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Economic Potential for Nutritional Improvement in Feed Grains

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ABSTRACT

Feed grains researchers have abundant technical opportunities to select various options for improvement of nutritional characteristics of feed grains. Choosing between those opportunities is a difficult issue for research funding organisations. In this paper, efforts to address the relative economic benefits from the different options for feed grains nutritional improvement are reported. The economic benefits arising from nutritional improvements in various feed grains are examined and compared to the benefits from increasing yields of the feed grains rather than improving their nutritional value. The results of the analysis of these options are presented in an economic surplus framework that enables the major beneficiaries and the relative gains for the different feed grains research options to be identified. The outcome of this analysis provides a basis for establishing priorities for feed grains research.

KEY WORDS: research, feed grain, nutrition, value

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1. Introduction

Feed grains researchers have suggested a number of options for improving the nutritional composition of feed grains that would make them more valuable to the livestock industries that use them (GRDC 1995). The aim of most of these new options is to introduce specific characteristics through genetic means to improve the nutritional value of the grains. An alternative strategy to research on improving the nutritional composition of feed grains is research aimed at increases in yield through high yielding varieties which would enable the feed grains to be supplied at a lower price, and hence reduce the cost of the feed mix for the livestock industry.

In assessing research priorities in the area of feed grains quality improvement, there has been a lack of information on the economics of the various research options. In recognition of that knowledge gap, the Grains Research and Development Corporation has funded a project, "Economic assessment of improving nutritional characteristics of feed grains". The analysis reported in this paper is the result of that project, which provides for the first time a comprehensive set of information on the value of improving different characteristics of feed grains for animal nutrition. The project also provides information on the distribution of the benefits of that research.

The objective of this paper is to assist in the determination of research priorities in the feed grains sector. The process that was undertaken in that project is outlined, and a report on the results that were obtained is presented. In the following section, the analytical approach taken is described, and the methods used to evaluate the impact of new feeds are explained. In section 3, the analysis of the selected set of potential new feed grains is outlined, and details of the data used for the analysis are given. In Section 4, the results of the analysis are presented, and in section 5, the economic potential of those new feeds is discussed, along with the issues associated with using these results to develop research priorities for feed grains. In the final section, some conclusions are drawn from the analysis that has been presented.

2. Potential New Feed Grains for Analysis

A number of options for improving nutritional characteristics in different feed grains have been identified by scientists and industry specialists. The aim of these new options is to introduce specific characteristics through genetic means that help to improve the nutritional value of the grains.

A comprehensive set of options for new feed types has been evaluated, to establish the options with the highest priorities for research. The options evaluated are listed in Table 1. The options involving nutritional improvement are classified as follows:

- Feeds involving change in protein content
- Feeds involving change in amino acid profile
- Feeds involving improvement in feed digestibility and efficiency
- Feeds involving reduction in anti-nutritional factors

Details of the nutritional specifications of each of the new feeds are found in Brennan and Singh (2000).

Table 1: Options for Improved Nutritional Feed Grains Composition Evaluated

Feeds involving change in protein content
High protein feed wheat
High protein barley
High protein oats
High protein lupins
Feeds involving change in amino acid profile
High lysine wheat
High methionine wheat
High threonine wheat
High sulphur amino-acid lupins
Feeds involving improvement in feed digestibility and efficiency
Hull-less barley
Low seed coat content barley
High seed coat digestibility barley
Naked oats
High oil barley
High oil oats
High oil sorghum
High oil maize
High oil lupins
Waxy sorghum
Low protein degradability lupins
Feeds involving reduction in anti-nutritional factors
Low arabinoxylan wheat
Low beta-glucan barley
Low beta-glucan oats
Low lignin oats
Low tannin sorghum
Low oligosaccharide lupins

For comparison, the value of the options for improvements in nutritional composition is also compared to the value of increases in yield that would enable the feed grains to be supplied at a lower price, and hence reduce the cost of the feed mix for the livestock industry (Table 2). In each case, the analysis is of a 20% yield gain.

The nutritional value of each of the new options was compared to the "standard" or unimproved feed grain. In some of the options, the nutritional quality of the grain can be changed without affecting its yield, and without any change in agronomic practices or the cost of production. In others, there were associated yield changes or changes in the level of inputs that would be needed to produce the nutritionally improved feed grain.

Table 2: Other Options Evaluated for Improving Feed Grains

Feeds involving increase in yield
High yielding feed wheat
High yielding triticale
High yielding feed barley
High yielding oats
High yielding sorghum
High yielding maize
High yielding lupins
High yielding sunflower
High yielding canola
High yielding field peas
High yielding faba beans
High yielding chickpeas
High yielding soybeans

3. Analytical Approach

3.1 Analytical framework

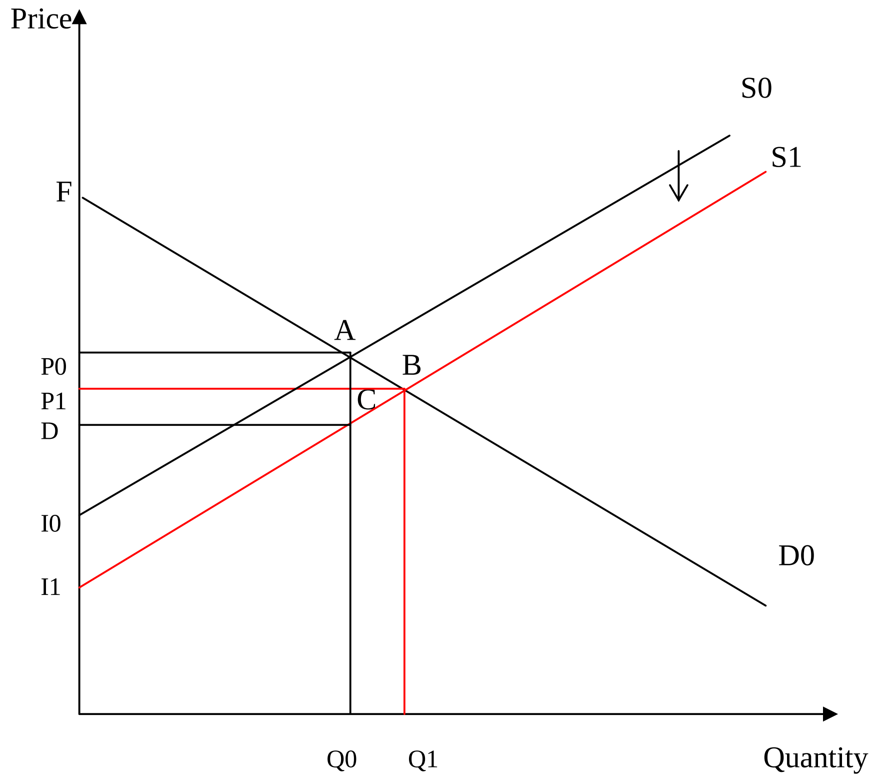
Research aimed at changing the quality characteristics of feed grains has its most direct impact in the livestock sector of the market (Brennan, Singh and Singh 1999). The higher-quality (in terms of improved nutritional composition) feed grain has the effect of lowering the cost of production for the livestock sector. In welfare analysis of the livestock sector, that cost reduction translates into a downward shift in the supply curve. There are different shifts for the different livestock industries, since a given quality improvement would be expected to have different impacts on their feed costs. In that situation, the demand for feed grains is a derived demand from the change in supply for the livestock sector.

Research that leads to a genetic improvement of the nutritional characteristics of feed grains allows livestock producers to obtain feed at lower cost. This is equivalent to a research-induced cost saving that will push the supply curve downwards, due to the reduction in the cost of feed, as shown in Figure 1. Research that increases the yields of feed grains can have a similar effect of reducing the cost of feed. The magnitude of the downward shift in the supply curve will depend upon the feed conversion efficiency (that is, the quantity of feed required for each additional unit of livestock product) for each livestock type.

3.2 Least cost feed mix model

The livestock industries are the end users of feed grains. Therefore, the economic value of nutritional improvements in different feed grains can be analysed by examining the extent to which they lead to reductions in the feed cost. Since feed grains are highly substitutable for each other both in supply and demand, in the livestock industries feed rations are formulated to provide the required nutrient intake at the least cost. Nutritional sources are substituted on the basis of nutrient price. The feed industries minimise the cost of producing a given quantity of mixed feed by exploiting the complex relationships that exist between feed ingredients. Least cost linear programming models which incorporate derived demand and cost functions are widely used in the industry for this purpose.

Figure 1: Introduction of Feed Grain with Improved Nutritional Characters: Livestock Sector



A linear programming model (using What's Best for Excel) has been developed for this study (Singh and Brennan 1998, Brennan, Singh and Singh 1999). The aggregate model considers 43 feed ingredients and estimates the least cost feed rations for 12 livestock industries simultaneously (Hafi and Andrew 1997). The livestock industries used in the analysis are shown in Table 3. For convenience, the data and results reported in this paper are aggregated into five broad industry groups also shown in Table 3.

The main features of the specification of the aggregate feed mix model (Brennan, Singh and Singh 1999) used for this analysis are:

(a) The minimum nutritional requirements for each of the 12 livestock industries have been specified;

(b) There are upper bounds on some ingredients, which a particular feed ingredient can not exceed in some feed rations;

(c) Two sources of supply availability of feed grains are allowed in the model: domestic production, and feed grain imports (at a price $70 per tonne above the domestic fob price);

(d) Domestic availability is limited to projected average production, while imports are available in unlimited quantities at the higher price.

The implicit assumption underlying this model is that livestock numbers and the output from livestock industries are fixed and are unresponsive to prices within the framework of the analysis.

Table 3: Livestock Industries Analysed

Industry Groups	Industries in Analysis
Poultry	Broilers -Starter
	Broilers - Finisher
	Layers - Pullet
	Layers / Breeders
Pigs	Weaners
	Growers / Finishers
	Breeders
Dairy	Dairy
Feedlot cattle	Feedlot cattle
Other	Live sheep exports
	Grazing ruminant supplement
	Other including horses

3.3 Data used

(a) Technical data used in feed mix model: The model required data on feed rates, minimum nutritional requirements for the 12 livestock industries, and details of nutritional components for each of the ingredients considered. Tony Edwards of ACE Livestock Consulting Ltd. supplied the technical livestock nutritional requirement and feed nutrition data. All the calculations in this model are based on the number of animals during the year 2004 for the livestock industries considered (ABARE 1999). Details of the nutritional composition of some of the feed grains analysed are available from the authors.

(b) Feed price data: The feed prices used in the model are those developed by ABARE (1999) from their supply and demand projections.

(c) Relationship between feed used and livestock product outputs: The feed included in the analysis accounts for the full feed ration for several livestock categories, but relates only to supplementary feed for the livestock categories of Dairy, Live sheep exports and Grazing ruminant supplement. These percentages (Table 4) have been derived from known feed conversion efficiency ratios and livestock production. Feed conversion efficiency is defined as the ratio of feed used to gain in live-weight (meat production), or milk production, eggs, etc. The feed conversion efficiency is the ratio of feed used to gain in animal product, such as live-weight, milk or egg production, etc. It varies from 2.2 in dairy to 5.5 for other meat-producing ruminants.

Table 4: Relationship between Feed and Livestock Product Outputs

	Feed analysed as % of total feed used *(%)*	Feed conversion efficiency
Poultry - Broilers	100%	2.7
Poultry - Layers	100%	3.5
Pigs	100%	5.0
Dairy	10%	2.2
Feedlot cattle	100%	5.5
Other including horses	various[a]	5.5

a: Live sheep exports 18%; Grazing ruminant supplement 2%; Other including horses 100%
Source: Based on estimates provided by A. Kaiser (personal communication, January 1999).

(d) Equilibrium quantity and price data: To estimate consumers' and the producers' shares of the total economic benefit, the information on equilibrium quantities and equilibrium prices of products of different livestock categories were required. The data on the total production of livestock products (Table 5) were estimated from ABARE (1999) and the feed conversion efficiency ratios above. The data on Australian market prices of these products (Table 5) were based on data for 1996.

Table 5: Equilibrium Quantities and Prices of Livestock Products

Livestock type	Quantity	Price	Elasticities[a]	
			Supply	Demand
Poultry - Broilers	844 kt	$3.00/kg	2.00	0.50
Poultry - Layers	138 m. dozen	$1.20/doz.	2.00	0.50
Pigs	419 kt	$2.27/kg	1.00	1.50
Dairy	8708 m. litre	$0.29/L	1.50	0.50
Cattle - feedlot	448 kt	$1.75/kg	1.00	1.50
Others	2693 kt	$1.75/kg	2.00	1.50

a: Elasticities differ for the different component industries of Poultry, Pigs and Other groups. Those reported here are for the predominant component.
Source*:* Production data based on estimates derived from ABARE (1999); Price data from Australian Bureau of Agricultural and Resource Economics, *Australian Commodities*; Elasticity estimates from G.R. Griffith (Personal communication, January 1999).

(e) Supply and demand elasticities: The supply and demand elasticities used (Table 5) are medium-term (3-5 years), based on the markets for livestock products, and are derived from a number of studies. Where data were not available for a given livestock sector, they were extrapolated from available data for similar industries.

(f) Farm gate price of the new feed: In evaluating the new feed grains with improved nutritional characteristics, the price at which they could be made available was estimated. The change in yield or inputs that was predicted by the industry experts was used to adjust the price of the new feed (Table 6) for feeds for which it was judged that there would be yield or input consequences. The minimum price at which a farmer would supply the new grain was estimated as the price that would give the same gross returns as would be obtained by growing the standard variety (Brennan, Singh and Singh 1999). For other feeds, there was no adjustment from the base price for the standard variety, on the basis that there would not need to be any adjustment for yield or inputs.

Table 6: Price Consequences of Agronomic and Input Requirements

New feed type	**Change in yield %**	**Increase in inputs $/ha**	**Local price Standard $/t**	**New $/t**
Hull-less barley	-20%	-	143	158
Naked oats	-40%	-	119	191
High yielding feed wheat	+20%	-	161	136
High yielding triticale	+20%	-	150	127
High yielding feed barley	+20%	-	143	121
High yielding oats	+20%	-	119	101
High yielding sorghum	+20%	-	169	143
High yielding maize	+20%	-	206	174
High yielding lupins	+20%	-	220	185
High yielding sunflower	+20%	-	280	235
High yielding canola	+20%	-	280	235
High yielding field peas	+20%	-	243	204
High yielding faba beans	+20%	-	250	210
High yielding chickpeas	+20%	-	320	268
High yielding soybeans	+20%	-	290	244

(g) Supply of new feed: To assess the impact of a new feed option on the reduction in the total cost of livestock feed, an arbitrary quantity of 100,000 tonnes of each new feed is made available in the market. To ensure that the nutritional benefits of the new grain are estimated, and not just an increase in the overall supply of grains, the supply of "standard" grain of the same type was reduced by the same amount. Thus 100,000 tonnes of hull-less barley, for example, was introduced, and the availability of standard barley was reduced by 100,000 tonnes.

(h) Downward shift in the supply curve (k value): The reduction in the total cost of the livestock feed as a result of the introduction of the new feed grain with improved nutritional characteristics means a lower cost of production of livestock products. The extent of the reduction in the cost of livestock products (*k*-value) depends upon the feed conversion efficiency (that is, the relationship between additional feed and the amount of livestock product produced) and the extent of the feed cost reduction.

4. Results of Analysis

The feed mix model was run separately for each option, using the nutritional specifications from Brennan and Singh (2000). The reduction in unit feed costs were calculated by comparing the outcome with that found in the base case in which none of the new feeds were available. The feed cost reductions vary for the different industries in each case. To translate these feed cost reductions to a supply-curve shift (*k*), these per-tonne unit cost reductions in feed cost need to be adjusted by the feed conversion efficiency from feed grain to livestock product, as shown in Table 4 above. Using those data, the downward supply shift (*k*-value) for each livestock industry was estimated (Table 7).

As noted in Brennan, Singh and Singh (1999), there are a number of instances in which the supply curve for a particular livestock industry shifts upwards rather than downwards with an improvement in feed nutritional quality. That occurs because:

(a) In some cases, the industries with the higher shadow prices on some feeds use up all available supplies of the preferred grain, forcing those putting less value on those feeds into more expensive alternatives;

(b) In other cases, the availability of a cheaper complementary feed means an increase in demand for a particular feed grain from other livestock industries, and hence a reduction in availability for some industries.

These effects lead to a loss of welfare for some industries with the introduction of new feeds. Using the model and the data described above, we derived estimates of the producer and consumer surplus (Table 7). The analysis shows a wide range of benefits for different industries from the alternatives examined. It is apparent that each option can have a wide range of implications for the livestock feeding industries.

The improvement of nutritional characteristics in the new feed options is generally aimed at addressing specific needs of a particular livestock industry, so that the benefits of each option are shared by the industries concerned. Although some industries gained due to substitution among feed ingredients, other industries experienced losses, while some other industries remained unaffected. The impacts of selected new feeds are illustrated in Table 8.

It is apparent that new feeds can have impacts on very different groups. For example in Table 8, High oil lupins and Naked oats have similar total benefits but have vastly different distributions of those benefits. Apart from the marked differences between the consumer and producer benefits from those feeds, the industries that gain and lose are very different. Poultry consumers and producers gain from naked oats to some extent at the expense of Dairy consumers and producers. For High oil lupins, the feedlot consumers and producers gains do not cause any negative impacts on other industries.

Table 7: Impact of New Feeds on Costs and Welfare Measures

	Cost reduction (k) ($/t)	Producer surplus ($000)	Consumer surplus ($000)	Total surplus ($000)
Feeds involving change in protein content				
High protein feed wheat	0.156	141	138	279
High protein barley	0.159	152	27	179
High protein oats	0.540	486	-22	464
High protein lupins	0.961	1190	1202	2392
Feeds involving change in amino acid profile				
High lysine wheat	0.233	327	254	581
High methionine wheat	0.003	17	27	44
High threonine wheat	0.000	1	5	7
High sulphur amino-acid lupins	0.062	26	131	157
Feeds involving improvement in feed digestibility and efficiency				
Hull-less barley	0.386	485	112	597
Low seed coat content barley	0.452	639	200	839
High seed coat digestibility barley	0.327	491	78	569
Naked oats	2.298	849	3813	4662
High oil barley	0.513	699	330	1029
High oil oats	0.877	730	404	1134
High oil sorghum	1.006	1442	1159	2601
High oil maize	0.638	811	719	1529
High oil lupins	1.918	2899	1964	4863
Waxy sorghum	0.000	1	5	7
Low protein degradability lupins	0.000	0	0	0
Feeds involving reduction in anti-nutritional factors				
Low arabinoxylan wheat	0.893	880	1134	2014
Low ß-glucan barley	0.072	110	67	178
Low ß-glucan oats	0.223	355	-682	-327
Low lignin oats	0.667	611	7	618
Low tannin sorghum	0.000	1	5	7
Low oligosaccharide lupins	0.421	627	418	1045
Feeds involving increase in yield				
High yielding feed wheat	1.008	1260	1242	2502
High yielding triticale	0.966	816	1618	2434
High yielding feed barley	0.096	575	1619	2194
High yielding oats	0.490	842	1384	2227
High yielding sorghum	1.058	527	2106	2633
High yielding maize	1.308	650	2599	3249
High yielding lupins	1.416	1767	1750	3517
High yielding sunflower	1.039	1001	1508	2509
High yielding canola	1.760	3078	1406	4484
High yielding field peas	1.572	1580	2324	3904
High yielding faba beans	1.267	1160	1992	3151
High yielding chickpeas	0.000	1	5	7
High yielding soybeans	1.754	870	3482	4352

Table 8: Welfare Effects of Selected New Feeds for Different Livestock Industries

		Producer surplus ($000)	**Consumer surplus ($000)**	**Total surplus ($000)**
High oil lupins	Poultry	1	5	**7**
	Pigs	0	0	**0**
	Dairy	0	0	**0**
	Feedlot	2859	1906	**4764**
	Other	39	53	**92**
	Total	**2899**	**1964**	**4863**
Naked oats (40%)	Poultry	1171	4683	**5853**
	Pigs	-21	-14	**-35**
	Dairy	-273	-819	**-1092**
	Feedlot	0	0	**0**
	Other	-28	-37	**-65**
	Total	**849**	**3813**	**4662**
High oil sorghum	Poultry	52	209	**262**
	Pigs	-510	-346	**-856**
	Dairy	0	0	**0**
	Feedlot	1856	1237	**3094**
	Other	43	58	**101**
	Total	**1442**	**1159**	**2601**
High protein lupins	Poultry	123	491	**614**
	Pigs	1067	711	**1778**
	Dairy	0	0	**0**
	Feedlot	0	0	**0**
	Other	0	0	**0**
	Total	**1190**	**1202**	**2392**
Low arabinoxylan wheat	Poultry	197	789	**987**
	Pigs	750	500	**1250**
	Dairy	-40	-119	**-158**
	Feedlot	0	0	**0**
	Other	-28	-37	**-65**
	Total	**880**	**1134**	**2014**
High oil maize	Poultry	60	241	**302**
	Pigs	-167	-118	**-285**
	Dairy	0	0	**0**
	Feedlot	941	627	**1568**
	Other	-24	-32	**-55**
	Total	**811**	**719**	**1529**
High yielding feed wheat	Poultry	120	482	**602**
	Pigs	0	0	**0**
	Dairy	0	0	**0**
	Feedlot	1140	760	**1899**
	Other	0	0	**0**
	Total	**1260**	**1242**	**2502**

5. Discussion of Economic Potential

5.1 Potential gains from improving nutritional characteristics of feeds

The analysis reveals that there are opportunities to improve the productivity and competitiveness of Australia's livestock industries by improving the nutritional characteristics of some feed grains. The feeds that provide the largest welfare benefits are: High oil lupins, Naked oats, High oil sorghum, High protein lupins and Low arabinoxylan wheat. The potential benefits from these feeds are sufficient to make them worthwhile research targets in the feed grains area.

However, there are a large number of technically feasible potential new feeds that are not likely to produce sufficient benefits to make them a reasonable research target. Of the 25 feeds with improved nutritional characteristics that were analysed, 11 had total welfare benefits of less than $0.5 million per year and a further 5 less than $1.0 million per year. Given the expected research costs, probabilities of success and the time lags involved in developing these feeds by plant breeding, it is unlikely that these options could be expected to provide a satisfactory rate of return on the research funds required. Research funds used for these projects could well be applied to more productive projects.

5.2 Nutrition improvement compared to yield improvement

One important issue for those determining research priorities in feed grains is the relative returns from improving the nutritional quality of the feed grain with the returns that could be obtained if yield was pursued rather than quality. As can be seen in Table 7, the level of returns that could be obtained from improving yields by 20% without quality change are superior to all but the best 2 or 3 of the feeds with improved nutritional characteristics. While this paper does not address the technical feasibility of a 20% increase in yield compared to a 20% increase in particular quality parameters, these results indicate that improving yield (and therefore reducing prices) are likely to be the most appropriate option for many livestock industries in many situations.

5.3 Distribution of benefits

It is apparent that different means of improving the nutritional characteristics of feed grains can have markedly different impacts in terms of the distribution of benefits. Overall, consumers of the livestock products receive about 45% of the benefits from nutritional improvement (on average), compared to about 60% of the benefits from increased yields.

In terms of the industries that obtain the benefits, each industry can gain or lose from particular improvements. As a result, the ranking of the options in terms of their benefits for each industry would be very different. Of the industries that benefits from the improvements, poultry and pigs are most often the beneficiaries from nutritional improvement, while the dairy industry is the one that most often suffers a loss from the new feeds. For most of the feeds with higher potential benefits, at least one industry suffers a loss of welfare from its introduction. The exception is for the higher-yielding feeds. In those cases, no industry is worse off with the introduction of any of the higher-yielding feeds.

5.4 Developing research priorities for feed grains

In assessing research priorities, the analysis undertaken here indicates that there are some important issues that need to be considered. First, some options for nutritional improvement involve the development of alternatives for which there are ready substitutes. For example, the development of high lysine wheat has a relatively low benefit because synthetic lysine is readily available. Clearly, the major benefits are likely to be restricted to feeds with nutritional characteristics for which there is no ready and low cost substitute.

Second, some improved feeds mean important benefits for one industry, but some negative impacts on other industries. The development of research priorities for feed grains from a whole industry-wide perspective means that those feeds which impact negatively on particular industries should only be considered if there is a means of minimising the possible negative impacts on those industries. It is of course likely that different industries will have different priorities, and that the maximum gains for some industries may only be gained at the expense of a loss of welfare by some other livestock industry.

Third, reliability of demand is clearly an important issue in ensuring that the new feed grains are made available. Where there are likely to be close substitutes, demand is likely to vary as prices change in the substitute feed market. As a result, the development of a feed grain for which the demand will fluctuate widely will be very risky compared to one for which there is no readily-available substitute that will cause a widely fluctuating demand. As a result, it is only those feeds for which there are clear advantages that will not be eroded in the event of a small price change for another ingredient that would be worthwhile for the grains industry to pursue. Given the general level of substitutability between feed grains, the examples where that is the case are relatively rare.

6. Conclusions

A wide range of options has been put forward as potential means of improving the nutritional composition of feed grains. The objective of the analysis reported in this paper was to assess those potential new feeds and determine the economic merit of research to develop those feeds. The analysis undertaken has revealed a wide range of outcomes from the options considered. Therefore, while there is scope to select from the list of options, the range of outcomes means that the selection process needs to be a careful one.

When the feeds were analysed to assess the economic benefits, a large number of the options were found to have small or very small returns that would not justify a significant research input. However, a small number of options were found to be economically worthwhile in the sense that they were expected to provide benefits well in excess of their research costs, and hence provide a good rate of return on that research investment.

However, several of those leading options for nutritional improvement had negative impacts on some industries, so that none were able to provide universal benefits to all the industries included in the analysis. As a result, different industries would rank the potential new feeds in different ways, often markedly differently.

An alternative would be to aim for yield improvement rather than seek to improve the nutritional quality of the feeds. That direction for research funding would provide economic benefits of similar or greater size than from nutritional improvement, and the evidence from the analysis presented in this paper is that those benefits would be more evenly spread across the different industries. This may provide research managers with a more palatable option than aiming for improvements that provide benefits to one industry often at the expense of another

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