Protein Products and Hulls for Animal Foods

R. ROBERTS, Research Manager, J. Bibby Agriculture Ltd.,
Liverpool, England

ABSTRACT

The acceptability of a raw material to the animal feed industry is based on two parameters—it must be both safe and economical. Approximately 90% of the world production of oilseeds is supplied by five materials—soy, cotton, groundnut, sunflower, and rape—and it is interesting that three of these materials contain significant antinutrients. The large use of soy in animal feeds is indicative of the part played by the seed processor in improving the value of a product, and work with both chicks and calves will be discussed in this area. The use of cottonseed in the U.K. is virtually restricted to ruminant feeds because of their tolerance to gossypol, but the significance of the processing in minimizing the level of free toxin and the antidote effect of soluble iron will be considered. Rapeseed is taking on a major role in the EEC. While the geneticist has made significant contributions in recent years and the processor still has his part to play, problems with the oilseed are not all solved, and this complex of activity will be discussed. The economic value of a commodity is a sum of the value of its individual nutrients and the rightness of dehulling, and the overall effect of processing conditions, both good and bad, can offer an optimum compromise. This optimum compromise is still our goal.

Nearly 90% of the total world production of oilseeds is provided by five materials—soy, cotton, groundnut, sunflower, and rape—amounting to a total of over 100 million tons. My own company is similarly dominated by these materials, and during 1974, 99.6% of vegetable "protein sources" emanated from these five materials which also accounted for 80% of our usage of both vegetable and animal protein materials. The United Kingdom's usage of rapeseed meal may be atypical in that soy and rape together accounted for 67% of all protein sources.

Such data clearly indicate the importance of these materials and highlight the need for the highest standards of seed processing to ensure optimum nutritive value in oilseed residues. One may occasionally get the impression that processing methods under commercial conditions are biased towards oil extraction rather than the residual meal quality but, in the context of intensive livestock production, safety of the product and availability of essential amino acids to the animal are vital parameters in the economy of meat production. It is the purpose of this paper to cover briefly the aspects of safety, protein quality, and material value in the complex of vegetable proteins and residues in an attempt to establish economic interactions which are significant and should be considered when one considers the value of further processing.

It is interesting that three of the selected vegetable materials in the raw state contain significant levels of antinutrients which are of primary consideration to the processor. Soybeans contain a number of such factors, including a trypsin inhibitor, a hemagglutinin, and saponins. It is very satisfying that, even with such a burden, it now dominates the vegetable protein field. The inhibiting effect of raw soybean meal on protein digestion has been the subject of extensive research, and the application of heat during processing of the beans has done much to minimize this effect. Some years ago, the repeatability of both the urease and dye binding tests were compared as monitors of heat treatment, and the data are presented in Table I.

Two major aspects emerged in that we found the dye binding technique more reproducible than the urease test and that both these tests classified the commercially heated soy extract as being slightly underheated. While it is well accepted that application of heat will significantly reduce trypsin inhibition, it must also be accepted that excessive heat can lead to damage of the protein itself. Evans et al. (1) examined the release of both cystine and methionine from soybean proteins before and after autoclaving under various digestive procedures.

Bielorai et al. (2) examined the digestion and absorption of raw and heated soybean meal along the intestinal tract of the chick. While confirming the poorer growth on raw material, they found that the absorption process was enhanced in the jejunum, which was the main site of absorption, and not impaired by raw soy, but the 20% net reduction in absorption resulted from inhibition in digestion beyond the duodenum probably due to inactivation of trypsin by inhibitor not allowing further digestion in this area. These authors could not explain the growth depression solely on the basis of reduced nitrogen digestion and

TABLE I

Influence of Mixtures of Commercially Heated Soybean Extract and Solvent Extracted Raw Soybeans on Wt Gain of Chicks, Urease Activity, and Dye Binding of Protein

HS[a] (%)	RS[b] (%)	Wt gain[c]	FCR[d]	Urease[e] (mg/g)	Dye binding[f] (mg/g)
100	0	223	2.10	37	3.64
80	20	209	2.18	84	3.18
60	40	184	2.46	177	2.75
40	60	176	2.54	228	2.18
20	80	147	2.80	403	1.86
0	100	145	2.88	526	1.33

[a]HS = commercially heated soybean extract.
[b]RS = solvent extracted raw soybeans.
[c]Wt gain of chicks between 10 and 20 days of age.
[d]Feed conversion ratio: g feed/g wt gain.
[e]Internal method.
[f]See ref. 13.

absorption. One may conjecture that progress in this field is still possible.

The use of soy protein concentrates, both with and without soy oil, in the feed of young calves and pigs as a replacement for milk protein has opened up a new field. The degree to which trypsin inhibition must be reduced is still open to debate, but our work would certainly indicate a continual superiority of milk protein over a variety of soy products in terms of both gain and feed efficiency. However, the potential for reducing feed costs is significant and stimulates further research.

Cottonseed ranks second in world vegetable protein production. In this case, one could look upon both oil and seed residue as by-products, with cotton fiber the primary product. Gossypol is the major antinutrient in this material and historically has limited its use in the United Kingdom to feed for ruminants. In the present economic climate, a greater flexibility of uses would be desirable; elimination of gossypol and cyclopropenoids would help this end considerably. While free gossypol is the major toxin, the level of bound gossypol is significant in the context of protein availability, and minimization of both would be the target.

Damaty and Hudson (3) describe the preparation of low gossypol cottonseed flour, but two separate solvent systems are involved, hexane and acetone. This may limit its application to human use because of cost. The production of gossypol-free cultivars is an exciting approach, but it would appear that glandless cottonseed has poor lint quality, late maturity, and reduced insect resistance.

The most practical approach at the moment would appear to be the selection of material with both a low bound and free gossypol level. Prepressed solvent extracted meals would appear to be the best compromise. To this can be added a complexing ion such as iron, and Shieh et al. (4) suggested that a one-to-one molar ratio is optimal, and the solubilizing effect on the gossypol:iron complex of phosphate could be counteracted by the addition of calcium.

While this treatment could increase the use of cottonseed meal in swine and poultry feeds, one must still consider the implications of cyclopropenoids in "mulberry heart" in pigs and pink whites in eggs. This, together with the relatively low energy content of cottonseed meal, may be the commercial economic barrier.

The third potentially toxic oilseed I would like to consider is rapeseed. This material has unique significance in the United Kingdom, with official encouragement as a crop within the EEC and an expected 200,000 acres in 1978. Blair and Scougall (5) examined 11 samples of rapeseed meal including both *Brassica napus* and *Brassica campestris*. They concluded that with reference to goitrogenic factors both *B. napus* and *B. campestris* had similar levels of isothiocyanate, whereas the levels of oxazolidenethione were much lower in the latter, with means of 6.71 and 2.51 g/kg for *B. napus* and *B. campestris*, respectively. One would, therefore, be tempted to favor *B. campestris* as a main crop, but *B. napus* seems more suited to the United Kingdom climate. However, it is recognized that the seed processor can play a significant part in reducing the effect of glucosinolates.

Myrosinase, an enzyme system capable of hydrolyzing glucosinolates to produce toxic compounds, can be effectively destroyed by the application of dry heat in a closed vessel at 90 C for 15 min. Higher temperatures produce additional improvements.

Josefsson (6) reported the effect of heat treatment on the low glucosinolate cultivar Bronowski, as he had previously found that heat treatment is necessary for the production of meal of high nutritional value even when the glucosinolate content is low. He concludes that treatment at 100-110 C for 15-60 min and 8% moisture is the best compromise between poor myrosinase destruction at 4% and high lysine damage at 12% moisture levels.

A further advance has been made in recent years by the genetic selection of varieties, not only low in their content of glucosinolates but also erucic acid, since this acid has possible implications with human heart disease. Erglu and Tower are examples of such varieties, but there is little information at the moment on their significance in animal nutrition, except that of Aherne et al. (7), who compared the inclusion of 15% low and high erucic acid rapeseed oil in the diet of pigs between 20 and 90 kg. Pig performance was not affected, and digestibility coefficients for energy nitrogen and lipid could not be differentiated. However, the pigs preferred the diet containing low erucic acid oil when given a free choice.

The palatability of rapeseed meal is a significant parameter limiting its inclusion in cattle and pig diets. In the case of poultry, the production of taint in eggs is currently excluding the material from all our poultry feeds. Overfield and Elson (8) worked with brown-egg laying birds and found that as little as 3% of rapeseed meal produced eggs with a taint described as fishy or crabby, with no effect on the health of the birds nor their production. This aspect was further investigated by Hobson-Frohock et al. (9), who found that the active principle for egg taint was trimethylamine and postulated a genetic defect in certain birds affecting their ability to oxidize trimethylamine to trimethylamine oxide. The nature of the active compound, possibly an inhibitor to trimethylamine oxidase, in rapeseed meal is as yet unknown.

The maximization of this important crop is therefore still limited by aspects of palatability and egg taint, despite vast strides in the areas of production technique, processing conditions, and genetics. However, time may prove that the most recent varieties will show improvements in all areas.

In contrast to soy, cotton, and rapeseed meals, groundnut and sunflower meals can be considered comparatively safe protein sources, and their use is mainly limited by the simple complex of nutrient value and cost. However, the impending regulations in the EEC may severely reduce the offtake of groundnuts and any other contaminated material through a maximum permitted level of aflatoxin produced by the mold *Aspergillus flavus*. Such regulations would stimulate efforts in improved storage, harvesting, and treatment, and Mann et al. (10) investigated the effect of heat on aflatoxin in oilseed meals with little practical effect. They treated contaminated cottonseed and groundnut meal at various temperatures and moisture levels for varying times and found that, for the cottonseed meal, the upper practical limit was 100 C for 150 min at 15% moisture, reducing the level of toxin by 70%. Their treatment of a contaminated groundnut meal was even less successful, as they only produced a reduction of 34% after treatment at 100 C for 120 min at 30% moisture. In addition to the problems of producing a plastic mass under such conditions, one could conjecture that the protein quality could well have suffered, as there was some darkening of the meal during processing, and the cost of such treatment coupled with some reduction in protein quality could make this type of approach completely uneconomical.

Reverting to my original brief—namely, the production of safe, high quality protein meals at economical prices—demands some consideration of the components that contribute to the value of the complete meal. Aspects of safety will restrict the inclusion of a product between complete exclusion of a highly toxic material to limited use at, say, 2.5 or 5% with one of limited toxicity. Considering the anticipated maximum permitted level of aflatoxin under EEC regulations as 0.02 mg/kg in supplementary feeds for dairy cows, the maximum tolerable level of cottonseed meal as used by Mann et al. (10) reported above would be 13.9%, and available data for aflatoxin B in groundnut samples would restrict the average usage to approximately 4%, with levels of 0.5 mg/kg in more than 90% of West African and Indian groundnut products. Such limitations could be extremely costly under certain commodity price

TABLE II

Nutrient Constraint Costs (£/unit)

	Cattle group[a]	Layers group[b]	Broiler finishers[b]
Energy	0.815	0.0336	0.06
Crude protein	0.522	0.656	--
Lysine	--	3.614	13.78
Methionine	--	8.600	9.36[c]
Phosphorus	5.522	5.453	6.04
Calcium	0.195	0.0917	1.05
Total	0.017	0.0344	--

[a]February, 1976.

[b]January, 1976.

[c]Methionine and cystine.

situations where considerably higher levels would be economical. This must act as a stimulus to producing countries to reduce the level of contamination. Similarly, the permitted maximum for free gossypol could be 500 mg/kg for supplementary dairy feeds and 100 for poultry other than layers, and such limits could restrict the inclusion of cottonseed meal in such feeds to 3.3 and 0.7%, respectively, by taking the level of free gossypol found by Damaty and Hudson (3) in hexane extracted cottonseed flakes. Here again, the cost of such limits could be considerable, as detoxification of contaminated groundnut with ammonia has been estimated as costing approximately £10/ton.

Following such considerations, however, one must assess the cost of any further processing and the added benefit of such processing in terms of improved nutritional value. The value of a commodity to the compounder and hence the livestock producer is a sum of the individual values of each contributed, cost limiting, nutrient. This is reflected in various dehulling operations aimed at improving the nutrient density of oilseed meals. The production of 50% soybean meal is long established, and Bayley and Hill (11) assessed the nutritional value of low and high fiber fractions of rapeseed meal while Kinard (12) published a paper on the feeding value of sunflower meal and hulls. One would suggest the use of the improved material in the diet of monogastric animals, while the high fiber fractions and hulls find a place in ruminant feeds. One can use the nutrient constraint costs of laying feeds and cattle feeds to assess the economic significance of such operations; Table II presents such costs for February 1976 in my company's forward buying program.

Using these data, one can calculate the value of sunflower meal containing 23% crude fiber as £84.01/ton and dehulled sunflower meal as £96.13/ton at 12% crude fiber. However, the value of the hulls in the cattle group amounts to only £23.54/ton and, assuming a 30% extraction, the dehulling operation results in a reduction in value of 11.5%. Carrying out a similar exercise with soybean meal produces a different picture, but the overall improvement in value is only 4.7%. It would be for the processor to decide whether such a markup in value would merit the additional cost involved in dehulling. The type of feed used in the exercise is extremely important in such calculations if one is to maximize the benefit of added processing and carrying out a similar exercise for soybean meal. However, in the context of a broiler finisher, feed using the constraint costs in Table II produces an overall improvement of 8.5%. It is quite clear that one should assess the market before becoming involved in new plant and equipment and to ensure that an adequate return can be realized from the partition of established commodities into fractions that will be accepted at realistic costs.

The same principles apply to heat treatment of raw materials to either enhance the protein value or conversely run the risk of reducing the availability of certain amino acids during the destruction of antinutrients. Lysine is an amino acid that is often first limiting in a formulation and therefore carries a significant cost in many finished feeds for monogastric animals. Lysine in current layer feeds accounts for approximately 10% of the total value of soy, rape, and cottonseed meals, but the relative figures of 12.6, 9.1, and 7.3% would suggest that avoidance of any "destruction" of this amino acid during processing would be more significant in the case of soy meal than in the case of cottonseed meal because of the different combination of nutrients in these three protein sources. Conversely, energy is a significant cost factor in most areas, and vegetable proteins tend to have comparatively low levels of energy. This entity amounts to approximately 40% of the total value of soy, rape, and cottonseed meals in layer feeds but, again, the percentages are 38.6, 36.7, and 44.5, respectively, and these would suggest a greater benefit in cottonseed from a dehulling procedure aimed at improving nutrient density. However, it would still be necessary to carry out the earlier exercise into real added value in the context of the market one hopes to satisfy.

A high proportion of the world's oilseeds contain factors that demand special treatment if the feeding of the protein residue following oil extraction is to satisfy the demands of present day poultry and livestock production. Application of additional heat has in most cases shown benefit, and it is the degree of sophistication in this application that will optimize the needs for oil extraction and meal quality. The availability of amino acids rather than crude protein content will limit animal performance, and one could hope that in the not too distant future some yardstick of quality could be included in the contract for sale. It is certain that national and international regulations will move progressively to upper permitted limits of toxic factors and here, too, a commodity should be purchased on the basis of such criteria.

The rightness of partition of meal into high and low value fractions will usually depend on factors of market need and relative product value, and the market is well geared to make such calculations. However, the world is a wide and heterogeneous market with very widely differing forces prevailing in terms of both economics and need, and these may often demand optimization of what one has in terms of indigenous materials rather than importation at high cost. Such pressures will continue to act as a stimulus to all involved in natural products to process a selected crop in a manner which provides the best in both safety and economic acceptability to the market.

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