Economic Assessment of Improving Nutritional Characteristics of Feed Grains

John P. Brennan
Senior Research Scientist (Economics),
NSW Agriculture, Wagga Wagga Agricultural Institute, Wagga Wagga, NSW.

Rajinder Pal Singh
Economist,
NSW Agriculture, Yanco Agricultural Institute, Yanco, NSW.

Report prepared for
Grains Research and Development Corporation

Economic Research Report No. 3

July 2000

GRDC Grains Research & Development Corporation

NSW Agriculture

ISSN 1442-9764

ISBN 0 7347 1212 X

***Authors' Contact*:**
John Brennan, NSW Agriculture, Wagga Wagga Agricultural Institute, Private Mail Bag, Wagga Wagga, NSW 2650
Telephone (02) 6938 1851; Facsimile (02) 6938 1809

Rajinder Pal Singh, NSW Agriculture, Yanco Agricultural Institute, Private Mail Bag, Yanco, NSW 2703
Telephone (02) 6951 2618; Facsimile (02) 6951 2557

Citation:
Brennan, J.P. and Singh, R.P. 2000, *Economic Assessment of Improving Nutritional Characteristics of Feed Grains*, Report prepared for Grains Research and Development Corporation, Economic Research Report No. 3, Wagga Wagga.

Economic Assessment of Improving Nutritional Characteristics of Feed Grains

Table of Contents

Page

Appendixes

List of Tables

List of Figures

Acknowledgments

We would like to acknowledge the financial assistance provided by the Grains Research and Development Corporation for the project DAN331A, which enabled this work to be carried out. The cooperation of Bryan Whan, Mike Perry and Mike Taverner in overseeing the project for the Premium Grains for Livestock Program with GRDC is very much appreciated. John Black also provided valuable guidance to us throughout the project.

In preparing the data and analysis, the cooperation of colleagues from ABARE, especially Ahmed Hafi and Vince O'Donnell and their key role in helping to develop the analytical tools is acknowledged gratefully. Others in ABARE who provided assistance at different stages of the project included Catherine Rees and Geoff Bailey. We also want to acknowledge the key role that Tony Edwards played in this project, and thank him or his cooperation throughout. We also acknowledge the assistance of the scientists and industry representatives who attended the project workshops for their valuable feedback.

Within NSW Agriculture, a number of colleagues have provided valuable assistance during the project. Inder Pal Singh was responsible for much of the early work on the project, and developed the aggregate feed mix model that was used for the analysis. Without his work, the project could not have achieved the progress that has been made, and we thank him for his vital role in the project. Garry Griffith and John Mullen provided valuable information, support and feedback in the project and the analysis we carried out. We are also very grateful to the scientists at the Wagga Wagga Agricultural Institute who provided valuable technical information and feedback included Alan Kaiser, Barbara Read, Malcolm Glennie Holmes and Peter Martin. We also acknowledge the valuable assistance of Debbie Hill of the University of New England for helping us to understand the conceptual issues involved.

Acronyms and Abbreviations Used in Report

ABARE	Australian Bureau of Agricultural and Resource Economics
ADF	Acid detergent fibre
DE	Digestible energy
EDM	Equilibrium displacement models
FOB	Free on Board
GRDC	Grains Research and Development Corporation
ME	Metabolisable energy
NDF	Neutral detergent fibre
RDP	Rumen degradable dietary protein
UDP	Undegraded dietary protein

Economic Assessment of Improving Nutritional Characteristics of Feed Grains

Executive Summary

The use of modern scientific practices such as biotechnology in agriculture has made it possible to introduce a specific characteristic in a particular grain that can improve its efficiency as a livestock feed. A wide range of options has been put forward by scientists and industry specialists as potential means of improving the nutritional composition of feed grains that would address the specific needs of different livestock industries.

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 (GRDC) funded a project, “Economic assessment of improving nutritional characteristics of feed grains (DAN331A)”. The project was a collaborative one under the leadership of NSW Agriculture, involving the Australian Bureau of Agricultural and Resource Economics (ABARE) and ACE Livestock Consulting Pty Ltd. That project aimed to provide for the first time a comprehensive set of information on the value of improving different characteristics of feed grains for animal nutrition, and information on who was likely to receive the benefits of the research. The objective of the analysis undertaken in this study was to assess those potential new feeds and determine the economic merit of research to develop those feeds.

A comprehensive set of options for new feed types has been evaluated, to establish the options with the highest priorities for research. In addition, to provide a benchmark for the value of the nutritional improvements, other forms of feed grains improvement were also assessed. The options analysed 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
- Feeds involving increase in yield
- New crop options

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.

In assessing the relative benefits from alternative forms of improvement of nutrition of feed grains, the cost-reducing impacts of the different options have been analysed in a linear-programming model that determines the least cost feed rations for the different livestock industries. The aggregate model considers 43 feed ingredients and estimates the least cost feed rations for the 12 livestock industries simultaneously. The cost-reduction from the new feeds was identified for each livestock industry. Economic welfare analysis was then used to estimate the size and distribution of the benefits of research from the feed grains quality-improving research between the producers (including input suppliers such as grain producers) and the

consumers (including processors and final consumers) of those livestock products. The analysis also identified which of the livestock industries were likely to receive the benefits from each of the new feeds.

All of the new feeds were analysed using the aggregate feed demand model, to give a comparative analysis of all the feeds. A selected subset of the new feeds was then analysed using ABARE’s regional model. That analysis allowed some of the key potential new feeds to be examined in detail, while still being comparable to the full set of options. The analysis also reveals that the aggregate national analysis provides a valuable assessment of the overall value of the new feeds.

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. The analysis reveals that there are some 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 and Naked oats. The potential benefits from several other feeds are also sufficient to make them worthwhile research targets in the feed grains area, including: High oil sorghum, High protein lupins, Low arabinoxylan wheat, Hull-less barley, High oil oats, Low seed coat content barley, and High seed coat digestibility barley.

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, 10 had total welfare benefits of less than $0.3 million per year and a further 6 less than $1.2 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.

Several of those leading options for nutritional improvement had negative impacts on some livestock industries, so that none were able to provide universal benefits to all the industries included in the analysis. As a result, different livestock 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 in this study is that those benefits may well be more evenly spread across the different industries.

Clearly, the selection of which new feeds to develop needs to be undertaken carefully, to ensure that scarce research and development funds are used to provide the best returns. The analysis in this study enables those feeds to be identified, so that research priorities for feed grains can be developed with improved knowledge of the economic consequences.

1. Introduction

1.1 Introduction

Although a total of over 8 million tonnes of feed grains are used each year by the livestock industries in Australia (Meyers Strategy Group 1995, Hafi and Rodriguez 2000), little attention has been paid to developing grain varieties that specifically address the needs of the different livestock industries. The Premium Livestock Grains Program, a partnership of the Grains Research and Development Corporation (GRDC) and the livestock industry R&D Corporations, has taken up that issue as one that needs to be addressed.

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.

1.2 Issues in Improving Feed Grains Nutrition

1.2.1 Production of feed grains versus food grains

In undertaking the project, an important step has been the identification of the key economic issues involved. One important issue in considering the role of improving the nutritional composition of feed grains is the extent to which farmers consider producing feed grains and food grains. A farmer will only produce feed grains if they provide higher returns, have lower costs, or provide some other agronomic advantage in the rotation, compared to higher-priced food grains with a more stable market. For example, in recent years the discount for feed wheat from Australian Standard White wheat has averaged around $40 per tonne. On that basis, unless there is a cost advantage (eg, a reduction in costs of handling or transport), price premium, or yield advantage of such grains over food grains, there is no incentive for the grain producer to aim to produce feed rather than food grains. It is generally only where there are cost savings (perhaps by being near a feedlot) that it will be worthwhile for farmers to grow feed rather than food wheat, unless there are large yield advantages available (they often need to be greater than 40%). Alternatively, farmers could be better off with feed grains than food grains if they received a premium for particular quality in a feed grain.

In some cases, 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 will be associated yield changes or handling costs required with the new grains. The likely impacts of these changes for different crops and for the livestock industries need to be incorporated into any analysis of the relative merits of different options.

1.2.2 Plant breeding as a solution

The resources devoted to meeting the different breeding objectives need to be appropriate to the benefits and costs involved (Brennan, Fisher and Oliver 1993). Small end-use markets may not be able to justify a breeding input, but may have to meet the opportunities through other means, or even be filled by some other grain (eg, perhaps use triticale rather than breed a special feed wheat). The critical issue is that breeding is not seen as the answer to all the questions that relate to small niche markets, even export markets.

For example, one option is to develop high-lysine feed wheat for the pig and poultry industries. However, it is possible to get the synthetic lysine directly rather than from the specially developed feed wheat. Often the most economic solution may be a more efficient mix of ingredients rather than attempting to breed a specific quality into a grain.

1.2.3 Industry structure and marketing systems

It is apparent that the extent to which the production of specific feed grains for the livestock sector would be economical depends on the marketing structure and systems in place. For example, if a feed grain with different levels of a specific nutrient is developed, the market must be such that that level can be measured and rewarded with a higher price. The ability to determine “quality” on a load-by-load basis is a pre-requisite for a feed grains industry that aims to produce particular feed qualities for particular livestock industries.

1.2.4 Improving feed grain quality or yield?

An important issue for those determining research priorities in feed grains is the relative returns from improving the nutritional quality of the feed grain compared with the returns that could be obtained if yield was pursued rather than quality. It may well be that improving yield (and therefore reducing prices) are likely to be a more appropriate option in particular situations. The comparison of improving feed quality compared to yield needs to be borne in kind at all times during the process of establishing the appropriate level of funding for research into quality improvement.

1.3 GRDC Project on Economics of Feed Grains Improvement

1.3.1 Objectives of project

In May 1996, a workshop sponsored by Grains Research and Development Corporation (GRDC) was held in Sydney to assess research priorities and develop specific projects in the area of feed grains quality. The need for more information on the economics of the various research options was highlighted in the workshop. The highest priority project from that workshop was for a proposal for an economic assessment of feed grains quality improvement.

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 GRDC has funded a project, “Economic assessment of improving nutritional characteristics of feed grains (DAN331A)”. That project aimed to provide for the first time a comprehensive set of information on the value of improving different characteristics of feed grains for animal nutrition, and information on who was likely to receive the benefits of the research. The specific aims of this project were:

(a) To define the relative economic importance of improving particular characteristics of feed grains;
(b) To identify the distribution of those benefits across industries; and
(c) To use that assessment to identify the priorities for research in feed grains.

The project was a collaborative one under the leadership of NSW Agriculture, involving ABARE and ACE Livestock Consulting Pty Ltd. Each of the State Departments of Agriculture or Primary Industries was also involved as a collaborator in the project. In addition, the project was closely linked with the other feed grains research programs being undertaken, and the whole of the integrated feed grains research program. Throughout the project, regular reports were made to the Premium Livestock Grains Steering Committee, and several feed industry funding bodies were involved in the project Workshops.

1.3.2 Outline of project activities

The likely research outcomes from the project were expected to be:

(a) The development of a comprehensive and objective means of determining priorities for feed grains research;
(b) Facilitation of the establishment of appropriate funding budgets for feed grains research;
(c) Identification of the appropriate level of industry investment by the various stakeholders in the feed grains industry.

There were four separate but closely integrated components of the project:

(a) Preparation of initial estimates of the value of selected nutritional factors, in time for consideration by GRDC Feed Grains sub-program in March 1997, using existing analytical tools developed by ABARE and ACE Livestock Consulting (for more details, see next section).
(b) Initially, analysis of a wide range of new feed options was carried out at the national level. Where interesting results were obtained, the more detailed regional analysis was undertaken. To undertake that regional analysis, further development of the ABARE demand model was needed, to increase its level of detail and the number of regions in the analysis. As part of the validation of the model estimates, representatives from each mainland State and each of the major livestock industries were asked to assess the validity of the model findings at a project Workshop in Canberra in September 1998. Where discrepancies were identified, differences were resolved before the finalising the estimates of the likely impacts of changes in the nutritional characteristics.
(c) An analysis of the distributional impacts of the benefits from different forms of nutritional improvement was developed, to determine who was likely to obtain the benefits from the different types of nutritional research. The process and the findings are detailed in section 5 below.
(d) From the previous analyses, preparation of a means to assist decision-makers in resource allocation decisions within the research area of feed grains nutrition. The findings of that work are also detailed below in section 5.

1.4 Preliminary Estimates of Value of Selected Nutritional Characteristics

As agreed in the original proposal, the existing analytical model developed by ABARE in an earlier project was used to make preliminary estimates of the value of selected nutritional characteristics of feed grains in time for the Feed Grains Steering Committee meeting in March 1997. This work was carried out largely by ABARE (Ahmed Hafi) and ACE Livestock Consulting (Tony Edwards), using the existing model of regional feed demand based on least-cost feed rations and 1994 livestock numbers. The ABARE model at that time incorporated 17 livestock types (6 pigs, 6 poultry, and 5 ruminant categories) and divided Australia into ten agricultural regions (2 in Queensland, 3 in NSW, 2 in Victoria, 1 in SA, 1 in WA, and 1 in Tasmania).

A total of 14 new feed ingredients were analysed, to determine the potential benefits that might be obtained if they were made available through research. The nutritional composition of each of these ingredients was defined by Dr Tony Edwards (Animal nutritionist) of ACE Livestock Consulting, based on a 20% change in the relevant parameter. The analysis was based on production of 50,000 tonnes of each of the new ingredients, replacing the standard variety of that type of feed. In the initial analysis, the new ingredient was evaluated at the same price as the standard variety. ABARE’s Regional Feed Demand Model was then used to analyse the impact of each new ingredient in turn on the feed costs of each of 17 livestock types in 10 regions in Australia (allowing for shipments of grain between regions)

The results of the analysis indicated that all the new ingredients analysed had the potential to provide some benefits to the livestock sector. The highest-ranked new feed was naked oats, followed by high-oil lupins, high-protein lupins and naked barley, while the lowest-ranked were wheats with high methionine, high lysine, high threonine and high protein. The broad conclusions that were drawn from the preliminary analysis were as follows:

- (a) There are potentially large benefits for the livestock sector from new feed types;
- (b) Those potential benefits will be lost if there are insufficient incentives to grain producers;
- (c) Energy in feed is more valuable than amino acid balance in the protein;
- (d) Gains from specific feed wheats appear lower than from other feed grains.

However, there were a number of reservations about these preliminary findings, in that they did not recognise the necessary yield trade-offs associated with feeds such as naked oats and naked barley. That analysis was limited in its value by having only limited geographical information. Further, the technical feasibility of achieving the different outcomes needs to be recognised before conclusions can be drawn about resource allocations for research in these areas. While the initial estimates provided were of interest to decision-makers, the lack of regional detail and the use of historical information was felt likely to obscure the possible impacts of some nutrition research, until a more detailed analysis could be carried out.

These preliminary estimates were presented to a meeting of the Premium Livestock Grains Steering Committee in Sydney in March 1997.

1.5 Outline of This Report

In undertaking the project, an important step has been the development of the appropriate methodology to assess each of the key issues. In the following section, the methodologies for addressing the key issues in feed grains improvement are developed. In the next section, case studies are presented to illustrate the approach used in the analysis, and some conclusions are drawn in the final section.

2. Economic Approach to Analysing Feed Grains Improvement

2.1 Approach to Analysis

There is a vast body of literature on measuring the benefits from research. The recent work of Alston, Norton and Pardey (1995) reviews the broad scope of the literature, and identifies the wide range of options available and the methods that can be used. The concept of economic surplus provides the basis for most assessments of the benefits of research, and provides a means of assessing both the size and distribution of research benefits in a consistent economic framework with a solid conceptual basis.

Research aimed at changing the quality characteristics of feed grains can conceptually be analysed as:

(a) a quality change in the feed grains sector, or
(b) a cost reduction in the livestock sector.

In the feed grains sector, research in feed grain nutrition may lead to a shift in the supply curve or a shift in the demand curve, or both at the same time. The nutritional improvement in feed grains results in a change in the quality of the output. The derived demand changes in the grains market as a result of that quality change can be analysed as either:

(a) a shift in demand curve for the particular feed grain, following the approach of Voon and Edwards (1992), whereby the improvement in quality translates to an upward shift in the demand curve, as it expands the possible uses of the grain or increases its value for a given use;
(b) a shift in the supply curve in two segments of the feed grains market, following the approach of Brennan, Godyn and Johnston (1989), whereby the improvement in quality translates to an upward shift in the supply curve for “high-quality” feed, and a corresponding downward shift in the supply curve of the “low-quality” feed.

The supply curve will shift upward where the per unit cost of production increases, which occurs where:

(a) the nutritional improvement involves some yield trade-off; or
(b) higher inputs are required to produce the improved feed grain.

Alston *et al.* (1995, pp. 243-45) consider the previous studies of analysing quality change in economic surplus models and assess the alternative approaches. They suggest that differentiated products that vary according to some quality characteristics face differential demands, so that the higher quality goods command a premium price. When analysing technical change and associated changes in quality, the options are to use a multi-product model, and either treat product characteristics as products or to treat different qualities of products as discrete products. They suggest that the later is the more practicable. Alston *et al.* (1995, p. 244) conclude that:

> “Technical change that leads to a change in product quality is a change in supply conditions *not* demand conditions, and it would be better to model it as such.”

However, one of the key characteristics of feed grains is the fact that they are substitutes for each other both in supply and in demand. In general, different feed grains are substitutes in supply, since grain producers can switch between feed grains depending on the relative returns from the different grains. While the extent of the substitution varies in different regions, in almost all cases there are substitution possibilities in the feed grains sector. At the same time, livestock industries can readily substitute between grains in determining their feed rations. The precise mix of feed grains will depend on the prices of the various feed components.

This ability to substitute between feed grains in both supply and demand means that the conditions required for the analysis based on equilibrium displacement models (EDM) are violated (for example, see Piggott, Piggott and Wright 1995, Hill, Piggott and Griffith 1996). In that case, there is no confidence that the results obtained from a detailed EDM analysis would be feasible or consistent (Hill and Griffith 2000).

Therefore, it is neither conceptually sound nor empirically feasible to undertake the analysis of the new potential feed grains in the feed grains sector itself. Rather, the decision was made to undertake the analysis within the livestock sector and to treat the result of the new grains as a cost reduction for the livestock sector.

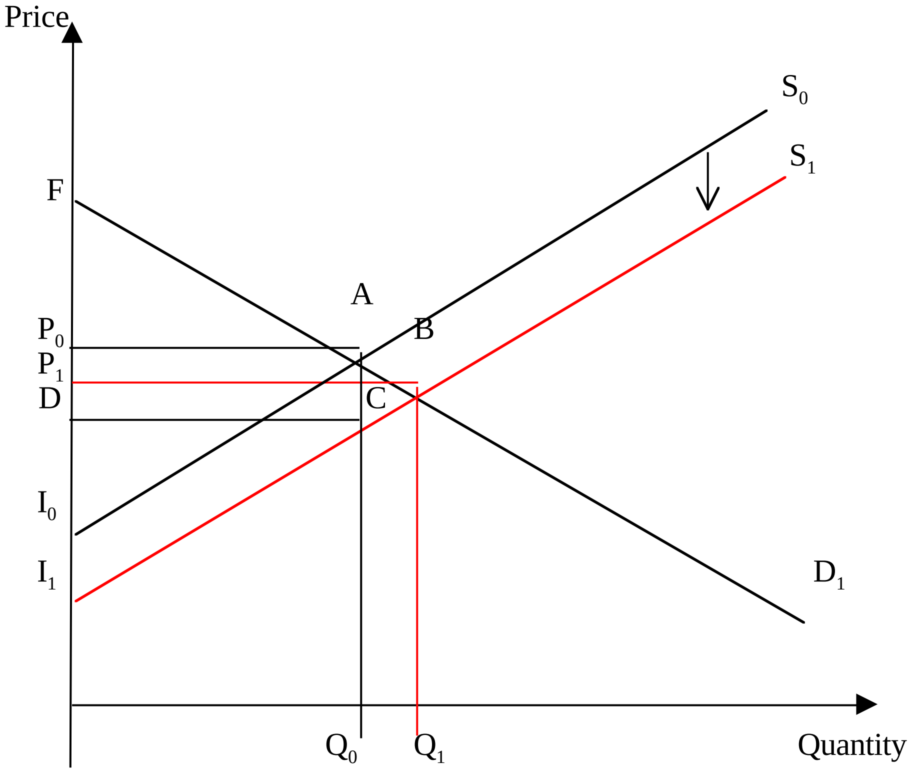
2.2 Livestock Sector Analysis

Research that leads to improved nutrition of feed grains allows livestock producers to obtain feed at lower cost. The higher-quality (in terms of nutritional composition) feed grain has the effect of lowering the cost of production for the livestock sector. In welfare analysis of the livestock sector, the cost reduction translates into a downward shift in the supply curve, as shown in Figure 2.1. Research that increases the yields of feed grains can have a similar effect of reducing the cost of feed. The genetic improvement of the nutritional characteristics of feed grains leads to a downward shift in the supply curve of the livestock industry as a result of the reduction in feed costs. The magnitude of the downward shift in the supply curve depends upon the relationship between the amount of feed used and the output of livestock product (see section 4.3 below for further discussion).

The cost-reducing research in the feed grain sector results in a downward shift of the supply curve from S_0 to S_1 in the livestock industry (Figure 2.1). The equilibrium price changes from P_0 to P_1 and equilibrium quantity from Q_0 to Q_1. For the purpose of simplicity parallel shifts in linear demand and supply curves are assumed (Rose 1978). Because of the changes in the equilibrium price and the quantity demanded, there will be a change in the total economic benefit that will further change the level of benefits accruing to the producers and the consumers of the new feed type based upon the relevant elasticities.

In this case, the consumers are those who use the livestock products, whether they are food or fibre processors or the final consumers of the livestock products. The producers are the livestock producers (whether they are cattle feedlots, dairy producers, pig producers, etc) and their input suppliers, which includes the grain producers. The analysis does not reveal the distribution of benefits within the producers (except in so far as the livestock sector has been disaggregated into industry segments for the analysis - see section 4.2 below). Therefore, this analysis does not allow determination of the benefits that flow to grain producers rather than livestock producers.

Figure 2.1: Feed Grain with Improved Nutritional Characteristics: Livestock Sector



Following Alston *et al.* (1995), the welfare measures are as follows:

Change in the consumer surplus (ΔCS) = P_1BAP_0
Change in producer surplus (ΔPS) = P_1BCD
Change in the total surplus (ΔTS) = P_0ABCD

Algebraically, the changes in economic welfare from a downward shift in the supply curve (see Alston *et al.* 1995, p. 210) can be expressed as follows:

$$\Delta CS = -P_0Q_0\, Z\, (1 + 0.5Zh)$$
$$\Delta PS = P_0Q_0\, (K-Z)(1 + 0.5Zh)$$
$$\Delta TS = P_0Q_0\, K\, (1 + 0.5Zh)$$

where P_0, Q_0 and K are the initial equilibrium price, equilibrium quantity and the relative downward shift in the supply curve, respectively; Z is the relative reduction in the equilibrium price (Z = Ke/(e+h)) due to the research, relative to its initial value; and e and h are the absolute values of the price elasticity of supply and demand, respectively.

2.3 Analytical Approach Used in This Study

Following identification of the issues and the possible options available, detailed consideration was taken as to the most appropriate form of the analysis to use in this study. That consideration drew heavily on work previously undertaken for the Beef Cattle CRC by Dr G. Griffith and Dr J. Mullen. Under their supervision, Ms Debbie Hill of UNE was employed to undertake a detailed review of the extent to which the required level of data were available to carry out a rigorous analysis of the distribution of benefits from such research. Because of data limitations and the conceptual difficulties of applying analyses that were not soundly based in this situation, the recommendation from that work was to undertake a simple analysis of producer and consumer benefits for each livestock industry (Hill and Griffith 2000).

As a result, the decision was made to undertake the analysis within the livestock sector and not to pursue the feed grains sector analysis. Thus, the approach used in this study was to consider the welfare impacts as those occurring from a reduction in feed cost in the livestock sector. The main drawback of the approach taken is that it does not permit firm analysis of the gains that might accrue to the grains sector alone. That is a major short-coming of the approach used. However, given both the conceptual difficulties of trying to undertake the analysis in the feed grains sector and the empirical requirements of data on the degree of substitution in production as well as consumption between all grains in all industries, such an approach would be beyond the scope of this study.

Different cost impacts are likely to be different, for a given nutritional change, for each livestock category. Thus the extent of the reduction in feed cost from the new feed, and the relationship between feed used and the output of the livestock products, will vary for each of the livestock categories analysed. This is discussed further in the following sections.

The analysis in this study is undertaken as follows:

1. Determine the feed cost reduction for each livestock category as a result of the introduction of each of the new feeds;
2. Determine the supply shift in each livestock industry resulting from those feed cost reductions; and
3. Estimate the changes in economic surplus measures that result from the shifts in the supply curves for each of the livestock sectors.

The steps in this process are outlined in the following sections, once the potential new feeds for inclusion in the analysis are identified.

3. Potential New Feed Grains for Analysis

3.1 Options for Improving Nutritional Composition of Feed Grains

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 3.1. 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

Table 3.1: Options Evaluated for Improving Nutritional Composition

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

In developing the appropriate nutritional specifications, Dr Tony Edwards, animal nutritionist, took a number of factors into account. In Appendix A, description of the basis for the specifications is provided, while details of the nutritional specifications, and the changes from the standard feeds, of each of the new feeds are found in Appendix B.

3.2 Other Options Evaluated

In addition to the options above, to provide a benchmark for the value of the nutritional improvements, other forms of feed grains improvement were also assessed:

- Feeds involving increase in yield
- New crop options

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 3.2). In each case, the analysis is of a 20% yield gain (see Appendix B).

Table 3.2: 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

New crop options
Cassava

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.

One new crop option considered was cassava, which is widely used as a feed source in some parts of the world. No information was available on the possible production costs, so the analysis was based on approximate nutritional specifications and price based on the average world price, to test whether cassava would have a role as a feed in Australia. This option was included to provide preliminary indicative information on cassava, rather than a prescriptive analysis.

4. Analysis of Impacts of Nutritional Improvements

4.1 Least Cost Feed Mix Concept

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.

4.2 Livestock Industries Analysed

To enable the analysis to take account of differences between livestock industries in their nutritional requirements and feed demand, categories of livestock needed to be determined. After widespread industry consultation, a compromise was reached between the number of livestock categories that was desirable to capture the main differences and the practical number that could be included in an analysis such as this

After consideration of the appropriate level of detail needed for the analysis, 12 different livestock categories were used in the feed demand analysis, as shown in Table 4.1. For convenience, the data and results reported in this report are aggregated into six broad industry groups: Poultry Broilers; Poultry Layers; Pigs; Dairy; Feedlot cattle; and Other.

Table 4.1: Livestock Industries Analysed

Industry Groups	Industries in Analysis
Poultry Broilers	Broilers -Starter Broilers - Finisher
Poultry Layers	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

4.3 Model Description

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 model considers 43 feed ingredients and estimates the least cost feed rations for the 12 livestock industries simultaneously (Hafi and Andrews 1997). The model determines the allocation of the feed ingredients across the 12 livestock industries simultaneously in such a way as to minimise the total feed costs of all industries.

The feed ingredients included in the determination of the least cost feed rations are shown in Table 4.2.

Table 4.2: Feed Ingredients Included in Analysis

Wheat*
Barley*
Oats*
Groats
Maize*
Sorghum*
Triticale*
Lupins*
Peas*
Faba beans*
Mung beans
Millmix
Rice pollard
Oats hulls
Cereal hay
Lucerne hay
Canola meal*
Soybean meal*
Full fat soya*
Sunflower meal
Cottonseed meal
Whole white cottonseed
Meat meal
Fish meal
Blood meal
Skim milk
Butter milk
Whey powder
Molasses
Tallow-mixer
Vegetable oil
Salt
Limestone
Rock phosphate
Dicalphos
Lysine-HCL
Tryptosine
Methionine
Threonine
Sodium bicarbonate
Urea
Choline
Chloride
Vitamin/Mineral
Primix

* Available for import in unlimited quantities (at 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.

The main features of the specification of the aggregate feed mix model are as follows:

- Minimum nutritional requirements
- Upper bounds on ingredients
- Limits on supply availability

Each of the 12 livestock industries has pre-defined minimum nutritional requirements, which the feed mix ration should supply for the proper growth and maintenance of the livestock. The model developed covers all the feed ingredients and identifies the cheapest source to meet these nutritional requirements.

There are some upper limits up to which a particular feed ingredient can enter in to some feed rations, defined on the basis of animal nutritional constraints. The model has been defined to take into account all of these nutritional limits.

Two sources of supply availability of feed grains are allowed in the model:
(i) domestic production of feed grains; and
(ii) feed grain imports.

Domestic production is limited to average production less exports. Imports are available for selected grains and meals (see Table 4.2) in unlimited quantities, at a price $70 per tonne above the domestic price used in the analysis to account for the costs of handling and transport to get the grain to Australia. For grains such as wheat and barley that have uses as both food and feed, the data used was based on estimates of the proportion sold as feed grain only.

4.4 Level of Aggregation in Analysis

The initial intention in the project was to undertake the all of the analysis at the regional level, using ABARE's regional feed demand model (Hafi and Andrews 1997). However, the complexity of that model, especially after the extra regions had been incorporated, meant that it was impossible to undertake the necessary number of runs with the model with the resources available. As a result, an aggregate (national-level) equivalent model was developed from the ABARE feed demand model. The aggregate feed demand model had the same basic structure as the ABARE model, from which it was derived, except that it had no regional disaggregation. The features of the aggregate model were:

- The feed ingredients, the nutritional components and the livestock types and the aggregate supply availability were the same as in the ABARE regional model;
- The aggregate supply availability was the same as the total availability in the ABARE regional model;
- Prices were the average of local equivalent of FOB prices used in ABARE model.

Using this aggregate model had the following advantages

- It provided broad estimates of the relative returns from the different new feed options, which were shown to be consistent with the results obtained from the regional ABARE model;
- It provided increased flexibility, and allowed a far wider set of feeds and specifications to be assessed;
- Its ease of use allowed sensitivity analyses to be undertaken for price changes, and for the development of feed demand elasticities (Singh and Brennan 1998).

However, the aggregate model had the following disadvantages:

- Because it could not account for regional transfers, it lacked detail in the implications of some of the feeds;
- It was not possible to undertake location-specific analysis of feed supply or demand;
- No insights could be obtained into any transport issues related to the new feeds;
- It was too aggregated to pick up some of the details of some new feeds.

However, on balance, it gave clear advantages for the analysis. All of the new feeds were analysed using the aggregate feed demand model, to give a comparative analysis of all the feeds. A selected subset of the feeds was then analysed using ABARE's regional model. That analysis allowed some of the key potential new feeds to be examined in detail, while still being comparable to the full set of options.

4.5 Data Used in Empirical Analysis

4.5.1 Technical data used in feed mix model

Data on livestock numbers and feed rates for each of the 12 livestock industries was derived from Hafi and Rodriguez (2000), based on projections for the year 2004 (Table 4.3). The minimum nutritional requirements for the 12 livestock industries, and details of nutritional components for each of the ingredients considered were supplied by Tony Edwards of ACE Livestock Consulting Ltd. Details of the nutritional composition of some of the feed grains analysed are available from the authors. The nutritional composition of the key feed grains and the proposed new feeds are shown in Appendix B.

Table 4.3: Livestock Numbers and Feed Rates Used in Analysis

	Animal Number (' 000/year)	Feed Rate (kg/head/year)
Broilers - Starter	460272	1
Broilers - Finisher	455225	4
Layers - Pullet	9635	8
Layers - Breeders	9216	44
Pigs - Weaners	5409	70
Pigs - Grower/Finishers	5207	242
Pigs - Breeders	327	1387
Dairy	1817	1096
Feedlot cattle	1591	1547
Live sheep exports	5186	22
Grazing ruminant supplement	13089	20
Other including horses	100	2000

The feed rates reflect the total consumption of the 53 selected feed ingredients (in kg/head) for the animals in that category. For example, broiler chickens are put on a "starter" ration for a short period before they are moved to the "finisher" ration. The total quantity of the feed diet consumed as a "starter" is 1 kg/head and as a "finisher" is 4 kg/head. Pullets and layers go through similar phases, as do pig weaners and grower-finishers. For animals for which the feed rations are a supplement to pastures, the feed rate is the amount of feed ration in addition to the (unmeasured) quantity of intake from pastures.

4.5.2 Feed price data

The results of the model are likely to be sensitive to the prices used for the different feed ingredients. It is thus important to use an appropriate set of prices. The data on prices of feed grains in Australia for the past ten years indicated a large year to year fluctuation in the prices of the feed grains. For instance, the price of feed wheat varied from $138/t in 1993-94 to

$235/t in 1995-96. To remove such seasonal variability and to represent long term trends in these prices, medium-term average prices have been used in the estimations. The feed prices used in the model are those developed by Hafi and Rodriguez (2000) from their supply and demand projections (see Table 4.4).

Table 4.4: Selected Feed Prices Used in Analysis

Ingredient	Price ($/t)	Ingredient	Price ($/t)
Wheat	161	Rice pollard	150
Barley	143	Oats hulls	150
Oats	119	Cereal hay	90
Groats	500	Lucerne hay	120
Maize	206	Canola meal	205
Sorghum	169	Soybeanmeal	290
Triticale	150	Full fat soya	490
Lupins	220	Sunflowermeal	205
Peas	243	Cottonseed meal	183
Faba beans	250	Whole white cottonseed	244
Mung beans	584	Meatmeal	430
Millmix	165		

4.5.3 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. For those industries, the percentage of the total feed consumed that is included in this analysis was estimated from known feed conversion efficiency ratios and livestock production data (Table 4.5). Feed conversion efficiency is defined as the ratio of the feed used to the gain in live-weight (meat production), or to milk or egg production. It varies from 2.2 in dairy to 5.5 for other meat-producing ruminants.

Table 4.5: 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).

4.5.4 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 4.6) were estimated from Hafi and Rodriguez (2000). The data on Australian market prices of these products (Table 4.6) were based on data for 1996.

Table 4.6: Equilibrium Quantities and Prices of Livestock Products

Livestock type	**Quantity**	**Price**[a]	**Elasticities**[b]	
			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: Prices are average saleyard prices, expressed as liveweight equivalent, except for poultry prices which are retail; milk prices are farm-gate prices.

b: Price 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 Hafi and Rodriguez (2000); Price data from Australian Bureau of Agricultural and Resource Economics, *Australian Commodities*; Elasticity estimates from G.R. Griffith (Personal communication, January 1999).

4.5.5 Supply and demand elasticities

The supply and demand elasticities used (Table 4.6) 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.

4.5.6 Supply of new feeds

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.

4.5.7 Farm gate price of the new feeds

In evaluating the new feed grains with improved nutritional characteristics, the price at which they could be made available was estimated. The price was determined as that at which producers of the new feed grain would receive the same gross margin per hectare as if they had continued to produce the standard version of the same grain. The following formula was used to estimate the farm gate price of a new feed grain:

$$(P_1-T) = (P_0-T)*Y_0/Y_1 - (VC_0-VC_1)/Y_1,$$

where P_1 and P_0 are the price per tonne of the new and the standard variety of a grain; Y_1 and VC_1 are the yield and the variable cost per hectare respectively of the new grain, and Y_0 and VC_0 are the yield and the variable cost of the standard variety of the grain; T is the per tonne transportation cost of the grain from farm to silo.

For the new feeds being analysed, the change in yield or inputs that was predicted by the industry experts was used to adjust the price of the new feed for feeds for which 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 (Table 4.7). 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 4.7: Price Consequences of Agronomic and Input Requirements

New feed type	**Change in yield %**	**Increase in inputs $/ha**	**Local price Standard $/t**	**Local price 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

4.5.8 Processing cost savings through the use of new feeds

For some new feeds, in addition to the nutritional change there is an additional benefit through the saving in processing costs for the livestock industry. These feeds are:

- Hull-less barley
- Low seed coat content barley
- High seed coat digestibility barley
- Naked oats

Using each of these feeds means that the grain would not need to be processed before feeding to ruminants. The extent of the saving depends on the feed processing system used by the livestock industry. In this analysis, we assume a processing cost saving of $10 per tonne of the new feed used by the ruminants.

4.5.9 Downward shift in the supply curve

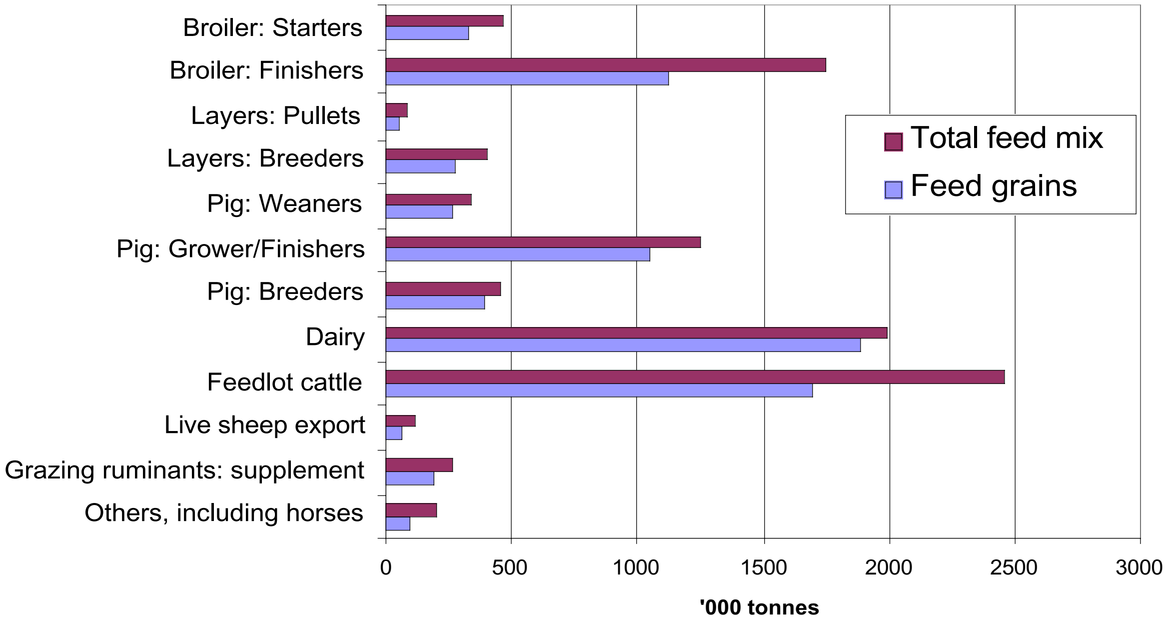
The reduction in the total cost of the livestock feed as a result of the introduction of the new feed grain with improved nutritional characteristics means a lower cost of production of livestock products. The extent of the reduction in the cost of livestock products (*k*-value) depends upon the feed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

4.6 Baseline Feed Demand

The baseline data used in the analysis were derived from projections for 2004 (Hafi and Rodriguez 2000), using data for livestock numbers and grain production for that year. As part of their validation of those projections, ABARE consulted widely with the industry throughout 1999, so that those baseline data had general industry acceptance before being used in this analysis. The data for the average feed demand per head for each livestock category were also based on Hafi and Rodriguez (2000) projections for 2004.

From the baseline run of the baseline data in the model, demand for fed grains by the livestock sector in 2004 is estimated to be 9.88 million tonnes, of which 7.39 million tonnes is comprised of grains and meals. The total cost of feed is estimated at $1816.5 million in that year, or an average of $183.77 per tonne. The feed grain demand by each livestock industry is shown in Figure 4.1. The industries that use the most feed grains are the dairy, feedlot cattle, broiler finishers and pigs grower/finishers. The feedlot cattle sector uses the most total feed. The feed quantities illustrated in Figure 4.1 are used as the baseline against which the new feeds are measured.

Figure 4.1: Baseline Demand for Feed Grains and Total Feed Mix, 2004



In this analysis, no account is taken of the substitution between grains and pastures. The total intake of grain by each industry is taken as fixed in this analysis. To the extent that some industries may substitute grain for pasture if feed grain costs can be reduced, the benefits measured in this analysis will underestimate the true benefits. However, the extent of any such underestimation is likely to be small, given that for of the Dairy and Grazing ruminant industries the changes in feed grain cost analysed in this study are relatively small and are unlikely to lead to any substantial substitution of grains for pasture.

One key distinction between the livestock industries is that for some sectors the feeds included represents the total rations, while for others it represents only a supplement to grazed feeds. That fact is critical in interpreting the results obtained. The two industries in which grazing accounts for significant feed quantities that are not included in this analysis are Dairy and Grazing ruminant supplement. For the other main sectors (Poultry, Pigs, Feedlot cattle, and Live sheep exports), the feeds included in this analysis represent the whole feed ration.

5. Aggregate Analysis of Improved Feed Grains

5.1 Economic Benefits from Feeds with Improved Nutritional Composition

The aggregate feed mix model was run separately for each option, using the nutritional specifications from Appendix A. The reductions 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 varied 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 needed to be adjusted by the feed conversion efficiency from feed grain to livestock product, as shown in Table 4.5 above. Using those data, the downward supply shift (*k*-value) for each livestock industry was estimated. In Table 5.1, the aggregate shifts (across all industries) are shown to illustrate the general levels of impact of the different feeds. The aggregate supply shifts varied from $0.00/t to $2.98/t for the different feeds.

Using the model and the data described above, we derived estimates of the total annual economic benefit resulting from the introduction of each new feed (Table 5.1). The analysis shows a wide range of total benefits for different alternatives examined, ranging from $0.00 million for several options to $4.86 million for High-oil lupins. Several had virtually no benefits, including High threonine wheat, Waxy sorghum, Low protein-degradability lupins, and Low tannin sorghum. Low beta-glucan oats has a negative, rather than a zero, impact because of the manner in which the analysis was carried out, whereby this new feed became available at the same time as a reduction in the availability of standard oats. When some industries used low beta-glucan oats with a small benefit, it meant less standard oats was available to other industries, and they were forced to purchase more expensive alternative feed. As a result, the overall feed costs were higher.

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.

A detailed description of the findings of the analysis for each of the new feeds analysed is provided in section 5.5 below.

Table 5.1: Impact of New Feeds on Costs and Total Welfare

	Cost reduction[a] (k) ($/t)	**Annual benefit ($million)**
Feeds involving change in protein content		
High protein feed wheat	0.156	0.28
High protein barley	0.159	0.18
High protein oats	0.540	0.46
High protein lupins	0.961	2.39
Feeds involving change in amino acid profile		
High lysine wheat	0.233	0.58
High methionine wheat	0.003	0.44
High threonine wheat	0.000	0.00
High sulphur amino-acid lupins	0.062	0.16
Feeds involving improvement in feed digestibility and efficiency		
Hull-less barley	0.789	1.60
Low seed coat content barley	0.679	1.40
High seed coat digestibility barley	0.565	1.25
Naked oats	2.298	4.66
High oil barley	0.513	1.03
High oil oats	0.877	1.13
High oil sorghum	1.006	2.60
High oil maize	0.638	1.53
High oil lupins	1.918	4.86
Waxy sorghum	0.000	0.00
Low protein degradability lupins	0.000	0.00
Feeds involving reduction in anti-nutritional factors		
Low arabinoxylan wheat	0.893	2.01
Low beta-glucan barley	0.072	0.18
Low beta-glucan oats	0.223	0.00
Low lignin oats	0.667	0.62
Low tannin sorghum	0.000	0.00
Low oligosaccharide lupins	0.421	1.05

a: Average agregate cost savings across all industries; the cost reduction for differs for each livestock industry.

5.2 Classification and Ranking of Results

To assist in the interpretation of the findings of the analysis, a method of classifying the results was needed. As a result, the following general classification method was developed. Based on broad averages, the following parameters were assumed:

- Research and development costs for a new feed would be $250,000 per year for five years;
- Once the selection methods were developed, it would cost an additional $50,000 per year (for the next 20 years) to incorporate selection into breeding programs across Australia;
- Each new feed has an 80% probability of success;
- The breeding lag before the new feeds are available from the start of research is 8 years.

For different levels of annual benefits, the implied benefit-cost ratio could be calculated on the basis of these parameters. For example, annual benefits of $400,000 per year would be needed for the project to have a benefit-cost ratio of 1.0. The basis for concluding that a certain level of annual benefits were likely to be Low, Medium or High was the level of the resulting benefit-cost ratio (Table 5.2). To be classified as Medium, returns need to be above $1.2 million per year, High above $4.0 million, and Very High above $8.0 million. While somewhat arbitrary, this classification allows the large list of potential new feeds to be put into a broader context for interpretation.

Table 5.2: Basis for Classification of Results

Annual Benefits	Benefit-Cost Ratio	Classification
< $0.4 m	<1	Very low (VL)
$0.4 m - $1.2 m	1-3	Low (L)
$1.2 m - $4.0 m	3-10	Medium (M)
$4.0 m - $8.0 m	10-20	High (H)
> $8.0 m	>20	Very high (VH)

Using this means of classification, new feeds are shown in Table 5.3 with their rating for each potential new feed with improved nutritional characteristics. The feeds involving change in protein content ranged from Very Low to Medium. The feeds involving change in amino acid profile were all rated Very Low or Low. The feeds involving improvement in feed digestibility and efficiency were generally higher, with all but one ranging from Low to High, while the feeds involving reduction in anti-nutritional factors were generally Very Low or Low (except for one which was Medium). In broad terms, then feeds involving improvement in digestibility and energy of grain were superior to those involving changes in amino acid profile, protein content or anti-nutritional factors.

Table 5.3: Classification of New Feeds by Level of Benefits

	Annual Benefit ($m)	Rating
Feeds involving change in protein content		
High protein feed wheat	0.27	VL
High protein barley	0.17	VL
High protein oats	0.46	L
High protein lupins	2.38	M
Feeds involving change in amino acid profile		
High lysine wheat	0.58	L
High methionine wheat	0.04	VL
High threonine wheat	0.00	VL
High sulphur amino-acid lupins	0.15	VL
Feeds involving improvement in digestibility and energy of grain		
Hull-less barley	1.60	M
Low seed coat content barley	1.40	M
High seed coat digestibility barley	1.25	M
Naked oats	4.66	H
High oil barley	1.02	L
High oil oats	1.13	L
High oil sorghum	2.59	M
High oil maize	1.53	M
High oil lupins	4.85	H
Waxy sorghum	0.00	VL
Low protein degradability lupins	0.00	VL
Feeds involving reduction in anti-nutritional factors		
Low arabinoxylan wheat	2.01	M
Low beta-glucan barley	0.18	VL
Low beta-glucan oats	0.00	VL
Low lignin oats	0.62	L
Low tannin sorghum	0.00	VL
Low oligosaccharide lupins	1.04	L

To highlight the comparative levels of the outcomes of the different feeds, they are ranked in terms of their total economic benefits in Table 5.4. High oil lupins and naked oats are the two with the highest level of economic benefits. Only a further seven feeds (High oil sorghum, High protein lupins, Low arabinoxylan wheat, Hull-less barley, High oil maize, Low seed coat content barley and High seed coat digestibility barley) provide sufficient returns to allow them to be classified as better than low-return options.

Table 5.4: Ranking of Economic Benefits

	Annual Benefit ($m)	Rating
High oil lupins	4.85	H
Naked oats (40%)	4.66	H
High oil sorghum	2.59	M
High protein lupins	2.38	M
Low arabinoxylan wheat	2.01	M
Hull-less barley (10%)	1.60	M
High oil maize	1.53	M
Low seed coat content barley	1.40	M
High seed coat digestibility barley	1.25	M
High oil oats	1.13	L
Low oligosaccharide lupins	1.04	L
High oil barley	1.02	L
Low lignin oats	0.62	L
High lysine wheat	0.58	L
High protein oats	0.46	L
High protein feed wheat	0.27	VL
Low beta-glucan barley	0.18	VL
High protein barley	0.17	VL
High sulphur amino-acid lupins	0.15	VL
High methionine wheat	0.04	VL
High threonine wheat	0.00	VL
Waxy sorghum	0.00	VL
Low tannin sorghum	0.00	VL
Low protein degradability lupins	0.00	VL
Low beta-glucan oats	0.00	VL

5.3 Estimates of Economic Benefits from Other Feeds

The aggregate feed mix model was also run separately for each of the other feed options, again using the nutritional specifications from Appendix A. For higher-yielding grains and oilseeds, there was no change in the specifications from that of the standard grains. The only change was a price reduction (see Table 4.7 above) to reflect the reduced costs of producing the higher-yielding grains. Again the reductions in unit feed costs were calculated by comparing the outcome with that found in the base case in which the new feeds were not available. The feed cost reductions were translated into a supply-curve shift (*k*) as for the feeds with new nutritional specifications. Using those data, the downward supply shift (*k*-value) for each livestock industry was estimated. In Table 5.5, for convenience the aggregate cost reduction (across all industries) is shown to illustrate the general levels of impact of the different feeds. The aggregate cost reduction varied from $0.00/t to $1.76/t for the different high-yielding feeds.

Table 5.5 Impact of Other Feeds on Costs and Total Welfare

	Cost reduction[a] (k) ($/t)	Annual benefit ($million)	Rating
Feeds involving increase in yield			
High yielding feed wheat	1.008	2.50	M
High yielding triticale	0.966	2.43	M
High yielding feed barley	0.096	2.19	M
High yielding oats	0.490	2.23	M
High yielding sorghum	1.058	2.63	M
High yielding maize	1.308	3.25	M
High yielding lupins	1.416	3.52	M
High yielding sunflower	1.039	2.51	M
High yielding canola	1.760	4.48	H
High yielding field peas	1.572	3.90	M
High yielding faba beans	1.267	3.15	M
High yielding chickpeas	0.000	0.00	VL
High yielding soybeans	1.754	4.35	H
New crop options			
Cassava	0.024	0.06	VL

a: Average aggregate cost savings across all industries; the cost reduction for differs for each livestock industry.

Also shown in Table 5.5 is the total annual economic benefit resulting from the introduction of each new feed. Apart from High-yielding chickpeas (which was still not used at the lower price), the analysis shows a much narrower range of total benefits than for the nutritional improvement, ranging from $2.19 million for High-yielding feed barley to $4.48 million for High-yielding canola.

The analysis of cassava (at $174/t) provided very low benefits, so provided little evidence that cassava would be a useful feed source unless it could be produced at a markedly lower price.

One important finding from this analysis was that the higher-yielding feeds, with no quality change, generally provided benefits greater than the majority of new feeds with improved nutritional characteristics. All higher-yielding grains were rated as “Medium” or “High”, apart from chickpeas. Only a selected number of the nutritional improvements were classified at those levels.

5.4 Distribution of Benefits from New Feeds

One of the key issues in feed grains research is the extent to which the benefits are likely to flow to the grains sector or the livestock sector. The distributional analysis used in this study is able to identify the likely distribution of benefits between the different sectors of the livestock industries for different types of nutrition research, as well as between the producers and consumers of the livestock products.

Since we have measured the welfare changes in the livestock sector, the only distribution of benefits that can be analysed is that between producers and consumers in each of the livestock industries. In this case, the producer surplus identified includes:

- (a) Economic benefits to livestock producers;
- (b) Economic benefits to all inputs suppliers, including feed grain producers and grain handling and transport industries.

Similarly, the consumer surplus identified in this analysis includes:

- (a) Economic benefits to meat (and other livestock product) producers;
- (b) Economic benefits to traders, wholesalers and processors of those products;
- (c) Economic benefits to the final consumers of the livestock products.

As mentioned earlier, the analysis possible in this study does not permit precise estimates of the benefits that will flow to the grains sector as opposed to the livestock sector. There is no analytical framework available that will allow that distribution to be identified. As a result, each new feed needs to be considered individually. In each case, the respective market power of the livestock sector compared to the grains sector, for that particular grain, is the key to the extent of the benefits being shared between the industries.

Livestock and grain producers share the producer surplus that is identified in the above analysis. However, for those shares to be determined, the cooperative or competitive nature of the market for that grain needs to be identified. Where livestock and grain producers cooperate, they will choose a price that provides some benefits to the grain producer for growing the new feed rather than the “standard” feed, while still retaining benefits of a cost reduction for the livestock sector. To the extent that the livestock producers have the market power to force down the feed grain prices to the minimum at which grain growers are prepared to supply it, the grain producers will receive a smaller portion of the total benefits. Where the producers of the grain have the market power to set a price and force the livestock sector to pay that higher price, the majority of the benefits can flow to the grains sector. Where the aim of the livestock sector is to minimise the cost rather than to maximise net returns (which diverge in this case), the benefits will be captured by the livestock producers and grains producers will get little or no gain from the new feed.

The relative market power will depend on factors such as the degree of geographical monopoly for a particular grain. That is determined by whether the cost of transport to alternative markets so high that grain producers in the region have little chance to sell the grain elsewhere for a reasonable price, for example, or whether there is only one feedlot in the region. The availability of a close substitute locally can also have an important effect on the extent of the power that a livestock industry has in a market for a particular feed grain.

There are a number of mechanisms that could be used to allow grains and livestock producers to share the benefits of a potentially significant new feed grain. These include:

(a) Contract growing, whereby the livestock industry agrees to pay a premium above the market price for the standard grain in return for the grain producer meeting the nutritional specifications required by the livestock industry;

(b) Payment of a premium for specific characteristics desired by the livestock industry, so that grains producers who met the requirements of the livestock industry receive a reward of a higher price;

(c) Vertical integration of the grains and livestock components, where the livestock industry and the grain production are undertaken by the same enterprise, so that the distribution of the benefits is immaterial to the overall benefits received.

A pre-requisite for arrangements based on payments for a precise quality specification is a system of load-by-load identification of relevant quality.

Within the grains sector, there can often be direct substitution between feed grains. As a result, the gains from producers of one grain can often come at the expense of producers of another grain, unless there are adequate price premiums. In some cases, these can lead to substitution of grain from one region for grain from another region, as where improved barley could replace sorghum in the feed ration. However, the substitution can often take place between grains produced in the same region, and often on the same farms. Thus, it is possible for example for the gains from an improved barley variety to come at the expense of oats produced by the same farmers. As a result of these substitutions, it is extremely difficult to identify the net impact of improving one particular grain for the livestock sector on grain producers in different parts of the grain belt.

The distribution of benefits between the “producers” and the “consumers” is shown in Tables 5.6 and 5.7. Note that there are minor differences between the “Total surplus” estimated in this analysis and the “Annual benefits” shown in previous tables. These discrepancies are the result of taking into account different prices responses, as represented in the supply and demand elasticities used (see Table 4.6 above).

Table 5.6: Impact of New Feeds on Producer and Consumer Welfare

	Producer surplus ($million)	**Consumer surplus ($million)**	**Total surplus ($million)**
Feeds involving change in protein content			
High protein feed wheat	0.14	0.14	0.28
High protein barley	0.15	0.03	0.18
High protein oats	0.49	-0.02	0.46
High protein lupins	1.19	1.20	2.39
Feeds involving change in amino acid profile			
High lysine wheat	0.33	0.25	0.58
High methionine wheat	0.02	0.03	0.04
High threonine wheat	0.00	0.00	0.00
High sulphur amino-acid lupins	0.03	0.13	0.16
Feeds involving improvement in feed digestibility and efficiency			
Hull-less barley	1.09	0.51	1.60
Low seed coat content barley	0.98	0.43	1.40
High seed coat digestibility barley	0.86	0.38	1.25
Naked oats	0.85	3.81	4.66
High oil barley	0.70	0.33	1.03
High oil oats	0.73	0.40	1.13
High oil sorghum	1.44	1.16	2.60
High oil maize	0.81	0.72	1.53
High oil lupins	2.90	1.96	4.86
Waxy sorghum	0.00	0.00	0.00
Low protein degradability lupins	0.00	0.00	0.00
Feeds involving reduction in anti-nutritional factors			
Low arabinoxylan wheat	0.88	1.13	2.01
Low beta-glucan barley	0.11	0.07	0.18
Low beta-glucan oats	0.36	-0.68	-0.33
Low lignin oats	0.61	0.00	0.62
Low tannin sorghum	0.00	0.00	0.00
Low oligosaccharide lupins	0.63	0.428	1.05

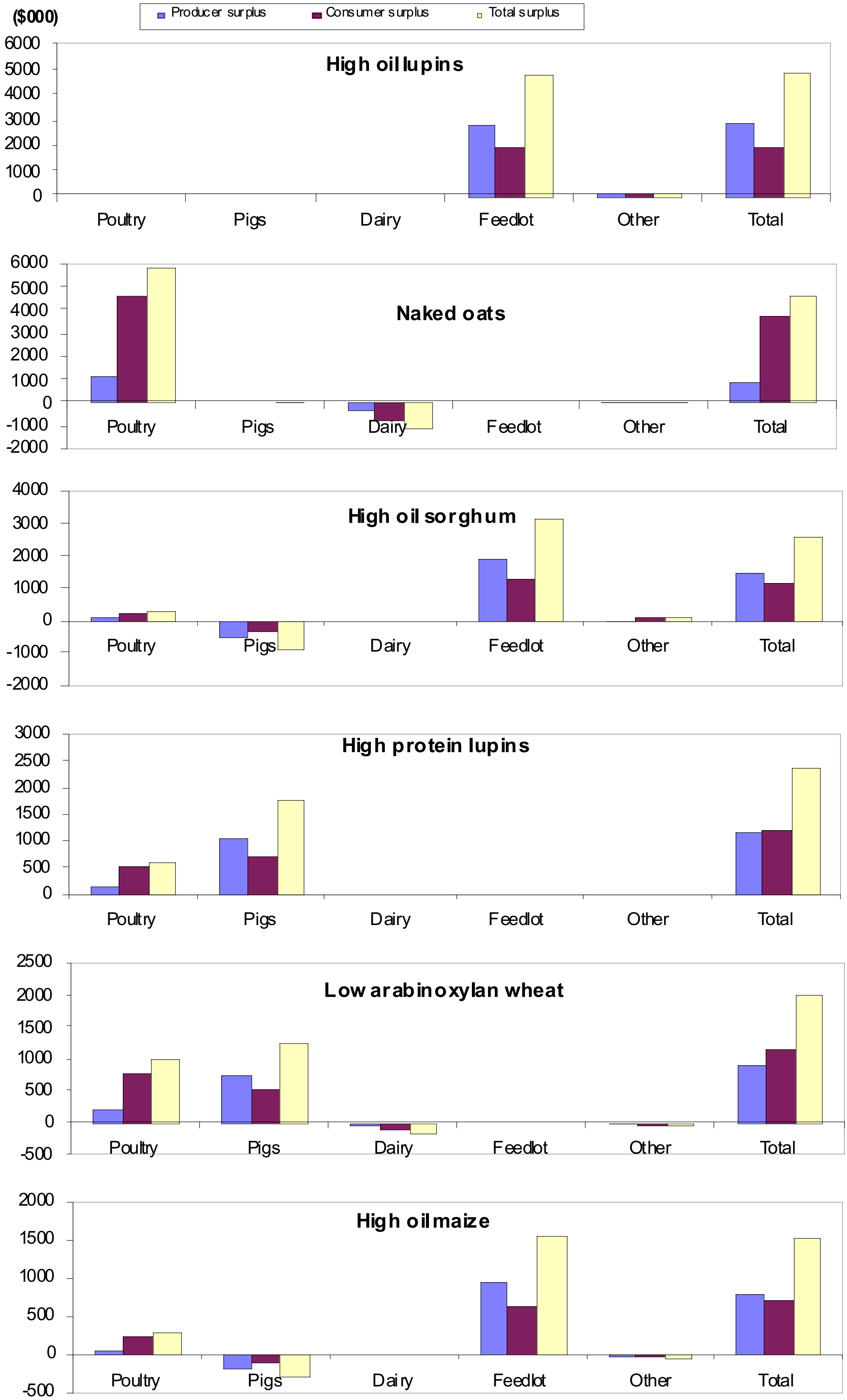
Table 5.7: Impact of Other Feeds on Producer and Consumer Welfare

	Producer surplus ($million)	Consumer surplus ($million)	Total surplus ($million)
Feeds involving increase in yield			
High yielding feed wheat	1.26	1.24	2.50
High yielding triticale	0.82	1.62	2.43
High yielding feed barley	0.58	1.62	2.19
High yielding oats	0.84	1.38	2.23
High yielding sorghum	0.53	2.11	2.63
High yielding maize	0.65	2.60	3.25
High yielding lupins	1.77	1.75	3.52
High yielding sunflower	1.00	1.51	2.51
High yielding canola	3.08	1.41	4.48
High yielding field peas	1.58	2.32	3.90
High yielding faba beans	1.16	1.99	3.15
High yielding chickpeas	0.00	0.00	0.00
High yielding soybeans	0.87	3.48	4.35
New feeds			
Cassava	0.06	0.00	0.06

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 Figure 5.1. The detailed welfare effects for each of the new feed options is shown Appendix C.

It is apparent that new feeds can have impacts on very different groups. For example in Figure 5.1, High oil lupins and Naked oats have roughly 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.

Figure 5.1: Welfare Effects of Selected New Feeds for Different Livestock Industries



5.5 Summary of Findings of Aggregate Analysis of New Feeds

A. Feeds Involving Change in Protein Content

High protein feed wheat

- Rating: Very low
- Total benefits: $0.27 million
- Substitution of high protein wheat for standard wheat allows lucerne hay and barley to replace more standard wheat.
- Mainly used by Beef feedlots

High protein barley

- Rating: Very low
- Total benefits: $0.17 million
- Substitution of high protein barley for standard barley allows lucerne hay and standard barley to replace the more expensive millmix.
- Mainly used by Beef feedlots

High protein oats

- Rating: Low
- Total benefits: $0.46 million
- Substitution of high protein oats allows barley and lucerne hay to replace more expensive wheat and lupins (with some small increase in imported soymeal).
- Mainly used by Broilers

High protein lupins

- Rating: Medium
- Total benefits: $2.38 million
- Substitution of high protein lupins for standard lupins allows barley to replace more expensive standard lupins and soymeal.
- Mainly used by Pigs

B. Feeds Involving Change in Amino Acid Profile

High lysine wheat

- Rating: Low
- Total benefits: $0.58 million
- High lysine wheat is substituted directly for standard wheat, but the cost saving comes from a slight reduction in meatmeal.
- All used by Pigs

High methionine wheat

- Rating: Very low
- Total benefits: $0.04 million
- High methionine wheat is substituted directly for wheat, allowing additional wheat to be used in place of barley and lucerne hay. Methionine use is also reduced.
- Mainly used by Beef feedlots and Layers

High threonine wheat

- Rating: Very low
- Total benefits: $0.00 million
- High threonine wheat is used in place of standard wheat, but there is no gain in feed costs
- All used by Pigs

High sulphur amino-acid lupins

- Rating: Very low
- Total benefits: $0.15 million
- Only a small proportion of the availability of the new feed is used. Straight substitution for standard lupins, but few other changes occur in feed use.
- All used by Broilers

C. Feeds Involving Improvement in Digestibility and Energy of Grain

Hull-less barley

- Rating: Medium
- Total benefits: $1.60 million
- Substitution of low seed coat content barley for standard barley allows lucerne hay and standard barley to replace the more expensive millmix and wheat
- There are savings in feed processing costs for ruminants included in this estimated gain.
- All used by Beef feedlots

Low seed coat content barley

- Rating: Medium
- Total benefits: $1.40 million
- Nutritionally, substitution of low seed coat content barley for standard barley allows lucerne hay and standard barley to replace the more expensive millmix and wheat.
- There are savings in feed processing costs for ruminants included in this estimated gain.
- Mainly used by Beef feedlots and Pigs

High seed coat digestibility barley

- Rating: Medium
- Total benefits: $1.25 million
- Nutritionally, substitution of high seed coat digestibility barley for standard barley allows lucerne hay and standard barley to replace the more expensive millmix.
- There are savings in feed processing costs for ruminants included in this estimated gain.
- Mainly used by Beef feedlots and Pigs

Naked oats

- Rating: High
- Total benefits: $4.66 million
- Substitution of naked oats for standard oats allows barley and lucerne hay to replace more expensive maize, lupins and meatmeal.
- All used by Broilers

High oil barley

- Rating: Low
- Total benefits: $1.02 million
- Substitution of low seed coat content barley for standard barley allows standard barley and lucerne hay to replace the more expensive millmix and wheat (amount of standard barley used actually increases).
- All used by Beef feedlots

High oil oats

- Rating: Low
- Total benefits: $1.13 million
- Substitution of high oil oats for standard oats allows barley and lucerne hay to replace more expensive wheat (with some substitution of soymeal for lupins).
- All used by Broilers

High oil sorghum

- Rating: Medium
- Total benefits: $2.59 million
- Substitution of high oil sorghum for standard sorghum allows wheat, tallow and meatmeal to replace millmix, full fat soya, soymeal and some barley.
- All used by Beef feedlots

High oil maize

- Rating: Medium
- Total benefits: $1.53 million
- Substitution of high oil maize for standard maize allows wheat, tallow and meatmeal to replace millmix, full fat soya and soymeal.
- Mainly used by Beef Feedlots and Broilers

High oil lupins

- Rating: High
- Total benefits: $4.85 million
- Substitution of high oil lupins for standard lupins allows more standard lupins to replace millmix and full fat soya.
- All used by Beef feedlots

Waxy sorghum

- Rating: Very low
- Total benefits: $0.00 million
- Waxy sorghum is substituted for standard sorghum, but there are no benefits in terms of feed cost reductions, because no nutritional advantages were identified with waxy sorghum.
- All used by Broilers

Low protein degradability lupins

- Rating: Very low
- Total benefits: $0.00 million
- Low protein-degradability lupins are used in preference to standard lupins, but there are no benefits in terms of feed cost reductions.
- Mainly used by Pigs and Broilers

D. Feeds Involving Reduction in Anti-Nutritional Factors

Low arabinoxylan wheat

- Rating: Medium
- Total benefits: $2.01 million
- The substitution of low-arabinoxylan wheat for standard wheat allows lucerne hay to be substituted for more wheat, and barley to be substituted for lupins and some synthetic feeds.
- Mainly used by Layers and Broilers

Low beta-glucan barley

- Rating: Very low
- Total benefits: $0.18 million
- Substitution of low beta-glucan barley for standard barley allows more standard barley to be used in place of wheat, which lowers the overall feed cost.
- Mainly used by Dairy and Layers

Low beta-glucan oats

- Rating: Very low
- Total benefits: $0.00 million
- Low beta-glucan oats are used in preference to standard oats, but there are no benefits in terms of feed cost reductions (in fact standard oats are preferred).
- Mainly used by Broilers

Low lignin oats

- Rating: Low
- Total benefits: $0.62 million
- Substitution of low lignin oats for standard oats allows barley, lucerne hay and soymeal to replace wheat and lupins.
- All used by Broilers

Low tannin sorghum

- Rating: Very low
- Total benefits: $0.00 million
- Low tannin sorghum is used in preference to standard sorghum, but there are no benefits in terms of feed cost reductions, because no nutritional advantages were identified with low tannin sorghum.
- All used by Broilers

Low oligosaccharide lupins

- Rating: Low
- Total benefits: $1.04 million
- Substitution of low oligosaccharide lupins for standard lupins allows barley to replace the more expensive wheat and lupins.
- All used by Pigs

E. Feeds Involving Increase in Yield

High yielding feed wheat

- Rating: Medium
- Total benefits: $2.50 million
- Straight substitution of high yielding wheat for standard wheat. The impact is that wheat users get cheaper wheat, with no other substitution involved.
- Mainly used by Beef Feedlots and layers

High yielding triticale

- Rating: Medium
- Total benefits: $2.43 million
- Substitution of high-yielding triticale for standard triticale means that some wheat and sunflower meal needs to replace barley and lucerne hay in the feed mix.
- Mainly used by Pigs and Layers

High yielding feed barley

- Rating: Medium
- Total benefits: $2.19 million
- Straight substitution for standard barley. The impact is that barley users get cheaper barley, with no other substitution is involved.
- Mainly used by Dairy

High yielding oats

- Rating: Medium
- Total benefits: $2.23 million
- Substitution of high yielding oats for standard oats allows wheat and barley to be replaced by (cheaper) lucerne hay.
- Mainly used by Grazing ruminants and Layers

High yielding sorghum

- Rating: Medium
- Total benefits: $2.63 million
- Straight substitution of high yielding sorghum for standard sorghum. The impact is that sorghum users get cheaper sorghum, with no other substitution involved.
- All used by Broilers

High yielding maize

- Rating: Medium
- Total benefits: $3.25 million
- Straight substitution of high yielding maize for standard maize. The impact is that maize users get cheaper maize, with no other substitution involved.
- All used by Broilers

High yielding lupins

- Rating: Medium
- Total benefits: $3.52 million
- Substitution of higher-yielding lupins for standard lupins allows wheat and standard lupins to replace barley, millmix and soymeal. However, main impact is that lupins users get cheaper lupins.
- Mainly used by Pigs and Broilers

High yielding sunflower

- Rating: Medium
- Total benefits: $2.51 million
- Use of additional sunflower meal allows wheat and lucerne to replace barley, lupins and standard sunflower meal.
- Mainly used by Pigs and Layers

High yielding canola

- Rating: High
- Total benefits: $4.48 million
- Substitution of high yielding canola meal for standard canola meal allows wheat and millmix to replace barley and lupins.
- Mainly used by Pigs

High yielding field peas

- Rating: Medium
- Total benefits: $3.90 million
- Straight substitution for standard field peas. The impact is that pea users get cheaper peas, with no other substitution is involved.
- Mainly used by Pigs and Broilers

High yielding faba beans

- Rating: Medium
- Total benefits: $3.15 million
- Lower price of high yielding faba beans allows them to be used to replace imported soymeal, barley, millmix and lupins.
- Mainly used by Broilers and Pigs

High yielding chickpeas

- Rating: Very low
- Total benefits: $0.00 million
- If chickpeas grown in place of field peas, chickpeas not used but feed costs rise because of lower availability of field peas.

High yielding soybeans

- Rating: High
- Total benefits: $4.35 million
- Straight substitution for standard soymeal. The impact is that soymeal users get cheaper soymeal, with no other substitution involved.
- Mainly used by Broilers

F. New Crops

Cassava

- Rating: Low
- Total benefits: $0.06 million
- Cassava at $174/t replaces millmix, and allows wheat to replace lupins and barley.
- Mainly used by Broilers

6. Regional Analysis of Selected Improved Feed Grains

6.1 ABARE Demand Model Development

Because of the limitations of the ABARE feed demand model as it was in 1996 (Hafi and Andrews 1997), a complete analysis required that the model be further extended to include greater regional break-down, so that issues relating to smaller regions could be more accurately analysed. In particular, the regional detail for WA (the highest-producing state) needed to be increased. That work was carried out by ABARE over the period 1997-1998. Each additional region increased the model's complexity and data requirements, so that the number of livestock categories was reduced to enable the analysis to be manageable. This required a new set of feed specifications and technical information to be supplied by Tony Edwards.

The 14 regions defined are shown in Table 6.1. They were based broadly on the GRDC's agro-ecological zones, although the State boundaries needed to be recognised because of some of the data requirements (see Hafi and Rodriguez (2000).

Table 6.1: Feed Grain Regions and Reference Points

State	No.	Region	Reference point
WA	1	Northern & Eastern WA	Merredin
	2	Central & Sandplain WA	Katanning
	3	South Coast livestock WA	Bridgetown
SA	4	All SA	Clare
Vic	5	Wimmera & Mallee	Horsham
	6	Victoria high rainfall	Benalla
NSW	7	North west NSW	Moree
	8	North east NSW	Walgett
	9	Central & NSW slopes	Wagga
	10	Northern NSW livestock	Armidale
	11	Southern NSW livestock	Goulburn
Qld	12	Central zone & Northern livestock	Emerald
	13	South-west Qld	Roma
	14	South-east Qld & Southern livestock	Dalby

For each region, a reference point (location) was defined to represent the economic centre of the region (Table 6.1), to enable estimates to be made of the costs of transporting grain between regions. Because of the large size of the regions and the range of costs between different points in each region, the reference point was, for simplicity, defined as a representative point in the region. The cost of transporting grain from one region to another was then assessed as the cost of transporting grain between the relevant reference points. While this is a simplification, and does not well represent the situation where grain is shipped between adjoining parts of two different regions, it was seen as a means of accounting for the transport costs in a consistent and objective way.

The lowest-cost means of transporting grain between each of the centres was then identified by examining two alternatives for each route, namely road freight and a rail-shipping option (Table 6.2). In general, road transport was cheapest for transporting grain between centres in the eastern States. SA was split about 50-50 between road and sea, with road for the nearer destinations. For WA, in all cases, shipping was a lower-cost option than using road freight. Intrastate transport was always cheaper by road.

The overall average (unweighted) cost of transporting grain from one region to another was approximately $53 per tonne, although there was considerable variability. The costs were as low as $8 per tonne, while several adjoining centres have freight costs of $10-$20 per tonne. Grain transportation from WA to the eastern States (and vice-versa) cost approximately $70-$80 per tonne, while grain transport between Victoria/southern NSW and Queensland was generally $60-$70 per tonne.

6.2 Impacts on Regional Feed Costs of Selected New Feeds

Because of the complexity of the model, running it for each of the new feed options was beyond the resources of the project. As a result, a selected sub-set of nine new feeds was analysed in the regional model. These were:

- High lysine wheat
- Low seed coat content barley
- Naked oats
- High oil oats
- High oil lupins
- Low arabinoxylan wheat
- Low beta-glucan barley
- Low lignin oats
- High-yielding wheat

For each of these new feeds, 100,000 tonnes of production was assumed in place of the same quantity of the equivalent standard feed. The availability of the production of the new feed was taken as proportional to current production of the standard feed. As a result, the analysis does not take account of the possibilities of any benefits of targeting the production of the new feeds in particular regions, and is therefore likely to understate the benefits of that strategy.

Again, given the complexities of the regional model and its data requirements, no economic welfare analysis of the results was undertaken. Instead, the analysis was undertaken to assess the reduction in feed cost as a result of the introduction of the selected new feeds. The reduction in total feed cost, by region and state, for the selected feeds is shown in Table 6.3. For some regions, there was no change in total feed cost with the new feeds, because those regions effectively had no demand for feed grains. In other regions, there was a significant effect for some feeds and not for others, depending on the mix of livestock industries in the region. In general, however, the selected new feeds led to gains through lower feed costs in most regions.

Table 6.2: Lowest-Cost Grain Freight between Centres
($ per tonne)

	Western Australia			S.A.	Victoria		New South Wales					Queensland		
	Merredin	**Katanning**	**Bridgetown**	**Clare**	**Horsham**	**Benalla**	**Moree**	**Walgett**	**Wagga**	**Armidale**	**Goulburn**	**Emerald**	**Roma**	**Dalby**
Merredin	0													
Katanning	**24**	0												
Bridgetown	**25**	**11**	0											
Clare	51	45	50	0										
Horsham	63	57	62	**40**	0									
Benalla	66	60	65	54	**29**	0								
Moree	75	69	74	63	65	68	0							
Walgett	82	77	81	70	72	**69**	**15**	0						
Wagga	78	73	78	67	**46**	**17**	51	**52**	0					
Armidale	77	71	76	65	67	70	**22**	**36**	53	0				
Goulburn	75	69	74	63	65	**34**	47	54	**19**	**49**	0			
Emerald	75	70	75	63	66	68	**57**	**71**	71	70	68	0		
Roma	78	72	77	66	68	71	**34**	**49**	74	**52**	70	**33**	0	
Dalby	72	67	72	60	63	65	**24**	**38**	68	**33**	65	35	**25**	0

Note: Numbers in bold indicate road freight; others rail-ship.

Table 6.3: Reduction in Total Feed Cost, by Region and State, for Selected Feeds ($ million)

	High lysine wheat	**Low seed coat content barley**	**Naked oats**	**High oil oats**	**High oil lupins**	**Low arabino. wheat**	**Low beta-glucan barley**	**Low lignin oats**	**High yielding wheat**
Northern & Eastern WA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Central & Sandplain WA	0.04	0.12	0.44	0.18	0.07	0.09	0.10	0.17	0.15
South Coast livestock WA	0.09	0.13	1.04	0.47	0.21	0.20	0.12	0.45	0.23
WA Total	***0.13***	***0.24***	***1.48***	***0.65***	***0.28***	***0.29***	***0.23***	***0.62***	***0.38***
SA Total	***0.09***	***0.26***	***1.08***	***0.29***	***0.21***	***0.18***	***0.22***	***0.27***	***0.24***
Wimmera & Mallee	0.05	0.13	0.55	0.10	0.10	0.10	0.10	0.08	0.18
Victoria high rainfall	0.26	0.55	1.52	0.32	0.48	0.51	0.43	0.30	0.91
VIC Total	***0.31***	***0.67***	***2.07***	***0.41***	***0.58***	***0.62***	***0.52***	***0.38***	***1.08***
North west NSW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North east NSW	0.13	0.03	0.54	0.00	0.11	0.14	0.02	0.00	0.23
Central & NSW slopes	0.13	0.27	0.95	0.33	0.19	0.23	0.24	0.33	0.37
Northern NSW livestock	0.09	0.00	0.49	0.00	0.18	0.27	0.00	0.00	0.34
Southern NSW livestock	0.15	0.14	0.94	0.13	0.32	0.28	0.09	0.10	0.38
NSW Total	***0.50***	***0.44***	***2.92***	***0.46***	***0.81***	***0.93***	***0.35***	***0.43***	***1.32***
Central zone & Northern livestock	0.00	0.02	0.77	0.00	0.19	0.00	0.00	0.00	0.00
South-west Qld	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South-east Qld & Southern livestock	0.28	0.03	1.36	0.00	0.44	0.38	0.01	0.00	0.63
QLD Total	***0.28***	***0.04***	***2.13***	***0.00***	***0.62***	***0.37***	***0.01***	***0.00***	***0.63***
Australia Total	**1.31**	**1.66**	**9.70**	**1.81**	**2.51**	**2.38**	**1.32**	**1.70**	**3.66**

From Table 6.3, it is apparent that the Victorian high rainfall region, South-east Queensland and NSW Central and Slopes are the three regions that generally gain most from the new feeds, reflecting the fact that these are the regions that have the most livestock on full feed rations. NSW and Victoria are generally the states that receive the greatest gains, while WA generally gains less from feed nutritional improvements than the other states, except for improvements in oats which give the highest gains to WA.

It is also apparent from the results of the regional analysis that the livestock sector in NSW gains most from wheat and lupins improvements, the livestock sector in Victoria gains most from barley improvements, and the livestock sector in WA gains most from oats improvements. In Queensland,, wheat improvements generally provide the greatest benefits, while SA has similar gains for all feeds except for Naked oats which provides more significant benefits.

6.3 Comparison of Regional and Aggregate Analyses

The results from the regional analysis were generally similar to those obtained in the aggregate analysis above, although there were often slightly higher gains in the regional analysis. This reflects the fact that regional analysis allows the extra benefits flowing from improved feed grains to be picked up by those industries that would gain the most benefits from them, thus pin-pointing the benefits more precisely than an overall aggregate analysis could. The total gains in the regional analysis were greatest for Naked oats and High-yielding wheat, with lower total benefits for the other new feeds analysed. A comparison of the results obtained from the aggregate and the regional analysis for the selected feeds is shown in Table 6.4.

Table 6.4 Comparison of Regional and Aggregate Results

	Reduction in feed cost		**Rating**		**Rank**	
New feed option	**Regional ($m)**	**Aggregate ($m)**	**Regional**		**Aggregate**	**Regio**
High lysine wheat	1.31	0.58	M	L	9	8
Low seed coat content barley	1.66	1.40	M	M	7	5
Naked oats	9.70	4.66	VH	H	1	2
High oil oats	1.81	1.13	M	L	5	6
High oil lupins	2.51	4.86	H	H	3	1
Low arabinoxylan wheat	2.38	2.01	M	M	4	4
Low beta-glucan barley	1.32	0.18	M	VL	8	9
Low lignin oats	1.70	0.62	M	L	6	7
High yielding wheat	3.66	2.50	H	M	2	3

With the exception of High oil lupins, the regional analysis provided higher benefits for each feed than the aggregate analysis. The higher returns from the regional analysis result from the fact that for local users the new feeds would be lower cost than in the aggregate analysis, where the costs were increased by an average transport cost. In the regional analysis, both within regions and between adjoining region, the costs of the new feeds would have been lower. The explanation for the exception for High oil lupins lies in the fact that in the regional analysis most of the production would have been in WA, where there is lower livestock demand for feed. In the aggregate analysis, the lupins was effectively available across the whole of Australia.

While it is apparent that the regional analysis allows greater detail and more precise identification of the beneficiaries of feed grains improvements, the ranking is very similar to that obtained from the aggregate model. This finding suggests that the aggregate analysis is likely to be valuable for determining priorities and ranking of new feed options. However, the aggregate analysis is likely to be less useful in determining the precise value of the benefits, or in identifying which regions and industries are most likely to gain from new feeds.

7. Discussion of Results

7.1 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 and Naked oats. The potential benefits from several other feeds are also sufficient to make them worthwhile research targets in the feed grains area, including: High oil sorghum, High protein lupins, Low arabinoxylan wheat, Hull-less barley, High oil oats, Low seed coat content barley, and High seed coat digestibility barley.

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, 10 had total welfare benefits of less than $0.3 million per year and a further 6 less than $1.2 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.

7.2 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 compared to the returns that could be obtained if yield was pursued rather than quality. As can be seen in Tables 5.4 and 5.5, the level of returns that could be obtained from improving yields by 20% without quality change are superior to all but the best 3 or 4 of the feeds with improved nutritional characteristics. While this study 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.

7.3 Location Issues

The analyses in this study have been conducted at two levels of aggregation. Given the complexity of regional analysis, all potential new feeds were analysed at the aggregate national level, which allowed a broad ranking of the new feeds by the expected level of returns. A selected sub-set of the new feeds was then analysed at the regional level, where more precise regional effects could be identified. While there were some differences in the ranking provided by the aggregate and the regional analyses, the differences were generally small. This finding supported the reliance on the aggregate model for the initial analysis, given that the regional analysis could be expected to have resulted in essentially the same outcomes.

However, there is an important limitation from the way that the new feeds have been analysed. In the regional analysis, the production (and therefore availability) of the new feeds was taken as proportional to the current production of the standard feed. Thus, some of the new feeds were taken as being produced in regions where there was little or no demand for them. Had the production of the new feeds been based in regions where the demand for the particular feed was greatest, the benefits are likely to have been higher than estimated from the analysis used. By allowing some of the new feeds to be produced in new areas near markets, or in production regions closest to the markets, the benefits would have been higher. While an exploration of those issues could prove significant if the new feeds are to be developed, that analysis was outside the scope of the resources available to this study.

7.4 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.

Of the portion of benefits that flow to producers, they are shared between livestock producers, grain producers and other input suppliers. In the analysis presented in this report, the new feeds have been priced in such a way as to provide none of those benefits to grain producers. However, if grain and livestock producers were able to cooperate in developing and producing the new feed grains for the livestock industry, those benefits could be shared between the two groups to provide a mutually beneficial result. The basis for that sharing would involve providing some reward to the grain producers for producing the new feeds to a given nutritional specification while still enabling a reduction in feed costs. It is beyond the scope of this study to develop strategies for cooperating so as to produce such an outcome, as they relate to market structures and industry strategies. However, it is clear that some significant benefits could well be lost if there is not recognition of the possibility of mutual benefits from cooperative action in these areas.

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. The poor results for Dairy are at least partly because the options selected for analysis were focussed on those likely to produce benefits for industries with complete rations specified, rather than the supplementary feeding common in the dairy industry.

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, all industries are better off with the introduction of any of the higher-yielding feeds.

7.5 Availability of New Feeds

In the analysis presented in this report, the new feeds were taken as being all available in the same quantity of 100,000 tonnes, to provide a consistent basis for examining the economic potential of each. While that analysis provides a consistent basis for comparison, it does not accurately assess the potential that some feeds may have. For example, because of the different amounts demanded of different feeds, for some new feeds the potential uses may be well in excess of 100,000 tonnes while for others the potential is for lower quantities. Since the current analysis does not take account of those differences, it may be penalising some of the new feeds that have the potential to provide possibly small unit benefits over a larger quantity than 100,000 tonnes. Only when the full level of demand for each new feed had been determined (which is dependent on its price and the location of production) could the full potential be analysed in more detail.

In undertaking the analysis, the sensitivity of the per-tonne benefits of the new feeds for quantities other than 100,000 tonnes was analysed. The results were that the benefits per tonne were found to be very insensitive to the quantities involved within a range of 50,000 to 250,000 tonnes of the new feeds.

7.6 Developing Research Priorities for Feed Grains

7.6.1 Use of results to determine research priorities for feed grains

For the results of the project to be used directly by research administrators in decisions about which areas of research to fund, and who should pay for it, the results of the economic analyses need to be translated into a form that can be useful to those decision-makers. The final component of the project is to develop a means of presenting the results of this analysis, in a form that can assist funding decisions.

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 capacity for substitution between feed grains, the examples where that is the case are relatively rare.

7.6.2 Research priorities for each livestock industry

On the basis of the results obtained in this analysis, the highest priorities from all the alternatives for each industry were identified (Table 7.1). It is apparent that there are considerable differences in the priorities for the different industries and the extent to which

Table 7.1: Priorities for New Feeds for Particular Industries

All Feed Options

Broilers	Layers	Pigs	Dairy	Feedlot	Other	Total
Naked oats (40%)	High yielding soybeans	High yielding canola	High yielding barley	High oil lupins	High yielding oats	High oil lupins
High yielding maize	High yielding wheat	High yielding lupins		High oil sorghum	High yielding barley	Naked oats (40%)
High yielding sorghum	High yielding triticale	High yielding field peas		Hull-less barley (10%)	High oil sorghum	High yielding canola
High yielding soybeans		High protein lupins		High yielding feed wheat	High yielding canola	High yielding soybeans
High yielding faba beans		High oil oats		High oil maize		High yielding field peas
High protein lupins		Low lignin oats		Low seed coat cont. barley		High yielding lupins
High yielding field peas		High yielding faba beans		High seed coat digest. barley		High yielding maize
High yielding sunflower		Low arabinoxylan wheat		High oil barley		High yielding faba beans
Low arabinoxylan wheat		Low beta-glucan oats		High protein barley		High yielding sorghum
High protein oats		High yielding sunflower		High protein feed wheat		High oil sorghum

Improved Nutrition Options only

Broilers	Layers	Pigs	Dairy	Feedlot	Other	Total
Naked oats (40%)		High protein lupins		High oil lupins	High oil sorghum	High oil lupins
Low arabinoxylan wheat		High oil oats		High oil sorghum		Naked oats (40%)
High protein oats		Low lignin oats		Hull-less barley (10%)		High oil sorghum
High oil sorghum		Low arabinoxylan wheat		High oil maize		High protein lupins
High S amino-acid lupins		Low beta-glucan oats		Low seed coat cont. barley		Low arabinoxylan wheat
High protein barley		High protein oats		High seed coat digest. barley		Hull-less barley (10%)
High lysine wheat		Low oligosaccharide lupins		High oil barley		High oil maize
High protein feed wheat		High lysine wheat		High protein barley		Low seed coat cont. barley
High threonine wheat		Low seed coat cont. barley		High protein feed wheat		High seed coat digest. barley
High oil lupins		High seed coat digest. barley				High oil oats

benefits are likely to flow to particular industries. For each industry, the ten most valuable options were identified; where there were fewer options with positive benefits for that industry, fewer than 10 were listed in the table. The lists have two parts: First the full list of options including high-yielding feeds as well as nutritional improvements; and second, only showing the nutritional improvements.

For the Broiler industry, there are many options to choose from, though 6 of the top-ranked 10 options are high-yielding feeds. For Layers, no feeds with improved nutrition composition were identified, though several high-yielding options were found. Pigs also had many options, half of which were high-yielding feeds. For Dairy, as with Layers, there were no nutritional improvements that would provide benefits, though High yielding feed barley would provide benefits to the Dairy industry. The Feedlot cattle industry was the industry in which there were the largest number of options for improved nutritional composition. Wheat was the only high-yielding feed that ranked in the top 10 options for Feedlot cattle. High oil sorghum was the only feed apart from high-yielding feeds that provided benefits for the “Other livestock” category. Overall, the highest priorities were High oil lupins and Naked oats, followed by seven high-yielding options.

The use by the livestock sector of the feeds that provide benefits when yields are increased is constrained by the current higher prices for those feeds. In each case, a reduction in the price of those feeds (however brought about) would have equivalent benefits for the livestock sector.

7.7 Limitations to This Analysis

Apart from the limitations to the data used (section 4.5) and the degree of aggregation in the analysis (section 7.3), there are some other important limitations to the analysis that was possible in this study. First, some ingredients are not specified in the feeds. For example, enzymes are not incorporated in the specifications used for the feeds. One result of that is that the benefits of a feed such as Low arabinoxylan wheat are likely to be over-stated, since there is an alternative means of obtaining the desired enzymes. Second, it has not been possible to capture the value of waxiness in grains appropriately in the analysis. Research has shown that there are certain improvements that result from waxiness, but no nutritional advantages could be identified for use in this analysis by the animal nutritionists involved (see Appendix A for more discussion). Therefore, there are likely to be some benefits from waxy grains that are not properly accounted for in the analysis in this study. As a result, the results presented in this study understate the value of improved waxiness of at least some grains. Third, by assuming the same quantity of each new analysed, this study understates the value of those feeds for which there is a greater level of demand (see section 7.5).

8. Conclusions

The use of modern scientific practices such as biotechnology in agriculture has made it possible to introduce a specific characteristic in a particular grain that can improve its efficiency as a livestock feed. A wide range of options has been put forward as potential means of improving the nutritional composition of feed grains that would address the specific needs of different livestock industries. It is essential that the increasingly limited funds for research and development be invested in the most beneficial areas. The objective of the analysis undertaken in this study was to assess those potential new feeds and determine the economic merit of research to develop those feeds.

In assessing the relative benefits from alternative forms of improvement of nutrition of feed grains, the cost-reducing impacts of the different options have been analysed in a linear-programming model of least cost feed rations for the different livestock industries. Once that cost-reduction had been identified, economic welfare analysis was then used to estimate the size and distribution of the benefits of research from the feed grains quality-improving research between producers and the consumers. The analysis also identified which of the livestock industries were likely to receive the benefits from each of the new feeds. The extent of the benefits received by the feed grains sector could not be determined without specifically relating them to particular marketing structures such as contract production or the payment of a premium for particular nutritional quality grains.

The analysis also reveals that the aggregate national analysis provides a valuable assessment of the overall value of the new feeds. While it lacked regional detail, it provided a basis for analysing a broad range of potential new feeds on a consistent basis. Given the complexity and the cost of regional analysis, this aggregate analysis provides a valuable tool for screening any other potential new feeds. Those feeds that provide important benefits from that analysis could then be subjected to greater scrutiny at the regional level.

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. These are clearly the feeds on which the research and development funding should be concentrated at this time. 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 study is that those benefits may well be more evenly spread across the different industries. That 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.

Clearly, the selection of which, if any, of the new feeds to develop needs to be undertaken carefully, to ensure that scarce research and development funds are used to provide the best returns. The analysis in this study enables those feeds to be identified, so that research priorities for feed grains can be developed with improved knowledge of the economic consequences.

References

Alston, J.M., Norton, G.W. and Pardey, P.G. (1995), *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*, Cornell University Press, Ithaca.

Brennan, J., Fisher, J. and Oliver, J. (1993), “Niche markets for Australian wheat”, *Agricultural Science* 6(2), 27-31.

Brennan, J.P., Godyn, D.L. and Johnston, B.G. (1989), “An economic framework for evaluating new wheat varieties”, *Review of Marketing and Agricultural Economics* 57, 75-92.

Brennan, J.P. , Singh, R.P. and Singh, I.P. (1999), “Economic issues in assessing research priorities in feed grains nutrition”, Contributed paper presented at the 43rd annual conference of the Australian Agricultural and Resource Economics Society, Christchurch, NZ.

GRDC (1995), *Feed Grains Quality Workshop*, Grains Research and Development Corporation, November 1995.

Hafi, A. and Andrews, N. (1997), *Regional Feed Markets in Australia*, Report prepared for the Grains Research and Development Corporation, Australian Bureau of Agricultural and Resource Economics, Canberra.

Hafi, A. and Rodriguez, A. (2000), *Projection of Regional Feed Demand and Supply in Australia*, Australian Bureau of Agricultural and Resource Economics, Canberra.

Hill, D.J. and Griffith, G.R. (2000), “Measuring the Distribution of the Benefits of Quality- or Yield-Enhancing Research in the Feed Grains Industry: Some Theoretical and Empirical Issues”, Draft Discussion Paper, NSW Agriculture.

Hill, D.J., Piggott, R.R., and Griffith, G.R., 1996, "Profitability of incremental expenditure on fibre promotion", *Australian Journal of Agricultural Economics*, 40 (3): 151-174.

Piggot, R.R., Piggot, N.E., and Wright, V.E., 1995,"Approximating Farm-Level incremental advertising Expenditure: Methods and an Application to the Australian Meat Industry", *American Journal of Agricultural Economics*, 77: 497-511

Rose, R .N. (1980), "Supply Shifts and Research Benefits: Comment,*" American Journal of Agricultural Economics*, 62(4), 834 -37.

Singh, I.P. and Brennan J.P. (1998), “Elasticities of demand for feed grains”, Contributed paper presented at the 42nd Annual Conference of the Australian Agricultural and Resource Economics Society, Armidale.

Voon, T.J. and Edwards, G.W. (1992), “Research payoff from quality improvement: The case of protein in Australian wheat”, *American Journal of Agricultural Economics* 74(3), 564-72.

Appendix A: Feed Grain Composition and Estimated Nutritional Implications

(Based on Notes prepared by Tony Edwards, August 1998)

A.1 Basis for Estimating Nutritional Composition

A standard nutritional composition was defined for each commodity involving protein and energy values commonly adopted in the livestock feeding industries. The carbohydrate profiles assumed represent "typical" values as an arbitrary reference point to compare the magnitude of the nominated adjustments in specific parameters. While there is considerable variability (with variety, season, site, and agronomic practice, etc) in those parameters, specific quantitative differences within the scope of plant breeding potential were nominated, and then a nutritional value was ascribed to the change.

In general, the new feeds were defined as a 20% change in the critical parameter, with other parameters then adjusted as appropriate. In the case of the protein, oil or specific amino acid variations, the implied nutritional adjustment is reasonably predictable. However, the nutritional significance of variations in the carbohydrate profile were not as easily translated due to the dearth of information on these relationships.

The following notes detail the logic applied in setting the revised nutritional values in response to the nominated shift in specific compositional parameters.

A.2 Wheat

The standard wheat chosen involved a protein level of 11% and typical levels of starch and pentosan.

The single amino acid adjustments (lysine, methionine, threonine) were made as simple 20% increases in the values for these individual amino acids, with all other aspects held constant. Since the levels of these specific amino acids can only be manipulated by changing the relative proportions of the contributing proteins or by the genetically engineered inclusion of a foreign protein, it is unlikely that the other amino acid levels would remain constant. However, in the absence of any specific information on the full amino acid profile of high lysine or high methionine wheats this simple approach was adopted. It could also be argued that promoting a specific amino acid level might also affect the carbohydrate, lipid and mineral status of the grain as well as its yield characteristics. Without comprehensive data on the full compositional analysis it is difficult to accurately reflect the overall nutritional value of the modified material.

High protein wheat involved a 20% lift in protein content and an adjustment in amino acid levels based on regression equations derived from a range of Australian wheat samples. This adjustment involved no change in the carbohydrate profile or in the availability of lysine, which is intended to reflect the value of elevated protein *per se* independent of any other changes.

Low arabinoxylan wheat was considered to be similar in most respects to the standard wheat with the exception that the pentosan levels were halved and soluble NSP levels reduced to 0.8%. This 8% energy uplift is commonly applied commercially where the pentosan effect is removed by the use of supplementary pentosanases. There was no adjustment in energy value for pigs, ruminants or horses as there was little evidence to suggest that pentosans compromise digestibility in these species.

A.3 Barley

Standard barley chosen was a 10% protein, feed barley of "typical" composition.

High protein barley involved a simple 20% increase in protein content and an adjustment in amino acid levels based on regression equations derived for a range of Australian barley samples. There were no changes to any other characteristics.

Low beta-glucan barley involved a reduction in the beta-glucan content from 4.2% to 1.0%. The only features of this barley that altered as a consequence of this shift were the poultry energy values, since the beta-glucan content is of less significance to pigs and of no concern at all to ruminants. The magnitude of the energy adjustment has been assumed to be of a similar order as observed when supplementary beta-glucanase enzymes are applied to poultry diets (i.e. about an 8% uplift in energy).

Hull-less barley was assumed to be of similar protein content to the standard material and hence there was no adjustment in amino acid content. The main adjustments were in the fibre and other carbohydrate components, which effect the energy values for all livestock species.

High oil barley involved an uplift in the oil content from 2% to 5% and it was assumed the additional oil displaced starch.

Low seed coat content barley was simply pitched at values midway between the standard material and the naked barley.

High digestibility seed coat barley was presumed to be of greater significance to ruminants, of minor value to pigs and of no consequence to poultry.

A.4 Oats

Standard oats was an 8% protein feed oats of typical composition.

High protein oats involved a 20% uplift in protein with a corresponding adjustment in amino acid values based on regression equations. No other characters were affected.

Naked oats involved higher protein and associated amino acids, higher starch and less fibre components. The energy effects of removing the hull are profound. Where values were not directly available for the naked product they were calculated from the relative differences between whole seed and hulls and the relative proportions of kernel and hull were presumed to be 65:35.

Low beta-glucan oats was assumed to have a beta-glucan level of 0.4% relative to the standard material at 2.8%. The only parameters adjusted as a consequence of this were the poultry energy values, as the shift in beta-glucan is presumed to be of little significance to pigs and ruminants. The energy uplift applied was again 8%, in line with responses to supplementary beta-glucanase.

High oil oats involved a lift in oil from 5.5 to 8.0%, which elevated the energy values for all species of livestock and was assumed to partially displace starch.

Low lignin oats involved a reduction in lignin content from 6.0% to 2.0% with a comparable reduction in acid detergent fibre (ADF) and crude fibre. The effect on energy values was calculated as simply removing a 4% dilution factor. The lignin was assumed to be replaced partially by starch and neutral detergent fibre (NDF) fractions.

A.5 Sorghum

Standard sorghum represents a 10% protein feed sorghum typical of southern Queensland.

Waxy sorghum simply involved a shift in the amylose:amylopectin ratio but as the nutritional consequences of this were unclear, the various energy values were unchanged (pending further research information).

Similarly, low tannin sorghum was identical to the standard product as most commercial sorghums employed in the feed trade would be considered low tannin (i.e. less than 0.2%). At these levels tannins would not be expected to interfere with nutrient utilisation.

High oil sorghum involved lifting the oil content from 3% to 6% at the expense of starch, which shifted the implied energy values for all species.

A.6 Maize

Standard maize has been set at 8% protein with typical compositional characteristics.

High oil maize involved the elevation of oil from 4 to 7% at the expense of starch with corresponding uplifts in energy values.

A.7 Lupins

Standard lupins represented *angustifolius* lupins typical of Western Australia.

High protein lupin involved a 20% lift in protein content (30 to 36%) with corresponding amino acid adjustments proportional to the protein. That elevated the energy value for pigs and to a lesser extent poultry, but be of little consequence in terms of ruminant metabolisable energy (ME) due largely to its fermentable nature.

High sulphur amino acid lupins involved a 20% lift in both methionine and cystine similar to the shift indicated for the high protein material but with no adjustment in any other parameters. That should reflect the value of elevated sulphur amino acid independent of any other effects.

High protein degradability or high bypass lupins were identical in all respects to the standard lupins with the exception that the undegraded dietary protein (UDP) level has been doubled from 7.5 to 15%, with a corresponding reduction in Rumen degradable dietary protein (RDP). No adjustment has been made for factors that might facilitate this such as elevated tannin levels, change of protein type, shifts in the carbohydrate profile.

Low oligosaccharide lupins involved a reduction in oligosaccharides (raffinose, stachyose, verbascose) from 5.16% to 1.0%. The only nutritional adjustment flowing from this was an elevation in pig digestible energy (DE) and an improvement in the availability of lysine. Oligosaccharide effects in poultry were unclear and they were of no consequence in ruminants.

High oil lupins involved a lift in oil content from 5.6% to 9.0% with corresponding uplifts in energy values.

A.8 Cassava

The values for the standard cassava represented the common commercial pelleted root material.

A.9 Yield Increases

The yield increases were defined as 20% higher yields, but no change in nutritional composition. For example, the high-yielding wheat was identical to the standard wheat, as there is little evidence to differentiate them. The variance between different winter wheat samples is as wide as that between spring wheat samples and when superimposed their means would be similar. There does not appear to be any unique property of winter wheats that give them a different feeding value.

Appendix B: Nutritional Composition of New Feed Grains (1)

(Changes from standard specifications)

	Wheat						Cassava
Nutrients	**Standard wheat**	**High protein**	**Low arabinoxylan**	**High lysine**	**High methionine**	**High threonine**	
DE-PIG	14.4						12.7
POULT.ME	13.0		14.0				12.1
RUMIN.ME	12.6						11.2
HORSE-DE	14.3						12.5
PROTEIN	11.0	13.2					2.5
FAT	2.0						0.5
FIBRE	2.5						4.0
ASH	1.5						5.0
N.D.F.	12.6						9.0
A.D.F.	3.6						6.0
UDP	2.2	2.6					0.5
RDP	8.8	10.6					2.0
LYSINE	0.340	0.360		0.408			0.08
ALYSINE	0.265	0.284		0.320			0.06
METHION	0.18	0.21			0.216		0.04
M+C	0.45	0.51			0.486		0.07
THREO	0.33	0.39				0.396	0.08
ISOLEUC	0.37	0.44					0.08
TRYPTO	0.13	0.15					0.02
ARGININE	0.53	0.62					0.12
HISTIDIN	0.27	0.32					0.03
LEUCINE	0.75	0.86					0.12
PHENYLAL	0.51	0.62					0.07
P+T	0.81	1.01					0.13
VALINE	0.48	0.55					0.11
LINOLEIC	1.05						0.00
CALCIUM	0.05						0.12
T.PHOS	0.30						0.10
AV.PHOS	0.10						0.03
SODIUM	0.01						0.04
POTASS	0.37						0.88
CHLORIDE	0.08						0.09
MAGNES	0.12						0.11
SULPHUR	0.12						0.05
NA+K-CL	76.4						218.0
ABC	130						100
CHOLINE	890						0
SALT	0.10						0.15
STARCH	62						66

Appendix B: Nutritional Composition of New Feed Grains (2)

(Changes from standard specifications)

	Barley						
Nutrients	**Standard barley**	**Hull-less barley**	**Low beta glucan barley**	**Low seed coat content**	**High seed coat digestibility**	**High oil**	**High protein**
DE-PIG	12.7	13.8		13.0	12.8	13.3	
POULT.ME	11.30	12.35	12.20	11.80		11.90	
RUMIN.ME	11.7	12.6		12.1	12.0	12.2	
HORSE-DE	13.4	14.0		13.7	13.5	14.0	
PROTEIN	10.0						12.0
FAT	2.0						
FIBRE	5.0	2.0		3.5	4.0		
ASH	2.5	1.8		2.1			
N.D.F.	23.0	10.6		17.0			
A.D.F.	7.0	1.9		4.5	5.0		
UDP	2.0						
RDP	8.0						
LYSINE	0.38						0.43
ALYSINE	0.30						
METHION	0.15						0.20
M+C	0.36						0.47
THREO	0.32						0.41
ISOLEUC	0.34						0.42
TRYPTO	0.12						0.14
ARGININE	0.51						0.61
HISTIDIN	0.24						
LEUCINE	0.68						0.84
PHENYLAL	0.50						0.60
P+T	0.82						0.97
VALINE	0.52						0.58
LINOLEIC	0.85						
CALCIUM	0.05						
T.PHOS	0.30						
AV.PHOS	0.11						
SODIUM	0.01						
POTASS	0.40						
CHLORIDE	0.15						
MAGNES	0.12						
SULPHUR	0.17						
NA+K-CL	64.0						
ABC	260						
CHOLINE	1040						
SALT	0.10						
STARCH	50	52		51		47	

Appendix B: Nutritional Composition of New Feed Grains (3)

(Changes from standard specifications)

			Oats			
Nutrients	**Standard oats**	**Naked oats**	**Low beta glucan oats**	**Low lignin**	**High oil**	**High protein**
DE-PIG	11.9	16.0		12.4	12.6	
POULT.ME	11.6	14.5		12.1	12.2	
RUMIN.ME	10.0	14.0		10.4	10.7	
HORSE-DE	12.1	13.0		12.6		
PROTEIN	8.0	12.0				10.0
FAT	5.5	8.5			8.0	
FIBRE	11.2	2.3				
ASH	3.0	2.0				
N.D.F.	32.0	9.2				
A.D.F.	14.5	3.1				
UDP	1.65	2.4				2.0
RDP	6.4	9.6				8.0
LYSINE	0.360	0.540				0.410
ALYSINE	0.270	0.456				
METHION	0.13	0.22				0.18
M+C	0.32	0.64				0.50
THREO	0.27	0.43				0.35
ISOLEUC	0.32	0.45				0.37
TRYPTO	0.13	0.17				
ARGININE	0.53	0.88				0.68
HISTIDIN	0.19	0.28				0.25
LEUCINE	0.61	0.95				0.72
PHENYLAL	0.41	0.61				0.57
P+T	0.68	1.10				0.90
VALINE	0.42	0.68				0.52
LINOLEIC	1.50	2.50			2.20	
CALCIUM	0.10					
T.PHOS	0.35					
AV.PHOS	0.14					
SODIUM	0.04	0.08				
POTASS	0.38	0.40				
CHLORIDE	0.12	0.07				
MAGNES	0.1	0.13				
SULPHUR	0.21	0.14				
NA+K-CL	80.5	117.4				
ABC	280	245				
CHOLINE	1070	1100				
SALT	0.10					
STARCH	37	55		38.5		

Appendix B: Nutritional Composition of New Feed Grains (4)

(Changes from standard specifications)

	Sorghum				Maize	
Nutrients	**Standard**	**Waxy sorghum**	**Low tannin**	**High oil**	**Standard**	**High oil**
DE-PIG	14.5			15.1	15.0	15.6
POULT.ME	13.6			14.2	14.45	15.05
RUMIN.ME	11.8			12.2	12.6	13.1
HORSE-DE	13.4			14.0	14.2	14.7
PROTEIN	10.0				8.0	
FAT	3.0			6.0	4.0	7.0
FIBRE	2.5				2.5	
ASH	1.5				1.5	
N.D.F.	17.0				7.9	
A.D.F.	8.1				2.6	
UDP	4.5				4.0	
RDP	4.0				4.0	
LYSINE	0.23				0.240	
ALYSINE	0.18				0.180	
METHION	0.18				0.17	
M+C	0.36				0.39	
THREO	0.34				0.33	
ISOLEUC	0.42				0.33	
TRYPTO	0.11				0.08	
ARGININE	0.40				0.40	
HISTIDIN	0.23				0.25	
LEUCINE	1.30				1.13	
PHENYLAL	0.50				0.43	
P+T	0.91				0.71	
VALINE	0.47				0.45	
LINOLEIC	1.00			2.00	2.10	3.70
CALCIUM	0.05				0.01	
T.PHOS	0.30				0.30	
AV.PHOS	0.05				0.10	
SODIUM	0.03				0.03	
POTASS	0.35				0.33	
CHLORIDE	0.08				0.04	
MAGNES	0.20				0.15	
SULPHUR	0.14				0.12	
NA+K-CL	80.0				86.0	
ABC	130				120	
CHOLINE	600				530	
SALT	0.10				0.07	
STARCH	64			61	62	59

Appendix B: Nutritional Composition of New Feed Grains (5)

(Changes from standard specifications)

			Lupins			
Nutrients	**Standard**	**High sulphur amino acid**	**Low protein degradability**	**Low oligosaccharide**	**High protein**	**High oil**
DE-PIG	14.4			14.9	14.8	15.2
POULT.ME	8.8				9.0	9.4
RUMIN.ME	12.0					12.5
HORSE-DE	14.2					14.8
PROTEIN	30.0				36.0	
FAT	5.6					9.0
FIBRE	14.8					
ASH	3.0					
N.D.F.	23.0					
A.D.F.	20.0				22.0	
UDP	7.5		15.0		9.0	
RDP	22.5		15.0		27.0	
LYSINE	1.48				1.77	
ALYSINE	1.14			1.23	1.36	
METHION	0.24	0.30			0.29	
M+C	0.71	0.86			0.85	
THREO	1.05				1.26	
ISOLEUC	1.30				1.56	
TRYPTO	0.35				0.42	
ARGININE	3.55				4.26	
HISTIDIN	0.84				1.00	
LEUCINE	2.11				2.53	
PHENYLAL	1.12				1.34	
P+T	2.19				2.63	
VALINE	1.23				1.48	
LINOLEIC	2.00					3.20
CALCIUM	0.22					
T.PHOS	0.30					
AV.PHOS	0.18					
SODIUM	0.05					
POTASS	0.85					
CHLORIDE	0.05					
MAGNES	0.17					
SULPHUR	0.20					
NA+K-CL	195.20					
ABC	730					
CHOLINE	3030					
SALT	0.1					
STARCH	*40*					

Appendix B: Nutritional Composition of New Feed Grains (6)

(Same nutritive composition as "standard" for each crop)

	High-yielding Pulse Crops				Other High-yielding Options		
Nutrients	**Field peas**	**Faba beans**	**Chickpeas**	**Soybeans**	**Triticale**	**Canola**	**Sunflower**
DE-PIG	14.2	13.7	13.5	12.0	14.4	12.0	9.5
POULT.ME	12.0	11.2	11.0	9.4	13.3	9.4	8.1
RUMIN.ME	11.7	12.0	12.0	11.0	12.0	11.0	10.0
HORSE-DE	12.9	13.0	12.0	11.9	14.2	11.9	10.0
PROTEIN	23.0	23.0	20.0	34.0	10.0	34.0	38.0
FAT	2.0	1.5	3.7	2.5	1.9	2.5	2.0
FIBRE	6.0	7.0	10.0	14.0	3.0	14.0	13.0
ASH	3.5	3.0	2.9	7.0	1.5	7.0	7.0
N.D.F.	12.0	16.0	28.5	30.6	14.0	30.6	24.0
A.D.F.	8.0	10.0	14.0	21.0	3.8	21.0	20.0
UDP	4.5	7.5	7.0	13.5	2.0	13.5	11.7
RDP	18.5	15.0	13.0	20.5	8.0	20.5	26.3
LYSINE	1.65	1.44	1.33	1.90	0.38	1.90	1.20
ALYSINE	1.40	1.22	1.10	1.60	0.30	1.60	0.96
METHION	0.22	0.18	0.29	0.68	0.18	0.68	0.85
M+C	0.54	0.51	0.60	1.56	0.42	1.56	1.50
THREO	0.87	0.81	0.76	1.50	0.35	1.50	1.35
ISOLEUC	0.98	0.86	0.90	1.40	0.35	1.40	1.75
TRYPTO	0.20	0.20	0.20	0.43	0.11	0.43	0.54
ARGININE	2.11	2.17	2.10	2.02	0.56	2.02	3.00
HISTIDIN	0.56	0.57	0.58	0.90	0.24	0.90	0.90
LEUCINE	1.60	1.65	1.49	2.32	0.75	2.32	3.36
PHENYLAL	1.07	0.94	1.16	1.33	0.47	1.33	1.66
P+T	1.80	1.72	1.71	2.28	0.76	2.28	2.55
VALINE	1.07	1.02	0.95	1.83	0.50	1.83	1.95
LINOLEIC	1.00	0.50	1.90	1.50	1.00	1.50	1.00
CALCIUM	0.05	0.12	0.15	0.50	0.10	0.50	0.40
T.PHOS	0.35	0.47	0.33	0.95	0.30	0.95	1.00
AV.PHOS	0.14	0.15	0.11	0.35	0.10	0.35	0.40
SODIUM	0.04	0.01	0.01	0.01	0.01	0.01	0.02
POTASS	1.08	1.20	0.90	1.42	0.37	1.42	1.48
CHLORIDE	0.09	0.07	0.07	0.06	0.08	0.06	0.14
MAGNES	0.11	0.16	0.15	0.47	0.12	0.47	0.48
SULPHUR	0.18	0.23	0.20	0.30	0.15	0.30	0.40
NA+K-CL	253.3	332.0	210.0	350.0	76.4	350.0	348.0
ABC	650	650	650	1050	130	1050	1100
CHOLINE	700	700	700	6450	460	6450	2900
SALT	0.10	0.05	0.05	0.10	0.07	0.10	0.10
STARCH	45	38	45	5	58	5	9

Appendix C: Distribution of Benefits from New Feeds (1)

		Producer surplus	Consumer surplus	Total surplus
		($000)	*($000)*	*($000)*
High protein feed wheat	Poultry	28	114	**142**
	Pigs	0	0	**0**
	Dairy	-14	-42	**-56**
	Feedlot	155	103	**258**
	Other	-28	-37	**-65**
	Total	**141**	**138**	**279**
High protein barley	Poultry	13	53	**67**
	Pigs	2	5	**7**
	Dairy	-44	-132	**-177**
	Feedlot	208	139	**347**
	Other	-28	-37	**-65**
	Total	**152**	**27**	**179**
High protein oats	Poultry	61	246	**307**
	Pigs	681	454	**1135**
	Dairy	-228	-684	**-913**
	Feedlot	0	0	**0**
	Other	-28	-37	**-65**
	Total	**486**	**-22**	**464**
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**
High lysine wheat	Poultry	3	14	**17**
	Pigs	324	240	**564**
	Dairy	0	0	**0**
	Feedlot	0	0	**0**
	Other	0	0	**0**
	Total	**327**	**254**	**581**
High methionine wheat	Poultry	1	6	**7**
	Pigs	0	0	**0**
	Dairy	0	0	**0**
	Feedlot	0	0	**0**
	Other	16	21	**37**
	Total	**17**	**27**	**44**

Appendix C: Distribution of Benefits from New Feeds (2)

		Producer surplus	Consumer surplus	Total surplus
		($000)	*($000)*	*($000)*
High threonine wheat	Poultry	1	5	**7**
	Pigs	0	0	**0**
	Dairy	0	0	**0**
	Feedlot	0	0	**0**
	Other	0	0	**0**
	Total	**1**	**5**	**7**
High sulphur amino-acid lupins	Poultry	34	136	**170**
	Pigs	-8	-5	**-13**
	Dairy	0	0	**0**
	Feedlot	0	0	**0**
	Other	0	0	**0**
	Total	**26**	**131**	**157**
Hull-less barley	Poultry	1	2	**3**
	Pigs	0	0	**0**
	Dairy	-84	-251	**-334**
	Feedlot	1197	798	**1995**
	Other	-28	-37	**-65**
	Total	**1086**	**512**	**1598**
Low seed coat content barley	Poultry	-19	-77	**-96**
	Pigs	197	135	**332**
	Dairy	-63	-188	**-251**
	Feedlot	891	594	**1485**
	Other	-28	-37	**-65**
	Total	**978**	**426**	**1404**
High seed coat digestibility barley	Poultry	-33	-131	**-164**
	Pigs	154	103	**257**
	Dairy	-27	-82	**-110**
	Feedlot	797	531	**1328**
	Other	-28	-37	**-65**
	Total	**863**	**383**	**1246**
Naked oats	Poultry	1171	4683	**5853**
	Pigs	-21	-14	**-35**
	Dairy	-273	-819	**-1092**
	Feedlot	0	0	**0**
	Other	-28	-37	**-65**
	Total	**849**	**3813**	**4662**

Appendix C: Distribution of Benefits from New Feeds (3)

		Producer surplus	Consumer surplus	Total surplus
		($000)	*($000)*	*($000)*
High oil barley	Poultry	1	5	**7**
	Pigs	0	0	**0**
	Dairy	-52	-156	**-208**
	Feedlot	777	518	**1295**
	Other	-28	-37	**-65**
	Total	**699**	**330**	**1029**
High oil oats	Poultry	172	687	**859**
	Pigs	858	572	**1431**
	Dairy	-273	-819	**-1092**
	Feedlot	0	0	**0**
	Other	-28	-37	**-65**
	Total	**730**	**404**	**1134**
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 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 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**
Waxy sorghum	Poultry	1	5	**7**
	Pigs	0	0	**0**
	Dairy	0	0	**0**
	Feedlot	0	0	**0**
	Other	0	0	**0**
	Total	**1**	**5**	**7**

Appendix C: Distribution of Benefits from New Feeds (4)

		Producer surplus	**Consumer surplus**	**Total surplus**
		($000)	***($000)***	***($000)***
Low protein degradability lupins	Poultry	0	0	**0**
	Pigs	0	0	**0**
	Dairy	0	0	**0**
	Feedlot	0	0	**0**
	Other	0	0	**0**
	Total	**0**	**0**	**0**
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**
Low beta-glucan barley	Poultry	-2	-8	**-10**
	Pigs	112	75	**187**
	Dairy	0	0	**0**
	Feedlot	0	0	**0**
	Other	0	0	**0**
	Total	**110**	**67**	**178**
Low beta-glucan oats	Poultry	-110	-441	**-552**
	Pigs	721	481	**1202**
	Dairy	-228	-684	**-913**
	Feedlot	0	0	**0**
	Other	-28	-37	**-65**
	Total	**355**	**-682**	**-327**
Low lignin oats	Poultry	76	303	**378**
	Pigs	835	556	**1391**
	Dairy	-272	-815	**-1086**
	Feedlot	0	0	**0**
	Other	-28	-37	**-65**
	Total	**611**	**7**	**618**
Low tannin sorghum	Poultry	1	5	**7**
	Pigs	0	0	**0**
	Dairy	0	0	**0**
	Feedlot	0	0	**0**
	Other	0	0	**0**
	Total	**1**	**5**	**7**

Appendix C: Distribution of Benefits from New Feeds (5)

		Producer surplus	**Consumer surplus**	**Total surplus**
		($000)	*($000)*	*($000)*
Low oligosaccharide lupins	Poultry	0	0	**0**
	Pigs	627	418	**1045**
	Dairy	0	0	**0**
	Feedlot	0	0	**0**
	Other	0	0	**0**
	Total	**627**	**418**	**1045**
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**
High yielding triticale	Poultry	303	1211	1514
	Pigs	501	390	890
	Dairy	0	0	0
	Feedlot	0	0	0
	Other	13	18	31
	Total	**816**	**1618**	**2434**
High yielding feed barley	Poultry	1	2	3
	Pigs	0	0	0
	Dairy	511	1532	2043
	Feedlot	0	0	0
	Other	64	85	149
	Total	**575**	**1619**	**2194**
High yielding oats	Poultry	185	740	924
	Pigs	111	74	184
	Dairy	-78	-233	-311
	Feedlot	43	29	72
	Other	582	775	1357
	Total	**842**	**1384**	**2227**
High yielding sorghum	Poultry	527	2106	2633
	Pigs	0	0	0
	Dairy	0	0	0
	Feedlot	0	0	0
	Other	0	0	0
	Total	**527**	**2106**	**2633**

Appendix C: Distribution of Benefits from New Feeds (6)

		Producer surplus	Consumer surplus	Total surplus
		($000)	*($000)*	*($000)*
High yielding maize	Poultry	650	2599	3249
	Pigs	0	0	0
	Dairy	0	0	0
	Feedlot	0	0	0
	Other	0	0	0
	Total	**650**	**2599**	**3249**
High yielding lupins	Poultry	171	686	857
	Pigs	1596	1064	2660
	Dairy	0	0	0
	Feedlot	0	0	0
	Other	0	0	0
	Total	**1767**	**1750**	**3517**
High yielding sunflower	Poultry	260	1039	1299
	Pigs	718	461	1179
	Dairy	-3	-8	-11
	Feedlot	0	0	0
	Other	26	16	42
	Total	**1001**	**1508**	**2509**
High yielding canola	Poultry	-195	-780	-975
	Pigs	3230	2128	5358
	Dairy	0	0	0
	Feedlot	0	0	0
	Other	43	58	101
	Total	**3078**	**1406**	**4484**
High yielding field peas	Poultry	359	1437	1796
	Pigs	1221	887	2108
	Dairy	0	0	0
	Feedlot	0	0	0
	Other	0	0	0
	Total	**1580**	**2324**	**3904**
High yielding faba beans	Poultry	366	1463	1828
	Pigs	794	529	1323
	Dairy	0	0	0
	Feedlot	0	0	0
	Other	0	0	0
	Total	**1160**	**1992**	**3151**

Appendix C: Distribution of Benefits from New Feeds (7)

		Producer surplus	Consumer surplus	Total surplus
		($000)	*($000)*	*($000)*
High yielding chickpeas	Poultry	1	5	7
	Pigs	0	0	0
	Dairy	0	0	0
	Feedlot	0	0	0
	Other	0	0	0
	Total	**1**	**5**	**7**
High yielding soybeans	Poultry	870	3482	4352
	Pigs	0	0	0
	Dairy	0	0	0
	Feedlot	0	0	0
	Other	0	0	0
	Total	**870**	**3482**	**4352**
Cassava	Poultry	-13	-53	-66
	Pigs	75	50	125
	Dairy	0	0	0
	Feedlot	0	0	0
	Other	0	0	0
	Total	**62**	**-3**	**59**

NSW Agriculture

Economic Research Report series

Number

1 Brennan, J.P. and Bantilan, M.C.S. 1999, *Impact of ICRISAT Research on Australian Agriculture*, Report prepared for Australian Centre for International Agricultural Research, Economic Research Report No. 1, NSW Agriculture, Wagga Wagga.

2 Davies, B.L., Alford, A. and Hollis, G. 1999, *Analysis of ABARE Dairy Data for Six Regions in NSW 1991-92 to 1996-97,* Economic Research Report No 2, NSW Agriculture, C.B. Alexander College, Paterson.

3 Brennan, J.P. and Singh, R.P. 2000, *Economic Assessment of Improving Nutritional Characteristics of Feed Grains*, Report prepared for Grains Research and Development Corporation, Economic Research Report No. 3, Wagga Wagga.