacturer of animal feeds in many countries, including South Africa, is controlled by legislation. The Federal Food, Drug and Cosmetic Act of the United States of America together with its numerous amendments, has been described as the most extensive law of its kind in the world. However, the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act No. 36 of 1947 of the Republic can also be con-

sidered as fairly comprehensive. The main acts of U.S.A. and the Republic together with related acts are set out in Table 1.

Furthermore, many states in the U.S.A. have passed into law a Uniform State Feed Bill which has been adopted by the Association of American Feed Control officials (A.A.F.C.O.). This Bill is enforced in conjunction with the main act.

In general terms, legislation seeks to assure the consumer that feeds and foods are wholesome, safe and effective for their intended uses and that they are produced under safe and sanitary conditions. It would appear that considerable attention, especially in European Economic community countries, is presently being given to factors such as chemical purity, pathogenic contamination, toxic residues in final product, drug resistance, occupational safety of mill workers and environmental impact.

Legislation coverage in the South African context is comprehensive. Nutritive elements in feedstuffs are given attention and consideration is given to toxic residues in the final product in S.A. e.g. hormones not permitted because of their possible carcinogenic effects. Furthermore, antibiotics, because of their possible effects on disease resistance in humans, are controlled.

The availability of nutritional elements in the raw materials and the palatability of such materials to the animal are not adequately covered. The A.A.F.C.O. of America has to some extent overcome this problem in their official and tentative definitions of feed ingredients.

The chemical or nutrient specifications of raw materials as set out in the regulations of Act 36 of 1947 (27 June, 1980) are in general satisfactory, but attention can be drawn to the example of Sunflower oilcake meal which can vary considerably in protein content depending on the cultivar available (Table 2).

Table 1*Acts related to the control of animal feeds in the R.S.A. and U.S.A.*

	R.S.A.	U.S.A.
Main Acts	Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act No. 36 of 1947.	The Federal Food, Drug and Cosmetic Act (21 U.S.C. 301 – 372)
Related Acts	<ol style="list-style-type: none"> 1) Animal Slaughter, Meat and Animal Products Hygiene Act No. 87 of 1969. 2) Medicines and Related Substances Control Act No. 101 of 1965. 3) Trade Meterology Act No. 77 of 1973. 	<ol style="list-style-type: none"> 1) Fair Packaging and Labelling Act (15 U.S.C. 1451 – 1461). 2) Sections of Public Health Service Act related to biological products (42 U.S.C. 262 – 263).

Table 2*Average Sunflower seed analysis for 1977/78 season*

	NORTHERN TRANSVAAL		EASTERN TRANSVAAL	
	FH Grade	F Grade	FH Grade	F Grade
Protein %	16,9	14,42	15,1	11,5
Oil %	42,6	29,6	41,8	32,3
Theoretical Cake Yield %	34,7	32,8	35,6	29,8
% Protein in Cake	48,7*	44,0	42,4	38,6*

Theoretical Cake Yield = $(0,944 D - H) 1,11$

Where D = 75 for FH and 60 for F Grade

H = Percentage oil in seed.

Table 3

Within laboratory analytical variation of a single sample of complete lay mash analysed a number of times

Nutrient	Times Analysed	Registered Specification	Mean	Percentage Variation from Spec.	% Variation > 4% of Mean	% Variation < 4% of Mean
Protein	55	15,0% (Min)	14,48%	3,59%	3,60%	1,80%
Calcium	32	2,7% (Min)	2,78%	2,96%	21,87%	15,62%
Phosphorus	30	0,60% (Min)	0,589%	1,86%	6,00%	10,00%

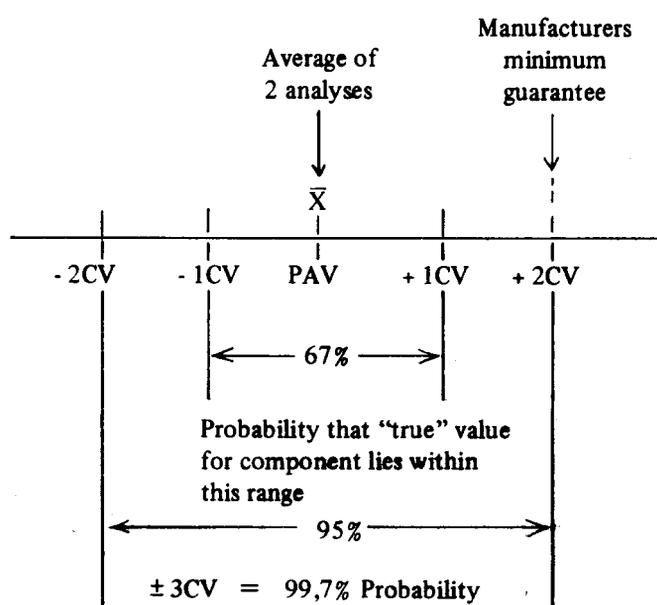


Fig. 1 Probability of "Truth" of analytical measurement (duplicate determination average) as compared to minimum guarantee for that component

This presents a great difficulty to the feed manufacturer whose raw materials must be available to the authorised inspectorate for analysis at anytime. Variation in tolerance levels is also not specified in the regulations. The importance of this can be illustrated by a within laboratory analysis of a single sample of a complete lay mash repeated 55 times for protein, 32 times for calcium and 30 times for total phosphorus over different days (Table 3).

While the variation range can be considered satisfactory it nevertheless exists and can only increase with inter-laboratory and sample variation. Some tolerance parameter would therefore seem necessary. The A.A.F.C.O. have suggested a rationale for use of permitted analytical variations (P.A.V.). It is based on the assumption that the control official would like to be reasonably well assured of the reliability of his judgement of deficiency or excess of that specific sample without allowing too large a margin necessary to provide a greater degree of reliability. Figure 1 represents the reliability ranges and philosophical basis for selecting 2 x Co efficient of variation as an appropriate P.A.V.

While the toxin and pathogenic organism contents of ingredients to be used in animals feeds are generally considered in sections 10 (1) to (4) in the regulations of Act 36 of 1947 it may be advisable to examine certain by-products commonly used by feed manufacturers in this light with a view to their more efficient utilisation by the industry. Clearer definitions of various ingredients used by the industry would undoubtedly assist in the more efficient utilisation of these ingredients. Adequate processing methods could be incorporated in definitions which would ensure not only the elimination of toxins, pathogens, inhibitory and antagonistic elements but could also increase the availability of nutritional elements to the animal.

Ingredients of Animal origin

(a) Availability of Nutritive Elements

Processing of products from the fishing and animal by-product industries have a profound effect on the availability of certain nutritive elements. The production of animal by-products requires heating for purposes of sterilisation and although heating results in some cases in an improvement in nutritional value, high tempera-

ture processing is generally harmful to protein quality. Very often overheating of a product, particularly carcass meal and blood meal, may result in a satisfactory analysis from a chemical point of view but would be unsatisfactory from an amino acid availability aspect.

It is important to note that the amino acid content of a protein, as determined by chemical analysis, does not necessarily reflect its corresponding availability to an organism. The crude protein content of a product is calculated by determining the nitrogen content and multiplying by a factor of 6,25. This factor is generally higher than the actual value and is used only to avoid confusion in the literature (Shemer, 1973). Dreosti (1970) states that for fish meal the crude protein as determined chemically is not affected by the freshness of the fish from which it is made nor by the period of storage of the fish meal nor by excessive heating during manufacture or storage. Although protein is hydrolysed by bacterial action during prolonged storage of fish the final breakdown products such as Amines and Ammonia do not escape from the fish material. There are two primary types of damage that heating may inflict on protein. The first is amino acid destruction which usually requires severe heating treatment. The second is inactivation of amino acids as a result of their combination with other food constituents such as sugar. Of all the amino acids found in food proteins, Lysine is the most often involved in an interaction with carbohydrates leading to inactivation and consequent impairment of nutritional quality.

This Maillard reaction is always accompanied by browning of the product. Several amino acids have been reported to be destroyed or inactivated during processing, especially Lysine, Arginine, Tryptophan, Histidine, Aspartic acid, Cystine and Methionine (Shemer, 1973). Other interactions such as those between proteins and lipids, protein and nucleic acid and protein and preservatives such as formaldehyde may occur (Anderson & Quicke, 1980).

South African fish meal plants often use up to 0,02 percent formaldehyde to 'firm up' fish before processing and Wessels & Marshall (1975) have shown that content of fish with 0,2% formaldehyde in most instances depressed available Lysine content of fish meal.

It is evident from the numerous reactions whereby Lysine may be rendered unavailable that the indiscriminate use of excessive heat and certain food preservatives in processing should be discouraged (Anderson & Quicke, 1980).

(b) *Presence or Absence of Toxic or Inhibitory Elements*

Harry, Tucker & Laursen-Jones (1975) have incriminated fish meal containing high levels of histamine as a cause of gizzard erosion in chickens. The amount of histamine occurring naturally in fish meals depends on the species of fish, usually pelagic, and the extent and nature of bacterial spoilage of the product. Dreosti (1970) reports that one of the most important modern methods of minimising the reactions between fat oxidation products and protein is by the use of anti-oxidants. The partial protection of Vitamin E is also important in this respect.

It is clear therefore that the most efficient utilisation of these valuable protein materials would depend on:

- 1) Correct processing.
- 2) Correct storage e.g. honeycombed temperature monitored stacks for fish meal.
- 3) Correct rotation of stocks.

In order to achieve this, more precise definitions of products may be necessary in the regulations of Act 36 of 1947.

(c) *Economic Impact*

Two trials, one on the use of overheated blood meal and the other on spoiled fish meal on the growth of chickens, illustrate possible economic implications in the poultry industry (Tables 4 and 5).

Although not strictly correct, the estimated loss which could occur, should poor raw materials be used in rations, can be very high.

Ingredients of vegetable origin

(a) *Availability of Nutritive Elements*

The problem of overheating raw materials in the process of sterilisation has been discussed in some detail in the previous section. The importance of sterilisation to eliminate pathogens cannot be overstressed but cognisance must be taken of the possible destruction of important nutritive elements such as amino acids if this process is taken too far. The major use of the heating process with regard to ingredients of vegetable origin is to eliminate inhibitory substances such as in the case of soyabean meal and this will be discussed later.

Table 4

Trial with blood meal (overheated) (1975)

1. **Biological Unit** 28 day Chick Growth Trial
 (3 Treatments, 4 replications)
2. **Analyses** (Rations Theoretically Isocaloric & Isonitrogenous)

	Blood Meal Overheated	RATIONS					
		1) Control		2) (2,5% BM)		3) (5% BM)	
		Actual	Theory	Actual	Theory	Actual	Theory
Protein	81,00%	22%	21,84%	22,9%	21,84%	21,5%	22,12%
Total Lysine	6,69%	-	1,18%	-	1,18%	-	1,26%

3. **Results** (Mass Gains)

	7 Days	14 Days	21 Days	25 Days	F.C.R.
Control	107,5	236,7	416,5	617,3	1,56
2,5% Blood Meal	101,5	227,7	401,7	602,1	1,60
5,0% Blood Meal	104,0	225,4	388,4	581,3	1,61

4. **Economics** (28 day mass)

Control - 5% Blood Meal Treat	=	36 gm
Dressing Percentage 74%	=	26,6 gm
Estimated Annual Market R.S.A.		
152 mill. Broilers	=	4043200 kg
x R1,25 per kg (Loss)	=	R5054000

Table 5

Fish meal trial (1976)

1. **Biological Unit** 35 Day Chick Growth Trial
 (2 Treatments, 4 Replications)

2. **Analyses**

	FISH MEAL		RATIONS WITH FISH MEAL	
	Source A	Source B	Source A	Source B
Protein	63,70%	67,50%	23,40%	23,20%
Lysine	4,05%	4,55%	1,29%	1,35%
Ornithine*	—	0,003%	—	—

3. **Results** Bodymass Gain 35 days

	<u>Mass Gain</u>	<u>F.C.R.</u>
Source A Ration	807,5 gm	1,79
Source B Ration	677,9 gm	1,97

4. **Commercial Trial** 2 x 10 Houses (432 000 Birds)
 53 day bodymass

	<u>Farm 1</u>	<u>Farm 2</u>	<u>Mean</u>
Source A Ration	1691 gm	1664 gm	1677 gm
Source B Ration	1619 gm	1625 gm	1622 gm
			55 gm

5. **Economics**

52 day bodymass

Treatment A – Treatment B	=	55 gm
Dressing Percentage = 74%	=	41 gm
152 million Broilers Market R.S.A.	=	6384000 kg
x R1,25 per kg (Loss)	=	R7980 000

* Presence of Ornithine indicates spoilage.

In many rations, particularly those for monogastrics, the form in which mineral nutrients are supplied is important. Inorganic sources are generally well absorbed by monogastrics which are, however, unable to absorb phosphorus in the phytic acid bound form (Oser, 1965; Scott, Nesheim & Young, 1968; Ensminger & Olentine, 1978). Further, phytin binds iron and calcium which interferes with their absorption. Wheaten bran, having many benefits, is often a major constituent of horse feeds but absorption of phosphorus from this feedstuff is reported by Borton (1974) to be only $29,5 \pm 3,0$ percent because of its chytin content. When formulating rations for monogastrics, care must be taken to ensure that there is sufficient available phosphorus in the rations.

(b) *Presence or Absence of Toxic or Inhibitory Substances*

(i) *Soyabean Meal*

Griessel (1979) has estimated that the Soyabean oilcake meal requirement in the Republic by the year 2000 could range between 346 000 to 425 000 tons primarily due to the declining fish meal production. Present Soya-bean production falls far short of this and warrants attention particularly since the oil expressing industry tends to avoid using Soya because of its low oil content compared to Sunflower.

Among the nitrogenous constituents in the meal are various toxic, inhibitory and stimulatory factors. These consist of antioxygenic, allergenic, goitrogenic, haemagglutinogenic factors and an anticoagulant factor which has been identified with a Trypsin inhibitor.

This factor can be destroyed by heat to make the protein available. Unprocessed Soyabean meal contains a urease enzyme, the activity of which, is associated with the destruction of the Trypsin inhibitor. This activity is relatively quickly and easily analysed and is therefore used as an indication of Trypsin destruction (Smith, 1979). Raw uncooked Soyabean meal shows a pH rise of around 2 which falls fairly rapidly as the meal is toasted. A pH rise of 0,2 during cooking is considered adequate. As the cooking time increases, the meal will eventually record a pH rise of zero. Since it is impossible to know whether a zero rise in pH indicates a meal that is perfectly cooked to the point of destroying the urease and antitrypsin enzymes or whether it was overheated and the protein damaged, the lower value of 0,05 is indicated as a check against overcooking. Therefore a mean value of 0,05 to 0,2 pH rise is considered a proper cook in Soyabean meal as illustrated in Table 6.

The effect of overheating on one amino acid, Methionine is illustrated in Fig. 2.

Table 6

Effect of proper processing on the nutritional value of soyabean (Adapted from Hayward, 1975)

	Urease Activity Increase in pH
Soyabean raw	1,90
Soyabean meal unheated	1,80
Soyabean meal mildly heated	0,75
Soyabean meal properly cooked	0,20
Soyabean meal overcooked	0,05

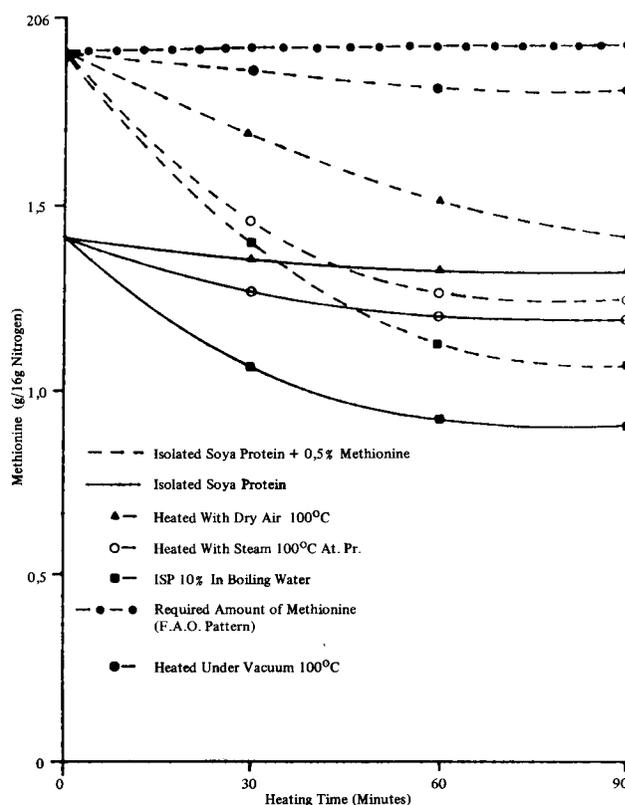


Fig. 2 *Methionine content of soyabean protein isolate as a function of heating time (Shemer, 1973)*

ii) *Cottonseed Oilcake*

Cottonseed oilcake meal is rapidly becoming an important ingredient in livestock feeds. However, cottonseed contains the toxic substance Gossypol which in the processing of the seed can lower the quality of the protein. In particular the amount of available lysine is reduced. Gossypol which binds with iron will depress growth and reduce feed intake. Since Gossypol is a pigment, probably its most important economic effect is in layer rations where it is transmitted to the egg and in combination with iron, produces an objectionable olive green discolouration of the yolk. This can occur when dietary levels of free Gossypol exceed 50 p.p.m. in the layer ration. Care must be taken in formulating layer rations not to exceed this free level of Gossypol. Levels of free Gossypol up to 150 p.p.m. may be used for broilers without adverse effect and pigs are unaffected by levels up to 100 p.p.m. In animals with a functioning rumen, the rumen fermentation action and by-products render the Gossypol inert (Smith, 1973). However, Jiminez (1980) reports that dairy cows receiving 1,78 kg of cottonseed meal per 50 kg livemass and having a Gossypol content of 0,225% showed a drastic drop in dry matter intake with a strong indication of decrease in persistency of milk production. The addition of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ to the meal will, to a certain extent minimise the effects of Gossypol.

iii) *Groundnut Oilcake Meal*

Groundnuts are probably the most susceptible of all crops to the growth of moulds, both in the field and under poor storage conditions. Of particular importance are the toxigenic strains of *Aspergillus flavus* which cause the disease aflatoxicosis. Experimentally all species of animals tested have shown some degree of susceptibility to aflatoxins. The carcinogenic effect on the liver has been demonstrated in several species. However, as opposed to other toxins provision has been made in the regulations of Act 36 of 1947 (Reg. 10 (3)) and the applicable table where maximum aflatoxin (B1) content in farm feeds is specified.

iv) *Grain Sorghum*

While Grain Sorghum cannot be considered a by-product in the true sense of the word, it is for economic reasons assuming great importance as an ingredient in livestock feeds. Certain cultivars, mainly the K.F. class, combining all the birdproof cultivars always have higher but widely varying polyphenol contents, than other cultivars. The K.F. class is popular because of its yield and its birdproof attribute. Comparative cultivar polyphenol content was reported by Daiber (1976) in (Table 7).

Table 7

*Polypheno. content of grain sorghum cultivars
(Expressed as tannic acid equivalent)*

Cultivar	Number of Analyses	Mean T.A. Equivalent
K.F.	34	1,128
K.R.	6	0,136
K.W.	2	0,062
K.M.	52	0,108

The polyphenols or tannins have anti-nutritional effects. Price & Butler (1980) suggest 6 lines of explanation for this anti-nutritional effect.

- (1) Tannin depresses feed intake.
- (2) Tannin complexes with dietary protein or other dietary compounds.
- (3) Tannin complexes with digestive enzymes interfering with normal digestion.
- (4) Tannin complexes with sufficient (high quality) endogenous protein to provide a drain on the nitrogen supply and essential amino acids in particular.
- (5) Tannin complexes with or injures parts of the alimentary tract itself interfering with its function and
- (6) Tannin or its hydrolysis products are absorbed and have a toxic effect elsewhere in the body.

It is suggested therefore that it is necessary to specify maximum polyphenol content of this raw material when it is used for animal feeds.

v) *Poultry Manure*

Much has recently been written on the use of poultry manure in livestock feeds. The potential effects of nutrient imbalances in this material and excess mineral

content such as copper have been reported (van Ryssen, 1980). Regulations of Act 36 of 1947 have defined specifications required for registration of this product with particular emphasis on sterility requirements. However, considering the looming protein shortage in this country and the current availability of some 373 200 tons of this product (Griessel, 1979) it is important to realise that even unsterilised poultry manure can provide a means of combatting this shortage if it is used more extensively in ruminant rations. One ton of this material can provide a protein equivalent of 200 kg which would be sufficient for a daily protein supplement for 1000 head of cattle grazing on natural pasturage.

It is common knowledge that farmers use considerable quantities of poultry manure registered as a fertiliser in the unsterilised form for use as a feed supplement for their livestock. Aside from the inherent danger of the presence of pathogenic organisms such as *Clostridium botulinum* in poultry manure, it is also unbalanced. It is therefore necessary, even if adequate inoculation programmes are carried out, to balance poultry manure with other feed ingredients to ensure maximum livestock response. Presently animal feed manufacturers are prohibited from manufacturing and advocating balancing supplements to be fed in conjunction with poultry manure and it is felt that some provision for this practice should be made in the regulations of Act 36 of 1947. The Minister of Agriculture has designated power in section 7 (bis) of Act 36 of 1947 to prohibit the use of poultry manure as a farm feed but it is felt that in the national interest it would be unwise to do so in view of expected protein shortage.

Processing of products in general

The economic performance of a feed is to a large extent dependent on the processing, chemical, thermal or physical. The thermal and chemical effects on protein availability have to a certain extent been discussed. Harris & Crampton (1972) list 7 purposes for the processing of feeds:

- (1) To isolate a specific part.
- (2) To improve acceptability.
- (3) To alter particle size.
- (4) To improve digestibility.
- (5) To extend shelf life or to preserve.
- (6) To alter material make-up.
- (7) To detoxify.

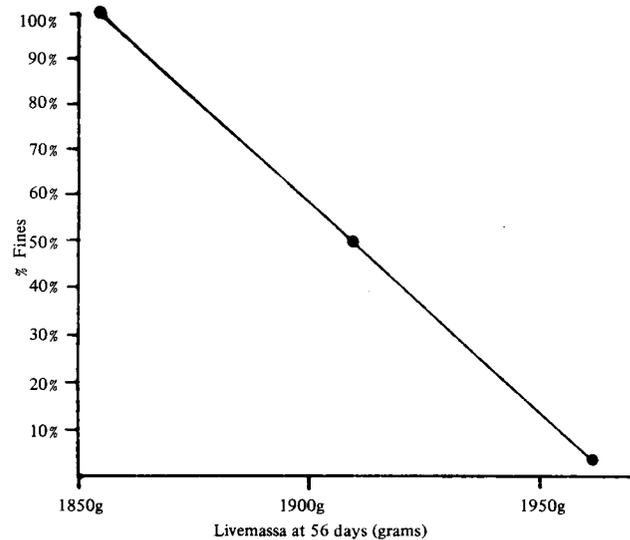


Fig. 3 Effect of pellets and fines on broiler livemass

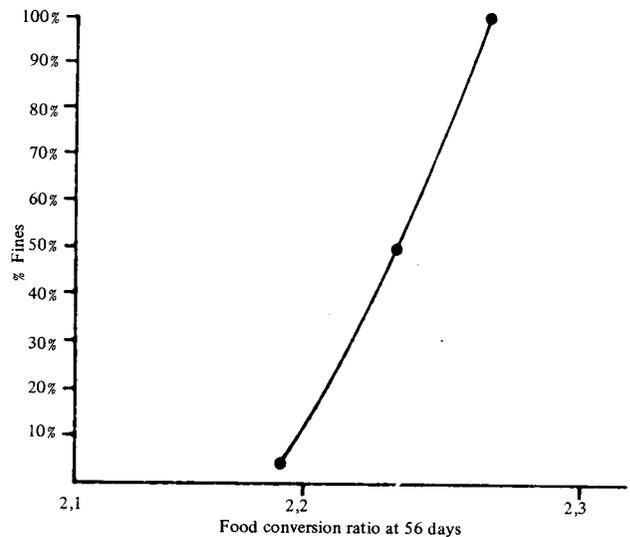


Fig. 4 Effect of pellets and fines on broiler feed conversion rate

The physical and correct thermal processing of feeds to a certain degree assists in meeting all these purposes. In general, when starches are cooked the starch granule absorbs water, swells and may finally rupture. Starch, when it has been cooked, is highly water absorbent and tends to form a gel which is more readily subject to breakdown to simple sugars (Pfof, 1971).

The pelleting process, where temperatures of approximately 80°C for short time periods are achieved, contributes to improved digestibility and the utilisation of feeds. Harmin & Stephenson (1960) fed diets which were composed of different proportions of mash and

Table 8

The effect of physical nature of feed on broiler performance

Feed	56 Day Body-mass	F.C.R.
Mash	1660 gm	2,31
Pellets	1961 gm	2,19
50% Mash 50% Pellets	1909 gm	2,24
Milled Pellets	1854 gm	2,28

pellets to broilers. In these experiments it was found that diets which were composed of 75 percent pellets and 25 percent mash, produced rates of gain superior to those of broilers fed entirely pellets. However, in a later South African factorial trial (1975) broilers were fed rations:

(a) consisting entirely of mash.

(b) pelleted rations.

(c) rations consisting of 50% pellets and 50% mash and

(d) rations previously pelleted and milled to mash.

Results are presented in Table 8 and Figures 3 and 4.

Improvement in final mass of broilers in this trial was linear depending on the percentage of pellets in the feed. Improvement in feed conversion rate also approached linearity indicating improved digestion and utilisation from the pelleting process. It is interesting further, to note that performance was superior on the mash that had been previously pelleted and milled when compared to unpelleted mash suggesting that the thermal process involved in pelleting improved digestibility. The 301 gram, 56 day bodymass difference found between the pelleted and mash treatments could on a national scale mean a loss to the broiler industry of some R42320 600 when calculated by the method used in Table 4.

Conclusions

The more efficient usage of proteinaceous by-products can be enhanced by extended legislation to allow for tolerance levels in analysing for chemical constituents of ingredients as also to allow for clearer definitions of ingredients involving processing requirements, to eliminate toxic elements and make nutrients more available and acceptable to livestock.

References

- ANDERSON, T.R. & QUICKE, G.V., 1980. Available Lysine 1. Factors Affecting Availability *S.A. Food R.* Oct – Nov. 1980.
- ASSOCIATION OF AMERICAN FEED CONTROL OFFICIALS, 1979. Off. Publ.
- BORTON, A., 1974. Trends in Phosphorus for Horses *Feedstuffs*, Oct 7th.
- CLOETE, J.G., 1978. Protein Requirements of the South African Livestock Industry during 1980. Res. Inst. for Anim. Husb. and Dairying Pretoria.
- DAIBER, K.H. & VAN BELLINGHEN, R., 1976. Polyphenol Content of Grain Sorghum Cultivars. B.B. 82 (Special report) C.S.I.R. Pretoria.
- DREOSTI, G.M., 1970. Good Quality Fish Meals. Fisheries Nutr. Symp. Washington D.C.
- ENSMINGER, M.E. & OLENTINE, C.G. Jr., 1978. "Feeds and Nutrition Complete" Ensminger Publ. Co. Cloris Falif. U.S.A.
- GRIESSEL, M., 1979. A Protein Utilisation Strategy for South Africa. *S. Afr. J. Anim. Sci.* 9, 119.
- HARRY, E.G., TUCKER, J.F. & LAURSEN-JONES, A.P., 1975. The Role of Histamine and Fish Meal in the Incidence of Gizzard Erosion and Pro-Ventricular Abnormalities in the fowl. *Br. Poult. Sci.* 16 69.
- HAYWARD, J.W., 1975. Precision Processing of Soybean Meal. *Feedstuffs*, Apr. 28th.
- JIMINEZ, A.A., 1980. Gossypol and the Lactating Cow. *Feedstuffs*, June 23rd.
- MENDOZA, E.G., 1972. Observations of a Feed Manufacturer. Effect of Processing on the Nutritional Value of Feeds. *Nat. Acad. Sci. Washington D.C.* p 228 – 235.

- OSER, B.L., 1965. "Hawk's Physiological Chemistry", 14th Ed. London McGraw-Hill Book Co.
- PFOST, H.B., 1971. Effect of Feed Processing on Digestibility of Animal Feeds. Nutr. Conf. for Feed Manufcts: 5. Eds. H. Swan & D. Lewis, London. Univ. Nott. Churchill Livingstone.
- PRICE, M.L. & BUTLER, L.G., 1980. Tannins and Nutrition. Dept. Biochem. Aq. Exp. Sta Purdue Univ. West. Lafayette Ind. Bull 272.
- REPUBLIC OF SOUTH AFRICA STATUTES, 1947. Fertilisers, Farm Feeds, Agricultural Remedies and Stock Remedies Act No. 36 of 1947. Govt. Printer, Pretoria.
- SCOTT, M.L., NESHEIM, M.C. & YOUNG, R.J., 1968. Nutrition of the Chicken Publ. M.L. Scott & Assoc. Ithaca, N.Y.
- SCHEMER, M., 1973. Studies on the Effect of Thermal Processing on the Chemical, Nutritional and Functional Properties of Soybean Protein. Phd. thesis Dept. Food Tech. Univ. Illinois, Urbana Champaign U.S.A.
- SMITH, K.J., 1973. Alternative Sources of Protein for Animal Production. Nat. Academ. Sci. Proc. Symp. Virg. Poly. Inst. Blacksburg Va. July 31, 1972.
- SMITH, K.J., 1977. Soybean Meal: Production, Composition and Utilisation. *Feedstuffs*, Jan 17th.
- U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE. Requirements of Laws and Regulations enforced by the U.S. Food and Drug Administration. Publ. Health Service U.S. Food & Drug Admin.
- WESSELS, J.P.H. & MARSHALL, B.C., 1975. Effect of Formaldehyde on Biologically and Chemically Available Lysine Content of Fish Meals. *Agroanimalia* 7, 1.
- VAN RYSEN, J.B.J., 1980. Poultry Waste and Copper Toxicity. *Vleis/Meat*, April 1980 p 13.

