INCREASED EFFICIENCY OF STRAW UTILISATION BY CATTLE AND BUFFALO

**ACIAR Projects 8203,
8601 and 8817**

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July 1998

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ISBN 1 86320 244 7

Editing and design by Arawang Communication Group, Canberra
Printed by Trendsetting, Canberra

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1. Summary

The Australian Centre of International Agricultural Research (ACIAR) has sponsored several research projects with the aim of increasing the efficiency of straw utilisation by cattle and buffaloes in some Australian and Indian situations. These projects involved research on upgrading technology and field testing specific feed formulations to determine their impact on improving livestock production in India. This report contains an economic assessment of three interrelated projects supported by ACIAR over a period of nine years, starting 1983–84.

Apart from validating the feasibility of improving the efficiency of straw-based diets through strategic supplements, the projects under review had played a significant role in the commercial introduction of urea molasses blocks (UMBs) in 1985 and bypass protein feed (BPF) in 1989. It was anticipated that the supply of these products, through the milk producers cooperatives organised under the Operation Flood Programme in India, would make a substantial contribution to Indian dairy farmers towards increasing the efficiency of milk production. Based on the adoption level of these products over a period of about eight years, an assessment was made on the likely contributions of the products over a period extending upto 2013.

The results of the analysis indicate that these projects are economically viable even under the most conservative set of assumptions regarding the project outcome. The internal rate return of the project was above 12 per cent and the benefit–cost ratio was 2.15 for the base level estimates, with a net present value of $4.7 million.

Sensitivity analysis has also clearly demonstrated that the cost incurred on these projects is justified by the potential economic benefits to the Indian dairy farmers.

2. Background

2.1 Introduction

India accounts for about 20 per cent of the world bovine population, but its share in the world's milk production is only 10 per cent. The experiences of many developing countries in Asia and Africa also indicate similar tendencies, and it has been identified that one of the major constraints for increased milk production in these countries is the inadequate supply of nutrients for milch animals. Further it has been observed that feed cost is the largest component in the cost of livestock production, accounting for about 70 per cent of the cost of milk and meat. Therefore it is important that any effort to improve the efficiency of livestock production should give adequate emphasis to improving feed availability and optimal use of available feed inputs, along with improvements in the genetic potential of the animals. Hence, the strategy adopted for increasing milk production in India through the Operation Flood (OF) program has emphasised breeding and feeding aspects.

A recent survey (Patel 1992) of member households of the milk producer co-operative societies in OF areas has indicated that about 43 per cent of the members had only one milch animal and about 75 per cent of the members belonged to the landless, marginal and small farmer category. The major feeds available to these small and marginal farmers, the landless labourers and village artisans rearing 1–2 milch animals, are crop residues and cereal by-products such as straw from rice, wheat, sorghum, barley and millet. However, the available feed and fodder resources indicate that the availability was far below the requirements of the total cattle population (George 1996). In this context, new technologies developed to upgrade the crop residues through enrichment of straw by ammonia treatment and use of urea molasses blocks were considered as potential means for effective utilisation of available supplies (Kunju 1988). Maximising the efficient utilisation of straw or alkali-treated straw by lactating animals was identified as an essential requirement of achieving the objectives of Operation Flood. The Australian Centre for International Agricultural Research (ACIAR) initiated several projects in India to increase the efficiency of straw as an integral part of OF. These projects involved research into the impact of improved feeding technologies on livestock production and development of specific products for farm level use by small scale cattle holdings.

This study analyses the economic impact of three linked projects initiated with the support of ACIAR: Project 8203—Increased Efficiency of Straw Utilisation by Cattle and Buffalo for Growth, Reproduction and Lactation; Project 8601—Research into Technologies for Increasing the Efficiency of Straw Utilisation by Cattle and Buffalo for Growth, Reproduction and Lactation; and Project 8817—Strategic Supplements for Improved Milk Production.

2.2 Livestock Situation in India

In order to appreciate the significance of these projects, it is relevant to review some aspects of the livestock situation in India. Cattle and buffaloes are an integral part of the Indian farm economy. It has been estimated that in 1990 India had a bovine population of 272.3 million, consisting of 197.3 million cattle and 75 million buffaloes. Traditionally, cattle have been raised for draught power for agricultural purposes, and buffaloes for milk production. However, this position has somewhat changed with the introduction of crossbred cows. In terms of the breeding population, the number of breeding cows was about 55 million (of which about 10 million were crossbred) and the number of breedable buffaloes was about 31.5 million. Between 1966 and 1987 the population of breeding cows increased at an annual rate of 0.53 per cent and breeding buffaloes at the rate of 1.79 per cent. According to the 1987 Cattle Census, the composition of animals in each category indicated that among the indigenous cattle adult males exceeded adult females, but among crossbred cattle and buffaloes adult females were dominant (Table 1).

Table 1. Composition of bovine population in India (per cent).

Category	Indigenous cattle	Crossbred cattle	Buffaloes
Adult males	38.4	21.6	9.8
Adult females			
in milk	14.5	25.6	31.0
dry	13.5	10.8	16.9
not calved	2.5	3.7	3.6
Total	30.5	40.1	51.5
Young stock below 3 years	31.1	38.3	38.7

Source: Livestock Census 1987.

The total milk production in India increased from 17 million tonnes in 1951 to 70 million tonnes in 1996. The growth rate in annual production of milk in the eighties and nineties has been faster than in the previous three decades. This is due to the increased productivity of milch animals and the changes in the composition of cattle, with the higher proportion of crossbred animals. For example, in 1978 the average daily milk yield of animals in milk in the Kerala State was 1.64 kg for indigenous cows and 3.23 kg for crossbred cows. By 1990 this increased to 1.75 kg for indigenous cows and 5.26 kg for crossbred cows (George and Nair 1990). During the same period the proportion of crossbred cattle in the total cattle population increased from about 44 per cent to 53 per cent. Analysis of the increased milk production for an earlier period indicated that yield and breed had approximately equal influence on the additional milk output (Nair 1979).

2.3 Operation Flood

A major step toward revitalising dairying in India was initiated by the OF program which replicated the achievements of villages in the milkshed areas of the Anand Milk Union Limited (AMUL) along the lines of what is commonly referred to as the Anand Pattern. The main aims of OF included the following:

- capturing a dominant share of the urban milk market;
- creating a procurement network to link numerous cooperative producer societies in different milkshed areas of the organised dairy industry; and
- upgrading the milk production capacity of the Indian bovine stock through a program of cross breeding, veterinary services and auxiliary activities.

The activities under the program were initiated in four phases. The first phase of OF (OF-I; 1970–1980) was launched using the supply of 126 000 t of skimmed milk powder and 42 000 t of butter oil from the World Food Programme. The total outlay of this phase was about rupees (R) 1200 million. The main objectives of this phase were to:

- make wholesome milk available to the bulk of city milk consumers at stable and reasonable prices;
- link 27 rural milkshed districts to the four metropolitan markets of Bombay, Calcutta, Delhi and Madras,

- improve the productivity of dairy farming in rural areas with the long term objective of achieving self sufficiency in milk, thereby increasing agricultural output and income; and
- remove dairy cattle from the cities where they represent problems of genetic waste, social cost and public health.

The second phase (OF-II; 1981–85) envisaged an outlay of R 4855 million, financed by the European Economic Community (EEC; 49%), a loan from the World Bank (36%), and OF-I loans. The major objectives of this phase were to:

- enable 10 million rural milk producer families to build a viable, self-sustaining dairy industry by mid-1985;
- enable the milk producers to rear a National Milk Herd of some 14 million crossbred cows and upgraded buffaloes during the 1980s; and
- erect a National Milk Grid which would link the rural milksheds to the major demand centres, with urban population totalling some 150 million.

The third phase (OF-III; 1987–1995) had an estimated outlay of R 8766 million. Its main objective was to ensure that cooperative institutions became self sustaining. The fourth phase of OF is ongoing.

A number of evaluation studies of OF have been carried out by both government and non-government agencies. While some of these studies were critical of the basic approach and its relevance to all regions, there is general agreement that the project has made significant contributions towards improving the conditions of rural milk producers (see Alderman 1987; Atkins 1998; Mascarenhas 1988; George 1985; Terhal and Doornbos 1983; Jha 1985;Doornbos et al. 1990). Further review of these studies is beyond the scope of this study.

2.4 General Approach to the Study

All three projects covered under this study involve substantial research inputs leading to specific product development. Though the approach followed in the analysis of each project is specified where appropriate, certain common features are applicable to all the projects.

Research is additive in the sense that current research builds upon the past efforts and the research results indicate a cumulative total of the outcome of a large number of observations over time. In this process, the success and failure of past efforts make valuable contributions towards building up a body of knowledge. As the research efforts indicate a cumulative outcome, it is natural to argue that the cost of research should also be considered in a cumulative sense.

While the argument that the present state of knowledge builds upon the past efforts is perfectly valid from a purely logical perspective, it does not offer a rationale for choice of projects worth funding, or for evaluating the contributions of past studies. In project analysis, it is often suggested that an incremental rationale should be used to estimate both costs and benefits. This is often achieved by constructing scenarios of costs and benefits in both cases of 'with the project' and 'without the project' and the difference between the two scenarios can be identified as the project cost and project benefit as the case may be. The incremental rationale is particularly applicable when the project costs and outcomes can be clearly specified in terms of identifiable components. The current study proposes to identify all possible items of costs and benefits that can be directly linked to these projects.

The identified costs and benefits can be either tangible or intangible. While it is relatively easy to value tangible items using either market prices or appropriate shadow prices, intangibles often create problems of valuation. It is proposed that in this study intangibles would be specified to the extent possible, but valuation will be attempted only if the analysis of the tangibles does not lead to a definite set of conclusions.

Another major difficulty in assessing the benefits of research output from projects of the type studied here is the gap between the potential and realised benefits. Research, often carried out in a controlled environment, provides responses which can be obtained under those conditions, but not necessarily transferred to the 'real world'. It is possible that a highly promising research finding may not produce the expected impact at the field level due to imperfections in the whole chain of organisations and the nature of field conditions. Therefore, economic analysis of projects involving research needs to distinguish between the maximum potential gains, and actual (or realistically likely) gains from the project outputs. In the context of the current study, Fleming (1991) carefully analysed the potential contribution that can be obtained from the two main products evolved from the research. These estimates can be considered as an upper limit of the benefits. The actual performance can be considered as the lower limit of the benefits. The gap between these two levels can be narrowed by appropriate policy and administrative interventions.

2.5 Data Sources

The data sources for the study include:

- secondary sources of information ;
- personal discussion and correspondence with those associated with the projects;
- project proposals submitted for approval prior to the project implementation;
- project evaluation reports;
- data from various sources on sale of products developed as outputs of the project and other relevant variables were obtained from various sources.
- Limited field observations were also made among those who had benefited from these projects.

Most of the persons who were directly involved in the project had already left the organisations that implemented the projects. However, discussions were held with those responsible for follow up action in these organisations. The framework for analysis of the cost and benefit data was based on the guidelines provided by the ACIAR for carrying out evaluation studies.

3. Project Information

3.1 Project Profiles

Project 8203
Increased efficiency of straw utilisation by cattle and buffaloes

This collaborative project between the University of New England, Australia, and the National Dairy Development Board, India, began in 1983. It had the major objective of maximizing the efficiency of straw or alkali-treated straw consumed by lactating animals, thereby substantially lifting milk production in India. The specific aims were:

- To increase productivity of lactating buffaloes by treating straw with alkalis. The treatments to be used included ensiling with urea and treatment with gaseous ammonia.
- By using supplements of fermentable nitrogen (molasses urea blocks) and bypass nutrients, increase intake and digestibility of the basal diet of straw and increase productivity of cattle and buffaloes.
- To maximise the intake and digestibility of treated and untreated straws by modification of the rumen microbes through manipulating the protozoal and bacterial populations and enhancing the growth of anaerobic fungi.

The project validated the feasibility of using multinutrient blocks introduced into India through a Food and Agriculture Organisation of the United Nations (FAO) project as a first step in the strategic supplements of large ruminants fed on cereal residues. These micronutrient blocks contained urea, molasses, micro- and macro-minerals and rumen activities. The project also demonstrated the vital role of catalyst bypass nutrients in increasing the productivity of cattle and buffaloes on straw-based diets. Arising from this, a strategy for feeding large ruminants under the tethered husbandry system practiced in India was developed. This strategy utilises the molasses urea nutrient block to improve the efficiency of the rumen ecosystem as well as oil seed meals fed in catalyst amounts to provide bypass nutrients for direct absorption by the animals post-ruminantly.

A series of experiments were initiated on urea molasses blocks (UMBs), starting in 1981 through an FAO research project which was integrated with Project 8203 in 1983. A number of experiments involving animals being fed a mixture of rice straw, compounded cattle feed and UMBs were taken up before commencing commercial production of UMBs in January 1985. Results of feeding trials carried out in six AMUL villages showeded milk production increases ranging from 10–46% when UMBs were made available to lactating animals. Increases in fat content of milk ranged between 13 and 75 per cent. Kunju (1988) reports that some of the factors that influenced variations in milk output included breed of lactating animals and the level of concentrates fed to them.

Commercial production of UMBs was initiated in January 1985. Each block had a weight of 3 kg and they were sold in packets of 10 blocks. The composition of the blocks had a different range of ingredients suitable for different climatic conditions.

These included:

Urea	10–15 per cent
Molasses	40–50 per cent
Mineral mixture	4–8 per cent
Common salt	3–8 per cent
Lime	6–9 per cent
Sodium betonite	2–4 per cent
Rice polish fine	20–30 per cent

The UMB licks are produced in solidified form either by steam heating the ingredients (hot process) or by addition of gelling agents followed by thorough mixing (cold process). Since the hot process is energy and labour intensive, the cold process is increasingly used.

Project 8601
Research into technologies for increasing the efficiency of straw utilisation by cattle and buffalo for growth, reproduction and lactation

This project evolved as a follow up to Project 8203 which had established the utility of urea molasses block technology. The commissioned organisation was the University of New England (Department of Biochemistry, Nutrition and Microbiology), with the intention of collaborating with the Indian Veterinary Research Institute, Izatnagar, the Central Institute for Research in Buffaloes (CIRB), Hisar, and the National Dairy Research Institute. Of the three Indian institutions, only CIRB actually contributed. The development of UMBs was considered to be a first step in the strategic supplementation of large ruminants fed on cereal crop residues. Research in India and Australia had also demonstrated the vital role of catalyst bypass nutrients in increasing the productivity of buffaloes and cattle on straw-based diets (as discussed in 2.1.1). Project 8601 aimed to further develop the strategy discussed in Section 2.1.1 through research into maximising the efficiency of rumen fermentative digestion by manipulation of the rumen ecosystem and investigation of the critical nutrients needed in terms of response relationships and cost effectiveness. It was envisaged that the resulting strategies would be field tested, validated and evaluated before packing for use by the target group of small holder farmers.

The specific objectives of the project were:

- To investigate the critical nutrients needed to increase the productivity of ruminants, and the levels at which they should be incorporated into straw-based. In practice this largely means supplementation of molasses urea nutrient blocks in strategic amounts of bypass protein.
- To increase the efficiency of rumen fermentative digestion by manipulations of the rumen ecosystem in animals whose basal feed consists of crop residues and other fibrous materials.
- To test the effect of manipulation of digestibility of feeds on various productive functions of animals.
- To determine the repeatability at the village level of the research results obtained under the first three aims, and to measure the increase in productivity resulting from the adoption of technologies based on the combined use of low quality forages, multi-nutrient blocks and bypass nutrients.
- To strengthen collaborative research in India on growth, reproduction and lactation in cattle and buffaloes on straw-based diets, facilitate the continuous development of new technologies, enable such technologies to be appropriately packaged and tested under village conditions, and evaluate the cost–benefits of the package.

Four institutions were expected to be involved in developing and field testing under village conditions, with close exchange of information among them. The research methods involved detailed studies of the rumen ecosystem, using animals with rumen cannulae. Simultaneously, there was provision for field trials and close interaction between the scientists involved in the two approaches. The target beneficiaries of the research were the small holder farmers who could use the technological packages expected to be developed in the project for providing nutrients to the animals through the use of compounded supplements.

Project 8817
Strategic supplements for improved milk production

This project was also a collaborative effort between the University of New England, Australia, and the National Dairy Development Board (NDDB) of India. It was a continuation of Projects 8203 and 8603. The principal objective of the research was to develop feeding strategies that would maximise output from the current production system using available resources. The application of the results of the project at the village level was through the development of technological packages.

The collaborative arrangement between the University and NDDB implied that the University would further develop the feeding strategies and NDDB would continue to develop the technologies for application at the village level, provide feedback on adaptation that may be necessary and field test the economic benefits of the resultant technologies through the milk cooperatives.

3.2 Project Reviews

All the three projects under evaluation have been subjected to earlier reviews. A review of project 8601 was conducted between November 1989 and February 1990 (see ACIAR 1990). A combined evaluation of projects 8203 and 8601 was taken up by Fleming (1991). Project 8817 was reviewed by Broadbent (1994). These reviewers had access to all the documents relating to the projects up to the review period as well as the benefit of discussions with those associated with the project implementation. Since the current evaluation is a follow up of the earlier reviews, it is appropriate to highlight the major findings of these reviews.

Project 8601

ACIAR (1990) indicated that although this project was envisaged as a collaborative research project among three Indian organisations and an Australian university, only one Indian organisation effectively participated. The review was restricted to the research program undertaken at this Indian organisation and the Australian university. The review indicated that the research program had made good progress in providing more precise definitions of the conditions necessary for the optimal urea treatment of wheat straw, and in discovering the anti-protozonal properties of the leaves of certain trees. The review also pointed out the need for evaluation of the urea treatment of straw under field conditions in villages, with the involvement of extension specialists for undertaking on-farm trials for growth, reproduction and milk production of buffaloes.

Projects 8203 and 8601

An economic assessment of these two projects, carried out by Fleming (1991), is a careful attempt to estimate the net benefits of these two research projects. Despite their separate identities in terms of project implementation, for evaluation purposes they were treated jointly because both projects have contributed in a combined fashion to the research results under review. In view of the limitations of available data on many aspects covered in the estimation of costs and benefits, the review made a series of assumptions on relevant variables. Fleming (1991) concluded that the project had the potential to be very successful. A major limitation of the review was a lack of information about the uptake of the feeding strategies evolved in the projects and their impact.

Project 8817

Broadbent (1994) points out the imprecise definition of the project objectives and the resulting difficulties in evaluating the achievements. The project involved both laboratory research and field trial components. The review concluded that the laboratory research proposed in the project was completed on schedule with satisfactory and applicable results. However development of the proposed feeds and feeding strategies, as well as institutional and village level testing, remained incomplete. In the absence of this information, it was not possible to carry out a cost–benefit analysis.

3.3 Product Performance

These three projects developed two products—UMB and BPF. The economic impact of the projects depends on the farm level use of these products and the likely benefits to the farmers.

Urea molasses block progress

Fleming (1991) pointed out that adoption of UMBs by the farmers from 1985 to 1988 was gradual, and disappointing from the point of view of the project. The following reasons were attributed to explain the disappointing performance.

- (a) Most farmers have not yet perceived any great advantages in using the blocks. Advantages of using UMBs are only substantial when their use is accompanied by a reduction in the level of concentrates. However farmers in India have not reduced the level of concentrates fed to their lactating animals as recommended. A greater impetus to their use should have come in 1989 with the introduction of BPF.

- (b) Some farmers mistakenly believe that UMBs provide only moderate financial benefit to farmers owning low-productivity cows, and are only suitable for high-performance cows. While this may be true for concentrates, it is not valid for the use of UMBs.

- (c) Another possible explanation is the management practices of the predominant category of small milk producers (those with one or two animals). These animals are commonly shifted from place to place during the day, and it might be too inconvenient for farmers to shift the UMBs along with the animals so that they can lick them ad libitum. While this reasoning might carry some weight, it is unlikely to be an overriding factor as it can be fairly easily overcome with a little effort on the part of the farmer.

- (d) The grazing of milk animals could also make it inconvenient to provide UMBs for them to lick ad libitum. However, the amount of grazing on common lands in Gujarat State is now quite limited. This explanation can therefore hardly hold for the majority of animals.

- (e) Some have questioned the liking of buffalo for UMBs relative to cows. There is no evidence to support this contention, which appears unlikely to explain the lack of UMB adoption by farmers.

- (f) Farmers' lack of sophistication to perceive the small gains to be made from the use of UMBs is yet another explanation that has been proffered. The cumulative evidence of smallholder behavior in developing countries weighs against this explanation. Providing farmers are using an improved technique correctly, they are usually quick to take it up provided it has no other attributes which adversely affect the farmer's circumstances.

- (g) Poor marketing of UMBs may be an important factor. Production and marketing of UMBs are undertaken by the same organisations that produce and sell concentrates—usually the cooperative mills. These organisations have little incentive to push the sales of UMBs which are meant to replace their main product. It is evident that the marketing process at the village cooperative society level is not working well. This is in contrast to the very successful introduction by feed producers of BPF in the villages, reaching down to the smallest of milk producers. Some problems have been experienced with packaging of the blocks and melting in extreme temperatures. These problems have not helped in marketing in the villages because of the storage problems they create. However, they are problems that can and should be fairly easily rectified.

- (h) Related to marketing above, it does not appear that the extension staff are convinced of the merits of UMBs, adversely affecting their role as catalysts to their use. Again, this is in contrast to the successful work performed by extension staff in introducing BPF, a feed input they clearly believe is good for milk producers.

- (i) Another criticism is that the sale of UMBs in 3 kg blocks makes them too costly for the small milk producer. However, in light of comments made in (f), even the smallest farmers could be expected to buy them if they were convinced these costs could be quickly recouped through reduced intake of feed supplements and increased milk output.

- (j) Finally, it could be argued that the input is not appropriate for milk producers. However, the evidence from those, mainly larger, farmers who do use UMBs as recommended is to the contrary. These farmers are convinced of the merits of the blocks and continue to use them.

Fleming (1991) considered that the most plausible explanations appear to be (a), (g) and (h), and perhaps (c) for some farmers.

Following the commercial introduction of UMB in January 1985, by 1991 it was manufactured in ten specially designed plants with daily capacity of 40 t. NDDB had set a target UMB production of 50 000 t by 1995 and 100 000 t by 2000. However, the sale of UMB was seriously affected by certain technical problems in the manufacturing process which resulted in molten masses of UMB blocks. With the melting of 10 individual blocks of 3 kg each in a packet, they were stuck together on account of the hygroscopic nature of the blocks. The process used in the manufacture of these blocks was the hot process using manual labour and handling of the hot product at a high temperature was also a major constraint. In view of this, efforts were made to develop a cold process using calcium oxide as a gelling agent. Laboratory experiments were successfully completed by 1997 to evolve a cold process and relatively inexpensive plants costing about 250 000 rupees were designed. However, the milk unions had attached a high priority only to the manufacture of cattle feed and there was very little interest on their part to take up UMB production. In this context, efforts are underway to start UMB production through private agencies. One manufacturer had initially purchased 1 000 blocks and, on the basis of interest shown by the farmers, has placed order for 50 000 blocks. Since the existing NDDB facilities could not meet this demand, it was decided to transfer technology to the private trader at a royalty of two per cent. The plants manufacturing UMB using the hot process have remained somewhat under-utilised, however conversion to the cold process is considered to be highly uneconomic as the cost of conversion is likely to be double the cost of a new plant.

The lack of enthusiasm for use of UMBs in the existing form is evident from the fact that during 1997–98, the effective capacity utilisation of the UMB plants was hardly five per cent. The UMB plants had a daily capacity of 60 t or 20 000 bricks of 3 kg. The total number of bricks produced during 1997–98 was 260 660 which represents the full capacity utilisation for 13 days in the year.

Against the 1995 target of 50 000 t and the 2000 target of 100 000 t fixed by the Technology Mission, the production level of 1997–98 was 620 t. The position during 1992–93 and 1993–94 had also been at low levels (309 t and 406 t, respectively). Some of the scientists at the CIRB (1989) consider that the whole concept of supplying UMB blocks may not be worth pursuing. While they recognise the relevance of the technology behind UMBs, it is felt that the farmers can conveniently mix the ingredients at the farm level with substantial cost savings. According to them, what is required is the extension efforts to make the farmers aware of the appropriate composition of the ingredients to be used in preparing the mixture.

Bypass protein feed progress

Conversion of commercial feed production to BPF was an important item in the strategy for increased milk production followed by the NDDB. The Technology Mission for Dairy Development had visualised that 60 per cent of the 44 cooperative feed plants in India would be converted to BPF production by 1992. Fleming (1991) considered that a realistic target for conversion would be 1999.

Experience since the introduction of commercial BPF production in 1988 indicates that the progress of conversion process was at a somewhat reduced level than expected. During this period only 17 feed mills were adapted to produce BPF, of which only two have been producing BPF alone. The remaining mills have a combination of traditional concentrates and BPF. The total installed capacity of these 44 feed mills is 4 957 t/day, of which the capacity for BPF is 1 750 t/day.

The monthly production of BPF in February 1998 was 20 882 t compared to 59 293 t of traditional cattle feed. During January 1998, the production of BPF and cattle feed was 20 830 t and 64 093 t, respectively. The annual average production data for the last three years is provided in Table 2 and indicates that BPF accounted for about 28 per cent of feed production. Monthly production data of traditional concentrates and BPF by the 44 mills for four years are available in Appendix 2.

Table 2. Production of cattle feed and bypass protein feed (BPF), 1994–1997 (t).

Year	Cattle feed	BPF	Total
1994–95	555 898	215 092	770 990
	(72.1%)	(27.9%)	(100%)
1995–96	600 002	232 318	832 320
	(72.1%)	(27.9%)	(100%)
1996–97	653 601	247 101	900 702
	(72.6%)	(27.4%)	(100%)

The main problem in acceptance of BPF appears to be the high cost of BPF as compared to traditional concentrates and the lack of conviction among the farmers that the incremental cost of BPF will be more than offset by the incremental benefits through increased milk production. When low cost feeds were available locally it was difficult to convince the farmers that higher priced BPF was more economical. In addition, price increases of ingredients used in feed manufacture were not uniformly felt, with those used in the manufacture of BPF having a relatively higher price increase as compared to the price of ingredients used in the manufacture of traditional feeds. Hence the gap between the two prices widened further. This situation had reached a climax when AMUL was persuaded to switch over from BPF to traditional concentrates for three months in 1997. AMUL was the first Union to switch over to 100 per cent BPF production and it had accounted for about half the total production of BPF in India during 1996–97. (AMUL production of BPF was 124 226 t against all-Indian production of 247 101 t). The price of ingredients used in BPF had gone up in 1997 and AMUL had completely switched over from BPF production to traditional concentrates owing to heavy pressure from the Kaira farmers. However, after three months, they switched back to BPF.

4. Economic Analysis

Economic analysis of the projects involves identification of project benefits and costs, valuation of these benefits and costs, and comparing the benefits and costs realised over time using appropriate methods. The framework used in the analysis and the rationale for quantifying project benefits and costs are briefly specified before presenting the results of the benefit–cost analysis.

4.1 Framework

While it would have been desirable to assess the three projects separately, a number of practical considerations have compelled me to treat all the three projects together. The main issues influencing this choice are the following:

1. All the projects had a common research objective. The lack of field level experimentation in the three projects has already been emphasised in the previous reviews. The follow up on these reviews from that point of view has been limited, and remains incomplete. Therefore the basic information required for carrying out an economic analysis of individual projects is not sufficient.

2. The implementation of the projects involved organisations in Australia and India. Although financial outlays of these organisations are available for each project it is difficult to ascertain the specific contributions of these organisations towards the project implementation and project output.

3. The field level applications of these research projects in terms of developing specific products that influence the farm income are confined to UMB and BPF. Here again, it is somewhat difficult to attribute the influence of individual projects on the development of UMB and BPF.

4. The current study is, in effect, an update on the previous ACIAR Economic Assessment, Series 3, conducted by Fleming (1991). In that study Projects 8203 and 8601 were combined though they were implemented by two different agencies. The third Project 8817 under review was implemented by NDDB which had the primary responsibility to commercialise UMB and BPF. The research findings of Project 8817 have led to modifications in UMB and BPF formulation, and therefore this project is treated as a continuation of the efforts initiated through Project 8203.

4.2 Scope

The concluding remarks of Fleming's study (1991) indicated that the major limitation of the study was lack of information about the uptake of the new feeding strategies. Some information is now available on these aspects for some years. This study provides an analysis of the additional information. Fleming provided detailed accounts of the potential benefits of the research outputs to the Indian Livestock Industry. His treatment included the contribution towards increased milk production, reduced milk production costs, increased draught power, increased meat production, reduced ecological damage, equity gains, reduced yield risk and reduced seasonality in milk output.

Among these various benefits analysed, the fresh information available relates only to use of the products UMB and BPF and milk procurement. These data can be used to quantify the gains to the farmers through increased milk production by analysing the likely changes in milk production and cost of feed. Although data are available on monthly procurement of milk by AMUL (Appendix 3) there are reasons to doubt whether Fleming's assumption of a constant ratio of procurement and production is any longer valid. Since changes in procurement levels may not reflect production levels this data may not reveal the changes in seasonality. This study is confined to carrying out a benefit–cost analysis of the project based on the impact on farm income from milk production.

4.3 Project Benefits

Among the various benefits likely to accrue from the project, this analysis is confined to the two quantifiable variables included in Fleming's analysis, namely, changes in value of milk output and cost of production of milk on account of the projects. However, in view of the various considerations mentioned in Appendix 1, the approach adopted by Fleming (1991) to quantity project benefits has been modified. For this purpose it was necessary to evolve a set of assumptions based on current information relating to the period subsequent to Fleming's study. These assumptions are related to the changes in quantity of milk produced, composition of milk and cost of concentrate feed when farmers change their feeding practices in favour of the project output. The basis for the set of assumptions used in the analysis is briefly discussed here.

Changes in milk output

As indicated earlier, the milk production strategy adopted in India gives strong emphasis to breeding and feeding policies. One of the major reasons for changing from traditional concentrate feeds to BPF was that with the same quantity of BPF and concentrates, BPF would be capable of producing more milk. While the short run benefit of BPF was to have a direct effect on milk production of the existing milch animals, a long term impact was envisaged from an improved quality of the next generation through more efficient feeding of the young stock. However, in the absence of field level data on the long term impact, this analysis is confined only to the short term impact.

Controlled experiments have clearly demonstrated significant yield effect when BPF was used. Kunju (1990) has reported milk yield increases ranging between 35 and 50 per cent when BPF was added to diets of rice straw and UMBs. The optimum quantity of BPF was 3 kg. In another experiment at NDDB, it was observed that mean production was 830 g more in the group fed bypass protein as compared to cattle fed at recommended levels. The milk production in the group fed with bypass protein was significantly higher than the group fed with cattle feed.

Although controlled experiments have demonstrated the higher efficiency of BPF over traditional feed concentrates, field level data are not adequate to quantify the benefits. One possible approach for this should have been to compare the milk procurement increases in a given locality and then decompose the increase in terms of breed changes and feed changes as suggested in the Fleming (1991) study. However, the validity of this approach holds good only under conditions where competition of milk unions from private traders did not influence milk procurement. Yet another variable influencing procurement is the production level itself. If the ratio between retention at home and marketed quantities change over time, procurement volume cannot be considered as an indicator of production. As indicated in Appendix 1, in spite of substantial increase in the crossbred cows in Kaira district, AMUL’s procurement has not increased. In this context, if a decomposition is carried out it will either conclude that crossbred animals did not contribute to increased production in the Kaira district, or that BPF had no effect on milk production. Both these conclusions are hard to justify. Regression equations using AMUL data on monthly milk procurement and sale of BPF have indicated significant coefficients associated with monthly dummy variables, and the coefficient of BPF was quite insignificant. In view of these difficulties it was not possible to derive production changes from AMUL procurement data.

Monthly data on procurement of milk and the distribution of cattle feed and BPF by all unions under the OF program were used to establish the relationship among milk procurement and use of feeds. Here again all the coefficients of monthly dummy variables were highly significant, indicating seasonality in procurement. However, the coefficient of cattle feed was negative and the coefficient of BPF was positive. The elasticity of milk procurement with respect to BPF was around 0.15 and if allowances are made for retentions at home, the elasticity could be around 0.20. However, since the milk procurement data are not available according to crossbred cows, buffaloes and local cows, this elasticity is only an aggregate estimate. Therefore, in order to get the milk output increase from different categories of milch animals it was necessary to depend on other information.

The review of all available information linking production with other variables, including feed, indicated that the most appropriate information is the regression results reported in Fleming's (1991) study. He established from the regression results that the partial elasticities were 0.21 for the period before the feed changeover and 0.52 when BPF was introduced, indicating an incremental benefit of 0.31. Thus a changeover of one kilogram of concentrate feed to BPF would increase the milk yield by 0.31 kg in crossbred cows. At the level of 2 kg of BPF, the additional milk production is 0.62 kg, which represents an increase of around 9 per cent. This compares favourably with the actual increase of 7.7 per cent reported in 1989. However, it is much less than the estimated BPF benefits of 35–50 per cent by Kunju (1990) and 80 per cent by Leng (cited in Fleming 1991) Fleming had assumed a minimum increase of 0.5 per cent to occur each year over the decade 1990–99 so that by 1999 there would be between 12 and 17 per cent increase in milk output. However, the procurement experience of AMUL up to February 1998 does not indicate that output increases of this magnitude have occurred.

In the case of buffaloes and indigenous cows the response level was observed to be low. For the purpose of this study it was assumed that each kilogram of BPF conversion provides an increase of 0.20 kg for buffaloes and 0.10 kg for cows. At 2 kg feed level of buffaloes, this is an increase of 8 per cent and at 1 kg feed level for indigenous cows this represents an increase of about 5 per cent. A comparison of feed price and milk price indicates unfavourable conditions for switching over to BPF by the farmers with indigenous cows, but if they are members of societies that only sell BPF, then they have no choice but to use BPF.

Composition of milk

Feed quality is only one of the factors involved in determining the composition of milk and therefore it is difficult to compare the composition of milk collected from different milk unions on the basis of the dichotomy between concentrate feed and BPF use. However, a limited comparison is possible from the data available for milk collection from the periods when the animals were fed completely on concentrates and when the same animals were fed BPF. AMUL had experienced substantial increase in the price of ingredients used for BPF manufacture in early 1997 with the effect that BPF price had to be increased. At the same time traditional cattle feed was available in the area from private manufacture at lower prices. The price difference of these feeds had encouraged the AMUL producers to raise demands for lower priced concentrates. Responding to this demand AMUL decided to discontinue BPF production in favour of production of traditional concentrates in May 1997. This decision was in effect until August 1997 when AMUL decided to switch back to the production of BPF. While these changes indicate the sensitivity of AMUL producers towards price changes, it is not clear if the changes on both occasions were fully endorsed by the farmers. In any case, for the purpose of our analysis of composition of milk, it provides data for a few months when the animals were entirely fed on concentrates or BPF. The composition of milk collected during these months follow the pattern shown in Table 3.

Table 3. Composition of milk collected by Anand Milk Union Limited (given as percentages; BPF = bypass protein feed).

Month	Feed type	Buffalo Solids non fat	Buffalo Fat	Cow Solids non fat	Cow Fat
March 97	BPF	7.20	9.30	4.20	8.50
July 97	Cattle feed	7.10	9.30	4.20	8.50
August 97	Cattle feed	7.10	9.30	4.20	8.50
January 1997	BPF	6.80	9.30	4.30	8.50
February 1997	BPF	6.90	9.30	4.20	8.50

In the absence of any clear pattern emerging from the above information, it was considered safe to exclude the changes in the composition of milk, and consequently changes in price realised by the farmers, being attributable to the feed factor.

Cost savings of concentrate feed

Cost savings on milk production were expected to accrue to the farmers on account of the lower requirements of BPF compared to cattle feed. Though BPF had a higher price as compared to concentrates, because of the lower quantity requirements of BPF, the daily feed cost for the quantity of milk produced using BPF was expected to be lower than the cost of producing the same quantity of milk using cattle feed. For example, the recommended dose of traditional cattle feed for crossbred cows was 400 g for each kg of milk produced and 3 kg for body maintenance. A crossbred cow producing 7 L of milk would require 5.8 kg of cattle feed which at the current level of prices would cost R 20.30. When the same cow is fed BPF at the recommended rates (250 g for each kg of milk and 2 kg of body weight maintenance) the daily cost would be only R 16.90. In the case of buffaloes, the recommended diet for production of 5 kg milk would cost R 19.25 for cattle feed and R 18.00 for BPF. However, in the case of an indigenous cow producing 2 kg milk there was no difference in the feed cost under either option.

While the recommended diet clearly demonstrates cost advantages for crossbred cows, there is insufficient data to verify this under field conditions. While there is no data available for different types of animals, separate milk collection data from milk unions using exclusively cattle feed or BPF from the same state indicate conflicting results. For example, in Maharastra state, Kolhapur was supplying only BPF and Akluj was supplying only traditional concentrates. During July 1997, the Kolhapur farmers had used 0 .468 kg of BPF/L of milk supplied to the society at a cost of R 2.20/L. During the same month Akluj farmers had used 0.480 kg of traditional concentrates per litre of milk supplied to the society at a cost of R 2.16/L indicating very little difference in the cost between Akluj and Kolhapur.

In August 1997, Kolhapur farmers had spent R 2.19/L of milk supplied using BPF and the corresponding amount was R 2.41 for the Akluj farmers indicating a clear advantage for BPF. However, by February 1998, Kolhapur farmers incurred an expenditure of R 2.84/L of milk supplied using BPF against the corresponding amount of R 1.98 by the Akluj farmers, which indicates an advantage of cattle feed. Similar comparison for AMUL using BPF and the nearby districts of Mehsana and Surat using traditional concentrates also indicates inconclusive results.

Although the comparison among districts using BPF and concentrates did not reveal a consistent pattern, during the period when AMUL had produced traditional cattle feed the cost per litre of milk procured was higher than the periods when BPF was supplied. The relevant data are reproduced in Table 4.

Table 4. Feed quantity and cost of feed/L of milk (supplied by AMUL farmers; BPF = bypass protein feed)

Month	Feed type	Feed quantity per litre of milk (g)	Cost (Rupees)
April 1997	BPF	0.422	2.01
May 1997	Cattle feed	0.562	2.14
July 1997	Cattle feed	0.582	2.21
August 1997	Cattle feed	0.635	2.41
January 1998	BPF	0.393	1.75
February 1998	BPF	0.429	1.95

The data in Table 4 indicates clear superiority of BPF. However, it cannot be established if the variation is due to seasonality. In view of the conflicting evidence available from different sources, it was decided to exclude the cost savings aspect from the present analysis.

Experimental results had indicated that the effectiveness of BPF was maximised when used in combination with UMB. Kunju (1988) had observed that 4 kg traditional cattle feed was required to be fed to sustain milk yield of 7.1 kg fat corrected milk in buffaloes. The same level of milk was produced when 2 kg of BPF plus UMB was fed, which was almost half of the earlier feed. However, in order to examine the contribution of UMB alone, it is necessary to analyse the use of UMBs and milk production prior to the introduction of BPF. Assuming unchanged milk consumption, Fleming (1991) had concluded that there had been no significant increase in milk procurement arising from usage of UMBs between 1985 and 1988. This was based on the findings of the regression equation when addition of the UMB variable in the feed supplement equation added nothing to the explanatory power of the equation. It was also expected that the introduction of UMBs would lead to an increased price of milk through increased fat content of milk. However, Fleming's (1991) regression analysis of the price for milk received by the farmers failed to discern any effect. In view of the poor yield response and the negligible impact on the price of milk received by the farmers due to UMB use, it is realistic to follow Fleming's assumption that the UMB contribution can be left out. Even when the UMB contribution in conjunction with BPF use is taken into account, the small quantity of UMB used by the farmers may not make a significant contribution. It is too early to ascertain if the changeover from the hot process to the cold process in the manufacture will substantially alter the situation. In view of these uncertainties it is reasonable to exclude the UMB contribution during 1985 to 1988 from the economic contributions of the project.

4.4 Project Cost

The procedure used in this analysis is an incremental reasoning which estimates the project cost as the difference in the total cost between the two scenarios of 'with the project' and 'without the project'. When the impact of the new feed is estimated, it is assumed that all other items of cost of milk remained unaltered. The scenario 'with project' would take into account the cost with BPF and the 'without' scenario would consider the cost with traditional concentrates. The price difference between one kilogram of BPF and traditional concentrates varied from region to region and from time to time. However, in most cases the difference was around one rupee per kilogram of feed. Therefore when the farmers switch over from traditional concentrates to BPF, for each kilogram of feed switched over there is an additional cost of one rupee which is included in the project cost estimates.

There are possible changes in the use of other inputs, especially household labour and green and dry fodder. The impact of the project on the use of these inputs could at best be a reduction in the cost level. However, in the absence of any realistic basis to estimate this, it was decided to follow the conservative principle of ignoring the possible cost reduction on this account.

The major item of the project cost is the research cost. The three projects were spread over a period of at least nine years and the three main parties involved in the project had incurred total research costs as indicated in Table 5.

Table 5. Cost of research ('000 $A; n.a. = not applicable).

Year	Project number	ACIAR costs	Costs by commissioned organisation	Partner country costs	Total
1984	8203	134	n.a.	n.a.	285
1985	8203	134	n.a.	n.a.	285
1986	8203	139	n.a.	n.a.	285
1987	8601	240	155	87	482
1988	8601	206	155	87	448
1989	8601	194	155	87	436
1990	8817	89	152	78	319
1991	8817	170	152	78	400
1992	8817	171	162	78	411

4.5 Benefit–cost Analysis

The review of various dimensions covered by the projects presented in the previous sections can now be synthesised to carry out a benefit–cost analysis. For this purpose, the guidelines provided by the ACIAR to achieve consistency across different projects were followed. The detailed results of the analysis are presented in Table 6 and the steps followed in obtaining this Table are briefly summarised below.

Step 1. Specification of time horizon

The projects under review cover three separate contracts on an interdependent theme. Considering the functional similarity and common beneficiaries, the projects are combined for the purpose of the analysis, despite different organisations being involved with project implementation. The first project was initiated in 1984, the second in 1987, and the third in 1990, each for a period of three years. The first visible output of the project was available in 1985 in the form of UMB. However, as explained before, the contribution of UMB from 1985–88 was excluded from the purview of the analysis. The second visible output, in the form of BPF, was available from 1989. Considering a total time framework of 30 years, the project benefits and costs were determined up to 2013.

Step 2. Specification of benefits

The most important benefit from the project is the increased farm income accrued to the Indian dairy farmers from increased milk production. In addition to the improvements in the economics of milk production, it was visualised that the project benefits would include increased draught power, increased meat production, reduced ecological damage, equity gains, reduced yield risks and reduced seasonality in milk output. In view of the difficulties explained in the text in quantifying the gains associated with many of these aspects, it was decided to include only the aspects associated with the economics of milk production. The project documents had specified likely spill-over effects in other developing countries. While the technologies developed in the projects have relevance to other developing countries which depend mainly on crop residues and by-products for livestock maintenance, there was no evidence that the project personnel had initiated any activities outside the Indian context. In view of this, the paper excludes these likely spill-over effects.

The annual benefits reported in column 3 of Table 6 are derived from a series of steps. The main contribution of the project is attributed to the development of BPF, which was commercially produced from 1989. Data on BPF sales were available for the period 1989 to 1997 and the likely sales volume were projected for the period beyond 1998. Partial elasticities for milk production using traditional cattle feed and BPF were used to derive the incremental milk output for each year. An analysis of the changes in milk price from 1989 to 1997 had indicated that the milk price changes were consistent with the increase in general price levels. Therefore, it was assumed that the valuation of incremental milk output using the 1989 price level would provide the incremental value of milk output at constant prices. When adjustments were made for the general price increases, there was a difference of about one rupee between the BPF price and the price of traditional cattle feed throughout the period 1989 to 1997. Hence the incremental feed cost was calculated at the rate of one rupee for each kilogram of BPF use. Here it should be mentioned that the prices used for costing are the market prices. Fleming (1991) has provided a detailed discussion on the difficulties encountered while adjusting to efficiency prices for major inputs used in the production of feed concentrates in relation to molasses, cereal straw and oil cake. His conclusion that the impact of this adjustment would be only marginal appears to be a reasonable one. The project benefits were assumed to be the difference between the incremental value of milk output and the incremental feed cost. The steps followed in deriving the annual benefits reported in column 3 of Table 6 are summarised in Appendix 4.

Step 3. Conversion of benefits to A$

The annual benefits in Indian rupees were converted to annual benefits in nominal A$ using an exchange rate of 1A$ at 26.919 Indian rupees.

Step 4. Research cost

Research cost included costs incurred by the three categories of participating organisations namely, ACIAR, commissioned organisation and developing country partners. The distribution of costs incurred by these organisations is available in Table 5.

Step 5. Net annual benefit in nominal A$

This column corresponds to the difference between the benefits in column 4 and the research cost in column 5.

Step 6. Net annual benefits in 1996 A$

Net annual benefits in nominal A$ were converted to benefits in 1996 Annual A$ using the adjustment factor for conversion provided by ACIAR.

Step 7. Discount factor

Table 6 uses a discount factor of 5 per cent. Since the net present values and benefit–cost ratios were favourable at 5%, the sensitivity of the results was assessed using discount rates of 8 per cent and 12 per cent.

Table 6. Summary of benefit–cost analysis.

Year	Year date	Annual benefits in nominal Rupees $R '000s	Annual benefits nominal A$ '000s	Research costs A$ '000	Net annual benefits A$ '000	Adjustment factor	Net annual benefits in $A 1996 A$ '000	Discount factor	Discounted net annual benefits A$ '000
1	2	3	4	5	6	7	8	9	10
1	1984	0	0	–285	–285	1.7498	–497.3	.952	–473.4
2	1985	0	0	–285	–285	1.6518	–470.8	.907	–427.0
3	1986	0	0	–285	–285	1.5377	–438.2	.864	–378.6
4	1987	0	0	–482	–482	1.4322	–690.3	.823	–568.1
5	1988	0	0	–448	–448	1.3366	–598.5	.784	–469.5
6	1989	9380	348.5	–436	–87.5	1.2297	–107.6	.746	–80.3
7	1990	10050	373.3	–319	54.3	1.1561	62.8	.711	44.7
8	1991	11390	423.1	–400	23.1	1.1093	25.6	.677	17.3
9	1992	12395	460.5	–411	49.5	1.0889	53.9	.645	34.8
10	1993	13400	497.8	0	497.8	1.0753	535.3	.614	328.6
11	1994	14405	535.1	0	535.1	1.0666	570.7	.585	333.9
12	1995	14850	551.7	0	551.7	1.0566	582.4	.557	324.4
13	1996	16355	607.6	0	607.6	1.0255	623.1	.530	330.2
14	1997	18090	672.0	0	672.0	1.0000	672.0	.505	338.0
15	1998	20100	746.7	0	746.7	1.0000	746.7	.481	359.2
16	1999	22110	821.4	0	821.4	1.0000	821.4	.458	376.2
17	2000	24120	896.0	0	896.0	1.0000	896.0	.436	390.7
18	2001	26130	970.7	0	970.7	1.0000	970.7	.416	403.5
19	2002	28140	1045.4	0	1045.4	1.0000	1045.4	.398	414.0
20	2003	28140	1045.4	0	1045.4	1.0000	1045.4	.377	394.0
21	2004	28140	1045.4	0	1045.4	1.0000	1045.4	.359	375.3
22	2005	28140	1045.4	0	1045.4	1.0000	1045.4	.342	357.5
23	2006	28140	1045.4	0	1045.4	1.0000	1045.4	.326	340.8
24	2007	28140	1045.4	0	1045.4	1.0000	1045.4	.310	324.0
25	2008	28140	1045.4	0	1045.4	1.0000	1045.4	.295	308.4
26	2009	28140	1045.4	0	1045.4	1.0000	1045.4	.281	293.8
27	2010	28140	1045.4	0	1045.4	1.0000	1045.4	.268	280.2
28	2011	28140	1045.4	0	1045.4	1.0000	1045.4	.255	266.6
29	2012	28140	1045.4	0	1045.4	1.0000	1045.4	.243	254.0
30	2013	28140	1045.4	0	1045.4	1.0000	1045.4	.231	241.5
Total	n.a.	466035	17312.5	–3351	138737.7	n.a.	n.a.	n.a.	n.a.
NPV (over 30 years)			4734.8						
NPV to 1997			–645.0						

Note: A$ = Australian Dollar, n.a. = not applicable, NPV = net present value.

Step 8. Net annual discounted benefits

Net annual discounted benefits for all years were obtained by multiplying the net annual benefits in 1996 A$ in column 8 of the Table with the present value multiplier at 5 per cent.

Step 9. Project viability

Project viability was determined using the investment criteria of net present value, benefit–cost ratio and internal rate of return. The sum of the discounted net present values of the benefits in 1996 dollars was A$4734.8 thousand. The benefits–cost ratio was calculated using the sum of the present values of the benefits and the sum of the present value of costs. Further, the net present value of benefits accrued from the project until 1997 was also calculated.

4.6 Discussion of the Results

The results presented in Table 6 indicate that the net present value (NPV) of all the projects over the project life time is A$4 734 800 as on the first year of the project. When the project costs and project benefits are considered, the benefit cost ratio (NPV benefits divided by NPV cost) was 2.15. The internal rate of return (IRR) was about 13 per cent. All these indicators reveal the economic viability of the projects. However, the NPV of benefits which has been realised by 1997 is negative, indicating that the full cost of the three projects have not been realised so far. If the cost incurred on project 8817 is excluded, the NPV of benefits turns out to be positive. Therefore, it can be concluded that the costs incurred on the first two projects have been recovered by 1997 and the cost on the third project is yet to be recovered . It can be observed from Table 6 that the combined cost incurred on the three projects will be realised by 1999.

4.7 Sensitivity Analysis

The estimates of benefits from the project are highly dependent on the use of BPF by the farmers. The base estimates presented in Table 6 were obtained using the assumption that BPF use will increase from the 1996–97 level of 247 000 t to 420 000 t by 2002 and will stabilise at this level for the subsequent years. Even if there is any increase beyond this period, it can be safely assigned to the effects of further modifications in the technology developed as a result of subsequent efforts, which may not be directly attributed to the projects under review. The assumed level of 420 000 t implied a capacity utilisation of 80 per cent of the existing feed mills working for 300 days in a year. However, this level corresponds to an increase of 70 per cent from the 1997 level in five years. The total increases for eight years from the introduction to 1996–97 was only 76 per cent. In view of this it was considered appropriate to analyse the effect of a reduced level of capacity utilisation to 70 per cent of installed capacity. This level corresponds to 370 000 t, or an increase of about 50 per cent sales from the 1996–97 level.

Another factor that influences the sensitivity of the results in Table 6 is the distribution of the total BPF use among the three major types of animals (crossbred cows, buffaloes and indigenous cows). Since there were no direct estimates of the distribution of BPF among these categories, indirect estimates were obtained on the basis of the number of cattle and the proportion of milk collected by the organised sector. The distribution of BPF among the three categories of animals was 40 per cent for crossbred, 40 per cent for buffaloes and 20 per cent for indigenous cows. Sensitivity analysis was carried out by varying this proportion at two levels: (1) 45 per cent for crossbred, 45 per cent for buffaloes and 10 per cent for indigenous cows and (2) 50 per cent for crossbred, 40 per cent for buffaloes and 10 per cent for indigenous cows.

A third factor influencing the benefit–cost analysis is the discount factor used to convert future streams of costs and benefits to the base year. While the results in Table 6 corresponds to a discount factor of 5 per cent, the sensitivity of the results were analysed using discount factors of 8 per cent and 12 per cent.

The results of the sensitivity analysis are presented in Table 7. The 18 situations reported in the Table 7 are grouped into two categories, category A relating to 80 per cent capacity utilisation and category B relating to 70 per cent capacity utilisation. Within each category, three scenarios are represented: (1) base level (A1 and B1) corresponding to 40 per cent BPF used by crossbred, 40 per cent by buffaloes and 20 per cent by indigenous cows; (2) scenario A2 and B2, represented by 45 per cent for crossbred, 45 per cent for buffaloes and 10 per cent for indigenous cows; and (3) scenario A3 and B3, represented by 50 per cent used by crossbred 40 per cent by buffaloes and 10 per cent by indigenous cows. As mentioned earlier, within each scenario three levels of discount rate at 5 per cent, 8 per cent and 12 per cent are considered. It may be noted that A1 at 5 per cent discount rate corresponds to the data presented in Table 6.

Table 7. Sensitivity analysis.

Category	Scenario	Discount rate (%)	NPV $A'000s	Benefit–cost ratio
A	A1	5	4734.8	2.15
		8	1697.8	1.53
		12	212.6	1.08
	A2	5	5292.4	2.48
		8	2233.8	1.71
		12	428.3	1.16
	A3	5	5474.4	2.53
		8	2421.4	1.79
		12	576.0	1.22
B	B1	5	4069.5	1.88
		8	1501.6	1.47
		12	46.1	1.02
	B2	5	4342.5	2.21
		8	1376.9	1.43
		12	113.3	1.04
	B3	5	4727.1	2.32
		8	1927.3	1.60
		12	316.6	1.15

Note: Category A refers to 80% Capacity Utilisation by 2002, Category B refers to 70% Capacity Utilisation by 2002, Scenario 1 assumes 40% BPF by crossbred, 40% buffaloes and 20% local cows. Scenario 2 assumes– 45% Crossbred, 45% buffaloes, 10% local cows. Scenario 3 assumes 50% crossbred, 40% buffaloes, 10% local cows; NPV = net present value.

The sensitivity analysis clearly demonstrates that the projects yield a minimum internal rate of return of 12 per cent even under the most conservative set of assumptions. The benefit-cost ratio ranged between 1.02 (70 per cent capacity utilisation and 12 per cent discount rate) and 2.53 (80 per cent capacity utilisation and 5 per cent discount rate).

5. Conclusions

The economic analysis of the three ACIAR projects has clearly established the economic viability of these projects. The projects' benefits, estimated using the most conservative set of assumptions, have indicated that the cost incurred on these projects is justified by the economic benefits to the

Indian farmers. Here it should be kept in mind that the outcome of technology development cannot be confined to the products developed during the particular research period alone. Further, the cost of development of a specific product may not be restricted to a specific research project. In the context of the current projects, two products that can be clearly identified with these projects are the UMB and BPF used in the NDDB-supported dairy cooperatives. When the benefits accrued to the members of the cooperative societies are directly related to the costs incurred on the three projects, the benefit–cost ratio was above 2 for the base level estimate. The sensitivity analysis of the results also indicated the economic viability of the projects. The rate of return on the investment would improve substantially if a number of benefits left out from the purview of measurement were included. The weakness in the existing technology transfer system to the small farmer households is a major constraint in the adoption of technologies developed through these projects.

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Appendix 1
Some points of departure from the Fleming (1991) study

As indicated in the text, this study has used Fleming's study as the starting point. Fleming had carefully reviewed all the evidence at his disposal to measure the impact of the two projects on the livestock economy. When he had carried out the study, there was very little information on the farm level acceptance of UMB and BPF. The present study incorporates subsequent data on this aspect. However, in the light of the progress regarding the use of UMB and BPF it was necessary to make some deviations from the approach followed by Fleming. This Appendix summaries the major areas of departure.

1. Conversion of commercial feed production process

As indicated earlier, one of the main concerns of NDDB in improving the efficiency of feed utilisation was the propagation of the BPF containing a large percentage of solvent extracted protein meals, grain byproducts, whole grains, molasses, minerals and vitamins. Conversion of commercial feed production process to BPF, which began in December 1988, was expected to take place at a rapid pace. The target set in the proposal for Technology Mission for Dairy Development was the conversion of around 60 per cent of the 44 cooperative feed plants in India to production of BPF by 1992. Fleming had visualised that this target was too optimistic. He had anticipated that a realistic timetable for the total conversion of cooperative feed mills was 1999, although Chotani (cited in Fleming 1991) had envisaged 90 per cent of the cooperative feed mills conversion by 1995. It was also visualised that the private feed mills would also follow suit to produce improved feed by 1999.

The current position is far below the expectation. The production of BPF is confined to 17 out of the 44 feed mills. Of these 17 plants only four were manufacturing BPF alone, while the remaining 13 produced both concentrates and BPF. Of the total daily capacity of 4 957 t of these 44 feed mills, the feed mills manufacturing BPF had daily capacity of only 1 750 t. During February 1998, the monthly production of BPF was 20 882 t against the production of 59 293 t of traditional cattle feed from these mills.

In view of the slow progress in the conversion process it is assumed for the purpose of the current study that the realistic annual production level of

BPF under the existing conditions would be 420 000 t, to be achieved by 2002. This will imply a capacity utilisation of 80 per cent of the existing capacity of 1 750 t/day if the plants work for 300 days in a year.

Anand Milk Union Limited base

At the time of Fleming's study the BPF experience was mainly confined to AMUL where there was a complete change over to BPF. In the absence of any alternative, it was quite practical to visualise what could be the impact to the AMUL producers and then attempt a generalisation of the all-India scenario. However, the AMUL scenario identified in the study did not materialise due to various reasons, which are difficult to assess in view of the reluctance on their part to release relevant information. However, based on the available information, some general observations can be made, as follow.

It was pointed in the Fleming study that AMUL expected the number of crossbred cows in Kaira district to increase rapidly. The 1988–89 population of 19 000 crossbred cows was projected to increase by 5 000 in 1990–91, 6 000 in 1991–91, 7 000 in 1992–93 and 8 000 in 1993–94 through introduction of animals from outside the district. Further, the artificial insemination in the district was expected to provide additional crossbred cattle numbers of 3 000, 4 000, 5 000 and 6 000 in the four years starting with 1990–91. This would have implied that the crossbred cows in Kaira by the end of 1993–94 would be around 68 000. Against this expectation, the Department of Animal Husbandry had estimated the number of crossbred cows in 1993–94 as 29 769.

►►►► 2. Milk production increase

In order to assess the impact of the new feeds on milk production, the milk output levels in AMUL societies and the likely changes were taken as the yardsticks. It was estimated that annual milk output in the AMUL societies could reach around 850 000 t by 1999, which was almost three times the level achieved in 1988. The increased milk production was decomposed into breed and feed effects. Also it was assumed that AMUL handled around 70 per cent of the total Kaira milk production in 1988. The recent AMUL procurement data raises serious questions about these assumptions. The annual average milk procurement of AMUL from 1993–94 is shown in Table A1.

Table A1. Anand Milk Union Limited's milk procurement, 1993 to 1997.

Year	Average daily procurement (t)	Annual procurement (t)	Annual production (t)[a]
1993–94	759.8	277 327	396 180
1994–95	627.7	229 110	327 300
1995–96	644.4	235 206	336 000
1996–97	735.7	268 530	383 610

[a]Assuming that procurement is 70 per cent of production.

Obviously the estimated production change based on AMUL procurement may not reflect the actual production scenario, especially in the context of increased number of crossbred cattle. Here again, in the absence of reasonable explanations for the procurement levels it is not appropriate to use AMUL procurement as an indicator of the production trends in Kaira.

Apart from the near stagnant procurement volume, it is also significant to note that the composition of milk procured by AMUL does not reflect the likely increase in the proportion of cow milk. During 1997–98, the share of cow milk in the total milk procurement remained between one-fourth to one-third of total procurement volume, which is in no way an improvement over the position in the 1980s. Some observers had pointed out the pricing policy followed by AMUL with emphasis on fat content might be influencing the farmers to divert cow milk to other sources.

Table A2. Share of different types of milk in Anand Milk Union Limited Procurement (%).

Year	Month	Cow milk	Buffalo milk	Mixed milk
1997	March	30.4	59.7	9.9
	April	29.6	57.5	12.9
	May	37.7	48.5	13.8
	July	35.0	49.1	15.9
	August	32.0	52.6	15.4
1998	January	22.7	62.7	14.6
	February	25.3	58.9	15.8

To estimate the likely yield increases due to BPF, Fleming had assumed that a minimum increase of 0.5 per cent would occur each year over the decade 1990–99. Improved supplementary feeding strategies would build up the quality of the milking herd and milk producers would improve their knowledge and application of improved supplementary feeding strategies. The annual increase in milk output was forecast to reach 12 per cent by

1999 without interactive effects of improved breeding and veterinary services. The annual increase in milk output with the interactive effects was assumed to be one per cent over the same period, giving an estimated annual increase in output of 17 per cent by 1999. This increase in milk output would be reflected in the milk procurement by AMUL. However, the procurement data of AMUL during the period 1989 to 1997 do not reflect the actual production increase in the Kaira district and, in the absence of any other reliable data to estimate the production increase, it was necessary to adopt an alternate procedure for estimating the yield increase to account for the shift from traditional concentrates to BPF. This procedure used the difference in the partial elasticities of milk production from traditional concentrate and BPF. The level of BPF sales was estimated independently and using the difference in the partial elasticities the incremental milk production was estimated.

3. Production Costs

There are some indications that the feed cost per kilogram of milk in AMUL societies is higher than in some of the neighbouring societies in Gujarat. During May to August 1997, AMUL discontinued production of BPF in favour of traditional concentrates. During these three months, the feed use per kilogram of milk produced (and consequently the feed cost) in AMUL societies remained at a higher level than the Mehsana Union when both AMUL and Mehsana farmers were using traditional concentrates, as shown in Table A3.

Table A3. Feed cost per litre of milk.

Month	AMUL[a] feed per kg of milk (g)	AMUL cost (R)	Mehsana feed per kg of milk (g)	Mehsana cost (R)
May 1997	562	2.14	400	1.50
July 1997	582	2.21	430	1.61
August 1997	635	2.41	398	1.55

[a]AMUL = Anand Milk Union Limited

In view of the different problems experienced in using the AMUL data as the basic framework for analysing the impact of the project at the all–India level, a different approach was used to estimate this scenario.

Appendix II
Monthly production of cattle feed (t) and bypass protein feed (BPF)

Month	Cattle feed				BPF			
	1994–95	1995–96	1996–97	1997–98	1994–95	1995–96	1996–97	1997–98
April	52 821	47 699	51 973	48 926	18 805	19 404	20 731	8 391
May	52 835	44 900	55 180	66 258	17 143	46 825	20 140	11 805
June	43 897	46 949	65 083	60 606	15 696	15 746	37 373	36 452
July	41 245	35 629	42 965	58 050	16 407	14 943	1 950	8 114
Aug	33 093	41 565	39 025	50 912	15 568	14 528	16 856	8 277
Sept	34 330	47 111	40 708	n.a.	15 611	15 615	18 404	n.a.
Oct	48 214	46 583	49 923	52 601	18 226	19 896	19 616	15 324
Nov	49 469	50 944	64 557	n.a.	16 671	19 378	22 031	n.a.
Dec	59 478	63 630	63 263	61 842	22 039	24 890	27 362	19 788
Jan	46 822	61 246	62 412	64 093	18 770	25 105	12 192	20 830
Feb	42 531	58 190	66 262	59 293	20 116	23 558	19 426	20 882
March	50 668	54 556	52 250	n.a.	25 040	22 430	13 823	n.a.
Total	555 898	600 002	653 601	215 092	232 318	247 101		

n.a. = not applicable

Appendix III
Anand Milk Union Limited's milk procurement ('000 kg/day).

Month	1989	1993–94	1994–95	1995–96	1996–97
April	715	858	798	657	784
May	610	726	661	575	670
June	570	613	582	507	578
July	550	512	527	419	548
Aug	510	549	500	464	526
Sept	530	594	473	462	567
Oct	680	694	512	542	661
Nov	830	827	596	685	779
Dec	870	926	699	794	885
Jan	725	974	752	887	765
Feb	750	980	761	891	973
March	725	880	703	838	909
Average	670	759	628	644	736

Appendix IV
Derivation of annual benefits of the project

Year	BPF Sales ('000 t)	Incremental milk output ('000 t)	Incremental value of milk (rupees [R] '000)	Incremental feed cost (R '000)	Project benefits (R '000)
1989	140	30.8	149 380	140 000	9 380
1990	150	33.0	160 050	150 000	10 050
1991	170	37.4	181 390	170 000	11 390
1992	185	40.7	197 395	185 000	12 395
1993	200	44.0	213 400	200 000	13 400
1994	215	47.3	229 405	215 000	14 405
1995	232	51.0	247 350	232 000	14 850
1996	247	54.3	263 355	247 000	16 355

Appendix IV (cont'd) Derivation of annual benefits of the project

Year	BPF Sales ('000 t)	Incremental milk output ('000 t)	Incremental value of milk (rupees [R] '000)	Incremental feed cost (R '000)	Project benefits (R '000)
1997	270	59.4	288 090	270 000	18 090
1998	300	66.0	320 100	300 000	20 100
1999	330	72.6	352 110	330 000	22 110
2000	360	79.2	384 120	360 000	24 120
2001	390	85.8	416 130	390 000	26 130
2002	420	92.4	448 140	420 000	28 140
2003	420	92.4	448 140	420 000	28 140
2004	420	92.4	448 140	420 000	28 140
2005	420	92.4	448 140	420 000	28 140
2007	420	92.4	448 140	420 000	28 140
2008	420	92.4	448 140	420 000	28 140
2009	420	92.4	448 140	420 000	28 140
2010	420	92.4	448 140	420 000	28 140
2011	420	92.4	448 140	420 000	28 140
2012	420	92.4	448 140	420 000	28 140
2013	420	92.4	448,140	420,000	28 140

Appendix V
Some findings of the studies on urea molasses blocks and bypass protein feed

Kunju and Mangat Ram (1989) report that studies conducted on lactating buffaloes have demonstrated minimum feed cost and maximum net return in response to feeding of UMBs and 40 per cent less concentrate mixture, along with small quantity of cotton seed meal. Twenty surti buffaloes of similar milk yield, body weight and stage of lactation were randomly divided into four groups of five and fed different combinations of feed. It was found that daily milk yield, fat yield and fat corrected milk (4%) were not significantly different among different groups. Feed cost was lowest for the feed combination involving bypass protein as compared to other groups. The relevant data for the four groups indicated the patterns in Table A5.

Table A5. Results of urea molasses block (UMB) trials.

	Group I	Group II	Group III	Group IV
Feed intake (kg)	6.18	6.23	4.45	3.45
Paddy straw (kg)	5.40	5.40	6.50	6.70
UMB (kg)	–	0.35	0.57	0.37
Cotton seed meal (kg)	–	–	–	0.42
Milk yield (kg)	5.46	4.87	4.68	5.33
Feed cost (R)	8.63	8.64	6.72	5.94

Kunju et al. (1992) reports the results of feeding trials using 25 matured lactating Kankraj ¥ Foreisien cows of about 400 kg body weight and of 2nd and 3rd lactation, which had calved 3 to 4 months previously. They were grouped into five groups, each being fed bypass feed of 0, 1, 2, 3 and 4 kg. The cows fed on 7 kg rice straw and UMB ad lib maintained 5.5 kg milk yield per day. Addition of 1 kg BPF yielded 1.2 kg more milk than the animals fed no BPF However, all those animals lost their body weight on an average by 120 g and 80 g per day, respectively. Further addition of BPF resulted in an increase of milk yield and gain in body weight. The maximum response was observed in cows fed 3 kg BPF, where the average milk yield was 8.6 kg. No further response was obtained in the cows fed 4 kg feed. The response level is shown below.

Level of by pass feed	Milk (kg)	Fat corrected milk (4%)
0	5.5	5.5
1	7.7	7.5
2	8.0	7.8
3	8.6	8.5
4	8.0	7.8

Chauhan et al. (1997) reports the results of feeding trials using 27 lactating buffaloes yielding 7–8 L of milk in their mid stage lactation. They were divided into five groups and experimental feeding was carried out for 84 days. All feed levels included wheat straw ad lib and 30 kg green berseem, and other items as shown below.

Control: concentrate mixture	
Treatment 1:	20% less concentrate mixture + urea molasses block (UMB) containing 15% cotton seed cake
Treatment 2:	20% less concentrate mixture + UMB containing 15% deciled mustard cake
Treatment 3:	20% less concentrate mixture + UMB containing 15% guar-meal
Treatment 4:	20% less concentrate mixture + UMB contain 15% groundnut cake

The milk yield and cost under these treatments indicated the following results:

Control	T-1	T-2	T-3	T-4	T-1
Average milk yield (kg)	6.90	7.30	7.0	7.67	7.20
Cost per kg of milk production	3.90	3.65	3.90	3.49	3.89

Appendix VI
Seasonality in milk output

With a greater role of concentrates in milk production through the introduction of UMB and BPF, it was expected that seasonality would decline, because of reduced reliance on seasonal supplies of green and dry fodder (Fleming, 1991). In the absence of milk production data, an attempt was made to test the incidence of seasonality using procurement data from AMUL. Although the non-reliability aspect of trends in AMUL procurent as an indicator of production trends in the Kaira district are acknowledged (see earlier discussion in this report), for the limited purpose of this analysis, the AMUL data is used. If the proportions of milk sold to AMUL in a given year remained somewhat stable within the year, the procurement data for the different seasons in the same year can indicate the nature of changes in seasonality. Further, since the number of members supplying milk to AMUL had changed over the years, the average quantity of milk supplied by one member was used for the analysis.

The average quantities of milk supplied by the AMUL society members for five years according to four quarters in the year are available in Table A6. In general, the supply was least during July–September and it was the highest during January–March. The 1996–97 average supply remained at the same level as the 1989 level. The deviation from the mean level for the year had indicated some positive changes. The coefficient of variation in 1989 and 1994–95 remained at the same level and during the remaining three years it was higher than the 1989 level. While the results do not offer a firm conclusion that variability has increased overtime, they definitely do not provide any evidence that seasonality had declined with the introduction of UMB and BPF.

Table A6 Average daily milk supplies of Anand Milk Union Limited society members (kg/day/member).

Month	1989	1993–94	1994–95	1995–96	1996–97
April–June	1.30	1.45	1.32	1.09	1.24
July–Sept	1.06	1.08	0.95	0.84	1.00
Oct–Dec	1.58	1.59	1.14	1.25	1.31
Jan–March	1.47	1.84	1.39	1.61	1.72
Average	1.34	1.49	1.20	1.20	1.34
Standard Deviation	0.19	0.27	0.17	0.28	0.26
Coefficient of variation (%)	14.2	18.1	14.2	23.3	19.4