Technology Options for Sustainable Livestock Production in India

National Centre for Agricultural Economics and Policy Research
International Crops Research Institute for the Semi-Arid Tropics
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Pratap S Birthal
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Contents

Foreword

Livestock are an integral part of agriculture in India, and are likely to be the instruments of future growth and development of the agricultural sector. They generate employment, provide draft power and manure, and earn foreign exchange through exports. Although the per capita consumption of foods of animal origin is low in India, demand has been rising due to the growing human population, sustained growth in per capita incomes, and increasing urbanization. This demand-driven growth, besides improving food and nutritional security, can benefit millions of landless and small landholders who constitute more than 60% of the total rural population and possess about three-fourths of the country's livestock wealth.

The issue that needs addressing is how current output trends of 4–5% per annum can be sustained without disturbing the equilibrium between crops and livestock. Improving food supply from animals through higher livestock numbers (as in the past) is now severely constrained due to the feed-fodder deficit and declining per capita land availability. Technological and management options are the only alternatives to accelerate the growth in productivity, which is currently low.

A number of livestock technologies are available for field application, but they are yet to gain wide acceptance. This poses several questions for researchers, research administrators, and policy-makers: Is the technology economically feasible and tested on-farm in different farming systems? To what extent have farmers' perceptions and needs been taken into consideration in the design of the technology? Have proper pathways been followed to transfer the technology?

The National Centre for Agricultural Economics and Policy Research (NCAP) of ICAR, and ICRISAT's Socioeconomics and Policy Program (SEPP) jointly organized a multidisciplinary workshop (*Documentation, Adoption, and Impact of Livestock Technologies*) on 18–19 January 2001 to deliberate on such issues, and identify technological, institutional, and policy interventions to improve livestock productivity. The workshop was organized under the ICAR-ICRISAT Partnership Program and was financially supported by the Systemwide Livestock Program (SLP) of the Consultative Group on International Agricultural Research (CGIAR). This volume contains the lead papers and key findings of the workshop, and will be a valuable source of information to all concerned with livestock development.

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Introduction and Overview of the Conclusions

Pratap S Birthal[1] and P Parthasarathy Rao[2]

Introduction

Growing human population, rising per capita income, and increasing urbanization are fuelling rapid growth in the demand for food of animal origin in the developing countries (Delgado et al. 1999). However, current per capita consumption is low. For instance, in India in 1993–94, per capita annual consumption of milk was 51 kg and meat 1.7 kg, much less than the world average of 75 kg milk and 34 kg meat. By 2020 the per capita consumption of milk is likely to more than double and that of meat more than triple (Kumar 1998; Delgado et al. 1999).

On the supply side, production of both milk and meat has increased at a rate of about 5% annum^{-1}. If these trends continue, increases in demand would be met adequately from domestic supplies. The sustainability of these trends, however, is uncertain. In the past, expanding livestock populations mainly contributed to the observed increases in production. India has a huge livestock population comprising different species, and further increase in the livestock population would be constrained severely by the declining land availability. Productivity of Indian livestock is low compared to many developed and developing countries. Cattle milk yield in India is about 12–15% that in the USA, Canada, and Israel. Meat yield of sheep and goats is about 60% less. Feed and fodder scarcity has been the main constraint in raising livestock productivity. Most of the feed requirement is met from crop by-products and grazing on common lands. The latter, however, have been dwindling quantitatively as well as qualitatively. The levels of adoption of breeding-, feed and nutrition-, and health-related technologies are low. It is imperative to raise these since future growth in the livestock subsector has to come from technological changes.

The importance of livestock in India goes beyond the function of food production. It is an important source of draught power, manure for crop

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production and fuel for domestic use. Thus, by minimizing use of nonrenewable energy, livestock make a positive contribution to the environment. Although crops and livestock are interdependent to a large extent, the latter constitute an important mechanism for coping with the risks of crop failure. In land-scarce economies livestock provide livelihood support in terms of income and employment generation to the millions of landless and small landholders. In India, livestock wealth is mainly concentrated among the majority of marginal and small landholders.

Technology-induced growth in the livestock subsector would thus improve food and nutritional security, alleviate poverty, and reduce interregional and interpersonal economic inequities. India spends only about 0.5% of the agricultural gross domestic product on agricultural research. This is low compared to the average of developing countries (0.7%) and developed countries (2.5%). Livestock research receives about 20% of the total agricultural research resources. This corresponds to the contribution of livestock to the agricultural gross domestic product (Birthal et al. 2001). Despite the low intensity of investment in research, animal science research over the last few decades has generated a number of technologies in the areas of animal genetics and breeding, feed and nutrition, health, and management. The technical feasibility of many of these has been proven under experimental conditions. Examples include crossbreeding in cattle, sheep, pigs, and poultry; chemical and biological treatment of cereal straws; and vaccines against rinderpest, influenza, and foot and mouth disease.

Studies on returns to investment in livestock research are limited. However, sporadic evidences indicate a very high payoff to investment in livestock research and development (Kumar et al. 1977; Gaddi and Kunal 1996). Despite this, the application of many technologies in the field remains limited. Except for crossbreeding, not much information is available regarding adoption and impact of other technologies. There is, thus, considerable scope to raise the productivity of livestock through application of the existing technologies.

It is against this background that the National Centre for Agricultural Economics and Policy Research (NCAP), New Delhi – an offshoot of the Indian Council of Agricultural Research (ICAR) – and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, jointly organized a workshop entitled *Documentation, Adoption and Impacts of Livestock Technologies in Mixed Crop-livestock Farming Systems in India* on January 18–19, 2001 at ICRISAT. The overall goal of the workshop was to assess the technological changes taking place in India's livestock subsector and their potential in sustaining the production of livestock in particular and agricultural economy in general.

The specific objectives were to:

- Document livestock technologies related to breeding, health, nutrition, and processing;
- Identify potential technologies whose adoption and impact assessment could be tracked; and
- Identify constraints in large-scale dissemination of these technologies.

Adoption and Impact of Livestock Technologies

The workshop was multidisciplinary in nature and was attended by 30–35 experts from animal, crop, and social sciences. The deliberations, apart from documentation and identification of potential technologies for their adoption and impact, also brought out some technical, socioeconomic, infrastructure, and policy issues that could help accelerate the pace of adoption of existing technologies. A synthesis of the major conclusions is presented below.

Adoption of Technologies

Over the past few decades, animal science research has offered a number of technological options that could raise the productivity of different livestock species if adopted area-wide. These include genetic enhancement of indigenous breeds through crossbreeding with exotic breeds, improvement of nutritive quality of feed and fodder through biological and chemical treatments, development of vaccines against animal diseases, improved livestock management practices, and post harvest management. Additionally, processing technologies have been developed to strengthen the vertical linkages between the farm and dairy industry. The adoption pattern of these technologies varies widely across species, farm typologies and regions.

Breeding Technologies

Genetics and breeding research have evolved many new breeds of cattle, pig, sheep, and poultry using crossbreeding techniques. These breeds have better production coefficients compared to indigenous ones. However, their adoption in the field is limited and sporadic; only about 8% of cattle, 5% of sheep, 15% of pigs, and 33% of poultry populations belong to the crossbred/ improved category. The adoption level is higher in urban areas compared to rural areas. In general wide scale adoption of crossbreeds is restricted due to their non-acclimatization to the tropical climates prevailing in most parts of the country. Besides, their higher maintenance cost, lower disease resistance, and the poor success of artificial insemination (AI) are other barriers to adoption of crossbreeding. There are also species-specific constraints. The crossbred cow has to be replaced frequently to maintain the flow of benefits. Thus, frequent and higher acquisition costs, lack of disposal facilities (cattle slaughter is banned in most Indian states), and poor draught characteristics of male cattle are important impediments to wide-scale adoption of crossbreeding technology in cattle. Nonetheless, under certain ecological and economic conditions, adoption of crossbreeding technology in cattle has been quite encouraging. The states of Kerala and Punjab, for instance, have a considerably higher proportion of crossbred cattle.

Sheep husbandry in India is practiced largely by the poor and is dependent on availability of grazing lands, which have been deteriorating in terms of both quantity and quality. In contrast to the indigenous sheep breeds that are capable of surviving even on sparse vegetation, the crossbred sheep require better nutrition. This also applies to pigs, which are often managed in scavenger systems.

In the dairy subsector the buffalo could emerge as a promising alternative to crossbred cattle because of its adaptability to varied ecological conditions, higher milk yield and higher fat content, realizing a premium price. Unlike cattle, buffalo slaughter is not banned and animals have a disposal value. These factors have favored a higher growth in buffalo population even without improved breeding interventions. However, in certain regions, nondescript low-yielding species have been upgraded using high-yielding breeds such as the Murrah.

The poultry subsector has responded well to technological changes and has grown faster than the dairy and ruminant meat sector. Enhancement of genetic potential has been the most important factor in the growth of this sector. However, this has been complemented by health and nutrition technologies. The growth trends are more prominent in specialized peri-urban/urban poultry systems, because of higher demand for poultry meat and eggs in urban areas. Here, the entry of the private sector has boosted the adoption of technology and growth in poultry outputs. Backyard poultry production, however, continues to languish technologically.

Feed and Nutrition Technologies

A large number of India's livestock, particularly in the arid and semi-arid environments, suffer from inadequate feeding. The feed and fodder shortages, in fact, have been the main limiting factors in raising livestock productivity. Cereal crop residues comprise the main feed for livestock. However, these are deficient in crude protein and several other nutrients. Concentrate feeding is restricted to lactating, high-yielding bovines and work animals. Small ruminants derive their feed requirements mainly from grazing on common lands.

Animal nutrition and crop breeding (straw/stover) research has yielded many new technologies that could augment production and improve the nutritional quality of feeds and fodder. Research on breeding for higher yield and superior quality crop residues (such as in rice, wheat, sorghum, and millets) is in progress. Studies have indicated that a 1% increase in digestibility of sorghum/millet straw increases bovine milk yield by 5–6% (Kristjanson et al. 1998). Apart from traditional techniques of fodder chopping and conservation, technologies such as urea treatment of fodder, strategic supplementation, urea molasses mineral blocks, and bypass protein use have the potential to alleviate feed and fodder scarcity. These technologies improve digestibility and palatability of feed, reduce feed requirements, avoid feed wastage, and contribute towards improving animal productivity.

Some of these techniques, such as fodder chopping and bypass protein use, have long been in practice in many parts of the country, but are not practiced widely. The main constraint to large-scale adoption of nutrition technologies in general has been the lack of information to users.

The area under green fodder crops is also low; constituting no more than 5% of the gross cropped area. The growth in area under fodder crops has been sluggish in most parts of the country, except in the irrigated regions. This is a reflection of the rising competition between food and fodder crops for limited land and other resources. Crop breeding research has evolved high-yielding varieties of a number of forage crops. However, these have not been adopted widely due to lack of awareness about new cultivars, nonavailability of irrigation water throughout the year, and problems of insect pests/diseases.

Common grazing lands comprise an important source of grasses, and there exists considerable scope to raise the production of grasses/shrubs from these lands through technological and management interventions. Technological interventions such as reseeding with high-yielding grasses and watershed development, complemented with appropriate management interventions such as preventing encroachment, promotion of rotational grazing practices, and charging grazing fees have helped raise the productivity of common grazing resources and thereby improved animal performance.

Disease Control Technologies

Diseases reduce the production potential of livestock. In India many deadly diseases such as rinderpest, foot and mouth disease, hemorrhagic septicemia, and black quarter are major threats to profitable livestock production. Livestock disease control has undergone a paradigm shift in recent years. A number of biological products (vaccines) have been developed for preventive and curative disease management. The infrastructure for disease control has also expanded considerably. The main limitations to effective livestock health management are an inadequate focus on preventive measures, lack of medicines and equipment in the veterinary clinics, and ignorance among the farmers about the diseases and preventive measures. This is reflected in the frequent occurrence of many of these diseases in most parts of the country.

Processing Technologies

Postharvest technologies help producers to realize better gains from technological changes in the primary production sector. But the postharvest processing facilities are lacking in the country. Only about 20% of the total milk production is processed into value-added products. The bulk of it, however, is processed into *ghee* and curds by the producers, and a large proportion of this is consumed at source. Although considerable efforts have gone into developing infrastructure for milk processing in the cooperative sector, only about 5% of the total milk output is processed into table butter, cheese, milk powder, and baby foods. Information on the proportion of other livestock products entering into the value-added chain is not available. There is a considerable demand for processed meat products, but it remains constricted due to inadequate processing facilities. The same applies to export of these products. Furthermore, not enough attention has been paid towards sanitary and phytosanitary measures. Slaughterhouses are often ill equipped and unhygienic.

Low-cost processing technologies have been developed for both cottage and large industries. The rising demand for processed milk products in urban and rural areas is expected to boost future adoption of processing technologies.

Impact of Technological Change

Technological change improves the production potential of livestock and is reflected in productivity growth. The improvements in production lead to increased welfare of the producers as well as consumers of livestock products. In India, although the intensity of adoption of different technologies is low, the technological changes as discussed above, together with improved management practices have contributed to the increased output of many livestock products.

Productivity and Production

In the last three decades milk production has increased at an annual rate of about 4.5%, and meat and egg production at about 5.5% each. The Total Factor Productivity (TFP) index, which is a joint measure of contribution of technology and technical efficiency, has grown at a rate of 1.4% a year since 1970, while the pre-1970 growth in TFP index was marginally negative. The growth in TFP is largely a result of yield-augmenting technological changes that have taken place in the dairy and poultry subsectors. The milk yield of cattle and buffalo has grown at a rate of 3.2% and 1.9%, respectively. In the case of poultry the egg yield has almost doubled and the feed conversion efficiency in broiler production has improved tremendously. The growth in productivity of species such as sheep and goats has been negligible.

Consumption, Prices, and Trade

Per capita consumption of livestock products has increased in the last three decades. The share of livestock products in food expenditure has almost doubled to 21% since 1972–73. This is due partly to increases in the availability of livestock products and a decline in prices of major products such as milk and eggs. The real prices of milk, eggs, and pork have declined, partly due to technology-driven growth in outputs. The real prices of products of sheep and goat, where technology uptake had been lacking, witnessed an upward movement.

Improvements in productivity of dairy animals have also helped achieve self-sufficiency in milk production. The imports of milk and milk products have declined to almost zero. Also, exports of certain livestock products are increasing.

Poverty and Equity

Livestock are an important source of income for the rural poor. The growth in the livestock subsector is expected to contribute to poverty alleviation, as the livestock wealth is largely concentrated among the marginal and small landholders. These categories of farmers, however, face the problem of feed and fodder scarcity. Technologies, particularly those related to nutrition and health, are not capital intensive and could easily be adopted by them. Nevertheless, the intensity of adoption of capital-intensive technologies such as crossbreeding cattle has been observed to be higher on the landless and marginal farms; in 1991–92 there were about 10% crossbreeds in the adult female cattle herds of large landholders, while the landless and marginal landholders maintained 20% of the crossbreeds in their herds. It is thus conjectured that technological change in the livestock subsector would generate more income and employment opportunities for the resource-poor households and contribute towards alleviation of poverty and improvements in interpersonal income distribution.

Rural-Urban Disparities

Peri-urban/urban livestock systems have long existed to cater to the urban demand for foods of animal origin. Rising urbanization and a higher growth in per capita income of the urban population is causing rapid growth in demand for food of animal origin. Developments in processing and packaging technologies have also contributed considerably to this. Thus, to meet the rapidly growing demand for milk, meat, and eggs, peri-urban livestock systems have developed much faster than the rural systems. Technology adoption and production coefficients are better in peri-urban systems. Thus this type of technological dualism is likely to strengthen with further increase in the urban demand for animal foods.

Looking Ahead

Several important points emerged from the deliberations in the workshop that need to be taken into consideration in future research and development programs for the livestock subsector. These are:

- The success or failure of crossbreeding technologies in certain species and in certain ecologically- and economically-different environments calls for a critical review of the crossbreeding program, particularly from the point of view of adaptability of the crossbreeds to different agroecological conditions and socioeconomic environments. The future research and development strategies should be devised accordingly, but with due consideration to animal biodiversity. In view of frequent and higher acquisition cost of crossbred cattle and a lack of outlets for surplus animals due to the ban on cattle slaughtering, the crossbreeding program should emphasize species with a short generation interval and high social demand.

- The success rate of AI is currently low (about 20%). AI services are largely in the public sector and are heavily subsidized. The low success rate seems to act as a deterrent to adoption. It is, therefore, imperative to improve quality of breeding material, techniques, and delivery services so as to instill and reclaim the confidence of livestock owners in AI.
- Buffalo should receive increased attention in research and development programs in view of their better adaptability to varied climates, higher milk yields, higher fat content, and disposal value.
- India is considered a storehouse of animal biodiversity in terms of species and breeds. Although India has a rich database on numbers of different species, their genetic characterization has been limited. This makes it difficult to assess the genetic diversity and evolve conservation strategies. Enumeration of breeds is a difficult task that needs considerable resources and the establishment of interdepartmental linkages, especially between those dealing with field surveys and animal husbandry.
- The huge livestock populations of different species are still growing (although at a slower rate) putting pressure on the feed and fodder resources. The numbers of different species thus need to be optimized considering the demand for their products and the availability of feed and fodder resources.
- Technological alternatives to improve quantity and quality of feed require greater emphasis. There are a number of traditional and new feed and fodder production and management technologies that are cost-effective and have sufficient potential to mitigate feed and fodder scarcity. The best way to promote these technologies is to generate wide awareness among the farmers and to publicize their improved benefit-cost ratios.
- Cereal crop residues form the bulk of the feed dry matter. Therefore, crop-breeding programs should emphasize breeding of superior quality straw/stover of dual-purpose crops without sacrificing grain yield. Straw quality should also be improved through better management of diseases.

- In view of the small proportion of total cropped area under fodder crops and sluggish growth therein, crop breeding should focus on high-yielding and high-quality fodder and forage varieties. Economic incentives (input subsidies for growing forage crops) and vertical integration of the livestock subsector, by developing marketing and processing infrastructure and institutions, would result in farmers bringing more land into fodder crop production.
- Deterioration of common grazing lands is a matter of concern, particularly for sustainability of small ruminant production in ecologically-fragile regions. It is therefore imperative to check quantitative and qualitative deterioration of common grazing lands through technological (watershed management, reseeding with improved grasses), social (participatory management), and policy interventions (legal action against encroachment).
- Disease monitoring should be accorded a high priority, considering the frequent occurrence of many potentially lethal animal diseases. The policy emphasis should shift from curative to preventive disease management. There is sufficient manpower available for this in the public sector that can be utilized gainfully without much additional overhead costs. Marginal investments in medicines and supplies would yield considerable economic and social benefits.
- Linkages between research and extension need to be strengthened for effective transfer of technologies. The huge numbers of field veterinarians and auxiliaries should shoulder the responsibility of technology transfer.
- Social scientists should play a proactive role in evaluation of technologies for their social acceptability, constraints, and impact. This kind of integration of biological and social sciences would help improve the social and economic efficiency of research.
- Developments in biotechnology are expected to provide solutions to many problems constraining livestock production. The biotechnology research however needs to be prioritized considering the importance of the production constraints. The largest impact of biotechnology in the short term can be realized in the field of animal nutrition and health.

References

Birthal, P.S., Joshi, P.K. and Anjani Kumar. 2002. Assessment of research priorities in livestock sector of India. Policy-15. National Centre for Agricultural Economics and Policy Research, New Delhi.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui S. and Courbois, C. 1999. Livestock to 2020: The next food revolution. Discussion paper 28. IFPRI, Washington D.C., FAO, Rome, and ILRI, Nairobi.

Gaddi, G.M. and Kunal, L.B. 1996. Sources of output growth in new milk production technology and some implications to research investment. Indian Journal of Agricultural Economics 51(3):389-395.

Kumar, P. 1998. Food demand-supply projections. Indian Agricultural Research Institute, New Delhi.

Kumar, P., Maji, C.C. and Patel, R.K. 1977. Returns on investment in research and extension: a study on Indo-Swiss cattle improvement project, Kerala. Indian Journal of Agricultural Economics 32(3).

Economic Contributions of the Livestock Subsector in India

Pratap S Birthal[1] and P Parthasarathy Rao[2]

Livestock are an integral component of agriculture in India and make multifaceted contributions to the growth and development of the agricultural sector. Livestock help improve food and nutritional security by providing nutrient-rich food products, generate income and employment and act as a cushion against crop failure, provide draught power and manure inputs to the crop subsector, and contribute to foreign exchange through exports. Also, by using crop residues as feed, livestock save land for food production that would otherwise be used for fodder production. Additionally, livestock make substantial contributions to environmental conservation, supplying draught power and manure for fertilizer and domestic fuel that save on the use of petro-products. This paper assesses the contribution of livestock subsector to the growth of agriculture and socioeconomic development.

Structure of Livestock Production

India possesses one of the largest livestock populations in the world. In 1992 the country had 205 million cattle, 84 million buffalo, 115 million goats, 51 million sheep, 13 million pigs, 1 million horses and 307 million poultry (Table 1). The livestock sector is both expanding and adapting in response to economic, technological, and environmental factors. In general, the numbers of different species are increasing; populations of poultry, pigs, goats, and buffalo have grown faster compared to other species. The populations of draught animals have witnessed negative and decelerating trend.

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Table 1. Structure and growth of livestock population.			
	Population (millions)	Compound growth rate (% annum^{-1})	
Species	1992	1972-82	1982-92
Cattle	204.6	0.8	0.6
Buffalo	84.2	2.0	1.9
Sheep	50.8	2.0	0.5
Goats	115.3	3.5	1.9
Equines	0.8	–0.3	–0.9
Pigs	12.8	3.8	3.4
Camels	1.0	–0.3	–0.4
Poultry	307.1	4.1	4.5

Broadly these trends indicate:

- Deceleration in growth of populations of almost all species except poultry. The decelerating trend is, however, stronger in the case of small ruminants. Thus there is a tendency towards stabilization of the livestock population in the long run.
- A gradual shift in favor of animals that are less capital intensive, have short generation intervals, and better feed conversion and economic efficiency.

In terms of output flow, milk continues to dominate the production structure (Figure 1), with meat and meat products coming next. However, the economic structure of livestock production is undergoing a gradual transformation. The shares of mutton and pork, beef, poultry meat, and eggs have been increasing, while that of milk is declining. The share of buffalo milk in total milk production is increasing. The structure of meat production is shifting from small to large ruminants, poultry, and pigs.

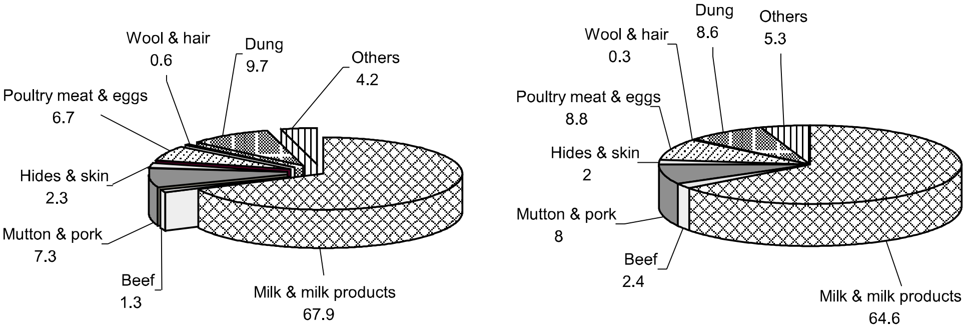

Figure 1. Composition of livestock outputs (percent to total): 1972 and 1992.

Livestock are linked closely with crop production. The linkages are stronger on smaller land holdings. Households having less than 2 ha of land (Table 2) possess a larger share of livestock. The average size of livestock holding is small. The average number of animals per 100 households is 198 bovines and 85 ovines. The number of animals owned, however, has a direct relationship with size of land holding.

Livestock production involves few cash expenses; animals are often fed on homegrown crop residues and grasses from common grazing lands. Crop residues account for more than 50% of the total dry matter intake in several regions (Kelley and Parthasarathy Rao 1995). Use of concentrate feed is low and is limited only to more productive bovines. Small ruminants are maintained mainly by grazing. This results in low productivity. Mean milk yield of lactating indigenous cattle is 620 kg annum^{-1}, crossbred cattle 2130 kg annum^{-1}, and buffalo 1340 kg annum^{-1}. Cattle milk yield is about half of the world average and about 12% to15% of that in the USA, Canada, and Israel. Average meat yield of goats, sheep, and pigs in India is 10, 12, and 55 kg annum^{-1} respectively; about 60% less than those of the above countries. Off-take rate of cattle and buffalo is low. About 6% cattle, 11% buffalo, 38% goats,

Table 2. Distribution of land and livestock holdings in India, 1992.

	Landless (<0.002 ha)	Marginal (0.002–1.0 ha)	Small (1.0–2.0 ha)	Medium (2.0–4.0 ha)	Large (>4.0 ha)	All
% households	21.8	48.3	14.2	9.7	6.0	100.0
Distribution of land						
% share	0.0	15.5	18.6	24.2	41.7	100.0
Size of holding (ha)	0.0	0.2	1.4	2.7	7.5	1.1
Distribution of livestock population (%)						
Bovine	2.5	43.8	23.3	17.7	12.7	100.0
Ovine	5.1	46.2	19.3	15.0	14.4	100.0
Poultry	6.4	54.9	19.0	14.4	5.3	100.0
Pig	7.7	49.9	20.4	13.9	8.1	100.0
Size of livestock holdings (no/100 households)						
Bovines	23	180	324	361	418	198
Ovines	20	81	115	131	203	85
Poultry	49	189	223	247	147	167
Pigs	1	4	6	6	6	4

Source: Govt. of India, National Sample Survey Organization. Land and livestock holdings.

and 33% sheep are slaughtered every year. These figures suggest considerable scope for raising livestock productivity and production.

Economic Contributions

Even at low productivity and off-take rates, livestock contribute significantly to economic development. Their developmental role in the mixed farming systems transcends direct economic benefits. Use of manure contributes to agricultural sustainability and conservation of the environment. Using draught animal power helps save nonrenewable energy such as petroleum. Livestock provide raw material for industry. Additionally, livestock act as a storehouse of capital and an insurance against crop failure. With production concentrated among small landholders, livestock help improve income distribution.

Contribution to National Income

In 1997-98 the livestock subsector accounted for about 23% of the agricultural gross domestic product (AGDP). This has increased gradually from 14% in 1980-81. On the other hand the contribution of the agricultural sector to gross domestic product (GDP) decreased from 35% in 1980-81 to 26% in 1997-98. In other words the livestock subsector has grown at a faster rate than the crop sector (Figure 2). The respective annual rates of growth in GDP from livestock and agriculture are about 7.3% and 3.1% respectively.

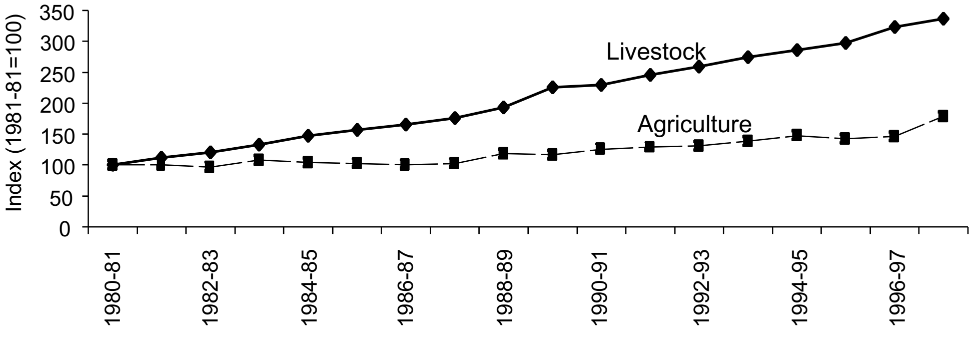

Figure 2. Trends in livestock GDP vis-à-vis agricultural GDP , 1993-94 prices

Inputs to Agriculture

Livestock provide draught power and dung manure to the crop subsector. In 1996–97, draught animals accounted for 14% of the total power available to the agricultural sector (Table 3). Share of livestock in the total power availability declined sharply from 69% in 1961–62 to 25% in 1981–82. However, its absolute contribution has remained almost unchanged at about 20 million kilowatt.

Dung manure is an important contribution. About half of the total dung produced is used as manure and the rest as domestic fuel. In 1970–71 dung manure accounted for about 43% of the total value of manure and fertilizers used in agriculture. This declined drastically to 23% in 1980–81 and to about 13% during the 1990s. However the absolute value of manure has been increasing steadily.

Employment and Poverty

Livestock provide livelihood support to millions of people having little access to land. About one-third of the population lives below the poverty line, mainly comprising of landless, marginal, and small farmers. Since the distribution of livestock is more equitable compared to land (Table 2), growth in the livestock

Table 3. Draught power and manure contributions of livestock.

	1970–71	1980–81	1990–91	1997–98
Draught power				
Total power available (mKW)	44.1	69.1	113.6	136.3
Share of draught animals (%)	45.8	24.7	17.1	14.1
Manure				
Value of manure (million Rs, 1980–81 prices)	11730	13520	15230	18110
Manure used as fertilizer (%)	49.5	51.2	47.3	48.2
Value of manure and fertilizers used in agriculture (million Rs, 1980–81 prices)	13440	29840	60170	67510
Share of manure in value of total soil nutrient inputs (%)	43.2	22.7	12.1	12.9

Source: Gyanendra Singh, p 73, Table 6 (this volume).
Govt. of India. Manure contributions from National Accounts Statistics, various issues, Central Statistical Organization, Ministry of Programme Planning and Implementation.

sector is considered to be anti-poverty and equity-oriented (Adams and He 1995; Birthal and Singh 1995).

Though the contribution of livestock to AgGDP has been rising continuously, contribution to rural employment is not so encouraging. In terms of principal activity status livestock employs about 5 percent of the rural work force (Table 4). Its share however has declined to 3 percent in 1990s. Low share in rural employment is because livestock rearing in India is taken up as a subsidiary to crop production.

Food and Nutrition

The diet of an average Indian is cereal-based and lacks nutrient-rich foods such as pulses, fruits, vegetables, and animal products. Low intake of these products results in nutritional deficiencies. About 30% of the population suffers from malnutrition (Kumar and Joshi 1999). The problem is severe in populations having little access to cultivated land. Diversification of diet towards animal products can help improve nutrition. Intake of livestock products, however, is low (Table 5) compared to that in many developing and developed countries. The food basket, though, is gradually diversifying towards livestock products. In 1972-73 livestock products accounted for about 14% of the food expenditure, which gradually increased to about 20% in 1993-94. Consumption of livestock products is expected to increase faster with sustained economic growth and attendant increases in per capita incomes.

Table 4. Contribution of livestock to rural employment.

Source	1972–73	1977–78	1982–83	1987–88	1993–94
	(million workers employed)				
Agriculture	158.3 (81.0)	172.8 (78.5)	171.1 (80.0)	174.8 (76.6)	195.8 (76.9)
Livestock	9.0 (4.6)	10.6 (4.8)	10.4 (4.9)	10.7 (4.7)	7.9 (3.1)
Total	195.4	220.1	241.2	252.2	254.6

Values in parentheses are percent of total number of workers by usual principal activity status.

Source: Govt. of India. 1999. Basic Animal Husbandry Statistics, Department of Animal Husbandry, Ministry of Agriculture.

Table 5. Consumption of livestock products in India.

Product	Consumption (kg capita^{-1} annum^{-1}) 1993–94	Expenditure shares (%) 1972–73	Expenditure shares (%) 1993–94
Milk	51.0	10.0	15.0
Meat, eggs, and fish	3.4	5.2	
Goat meat	0.7	-	-
Mutton	0.2	-	-
Beef	0.3	-	-
Buffalo meat	0.3	-	-
Chicken	0.3	-	-
Total meat	1.7	-	-
Eggs (number)	10.5	-	-
Total livestock products	-	13.4	20.3

Source: Govt. of India. National Sample Survey Organization, Ministry of Statistics and Program Implementation.

Trade

India has a negligible share in world trade in livestock products. During the triennium ending 1998, the average value of livestock product exports was Rs 13500 million annum^{-1}, which was only 1% of the total export earnings and 6.2% of the agricultural export earnings (Table 6). Meat and meat products are the main livestock products exported, accounting for over 90% of the total export earnings from the livestock subsector. In recent years the export performance of livestock products has improved due to trade liberalization.

Table 6. Export and import of livestock products.

	1980–82	1989–91	1996–98
Exports			
Value of exports of livestock products (million rupees)	761.0	1830.0	13505.0
Share of livestock exports in total exports (%)	1.0	0.5	1.1
Share of livestock exports in agricultural exports (%)	3.5	3.3	6.2
Imports			
Value of imports of livestock products (million rupees)	1824.0	910.0	1877.0
Share of livestock imports in total imports (%)	1.4	0.1	0.1
Share of livestock imports in agricultural imports (%)	14.3	4.8	1.5

Source: FAO Trade Year Book, various issues.

In 1998 India imported livestock products worth Rs 1877 million comprising 0.1% of total imports and 1.5% of agricultural imports. Hides and skins account for 95% of the total value of livestock product imports. India's import of milk, hides, and skins has declined sharply in the last few years. At present almost the entire demand for milk is met through domestic supplies.

Livestock also contribute towards environmental conservation, although in recent years this has been criticized by environmentalists due to certain negative externalities caused by overgrazing and greenhouse gas emissions. Despite these criticisms, the livestock subsector will remain an important economic activity benefiting millions of landless, marginal, and small farmers in the country.

References

Adams Jr., R.H. and He, J.J. 1995. Sources of income inequality and poverty in rural Pakistan. International Food Policy Research Institute, Washington, D.C.

Birthal, P.S. and Singh, M.K. 1995. Structure of rural income inequality: a study in western Uttar Pradesh. Indian Journal of Agricultural Economics 50(2):168-175.

Kelley, T.G. and Parthasarathy Rao, P. 1995. Availability and requirement of different sources of livestock feed in India, with special reference to sorghum and millet straw. Page 146 *in* Global Agenda for Livestock Research: proceedings of the consultation for the South Asia Region, 6-8 Jun 1995, (Devendra C. and Gardiner P., eds.). ICRISAT Asia Center, Patancheru, India. International Livestock Research Institute (ILRI) Nairobi, Kenya.

Kumar P. and Joshi, P.K. 1999. Socioeconomic factors contributing to nutritional security of rural households. *In* Diversification of agriculture for human nutrition. National Academy of Agricultural Science and National Institute of Nutrition, Hyderabad.

Technological Change in India's Livestock Subsector: Evidence and Issues

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The contribution of science and technology to the growth and development of India's agricultural sector since the mid-1960s is self-evident. Developments in research and production infrastructure and encouraging government policies acted as catalysts for the technology-driven growth in agriculture, helping the country achieve self-sufficiency in foodgrains and many other commodities. In other areas such as horticulture, fisheries, and livestock considerable technical progress has taken place, but impacts have been slow and sporadic, and its analysis in an economic framework has largely remained undocumented.

The contribution of livestock to income and employment generation is second only to that of crops. However, its productivity is low compared to the world average. Cattle milk yield is about half the world average of 2072 kg annum^{-1}, and the same applies to beef and pork production. The situation becomes more depressing when compared with the developed countries. Average milk yield of cattle is 13% that of the USA and 16% that of Canada. Sheep and pork yields are about 60% less. These figures suggest considerable scope for improvement of India's livestock productivity.

Nonetheless, in recent years certain outputs of livestock such as milk, meat, and eggs have been growing at an annual rate of 5% or more. The sustainability of these trends in the long run is unclear, as the current production environment has several constraints. Feed has been a limiting constraint to ruminant livestock production and this problem is likely to continue in the near future, considering the huge dimensions of livestock populations. Common grazing lands have been deteriorating quantitatively as well qualitatively (Jodha 1991). Animals are fed on crop by-products and grasses from roadsides and other marginal lands. Feeding of grains and other concentrates is inadequate, and the competition for grains will intensify with increasing human and livestock populations. Thus technology will be a key factor in improving the productivity of India's livestock subsector.

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Status of Technological Change

Significant research advances have been made in the areas of animal breeding, nutrition, and health. Many research products have been found to be technically and economically viable under controlled experimental conditions, but the extent of their on-farm application has been rather low. Examples of such technologies include improved animal breeds, and chemical/biological treatment of straw and fodder. A brief review of the existing, as well as potential, technologies that could influence the growth of the livestock subsector is presented below.

Breed Improvement

Crossbreeding of low-yielding indigenous breeds with high-yielding exotic breeds has been widely acknowledged as a valuable strategy to improve animal productivity. Sporadic attempts to improve the genetic potential of different livestock species (poultry, sheep, and cattle) in India were initiated during the latter half of the nineteenth century, but no significant achievements were reported. In the 1950s, systematic crossbreeding research and development programs were initiated. Crossbreeding research has focused mainly on cattle because of their dual role of milk production and use as draught animals in the crop subsector. A number of crossbreeds with improved production potentials have evolved, which include Haryana × Friesian, Haryana × Jersey, Haryana × Brown Swiss, Rathi × Jersey, Gir × Jersey, Gir × Friesian, and Sahiwal × Jersey.

Adoption of crossbreeding technology has been slow. Only 7.5% of the cattle population consists of crossbreeds (Table 1). In other animal species too the status of crossbreeding is similar. About 5% of the sheep and 15% of pigs are crossbreeds. The reasons are nonacclimatization of crossbreeds to the Indian climate and lack of resistance to disease. The poultry subsector, however, has achieved notable success. Improved poultry constitute about 34% of the total population. Crossbreeding is also practiced in other species. Statistical information regarding these, however, is lacking.

Between 1982 and 1992, the population of crossbred cattle increased at an annual rate of 5.6% (Table 2). On the other hand, indigenous stock seemed to be approaching stabilization. The annual growth rate of indigenous cattle was 0.5% although the female population witnessed a slightly higher growth. Low milk yield and decreasing demand for draught animals are the main factors for slow growth in indigenous stock. These trends indicate a gradual substitution of indigenous cattle by crossbreds.

Table 1. Percentage of crossbreds in different livestock populations.						
	Rural		Urban		All	
	1982	1992	1982	1992	1982	1992
Cattle						
Total	4.3	6.9	15.6	20.2	4.7	7.4
Male	3.9	4.4	11.9	11.5	4.1	4.6
Female	4.7	9.4	17.5	25.6	5.3	10.3
Sheep	3.1	4.9	8.8	7.5	3.3	5.0
Pig	8.8	14.2	15.7	16.1	9.5	14.5
Poultry	20.1	31.9	42.1	44.8	21.7	32.9

Source: Computed using data from Livestock Census reports.

Despite being an important milch species, the buffalo has not received much attention in breed improvement. Development efforts have focused on upgrading low-yielding breeds through artificial insemination. The buffalo population increased at a rate of 1.9% per year between 1982 and 1992. The female population witnessed faster growth than the male population. Its adaptability to a wide range of climatic conditions, higher milk yield compared to indigenous cattle, and price premium on milk due to its higher fat content have favored faster growth in the buffalo population. Furthermore, the disposal value of buffalo is higher; unlike cattle there are fewer restrictions on buffalo slaughter.

The population of improved poultry grew at an annual rate of about 9%, more than double that of indigenous poultry (Table 2). Technological transformation of the poultry subsector seems to be market-driven as the demand for poultry meat and eggs is income-elastic and has been rising continuously. The populations of crossbred sheep and pigs also grew faster than their indigenous counterparts.

Empirical evidence from the field proves the scientific claims of better economic performance of crossbred animals (Sharma et al. 1995; Gaddi and Kunal 1996; Dhaka et al. 1998; Lalwani 1989). Despite this, crossbreeding technology has not gained a foothold. One of the possible reasons is non-acclimatization of crossbred animals to varying climatic conditions in the country, causing a number of health- and physiology-related problems. In this context, Steane (1999) mentions that 'in using exotic breeds as a strategy for

Table 2. Growth in crossbreds vis-à-vis the indigenous livestock population, 1982–1992.

	Annual compound growth rate (%)		
	Rural	Urban	Total
Cattle			
Crossbred			
Total	5.5	6.4	5.6
Male	1.3	4.8	1.6
Female	8.4	6.9	8.2
Indigenous			
Total	0.4	3.1	0.5
Male	0.2	5.3	0.3
Female	0.7	1.8	0.7
All cattle	0.7	3.7	0.8
Male	0.3	5.2	0.4
Female	1.2	2.9	1.3
Buffalo			
Total	1.9	2.8	1.9
Male	0.7	0.3	0.7
Female	2.2	3.2	2.3
Sheep			
Crossbred	4.8	2.7	4.7
Indigenous	0.3	4.3	0.4
All	0.4	4.2	0.5
Goats	1.8	5.1	1.9
Pigs			
Crossbred	8.4	4.9	7.9
Indigenous	2.6	4.6	2.9
All	3.3	4.6	3.4
Poultry			
Improved	9.4	6.1	9.0
Indigenous	3.9	5.1	3.9
All	4.4	5.5	4.5

Source: As in Table 1.

improvement it seems to have been assumed that genotype-environmental interactions do not exist or the optimal economic and sustainable crossing structure would automatically be developed. Indeed in much of Asia, there appears to be a history of introducing breeds without proper evaluation and with little or no thought given to the breeding structure which will best use the available material'.

Higher initial investment and maintenance costs also limit widespread adoption of crossbreds. The first cross animals perform very well, but the performance of animals from subsequent crosses declines significantly. Therefore crossbred animals need to be replaced frequently in order to sustain the flow of benefits. Frequent acquisition of first crossbreds, without realizing appropriate disposal value of the subsequently crossed animals, renders crossbreeding technology capital intensive. In this context, Alderman (1987) observed that more than 50% of the farmers in Karnataka maintaining crossbreeds depend on the market for replacement of first cross animals. This is to avoid the risk of getting unwanted male calves and the associated problems of breeding and feeding the calf.

As indigenous cattle are sources of both milk and draught power for agriculture, their replacement by crossbred cattle has been slow. Crossbred males are considered inefficient for draught purposes compared to indigenous males, although animal physiology research has shown that the difference is marginal. Furthermore, machines have emerged as a major source of power in Indian agriculture, although mechanization does not appear to have affected the population of working animals significantly. The number of tractors per thousand ha increased from 0.6 in 1972 to 10.9 in 1992, while the working bovines declined marginally (Table 3). Mechanization has affected working bovines mainly on medium and large farms. The number of working bovines declined from 410 in 1972 to 180 per 1000 ha in 1992 on medium farms and from 210 to 50 on large farms. On small and marginal farms, most of which did not have tractors, working animals provided most of the draught power requirement in 1972. In 1992, the number of tractors on these farms had increased to 4.1 and 7.8 per thousand ha without a concomitant decline in the number of working animals.

Nonetheless, crossbreeding strategies have been successful under certain environments and economic conditions as in Kerala and Punjab. In Kerala the milk production system is cattle-based. Indigenous breeds are poor as milk producers and for draught power (Rajapurohit 1979). Cropping pattern is largely plantation-oriented, requiring less draught power. Furthermore, unlike in many other states, cattle slaughter is not prohibited by law in Kerala, thus making it easier to cull out the low-yielding and unwanted animals. In Punjab,

Table 3. Changes in number of tractors and working bovine stock, 1972–92.

	Tractors/1000 ha		Working bovines/1000 ha	
Category	1972	1992	1972	1992
Marginal	0.0	4.1	1600	1540
Small	0.0	7.8	1060	810
Semi-medium	0.1	10.5	700	420
Medium	0.7	15.4	410	180
Large	1.2	14.7	210	50
All	0.6	10.9	650	590

Source: NSSO 1997. Report on Land and Livestock Holdings.

on the other hand, increasing intensification of agriculture required more power to perform agricultural operations on time, which indigenous cattle were not capable of providing. Moreover, feed resources have never been a problem in Punjab.

Feed and Nutrition

Adequate provision of feed is essential to livestock production, and its scarcity has been one of the major limiting factors in improving productivity in India. Crop residues and by-products comprise the main feeds, accounting for 40% of the total consumption (World Bank 1996). Green fodder contributes 26%, while concentrates contribute only 3 percent. The rest comes from grazing. Stall-feeding is largely confined to buffalo, crossbred cattle, and draught animals. Small ruminants mainly feed on grasses from village common property resources, roadsides, and harvested fields, and supplementary feeding is lacking except in large commercial herds.

There is a large gap between requirement and availability of feed at the national level. Recent estimates indicate that in India the dry fodder deficit is 31%, green fodder 23% and concentrates 47% (Table 4). Regional deficits are however, more important than the national deficit. Of 55 micro-agroecoregions, 43 are deficient in feed (Singh and Mazumdar 1992). Most of the deficient regions lie in the arid and semi-arid agroecological zones. The feed deficiency is due to heavy population pressure, the quantitative and qualitative deterioration in common grazing lands resulting in low biomass production, and the lack of adoption of fodder production technologies.

Table 4. Feed availability and requirements, 1993.

Feed stuff	Availability (million t)	Requirement (million t)	Deficiency (%)
Straw	399	584	31
Green fodder	574	745	23
Concentrate	42	79	47

Source: Govt. of India. 1993. Ministry of Environment and Forests.

The problem of underfeeding can be overcome partly through technological interventions such as the biological/chemical treatment of feed. Techniques such as urea treatment of straws, urea-molasses mineral blocks, and bypass protein improve nutritional value of feed and its palatability. Urea treatment has been reported to reduce green fodder requirements by about 20–40% and increase cattle milk yield by 10–20% (Patil et al. 1994; Rai et al. 1994; Saha and Singh 1994). Under experimental conditions, bypass protein technology has been found to reduce concentrate requirements by 40% and dry matter requirements by 24% (Chatterjee and Acharya 1992, Tripathi 1997). Despite such benefits, its application is limited because of supply constraints and a lack of concerted efforts to transfer the technologies and demonstrate their cost-benefit ratios.

The area under fodder crops in the country has hardly ever exceeded 5% of the gross cropped area and it is uncertain whether this will increase in the future. Increasing demand for livestock products calls for more allocation of land to fodder crops, but current priorities for food grains, pulses, and oilseeds seem to constrain the fodder area expansion. Availability of by-products of food crops as animal feed is expected to increase with an increase in area under these crops.

Plant breeding research has also focused more on increasing grain yield than vegetative yield, both in terms of quantity and quality. In an ex-ante framework Kristjanson et al. (1998) have estimated that a 1% improvement in digestibility of coarse cereal fodder through genetic manipulation would enhance production of different livestock outputs by 3–10%.

Animal Health

Diseases reduce the production potential of livestock. There are a number of diseases such as rinderpest (RP), foot and mouth disease (FMD), hemorrhagic septicemia (HS), mastitis, brucellosis, tuberculosis, and black quarter (BQ) that affect livestock production and cause enormous economic losses. An estimated livestock output worth Rs 50 billion is lost annually due to disease. In view of this, the National Commission on Agriculture (1976) observed that 'livestock development programs cannot possibly succeed unless a well organized animal health service is built up and protection of livestock against diseases and pests, particularly the deadly infectious ones, is assured'. To this end, animal health infrastructure has been strengthened. Between 1984–85 and 1997–98 the number of veterinary polyclinics, hospitals, and dispensaries has increased considerably (Table 5). There are 27543 first aid centers and mobile dispensaries. Apart from these, there are 250 diagnostic laboratories and 26 veterinary vaccine production units. Twenty-one viral vaccines, 14 bacterial vaccines and 13 diagnostic reagents are now produced in the country.

Impact of Technological Change

Contribution of Technology

The contribution of the livestock subsector to agricultural gross domestic product has increased from 14% in 1980–81 to 23% in 1998–99 at 1980–81 prices. Since 1970–71 the livestock subsector has been growing at a rate of about 3.6% a year. The growth is a result of technological change, better feeding and management (Table 6). The Total Factor Productivity (TFP) index, a joint measure of contribution of technology and technical efficiency, has been growing at an annual rate of 1.4% since 1970, while in the pre-1970s growth in the TFP index was marginally negative. This implies that technology along with management is gradually becoming a driving force in the growth of the livestock subsector.

Table 5. Growth in animal health infrastructure.

	1984–85	1997–98
Number of veterinary polyclinics, hospitals, and dispensaries	14500	23303
Number of veterinary aid centers, stockman centers, and mobile dispensaries	14800	27543
Number of professional veterinarians	25300	36000
Number of veterinary auxiliaries	51000	70000

Source: 1. Govt. of India, Deptt. of Animal Husbandry and Dairying, Ministry of Agriculture.
2. FAO/WHO Animal Health Year Books.

Table 6. Compound growth rates of output, input, and total factor productivity indices.

	1950–51 to 1970–71	1970–71 to 1995–96	1950–51 to 1995–96
Output index	1.3	3.6	2.6
Input index	1.3	2.2	1.8
TFP index	–0.04	1.4	0.8

Source: Birthal et al (1999).

Production and Productivity

From the point of research and development priorities, it is more important to assess the contribution of technology at the commodity or species level. However the data limitations, particularly on the input side, make it difficult to generate commodity-specific estimates of TFP. Still, productivity trends provide a fair assessment of the impact of technological change (Table 7).

Milk

Between 1972 and 1997 cattle and buffalo milk production grew at rates of 5.2% and 4.4% a year, respectively (Table 7). The productivity of cattle and

Table 7. Annual growth rates (%) in production and yield of livestock products, 1972–1997.

	1972–1988		1989–1997		1972–1997	
Commodity	Production	Yield	Production	Yield	Production	Yield
Milk						
Cattle	5.2	3.0 (58.4)	4.9	4.0 (82.8)	5.2	3.2 (61.4)
Buffalo	4.4	1.7 (38.1)	4.7	3.8 (80.8)	4.4	1.9 (44.0)
Meat						
Beef and veal	7.5	–0.13 (–1.7)	4.2	2.1 (49.2)	7.1	0.15 (2.1)
Buffalo	4.0	–0.07 (–1.7)	4.6	0.4 (8.5)	4.1	0.01 (–0.2)
Mutton and lamb	2.0	0.3 (16.7)	3.9	3.3 (86.5)	2.2	0.07 (3.2)
Goats	2.5	0.6 (25.2)	1.7	–0.02 (–1.2)	2.4	0.52 (22.0)
Pigs	6.4	0.13 (2.0)	5.1	0.01 (–0.2)	6.3	0.12 (1.9)
Poultry	5.1		9.3		5.7	
Total meat	4.2		4.6		4.2	
Eggs	6.2		3.9		5.6	

Figures in parentheses indicate percent share of yield growth in output growth.

Source: Computed from data in FAO Production Year Book, various issues.

buffalo increased at a rate of 3.2% and 1.9%, respectively, and thus contributed about 61% (cattle) and 44% (buffalo) to their output growths. Over time the growth in production, as well as in productivity, has accelerated, although productivity has increased faster than production. This indicates that milk production growth is gradually becoming productivity-centered. In cattle, acceleration in productivity growth is partly due to an increase in the population of crossbreeds with high milk yielding capacity.

Average milk yield of a crossbred lactating cow in 1993-94 was 5.8 kg day^{-1}, about 3.5 times more than that of a lactating indigenous cow (Table 8). Lactating crossbred cows comprised 14.2% of the total lactating cows and contributed 36.3% to total cattle milk production. Buffalo accounted for 45% of total lactating bovines and contributed 57% to total milk production.

Despite substantial growth in productivity, a large gap remains between obtainable and realized yield (Table 9). In 1993–94 mean annual yield of indigenous cattle was 618 kg, while the lactation yield on research farms for some of the important milch breeds varied from 1137 kg to 1931 kg. In crossbred cows and buffalo the yield gap, however, is not as large as for indigenous cows. Average milk yield of crossbred cows was 2127 kg a year, as against the obtainable lactation yield range of 2326 kg to 3196 kg. Similarly in buffalo, the annual milk yield was 1333 kg, while the obtainable yield varied between 1111 kg to 1855 kg per lactation depending on the breed.

In the eastern and northeastern states milk yield is abysmally low. In Orissa, Nagaland, Mizoram, Meghalaya, and Assam the average milk yield of indigenous cattle ranges between one-fourth to one half of the national average. Buffalo milk yield in these states is also much less than the national average. These figures indicate both the severity of constraints and opportunities in raising milk production in such areas.

Table 8. Contribution of crossbred cows to milk production, 1993–94.

	Indigenous cow	Crossbred cow	Buffalo
Share in milch stock (%)	47.4	7.9	44.7
Share in milk production (%)	27.7	15.8	56.5
Milk yield (kg animal^{-1} day^{-1})	1.7	5.8	3.7

Source: Govt. of India. 1999. Dept. of Animal Husbandry and Dairying, Ministry of Agriculture.

Table 9. Obtainable milk yields of some important breeds of cattle and buffalo.

Species/breed	Lactation yield (kg)	Lactation length (days)	Realized yield, 1993–94 (kg annum^{-1})
Indigenous cattle			618
Gir	1403	257	
Haryana	1137	232	
Kankrej	1850	351	
Rathi	1931	331	
Red Sindhi	1605	284	
Sahiwal	1719	284	
Tharparkar	1659	280	
Crossbred cattle			2127
Haryana × Friesian	3196	340	
Haryana × Brown Swiss	2785	336	
Haryana × Jersey	2868	308	
Gir × Jersey	2713	324	
Gir × Friesian	2713	324	
Red Sindhi × Friesian	2326	284	
Rathi × Jersey	2802	321	
Tharparkar × Friesian	2600	311	
Sahiwal × Friesian	2357	294	
Sahiwal × Jersey	2660	314	
Buffalo			1333
Bhadwari	1111	276	
Mahsana	1744	279	
Murrah	1597	296	
Nili-Ravi	1855	316	
Surti	1772	350	

Source: 1. Pundhir and Sahai (1997) for obtainable yield.
2. Realized yield is based on the source in Table 8.

Meat

Total meat production in the country grew at a rate of 4.2% annually between 1972 and 1997. The growth in contributions from different species, however, varied widely. Maximum growth occurred in beef and veal output (7.1%), followed by pork (6.3%), poultry meat (5.6%), buffalo meat (4.1%), goat meat (2.4%), and mutton and lamb (2.2%). Growth in total meat production has improved slightly in recent years, mainly due to accelerated growth in contributions from buffalo, sheep, and poultry.

Growth in meat production is due largely to increases in the number of animals slaughtered, as the increase in yield is negligible in almost all species. Recent trends, however, indicate improvement in meat yield of cattle, buffalo, and sheep, and a decline in meat yield of goats and pigs. A number of factors are responsible for poor meat productivity and growth. Cattle and buffalo are raised mainly for milk and provide meat as an adjunct. Poor quality animals are slaughtered. Only surplus buffalo males and unproductive cattle and buffalo stock, often old, infertile, and malnourished are sent to slaughterhouses. Among the reasons for stagnation in yields of small ruminants are a deterioration of common grazing lands (Jodha 1991, Pasha 1991), and lack of supplementary feeding. Improved nutrition and veterinary care would help raise meat yields. However, in the long run, genetic improvement would be a key factor in sustaining the output growth of these animals.

Eggs

During 1972–97, egg and poultry meat production increased at the rate of 5.6% a year. However, in recent years, growth in poultry meat production accelerated while egg production growth decreased substantially. Genetic improvement efforts contributed substantially to fast growth of the poultry subsector. About two-thirds of the total egg production in the country in 1993-94 came from improved layers that comprised 48% of the total egg laying population (Table 10). Average egg yield of an improved layer is 232 eggs annum^{-1}, more than double the yield of an indigenous layer. There is clearly considerable scope for increasing egg production by substituting indigenous layers with improved breeds.

Incidence of disease

Many diseases such as FMD, BQ, HS, and anthrax still prevail in varying intensities despite the substantial growth in animal health infrastructure. However concerted efforts under the rinderpest eradication program have achieved notable success in alleviating the incidence of the disease (Fig. 1). On the other hand, the incidence of FMD, BQ, and HS has increased in recent years (Figs. 2, 3, and 4). This implies a lack of focus on preventive disease management.

Table 10. Contribution of improved poultry in total egg production, 1993–94.

	Fowl	Ducks
Population (millions)		
Improved layers	65.0 (48)	0.5 (5)
Indigenous layers	70.2 (52)	9.9 (95)
Total	135.3 (100)	10.5 (100)
Egg production (millions)		
Improved layers	15095.3 (66)	103.9 (8)
Indigenous layers	7671.9 (34)	1139.5 (92)
Total	22767.2 (100)	1243.4 (100)
Egg yield (number $bird^{-1}$ $annum^{-1}$)		
Improved layers	232	193
Indigenous layers	109	114

Figures in parentheses are percent of total.

Source: As in Table 8.

Prices of Livestock Products

Technological change influences commodity prices via a shift in supply. A downward shift in supply of a commodity is expected to bring down its price, *ceteris paribus*. Trends in real wholesale prices[2] of some major livestock products since 1970 are shown in Figures 5 to10.

The price of milk did not exhibit any definite trends during the 1970s (Figure 5). It showed some stability during the 1980s and thereafter started declining. A similar trend is observed in the case of butter (Fig. 6), except during the late 1980s when its price showed an upward trend. There has been significant growth in milk production in the country since the initiation of the Operation Flood program under which concerted efforts have been made to create a production and marketing infrastructure. Besides raising domestic production it also helped reduce dependence on imports, so that about 99% of the milk demand in the country is met through domestic production.

The real wholesale price of mutton has shown a rising trend with slight year to year fluctuations (Fig. 7). This is because of slow growth in mutton production. On the other hand, beef prices showed a declining trend between

2. The prices are averages of prices in different markets. The Agricultural GDP deflator was used to convert the current prices into real prices.

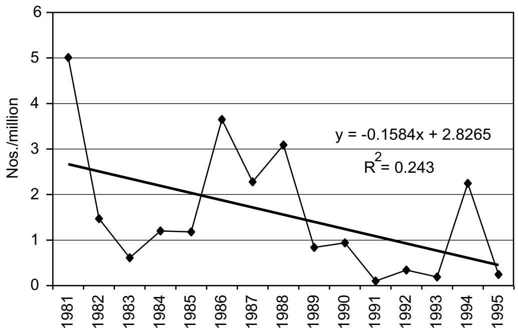

Figure 1. Trends in the incidence of rinderpest in bovines in India.

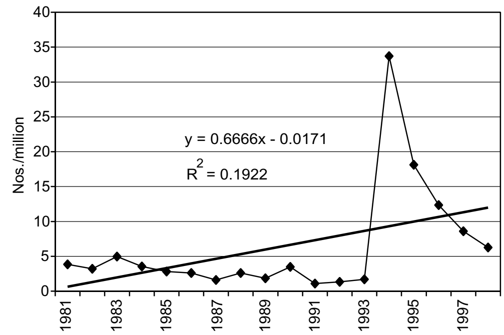

Figure 3. Trends in the incidence of black quarter in bovines in India.

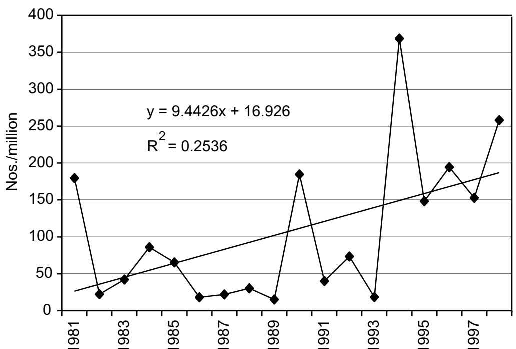

Figure 2. Trends in the incidence of FMD in bovines in India.

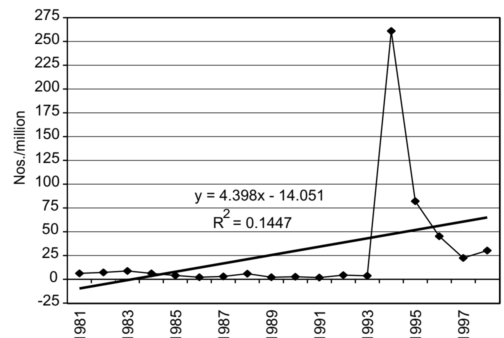

Figure 4. Trends in the incidence of HS in bovines in India.

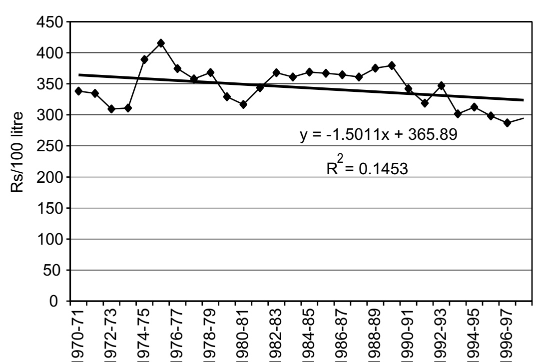

Figure 5. Trends in real wholesale price of milk.

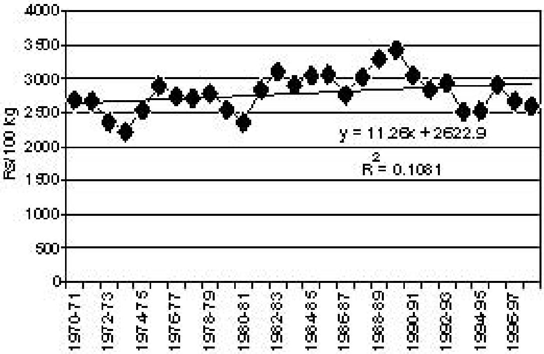

Figure 6. Trends in real wholesale price of butter.

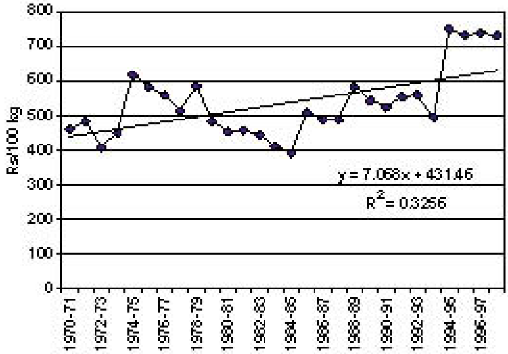

Figure 8. Trends in real wholesale price of beef.

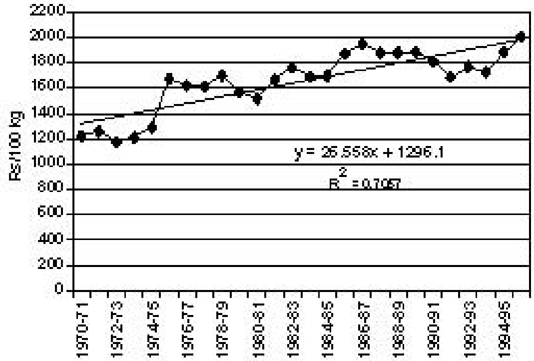

Figure 7. Trends in real wholesale price of mutton.

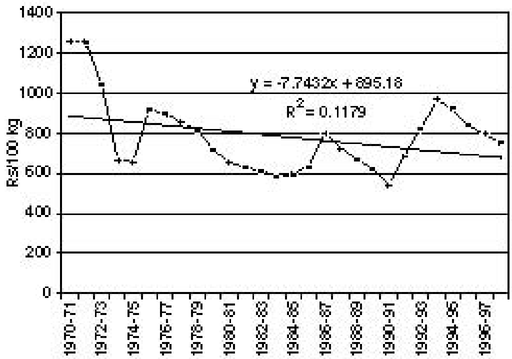

Figure 9. Trends in real wholesale price of pork.

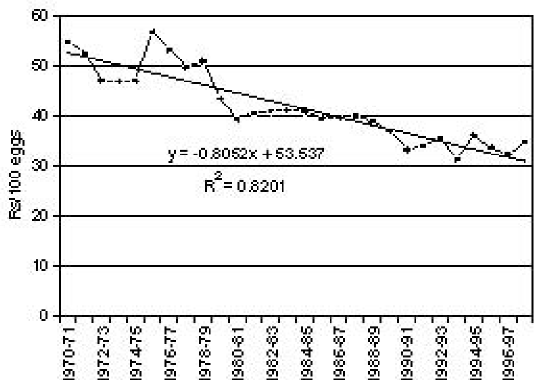

Figure 10. Trends in real wholesale price of egg.

1974–75 and 1985–86, and began increasing thereafter due to a rise in export demand (Fig. 8). The general trend in the price of pork is declining but with wide fluctuations (Fig. 9). The real price of eggs has been declining steadily (Fig. 10).

Putting together price and productivity trends gives an idea of the impact of technological change in the livestock subsector. In general a negative relationship exists between productivity and real price trends in the case of milk, egg, and pork, supplies of which have partially increased due to adoption of improved technology.

Equity

Improving efficiency of livestock production through technological interventions is considered equity-oriented on the premise that the livestock wealth is more equitably distributed than land (Adams and He 1995; Birthal and Singh 1995). The relationship between rate of adoption of crossbred cattle and size of land holding shows higher proportions of crossbreeds in total cattle stock in the landless and marginal farm categories, although the size of cattle holding there is smaller (Table 11). It is thus conjectured that technological change would create more income-generating opportunities for landless and marginal farmers. But larger farmers would benefit more from it by virtue of having larger number of crossbreeds and better access to feed resources. This is however a contentious issue and needs to be examined further.

Table 11. Distribution of adult female crossbred cattle by size of land holding, 1992.

Size of land holding (ha)	Indigenous	Crossbred	Total	% crossbreeds
	.... (number per household)			
Landless	0.04	0.01	0.05	20.1
< 1.0	0.35	0.08	0.43	18.2
1.0–2.0	0.59	0.08	0.67	11.9
2.0–4.0	0.61	0.09	0.70	12.9
4.0–10.0	0.64	0.10	0.74	13.5
>10.0	0.75	0.07	0.82	8.5
All	0.36	0.07	0.43	15.4

Source: As in Table 3.

Rural-Urban Disparities

The rising urban populations are causing a rapid increase in the demand for animal foods. This has resulted in the rapid growth of peri-urban livestock systems. Higher growth in urban livestock populations is an indicator of this (Table 2). Unlike rural livestock systems, peri-urban systems are commercially oriented and intensive in nature, depending mainly on purchased inputs. Technical coefficients of crossbred animals are better under peri-urban systems (Birthal et al. 1999) and adoption of technology is therefore also expected to be higher (Table 1). For instance, in 1992 about 20% of the cattle and 45% of the poultry population in urban areas were that of crossbred/ improved species. Corresponding figures for rural areas stood at 7% and 32 percent. Adoption of technologies related to health, nutrition, and management is also expected to be higher in peri-urban areas. Thus there might be increasing technological dualism between rural and urban areas with the rising demand for livestock products.

Future Perspectives

India's livestock subsector is at the crossroads. On the one hand India has an enormous and diverse livestock population, the production potential of which remains untapped due to feed and fodder scarcity and poor application of technologies. On the other hand sustained economic growth, market-oriented policies, and trade liberalization are opening up opportunities for the growth and development of this subsector. The demand for livestock products is income elastic and is expected to grow further (Kumar 1998). India can also derive substantial benefits from the emerging international economic order under WTO through export of livestock products. At present, export of livestock products is constrained by low livestock productivity, lack of value addition, and inadequate phytosanitary standards. The pace of development and diffusion of yield-improving technologies and the development of processing infrastructure would determine largely how best the emerging opportunities could be used for the benefit of producers and consumers.

- Crossbreeding programs should be reviewed at regional levels for their success as well as failure. The strategy of introducing exotic breeds to improve the local breeds also requires rethinking.
- The buffalo, which holds the promise of increasing milk production considering its adaptability to a wide range of climatic conditions and better feed conversion efficiency, should be studied intensively. Unlike cattle,

there are few restrictions on buffalo slaughter and a breakthrough in buffalo crossbreeding would provide a big impetus to the livestock economy.

- Optimization of the livestock population and qualitative improvements in feed resources are the main ways to improve productivity. This involves culling of unproductive and unwanted surplus population, which is often not feasible because of restrictions on cattle slaughter and sociocultural and religious taboos on meat consumption. The export of live cattle to countries where demand for beef is high is a possibility that should be explored (Mishra 1995). Besides earning foreign exchange, this would also relieve pressure on feed resources and improve productivity of the remaining stock. Improving quality of available feed resources is technology dependent and should be accorded high priority in the research agenda of both crop and animal science research.
- Disease prevention and control must complement these efforts. Veterinary institutions often lack the essential medicines and equipment, and the quality of veterinary services is poor. The emphasis should shift from curative to preventive disease management and to improvement of infrastructure.
- Developments in biotechnology are expected to provide solutions to many problems currently constraining the livestock production potential. The role of biotechnology in improving fodder quality is well established. Similarly, research in the areas of animal breeding, embryo transfer, and gene cloning could help improve animal productivity.
- Research strategies must be prioritized on the basis of their urgency, gestation period, probability of success and adoption, availability of research resources, and economic outcomes. Research strategies that are less capital intensive, with a low gestation period, a higher probability of success and acceptability by clientele, and that yield a good rate of return should be emphasized. Animal nutrition and health fall in this category. In the long run however, genetic research would be a key factor in growth and development of the livestock subsector.
- Current livestock economics research is inadequate for a proper understanding of the livestock subsector as it has focused mainly on assessment of microlevel production efficiency of crossbred cattle vis-à-vis other dairy animals. Aspects related to nutrition, health, and processing technologies have remained largely unexplored. There is a similar lack of socioeconomic studies on ovine, caprine, equine, and poultry production

systems. Social sciences, particularly economics, should therefore be integrated into biological research in a significant way from the initiation of technology generation to its diffusion and impact assessment.

- Other issues of economic importance that should be addressed are estimation of feed consumption, and economic losses due to disease. The former are currently based on feeding norms and few efforts have been made to estimate actual feed fodder consumption or the contributions from grazing lands and forests. Similarly, information available on economic losses due to disease is based on guesses rather than on sound economic principles. These issues need to be addressed in a multidisciplinary mode for proper planning of development of the livestock subsector.
- Issues of sustainability of livestock production systems, their environmental effects, and the role of technology in addressing these issues also merit attention for an in-depth empiricism in a resource economics perspective.

References

Adams, Jr. R.H. and He, J. J. 1995. Sources of income inequality and poverty in rural Pakistan. International Food Policy Research Institute, Washington, D.C.

Alderman, H. 1987. Cooperative dairy development in Karnataka, India: an assessment. International Food Policy Research Institute, Washington, D.C.

Birthal, P.S. and Singh, M.K. 1995. Structure of rural income inequality: a study in western Uttar Pradesh. Indian Journal of Agricultural Economics 50(2):168-175.

Birthal, P.S., Kumar, A., Ravishankar, A. and Pandey, U.K. 1999. Sources of growth in the livestock sector. Policy Paper 9, National Centre for Agricultural Economics and Policy Research, New Delhi.

Chatterjee, A.K. and Acharya, R.M. 1992. Heading for 21st century. Dairy India, 1992. Gupta Publishers, New Delhi.

Dhaka, J.P., Jain, D.K., Kesavan, V.K. and Singh, L. 1998. A study of production and marketed surplus functions for milk in India. National Dairy Research Institute, Karnal.

FAO/WHO Animal Health Yearbook. Various years.

FAO Production Yearbooks. Various years.

Gaddi, G.M. and Kunal, L.B. 1996. Sources of output growth in new milk production technology and some implications to research investment. Indian Journal of Agricultural Economics 51(3):389-95.

Government of India. 1999. Basic animal husbandry statistics. Department of Animal Husbandry and Dairying, Ministry of Agriculture, New Delhi.

Jodha, N.S. 1991. Rural common property resources – A growing crisis. GateKeeper Series 24, International Institute for Environment and Development.

Kristjanson, P.M., Zerbini, E., Rao, K.P.C., Kiresur, Hofs, V. P. and Ravindra, K.V. 1998. Genetic enhancement of sorghum and millet residues fed to ruminants – An ex-ante assessment of returns to research. International Livestock Research Institute, Nairobi.

Kumar, P. 1998. Food demand-supply projections. Indian Agricultural Research Institute, New Delhi.

Lalwani, M. 1989. Technological change in India's dairy farming sector: Distribution and Decomposition of Output Gains. Indian Journal of Agricultural Economics 44(1):55-66.

Mishra, S.N. 1995. India's livestock economy: A perspective on research. Indian Journal of Agricultural Economics 50(3):255-63.

National Commission on Agriculture. 1976. Report of the National Commission on Agriculture, Part VII, Animal Husbandry, Ministry of Agriculture and Irrigation, Govt. of India, New Delhi.

National Sample Survey Organisation. 1997. Report on land and livestock holdings. Ministry of Programme Planning and Implementation, Govt. of India.

Pasha, S.A. 1991. Sustainability and viability of small and large farmers: animal husbandry and common property resources. Economic and Political Weekly 26(13):A27-30.

Patil, B.R., Pradhan, P.K., Rangnekar, D.V. and Udo, H. 1994. Supplementation of milking cows in Gujarat. *In* On-Farm Research for Testing of Appropriate Technologies in Crop-livestock Production Systems (Singh, K. and Schiere, J.B., eds.). Indian Council of Agricultural Research, New Delhi, India and Wageningen Agricultural University, The Netherlands.

Pundhir, R.K. and Sahai, R. 1997. Conservation of indigenous cattle breeds. Dairy India, 1997. Gupta Publishers, New Delhi.

Rai, S.N., Singh, C.B. and Dhaka, J.P. 1994. Response of crossbred dairy cattle and buffaloes to feeding of urea-treated paddy straw, Karnal district, Haryana. *In* On-Farm Research for Testing of Appropriate Technologies in Crop-livestock Production Systems(Singh, K. and Schiere, J.B., eds.). Indian Council of Agricultural Research, New Delhi, India and Wageningen Agricultural University, The Netherlands.

Rajapurohit, A.R. 1979. Crossbreeding of Indian cattle: an evaluation. Economic and Political Weekly 14(12/13):A9-24.

Saha, R.C. and Singh, R. B. 1994. Response of dairy cows to feeding of urea-treated straw, West Bengal. *In* On-Farm Research for Testing of Appropriate Technologies in Crop -livestock Production Systems (Singh, K. and Schiere, J.B., eds.). Indian Council of Agricultural Research, New Delhi, India and Wageningen Agricultural University, The Netherlands.

Sharma, S.C., Riyazuddin, and Rawat, P.S. 1995. Evaluation of crossbreeding programs in sheep in Rajasthan. Wool and Woolens of India, January-March.

Singh, P. and Majumdar, A.B. 1992. Current status of feed and fodder management of livestock. Agricultural Situation in India, August:375-382.

Steane, D.E. Introduction to the objectives of the workshop: proceedings of the Workshop on Implications of the Asian Economic Crisis for the Livestock Industry, 6-9 July 1999. FAO Bangkok.

Tripathi, A.K. 1997. New concepts in feeding. Dairy India 1997. Gupta Publishers, New Delhi.

World Bank. 1996. India livestock sector review: Enhancing growth and development, The World Bank, Washington D.C.

Crossbreeding of Indigenous Indian Cattle with Exotic Breeds to Increase Milk Production: A Critical Analysis

M P G Kurup[1]

Planned development of the livestock subsector in India began with the launch of the first Five Year Plan in 1951. This sought to break the centuries-old vicious cycle of large numbers, acute shortage of feeds, recurrent animal epidemics, and low productivity. The First Plan goals in cattle development were primarily to:

- Increase milk production;
- Improve milk supply to the large urban demand centers; and
- Improve the quality and supply of draught animals for agriculture.

The policies laid down for achieving these goals were selective breeding of indigenous cows belonging to the descript dairy breeds, upgrading of nondescript cows with indigenous dairy breeds, and selective breeding of draught breeds.

The launch of the Key Village Scheme (KVS) in 1951 was the action program to increase milk production and, to an extent, alleviate the shortages in fodder supply. The Livestock Improvement Act enabling compulsory castration of scrub bulls was an attempt to regulate the cattle population growth as well as to enforce a degree of selectivity in breeding. Artificial insemination (AI) was introduced around the same period, as a tool for rapid improvement in the genetic make-up of the stock. Crossbreeding of Indian cattle with European dairy breeds was introduced as an experiment in the hill areas during this period.

The country's milk production continued to be stagnant over the first two decades postindependence. The increase in milk production during the first three plan periods was a mere 3 million tonnes. By the end of the third plan the inadequacies of the KVS were apparent, and serious policy

1. International Consultant: Livestock and Dairy, Anand, Gujarat, India.

reorientation was required to engineer sustained increases in milk production. The interval between the third and fourth plans during 1966–69 witnessed some of the most momentous policy initiatives by the government in the livestock subsector, particularly for cattle. Development of rural milk sheds and movement of processed milk from the rural areas to urban demand centers became the cornerstone of government policy. This single, epoch-making policy of the government in the late 1960s – to develop dairying in rural milk sheds through milk producers' cooperatives – galvanized the Indian dairy industry to erupt into unprecedented growth.

This policy found institutionalization in the National Dairy Development Board (NDDB), its translation into action in the "Operation Flood Project" and the nationwide cooperative movement launched under the project for marketing the rurally produced milk during the early 1970s. The sluggishness in milk production gave way to rapid growth – from 22 million tonnes in 1970 to nearly 69 million tonnes in 1996. The KVS matured into the Intensive Cattle Development Project, which later became the Government's flagship program for cattle development. Crossbreeding of nondescript cattle became the National Policy for increasing milk production and gained momentum and economic relevance, as the cooperative network under Operation Flood provided the much needed market stimulus and price support for milk.

Under the different Five Year Plans, the central policy for cattle development was direct action through state departments. All breeding support activities such as production of bulls, evaluation of bulls, and production of semen are part of the direct action of the various state governments. Infrastructure for generating these inputs, such as breeding farms, semen production stations, and training institutions, is exclusively in the government sector. Over the fifty years of planned development, this has saddled the state governments with a vast infrastructure and an army of professionals.

Breeding Policy for Cattle

Breeding policies for cattle were formally attempted and finalized by the state and central governments based on the recommendations of the working group appointed by the Ministry of Agriculture in 1962. The breeding policy recommended:

- Selective breeding of the pure Indian dairy breeds of cattle for milk production.

- Selective breeding of pure Indian draught breeds of cattle for better draught animals.
- Selective breeding of dual-purpose breeds for improving both their milk and work output.
- Upgrading of the nondescript Indian cattle with selected Indian donor breeds for improving body size and milk/work output.

Crossbreeding of Indigenous Cattle

Crossbreeding of Indian cattle with exotic dairy breeds was a practice encouraged by the British in the late 19th century and there were many pockets of high-yielding crossbred cows, particularly the plantation areas in the hills. With the advent of AI and the limited introduction of crossbreeding in the hill areas (1961), official policy started recognizing crossbreeding of cattle with European donor breeds as a major option for improving milk production. Several bilateral crossbreeding projects in collaboration with external agencies (UNDP in Haringhatta, West Bengal; Indo-Danish Project in Hasserghatta, Bangalore, Karnataka; and the Indo-Swiss Project in Mattupatty, Kerala) were established during 1962–64, to study the potential of the policy and to evaluate its impact on milk production and sustainability under Indian conditions.

Crossbreeding of nondescript Indian cattle on field scale started only in 1964 with the launch of the Intensive Cattle Development Project (ICDP) by the Government of India. By 1969 it had become the official policy. The pioneering work on large-scale crossbreeding in different parts of India by the Bharathiya Agro-Industries Foundation (BAIF) and the strong recommendations of the National Commission on Agriculture (NCA) in 1974, laid all adverse criticism to rest and legitimised crossbreeding as a powerful tool to rapidly enhance milk production in India.

The technical program for crossbreeding approved by the governments was to use nondescript cattle as the foundation stock and to breed them using semen from exotic donor breeds. This would produce half-breeds with equal inheritance from the two widely different parents, one contributing endurance and the other the much-needed higher productivity. The policy thereafter was to breed the half-breeds among themselves inter se in subsequent generations, to create large intermating populations of half-breeds, perpetually maintaining the share of inheritance halfway between the Indian and the exotic parents. Genetic progress in the intermating populations would be maintained and promoted through use of genetically evaluated half-bred sires for the inter se mating. The exotic donor breeds initially used were Jersey, Brown Swiss, Red Dane, and Holstein-Friesian. The choice of the exotic donor has now narrowed down to Jersey and Holstein – with Holstein predominating by popular choice.

The government did not plan to crossbreed pure Indian breeds of cattle, but the spectacular increase in milk yield in the crossbred progenies generated overwhelming demand for such cattle all over India. This necessitated the expansion of the crossbreeding program nationwide; even to the home tracts of the pure Indian breeds. The policy for selectively breeding indigenous breeds of cattle did not take off for various reasons:

- Improvement in production and productivity were not spectacular enough to encourage farmers to progressively support it.
- Proven sires among these breeds were not available.
- There were no breeders' organizations for these breeds in their respective home tracts to provide technical and advisory services to breeders.

Technologies involved in Crossbreeding of Cattle

Crossbreeding of cattle is based on the following techniques from two major branches of biological sciences, reproductive biology, and quantitative genetics:

- Genetic evaluation of sires and dams as aids for selection.
- Artificial insemination for moving massive genetic payloads into animal populations.
- Multiple ovulation and embryo transfer to improve the intensity and accuracy of selection and to reduce the period of evaluation.

The rapid growth of molecular biology and biotechnology found application in the field of animal reproduction not only to develop and exploit domesticated animals, but also as models for epoch-making research in embryo biotechnology such as cloning, gene therapy, gene transfers, and transgenic animals. This explosion of knowledge has influenced breeding technology, particularly in bovine species, and presented the professionals in this field with powerful technologies and precision techniques.

For inter se mating of half-breeds, genetically evaluated half-breed bulls are a basic requirement that India does not have in adequate numbers. Bulls to be used for AI are evaluated for their ability to transmit economic traits advantageous to the breeders and the industry, i.e. milk yield, fat and protein percentage, fertility, and a number of allied factors. None of these factors can be measured on the bull itself. The bulls are evaluated on the basis of actual measurement of the desired traits in their daughters (progeny tests) or siblings, both full and half (sibling tests in open nucleus breeding systems or ONBS).

Genetic Evaluation of Crossbred Sires

Sire Evaluation through Progeny Tests

A progeny-testing program requires (1) a large ongoing AI service and (2) a well-structured Field Performance Recording Program. The duration of the test under Indian conditions would be about 60 months for the provisional evaluation based on past records of daughters, and 65 months for evaluation based on full first lactation records. By the time the test is completed the bull is 5 to 6 years old. Only a few select institutions have succeeded in producing proven crossbred sires through progeny tests. The Kerala Livestock Development Board (KLDB) has been successfully testing several batches of crossbred bulls for the past 20 years. The BAIF, Pune and the Sabarmati Ashram Gaushala, Bidaj, Gujarat, have ongoing programs for progeny testing of crossbred bulls.

The test involves complex statistical models for analysis of the data once collected, but the data themselves and the data collection procedures are simple enough, even though they need organization and accuracy. The statistical design involves testing of provisionally selected bulls, at least 20 to a batch, testing mating (a minimum of some 2000 randomly identified mates per bull spread over several districts or even states), and collection of the first lactation records of at least 200 randomly chosen daughters per bull.

The principle of the test is to analyze the variance among the records, partition the genetic variance from the total variance, and work out the breeding value of the bulls. The actual procedure practiced is to compare the standardized records of the daughters of each bull with the daughters of all other bulls in the batch and estimating the breeding values of the bulls using best linear unbiased prediction (BLUP) or similar procedures. The bulls are then ranked according to their breeding value for milk yield as well as fat and protein yield and percentage (Sire Index). The top two or three bulls in each batch are used to produce the breeding stock for the next generation. This process is continued generation after generation and brings in steady genetic improvement in the population with each successive generation. Data on the crossbred bull progeny-testing program from the KLDB are given in Table 1, an example of the sire-evaluation programs for crossbred bulls in the country.

The steadily increasing milk yield of the test daughters is a measure of the genetic progress in the population. The data on standard first lactation milk yield are presented in Figure 1. Milk yield is an additive genetic trait with thousands of gene pairs interacting in its inheritance and manifestation. Therefore, heterosis has very little role to play in these hybrids and their inter se mating populations.

The behavior of the inter se mated populations of crossbreds in Kerala with regard to nonadditively inherited traits such as age at first calving, calving interval, and service period show higher variance over several generations of inter se mating, but no decline in the mean values (Fig. 2). These traits show not only some heterosis, but also the mitigating impact of selection on heterosis.

Sire Evaluation through Sibling Tests

With the advent of multiple Ovulation and Embryo Transfer (MOET), it is now possible to produce genetically evaluated crossbred bulls for the AI

Table 1. Crossbred bull progeny test program in Kerala, 1977–2000.

Batch	Test Year	Bulls	Test AI	*Daughters	Batch	Test Year	Bulls	Test AI	*Daughters
1	1977-78	10	4289	709	12	1989	39	76731	9831
2	1978-79	9	12657	1351	13	1990	40	75050	8360
3	1979-80	12	22416	2956	14	1991	39	62215	7090
4	1980-81	18	26001	3252	15	1992	40	58939	6759
5	1981-82	23	44704	4638	16	1993	43	63498	6574
6	1982-83	29	40221	4423	17	1994	51	62219	5843
7	1983-84	36	45415	5887	18	1995	38	41607	4124
8	1985-86	40	54174	7124	19	1996	38	39611	4446
9	1986-87	48	65646	8317	20	1997	26	Incomplete	Incomplete
10	1987-88	45	69682	9045	21	1998	44	Incomplete	Incomplete
11	1988-89	53	78206	9052	22	1999	39	Incomplete	Incomplete

Notes: * Daughters born reported.

Source: Kerala Livestock Development Board Annual Report 1998-99 and 1999-00.

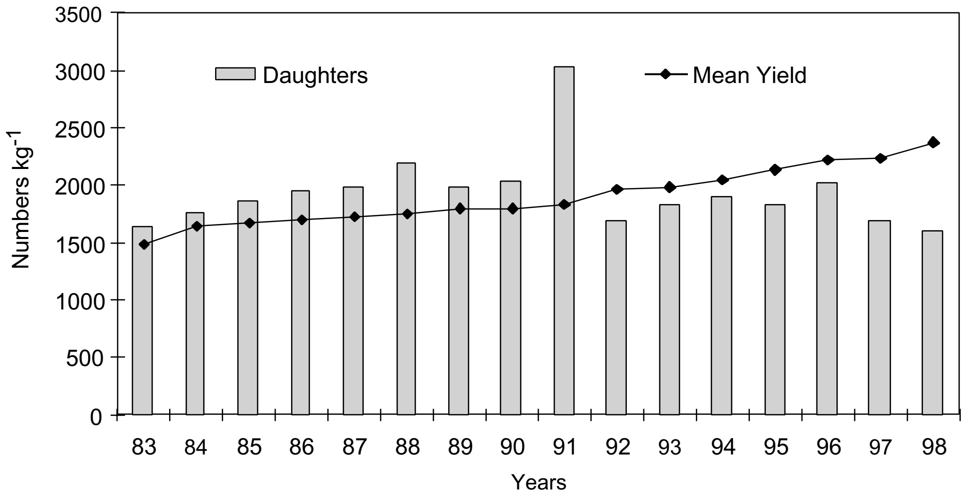

Figure 1. Mean milk yield of test daughters: standard first lactation.

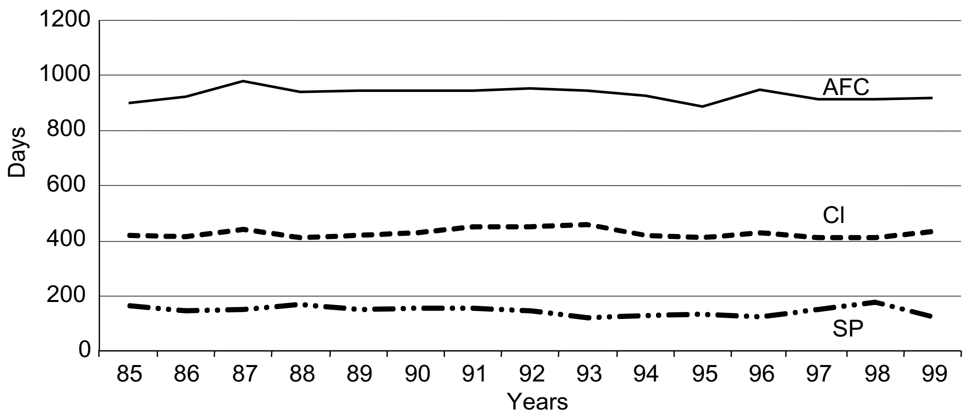

Figure 2. General production traits of Sunandini cows (nonadditive inheritance).

Notes:
1. AFC: Age at First Calving; CI: Calving Interval; SP: Service Period;
2. Data relate to institutional herds in the KLDB Farms at Mattupatty, Dhoni and Peermedu.

Source: KLDB Annual Reports 1998-99 & 1999-2000.

system in about half the time required under the conventional progeny test route. MOET enables the production of several embryos per cow per year and therefore many offspring per bull mother per year. It is thus possible to evaluate young bulls while they are growing up, using what is called a Sibling Test, based on the records of the number of contemporary full sisters (full-sibs) and half sisters (half-sibs). Using the Sibling Test it is possible to prove a bull in less than 40 months while traditional progeny tests take up to 65 months.

Generation interval being the denominator of the equation, genetic gain per generation would double when the generation interval is cut by half:

$$g / year = \frac{Im \times Rm + If \times Rf}{Gm + Gf} \times \sqrt{h^2}$$

Where:

- Im and Rm are intensity of selection and accuracy of selection among males;
- If and Rf are intensity of selection and accuracy selection among females;
- Gm and Gf are generation interval among male and female; and
- h^2 is the heritability of milk production.

Other things being equal, the accuracy of the selection under Sibling Test in ONBS could be lower than that achieved under the progeny test, but this is more than compensated for by the greatly reduced generation interval and therefore the greater genetic gain per generation. The Sibling Test is a new technique and the accuracy of genetic evaluation in this test has yet to be correlated with that under the progeny test. For this reason, bulls produced through Sibling Tests in ONBS must be put through conventional progeny test procedures for at least the first ten batches. This is possible while the young bulls are already in use for AI.

Selection of AI bulls through Sibling Tests in ONBS are of immense importance to the national crossbreeding program as it gives the program a head start even in the absence of sires proven through progeny performance. This technique will provide genetically evaluated bulls in large numbers for the inter se breeding programs within four years of its inception.

The Sibling Test needs an open nucleus herd of donors (dams) of some 100 elite breeding females from a selected Indian dairy breed (Sahiwal/Red Sindhi/Gir), of which 20% move out and 20% move in each year. This herd can be in a farm or preferably in a compact area of some 20 selected villages. Each year 32 dams from these are selected and divided into 8 sire families

(4 cows to each sire; exotic frozen semen from top proven Holstein/Jersey bulls from the world market). The dams are superovulated and inseminated to produce about 16 embryos per cow. These are transferred to recipients in the farm or the villages, resulting in 8 offspring per cow, 4 male, and 4 female. Each male under this arrangement will have 4 full sisters and 12 half sisters (probability).

Evaluation of the bull is based on the first records of the full and half sisters, the available records of the dam, and breeding value of the sire. Sibling Tests in ONBS are currently in operation only in the Sabarmati Ashram Goshala, managed by the NDDB in Bidaj, Gujarat. So far three sets of bulls have been produced, of which the first set of siblings have completed their first lactation. The first set comprises 4 exotic bulls, and 4 sire families, and yielded 143 offspring. Of these 11 bulls were selected and are now in semen production.

Artificial Insemination

Artificial insemination is the most significant scientific invention for increasing animal productivity in the 20th century. This is still the only tool available to mankind for moving massive genetic payloads into populations and for rapidly re-engineering the desired changes in their genetic architecture. Planned and systematic use of AI, combined with the principles of quantitative genetics, has aided genetic improvement programs in bovines the world over with spectacular productivity gains. Although developed in the early part of the 20th century, application of AI for breeding cattle began only in the late 1940s in developed countries. Large-scale use of AI in India started with the First Five Year Plan in 1951.

AI made a quantum leap when the technique of cryopreservation of bovine semen was developed for commercial application in the late 1950s. The next major development occurred in the early 1980s, when MOET and the many allied applications of embryo biotechnology such as cryopreservation, splitting, cloning, and sexing of embryos became routinely available. The infrastructure for the development and application of these techniques is available in India.

India established its first large scale Frozen Bovine Semen Production Station in Mattupatty, Kerala in 1965. Extensive use of frozen bovine serum for AI began here. Today virtually all AI carried out in India uses frozen semen.

In 1999 about 19 million AIs were carried out in the country by the state departments (5% of them in buffalo), 5 million AI by the milk cooperative system (3.3 million in cattle, 1.7 million in buffalo) and 0.5 million jointly by NGOs and other private AI practitioners.

Institutions for Technology Development and Delivery of Services

The State Departments of Animal Husbandry and Dairy Development and the Milk Producers' Cooperative Unions are the institutions responsible for development and dissemination of AI technologies, and for training and human resources development. The Animal Sciences Research Institutes under the ICAR and the State Agricultural Universities (SAUs) provide support to the AI system.

India has perhaps the world's largest AI network – over 40 thousand AI outlets altogether – of which 28 thousand are owned by the government, 10 thousand by the milk cooperatives, and the rest by NGOs and others. The 28 thousand AI centers directly operated by the government departments are stationary centers where the farmer has to bring the animal for service. This limits their reach, covering approximately 500 adult females per center. The cooperative sector AI centers are located in the village dairy cooperative societies and deliver AI at those premises within the village. The nongovernmental, voluntary, and private sectors deliver AI to the farmer's doorstep.

In spite of such a vast spread of institutions the reach of the system is limited to less than 20% of adult females among cattle and less than 10% in buffalo. The service is of poor quality and the conception rate is less than 20%. The bulls are not genetically evaluated and therefore, AI does not result in superior progeny generation after generation. The central and state governments have recently reviewed the AI system and initiated a major restructuring of the entire cattle and buffalo breeding program, infrastructure, institutions and breeding operations in the country. The aim is to maximise the returns on existing investments, to ensure that the system covers much larger populations of breeding animals, and creates genetically superior progeny generation after generation. To this end, the Government of India has now launched a *National Project for Cattle and Buffalo Breeding.*

Adoption of Crossbreeding

After the initial slow start, crossbreeding spread throughout the country and in its wake brought problems of overzealous application and issues related to sustainability. The breeding policy prescribed by the government was scientifically and environmentally appropriate, but the application of the policy was mismanaged by almost all states except Kerala, parts of Gujarat, and Andhra Pradesh. The adoption of crossbreeding across the country, and the speed with which it spread, is clearly established in the successive rounds of the Livestock Census. Separate enumeration of crossbreds started only with the 1982 Census round (Table 2).

The growth rate of the crossbreeds would have been much higher if the AI service in India was of higher quality. Eighty-five percent of the total 24.5 million AIs are conducted to generate crossbreeds, but less than 20% of these result in pregnancies and even fewer calves are born.

Table 2. Growth in crossbred population.

	1982	1987	1992
Population (million)			
Indigenous			
Total	180.3	188.3	189.3
Adult female	55.7	56.4	56.7
Crossbred			
Total	8.8	11.4	15.2
Adult female	3.0	4.5	6.4
Compound annual growth (%)			
Indigenous			
Total	-	0.9	0.1
Adult female	-	1.2	-0.03
Crossbred			
Total	-	5.9	5.9
Adult female	-	10.5	7.0

Source: Animal numbers are based on Census Tables of Livestock Census Rounds 1982, 1987, and 1992.
Growth rates for 1982-87 are derived from census figures.
Growth rates for 1987-92 are derived from tables in Basic Animal Husbandry Statistics 1997, AHS Series 6, Department of A H & D, Government of India.

The demand for crossbreeding of cattle is high in all states except Rajasthan and Gujarat, where the agroclimatic conditions are extremely unsuitable for crossbred cattle to thrive. Also the indigenous breeds of cattle in Rajasthan and Gujarat are some of the best dairy and draught breeds in India and there is immense scope for their development through selective breeding. In states such as Kerala and Punjab crossbred cattle have virtually replaced the indigenous cattle and now account for 70% of the cattle population in Kerala and 80% in Punjab (Livestock Census 1997). The other states with large crossbred cattle populations are Uttar Pradesh, Tamil Nadu, Maharashtra, and West Bengal.

Impact of Crossbreeding

The impact of crossbreeding on the Indian economy and at the farm level is impressive. However the enormous increase in milk production in the country is more due to market pull, improved though discriminatory feeding practices, and increase in the number of animals.

Milk production in India increased from 19 million tonnes in 1951 to 74.7 million tonnes by 1999. Of this, 55% comes from buffalo, cattle accounting for only 41%. The projected population of crossbred cows in 2001 is about 9.35 million and their estimated contribution to total milk production is 10 million tonnes or 33% of the total cattle output. The contribution of the milk group to the total output value of the livestock subsector in 1998-99 was Rs 826.24 billion, with crossbred cattle contributing about Rs 110.61 billion.

At the farm level the impact is more dramatic as the milk yield increase in crossbred cows is three- to five-fold (Garcha and Dev, 1994; Venkitasubramanian and Fulzele 1996; Rao et al. 2000). The farmers profit from the much higher output of milk and comparatively lower cost per unit of milk output. Yield increases and better breeding parameters in the crossbred cows are universally accepted facts even under farm conditions.

While most states were indifferent to the prescribed breeding policy Kerala had been following it strictly with commendable results. Punjab completely deviated from the central prescription and followed a policy of its own, for progressive upgrading of the local cattle with Holsteins, taking into account the quality of farmers in Punjab, and the resources available in the state. Several years of this policy implementation endowed Punjab with a highly productive population of cattle closer to the Holstein both in production traits and appearance.

There are many micro-studies establishing the advantages of crossbred cows in household herds. One of the most documented schemes in India on this front is the *Intensive Mini Dairy Project* (IMDP) of the Uttar Pradesh Dairy Development Department. This is primarily a rural employment scheme enabling eligible milk producers in dairy cooperative society areas access to commercial credit for replacing their local milch animals with two to four crossbred cows or improved milch buffalo. A comprehensive review of the project (impact study involving over 10 thousand project units) carried out by the ICCMRT, Lucknow in 1994 shows that income from dairying increases dramatically without altering the quantum of income from other sources, if two crossbred cows are added to the farm (Fig. 3).

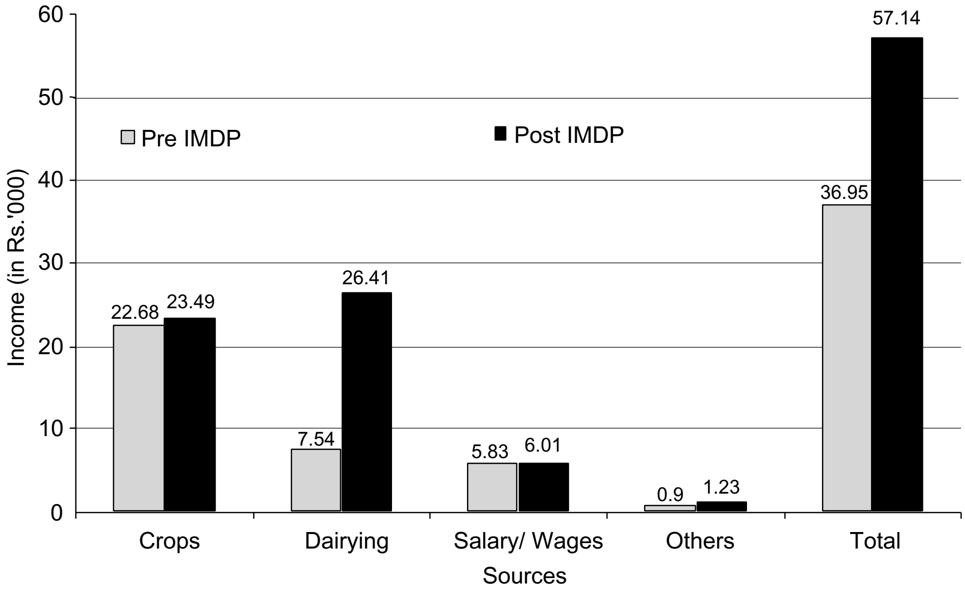

Figure 3. Rural household incomes: influence of crossbred cows.

Source: Based on data presented in evaluation study of the "Saghan Mini Dairy Project" Phase I 1991–94 by the Institute of Cooperative and Corporate Management Research and Training (ICCMRT), Lucknow 1994.

Farming Systems and Social Dimensions

In India milk is produced in over 70 million small, marginal, and landless holdings scattered across the length and breadth of the country. The vast majority of these holdings are comprised of mixed crop-livestock systems and farmers keep livestock depending on the crop residues available. The stock holdings are tiny – two to three animals, cows, and/or buffalo per holding is the modal holding size. Large holdings are seen only among the nomadic herders in Gujarat and Rajasthan; and in stables in cities such as Mumbai and Kolkata. There are some specialized dairy farms among the smallholders, but the numbers are very few and they are mostly in the peri-urban areas, dairy cooperative society villages, or close to processing plants. Organized modern dairy farms also exist, but their numbers are far too small to express as a percentage of total holdings. Larger landowners tend to hold larger herds and the stock holding size is larger as a rule in Punjab, Haryana, and Western UP.

Livestock holdings seem to be less skewed compared to land holdings and therefore, gains from livestock production are more equitably distributed. In 1977, the bottom 60% of the households in rural areas owned only 41% of the total milch animals. This inequity in the distribution of livestock appears to be declining over time. All-India Input Surveys in 1981–82 and 1986–87 indicate that the share of the bottom 60% households in the ownership of bovines increased from 59 to 66% during this period (Table 3). By 1992, the small and marginal farmers accounted for 62% of all rural households. They constituted the core of the milk production subsector and owned two-thirds of all milking

Table 3. Distribution of bovines according to size of land holding.

Size of holding (ha)	No. of holdings (million)		Area per holding (ha)		No. of bovines per holding	
	1981–82	1986–87	1981–82	1986–87	1981–82	1986–87
< 1.00.	46.8	50.9	0.4	0.4	1.6	2.3
1.00-1.99	16.0	16.4	1.4	1.5	3.8	3.7
2.00-3.99	12.0	12.4	2.7	2.8	4.7	5.5
4.00-9.99	7.5	7.4	6.0	5.9	6.4	7.3
10.00 >	1.9	1.8	16.2	14.3	9.4	9.2
All	84.1	89.0	1.8	1.7	3.3	3.7

Source: All India Input Surveys 1981-82 and 1986-87, vide " Report of the Technical Committee of Direction for Improvement of Animal Husbandry and Dairying Statistics": AHS Series 4 1993.

animals. The more productive crossbred cows too seem to fit this distribution pattern. Many among the landless, who account for some 20% of rural households, also own milch animals and participate in milk production.

Among all livestock in India, cattle are the most critical threat to sustainability as they account for the bulk of the livestock load on land. Production of work animals for the crop system was all along the excuse for the relentless increase in overall cattle population size. With draught animals becoming increasingly redundant, this excuse is no longer valid. Even though there is a decreasing trend in the cattle population over the last two decades, an increase in mechanization of farm operations and growing numbers of higher-yielding crossbred cows have not yet produced a matching reduction in cattle numbers. Progressive replacement of the indigenous cattle population by crossbreeds and cows of developed Indian dairy breeds would reduce overall cattle numbers and improve sustainability. Crossbreeding of nondescript indigenous cattle is thus a major solution to India's oversized cattle population.

Constraints in Adoption of Crossbreeding

- The millions of tiny stock holdings across the country comprising two or three animals per holding are a major constraint in the spread of newer technologies. Fragmentation of these smallholdings year after year, reducing their size and viability, relentlessly pushes the smallholders below the poverty line. This compels the state to invest increasingly larger resources on poverty alleviation and livelihood protection measures. Often the bottom end of the smallholder spectrum is therefore unable to adopt newer technologies without subsidy/credit support.
- There are huge and progressively widening gaps between supply and demand of feed for livestock as shown by estimates over the last fifty years. These estimates are mostly inaccurate (population numbers grew two- to three fold and output of all species grew four times between 1951 and 1991). However it is a fact that feed resources in the country are scarce and inadequate. A reduction in bovine numbers, therefore, assumes high priority in the policy framework.
- The common property resources have shrunk by 30% between 1950 and 1990. What little is left can no longer support any meaningful livestock production, as it is in an advanced state of degradation, with scanty biomass cover and little or no maintenance.

- Almost all diseases of livestock, many of them already eradicated or under control in the more developed countries, are still rampant in India. Livestock production is seriously hampered by the regular recurrence of devastating epidemics in all species throughout the country, leading to annual losses of over Rs 50 billion, thus denying India access to lucrative global markets for animal products. Development of high-yielding milch animals without adequate protection against disease is a very high-risk investment.
- All services in the livestock subsector such as veterinary services, AI, and production support are offered exclusively by the state departments of animal husbandry and are usually absolutely free. This overwhelming government monopoly in delivery of free services has compromised quality and accountability, and crowded out the emergence of free markets for these services.
- The need to take the animals to the center for AI services limits its reach and coverage and also causes severe stress to the animal. Stress being inconducive to pregnancy, is one of the major causes for low conception rates due to AI in India.
- Breeding of cattle is almost random, as 80% of the breeding females receive no scientific or organized human intervention. The vast state government AI network currently covers less than 20% of the breeding female cattle and only 10% of the buffalo.
- Use of unselected bulls for AI leads to progeny with virtually no genetic progress from generation to generation.
- The apparent fertility problems in crossbred bulls seriously hamper their selection. The rejection rate among crossbred bulls is as high as 40% and there is no research support to mitigate the problem.
- Extension support to agricultural production was recognized as essential when planned increases in agricultural production were initiated in the early 1950s. Despite a promising start, by the end of the Third Five Year Plan, extension services degenerated into mere delivery of services by animal husbandry departments. While a reasonably effective extension network evolved in the crop production subsector nationwide, no such effort was made in the livestock subsector. Absence of a well-conceived extension support system seriously undermined the pace of development under the different plans.

- Sociocultural factors are a negative influence on dairy enterprise in the country. Culling of unproductive cattle is seldom undertaken, leading to large numbers in the population. Over 30% of the adult female cattle are not fit for breeding. Lack of reforms in the alternate use of animals saps the Indian dairy industry of almost 40% of its supplementary revenue, greatly compromising the interests of the dairy farmer.
- Accelerating livestock subsector development in India has to be balanced with conservation of ecology, as livestock – particularly cattle – are a major cause of environmental degradation. The relentless growth of the cattle population far beyond the land's capacity to support it is a threat that needs well-focused policy attention while exploiting livestock potential for livelihood generation and alleviation of poverty.

References

Garcha, D.S. and Dev, D.S. 1994. Factors affecting milk yield performance of crossbred cattle under field conditions of Punjab Journal of Dairying, Foods, and Home Science 13(1):48-32.

Rao, S.J., Rao, B.V.R. and Rao, G.N. 2000. Performance of crossbred cows and buffalo under village conditions of Visakhapatnam district of Andhra Pradesh. Indian Journal of Dairy Science 53:3.

Venkitasubramanian, V. and Fulzele, R.M. 1996. Factors influencing production performances of cross and indigenous cattle under field conditions. Indian Journal of Dairy Science 49:5.

Milk Production Technology and its Impact on Dairying in Tamil Nadu

R A Christopher Dhas[1]

Technology has played an important role in the growth of the dairy economy of Tamil Nadu state (Kalamani 1984, Dhas 1990). High-yielding bovines have been introduced and the existing stocks are being improved by crossbreeding through artificial insemination (AI). Feeding practices have undergone considerable changes to facilitate realization of the potential of crossbreeding technology. The paper examines these changes and their impact on milk production in the state.

Technological Change in the Dairy Sector

Changes in Breeding Technology

Crossbreeding of cattle and upgrading of buffalo are the main thrust of the breeding policy, the rationale being that new breeds are more productive and their unit cost of milk production is lower than the local nondescript animals. Although crossbreeding of indigenous breeds with exotic breeds of cows and Murrah buffalo could be carried out naturally or by AI, the latter has been emphasized in all dairy development programs.

The progress in diffusion of breeding technology is reflected in the trends in the number of AIs done in the state. The Department of Animal Husbandry and the Milk Producers' Cooperative Societies extend artificial insemination facilities to farmers. The former carries out about 75% of the AI. Those carried out through milk cooperatives have increased from 10% in the early 1980s to 25% in the mid-1990s. During this period, there was a steady increase in the number of AIs performed, from 1.5 million (1981–82) to 3.6 million in 1997–98 (Table 1).

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Table 1. Trends in artificial inseminations in Tamil Nadu.

Year	Number of AIs (millions)			Share of AIs (%)		
	DAH-VI	TCMPF	Total	DAH-VI	TCMPF	Total
1981–82	1.3	0.2	1.5	88.5	11.5	100
1989–90	2.6	0.7	3.3	79.6	20.4	100
1990–91	2.7	0.7	3.4	79.9	20.1	100
1991–92	2.3	0.7	3.0	76.5	23.5	100
1992–93	2.6	0.8	3.4	77.1	22.9	100
1993–94	1.6	0.9	2.5	65.8	34.2	100
1994–95	2.6	0.9	3.5	74.3	25.7	100
1995–96	2.6	0.9	3.5	73.8	26.2	100
1996–97	2.5	0.9	3.4	74.4	25.7	100
1997–98	2.7	0.9	3.6	74.9	25.1	100

Source: Tamil Nadu Economic Appraisal (various years).
Note: DAH-VI – Department of Animal Husbandry Veterinary Institution.
TCMPF – Tamil Nadu Cooperative Milk Producers Federation Ltd.

Changes in Feeding Technology

The feeding technology adopted can be examined by studying feeding practices and the composition of feeding inputs. Milch animals are stall fed with a standard ration of nutrients containing high levels of concentrates and green fodder. In the mid-1960s no animals were exclusively stall-fed, although about 77% of milch cattle and 84% of milch buffalo were maintained on a combination of grazing and stall feeding (Table 2). By the late 1970s, the dependence on grazing had declined to 9.7% in cattle and 7.5 % in buffalo.

Table 2. Percent distribution of milch animals by feeding practices in Tamil Nadu.

Year	Cattle				Buffalo			
	Grazed	Stall fed	Combined	Total	Grazed	Stall fed	Combined	Total
1965–66	22.6	-	77.4	100	16.1	-	83.9	100
1977–78	9.7	9.7	80.6	100	7.5	5.4	87.1	100
1980–81	9.0	8.8	82.2	100	0.3	7.4	92.3	100
1991–92	3.9	33.9	62.2	100	5.2	25.2	69.6	100
1995–96	3.4	16.2	80.4	100	4.2	14.8	81.0	100

Source: Government of Tamil Nadu: Integrated Sample Survey Reports(various years).
Singh, D. et al. (undated).

About 10% of cows and 5% of buffalo were exclusively stall-fed and the share of animals that were grazed and stall-fed had also increased. During the 1990s, feeding practices changed significantly. About 3% to 4% of milch animals were under grazing system, 14% to 16% under stall-feeding system, and the rest were maintained under combined feeding system (grazing and stall-fed).

As the genotype of milch animals improved due to the breeding efforts, the resultant high-yielding breeds required better feeding and therefore stall-feeding had to be practiced. At the same time, due to population pressure the amount and quality of land available for grazing had been declining in the state. These aspects played a part in the decrease in dependence on grazing and the concomitant shift in feeding practices.

Impact of Technological Change on Dairying

Breed Composition of Milch Animals

According to the various Livestock Censuses (1982, 1989, and 1994), the cattle population is divided into exotic, crossbred, native pure, and indigenous breeds. Buffalo are similarly divided into Murrah, graded, and indigenous breeds. Among cattle, exotic and crossbreeds are high yielding, while native (pure) and indigenous breeds provide both draught power and milk. Murrah and graded buffalo give high milk yields.

According to the 1994 Livestock Census, high-yielding breeds accounted for about 21%, native-pure about 14% and indigenous breeds about 65% of the cattle population (Table 3). Only about 18% of the buffalo were high-yielding stock and the remaining 82% were indigenous. Thus, the data indicate that the diffusion of high-yielding types of both cattle and buffalo was low in the state.

A comparison of the breed data of the 1994 Census with those of 1982 and 1989 indicated only marginal changes in the breed composition. The absolute figures showed a reduction in the exotic, native-pure, and indigenous cattle population and an increase in the crossbred cattle population. In buffalo there was an absolute decline in numbers of all breeds during the early 1990s. While the share of crossbreeds in the total cattle population had increased marginally, there was no change in composition of the buffalo population. The diffusion and adoption rate of crossbred cattle was thus relatively higher than that of graded buffalo. It must however be taken into account that the breeding policy had focused on increasing milk production through crossbreeding of cattle, without much attention paid to buffalo.

Table 3. Trends in breed composition of bovines in Tamil Nadu, 1982–1994.

Year	Composition of cattle population (%)				Total	Composition of buffalo population (%)			Total
	Exotic	Crossbred	NativePure	Indigenous	(million)	Murrah	Graded	Indigenous	(million)
Male									
1982	0.5	6.2	14.2	79.1	5.2	1.7	12.2	86.1	0.7
1989	0.1	7.9	12.5	79.5	4.3	2.0	11.9	86.1	0.5
1994	0.3	12.2	13.5	74.0	3.7	2.4	13.5	84.1	0.5
Female									
1982	1.0	9.5	14.4	75.1	5.2	1.8	13.1	85.1	2.5
1989	0.3	15.5	14.3	69.9	5.1	2.1	15.7	82.2	2.6
1994	1.8	24.5	15.0	58.7	5.4	2.0	16.0	82.0	2.4
Total									
1982	0.7	7.8	14.3	77.2	10.4	1.7	13.0	85.3	3.2
1989	0.2	12.0	13.5	4.3	9.4	2.0	15.1	82.9	3.1
1994	1.1	19.5	14.4	65.0	9.1	2.1	15.6	82.3	2.9

Source: Livestock Census Reports for the years 1982, 1989, and 1994.

Advanced breeding and feeding technologies have caused changes in distribution of milch animals by milk yield levels, lactation order, and productivity levels.

Distribution of Animals by Milk Yield

In the mid-1960s, 86% of milch cows and 74% of buffalo were yielding less than 2 kg of milk and only between 2–4% were yielding 4 kg and above. This pattern of distribution of milch cows and buffalo then underwent a significant change over time (Table 4). In the late 1970s and thereafter, the number of milch animals giving lower milk yields had declined significantly. By the mid-1980s there was a sharp increase in the number of animals yielding more than 4 kg of milk and a significant decline in the share of those yielding less than 2 kg.

The distributional changes in the milch animals could be partially affected by the changes in the breed composition of cows. As exotic and crossbred animals are high yielding and economical to maintain, an increase in these would certainly alter the distribution of animals. Table 5 shows the extent of variation in the distribution of animals by yield rates across breeds and its trend over time. While a large number of indigenous cows are distributed in the lower milk yield levels, most of exotic and crossbreeds are

Table 4. Distribution of milch animals by milk yields in Tamil Nadu.

Year	Percentage distribution of animals by milk yield (kg day^{-1})					
	< 0.9	1-1.9	2-2.9	3-3.9	4+	Total
Cattle						
1965–66	64.2	21.8	7.6	4.4	2.0	100
1977–78	18.4	34.2	15.1	10.4	21.9	100
1980–81	9.2	38.5	28.5	15.1	8.7	100
1985–86	12.7	21.2	21.6	16.6	27.9	100
1990–91	1.7	4.8	34.6	28.9	30.0	100
1995–96	2.0	6.7	25.0	17.4	48.9	100
Buffalo						
1965–66	46.0	28.2	12.8	8.7	4.3	100
1977–78	6.5	23.2	27.9	22.0	20.4	100
1980–81	4.6	19.5	33.7	18.7	23.5	100
1985–86	5.2	13.7	28.7	24.3	28.1	100
1990–91	1.5	4.9	26.8	43.5	23.3	100
1995–96	0.7	5.0	20.5	26.9	46.9	100

Source: Compiled from the records of the TCMPF, Chennai.

Table 5. Distribution of cows by milk yields and breeds in Tamil Nadu.

Breed	Year	Distribution of cows by milk yield (kg day^{-1})						
		< 0.9	1-1.9	2-2.9	3-3.9	4-4.9	5+	Total
Indigenous	1991–92	2.4	28.5	62.6	6.3	0.2	-	100
	1992–93	2.6	31.1	45.1	20.7	0.5	-	100
	1993–94	4.0	27.9	41.9	17.7	6.6	1.9	100
	1994–95	3.6	27.0	44.2	16.9	7.1	1.2	100
	1995–96	4.6	15.0	47.7	25.0	4.8	2.9	100
Exotic and crossbred	1991–92	-	-	4.1	27.8	64.2	3.9	100
	1992–93	-	15.0	34.6	39.5	9.5	1.4	100
	1993–94	-	0.7	2.4	8.1	20.5	8.3	100
	1994–95	-	0.8	2.9	8.2	20.6	7.5	100
	1995–96	0.3	1.6	11.2	13.0	17.7	6.2	100

Source: Integrated Sample Survey Reports, various years.

distributed towards higher yield levels. It is interesting to observe that the share of exotic and crossbreeds yielding less than 1 kg of milk is almost nil. Moreover, in both indigenous and exotic/crossbred cows, the share of animals yielding more than 4 kg had been increasing steadily.

Productivity of Milch Animals

A survey conducted by the Indian Agricultural Statistics Research Institute (IASRI) showed that, in the mid-1960s, the average milk yield per day per lactating cow was about 1.2 kg and for female buffalo it was 2.0 kg (Table 6). The yield of buffalo was almost 60% higher than that of the cow. By the mid-1970s, the yield rates of cattle and buffalo showed a sharp increase (Integrated Sample Survey Reports). Furthermore, between 1977–78 and 1995–96, the yield of both species once again showed an increasing trend. The productivity of cows was 3.3 kg and of buffalo was 3.5 kg in 1995–96. A similar trend in the milk yield rates per lactating stock was also observed.

Interestingly, although the average milk yields per day of buffalo have been higher than that of cattle, the divergence between the yield rates has been declining over time due to a faster growth in the yield of cattle. This is reflected in a steady upward trend in the yield ratio (yield of cow to buffalo).

Milk Production

According to the IASRI estimate, the total milk production in Tamil Nadu in 1965–66 was about 0.87 million tonnes. The estimated milk production as per the Integrated Sample Survey (ISS) Report was about 1.7 million tonnes in 1977–78. Thus, within a period of about 13 years, the production of milk had almost doubled and the annual average growth rate was 7.2% (Table 7).

During the subsequent two decades beginning 1977–78 there was a steady increase in milk production and this trend was maintained with a

Table 6. Trends in milk yield per day per lactating animal / milch animal.

	Milk yield (kg day^{-1})				Yield ratio (cow / buffalo)	
	per lactating animal		per milch animal			
Year	Cow	Buffalo	Cow	Buffalo	In milk	Milch
1965–66	1.2	2.0	0.5	1.0	0.60	0.50
1977–78	1.9	2.5	0.7	1.2	0.76	0.58
1981–82	2.0	2.8	0.7	1.4	0.71	0.50
1985–86	2.5	3.5	1.5	2.2	0.71	0.68
1991–92	2.8	3.3	1.8	2.0	0.85	0.90
1995–96	3.3	3.5	2.0	2.2	0.94	0.90

Source: The same as for Table 2.

Table 7. Trends in milk production and its composition.

Year	Total milk production (thousand tonnes)			Composition of milk production (%)		
	Cow	Buffalo	Total	Cow	Buffalo	Total
1965–66	458.0	411.0	869	52.7	47.3	100
1977–78	894.4	785.6	1680	53.2	46.8	100
1980–81	906.1	831.9	1738	52.1	47.9	100
1985–86	1818.8	1299.6	3118	58.3	41.7	100
1990–91	2021.6	1353.1	3375	59.9	40.1	100
1995–96	2273.5	1517.4	3791	60.0	40.0	100

Source: The same as for Table 2.

marginal decline in a few years. The total milk production during 1995–96 was 3791 thousand tonnes, comprising of 60% cow milk and 40% buffalo milk. In general, a differential growth pattern and a shift in the composition of milk production were observed during the period. The growth of milk production was at the higher order up to the mid-1980s and slowed down thereafter. The share of cattle and buffalo milk remained steady up to the mid-1980s, and decreased slightly thereafter.

Alhough the official estimates of milk production in Tamil Nadu provide a broad understanding of the trends in milk production and its composition, there are some problems in using the data as such for an in-depth analysis. There are significant differences between the estimated number of milch animals based on the ISS and the Livestock Census data. During 1966 and 1982, the estimates of milch animals from the ISS were lower than those reported in the Livestock Census; in 1989 and 1994, they were higher than the latter, and the difference between them was minimal (4%) during 1977 (Table 8). According to the Livestock Census, the total milch animals, both in-milk and dry, in the state were about 4.3 million in 1989, but the ISS estimated this at 5.3 million; about 24% higher than the Census data. For other years also, similar discrepancies were observed. Moreover, while the Census showed an increase in the population during 1982 over 1977, the ISS showed a decline. Since the ISS provided an underestimate of the number of milch animals in some years and an overestimate in other years, the difference between the Census and ISS estimates varied significantly over time. Thus, to obtain comparable estimates of milk production, it becomes imperative to re-estimate total milk production.

Table 8. Comparison of milch animal populations from the Livestock Census and Integrated Sample Surveys.

		1966	1977	1982	1989	1994
		(millions)				
Census	Cattle	2.5	2.6	3.0	2.8	2.9
	Buffalo	1.1	1.4	1.5	1.5	1.3
	Total	3.6	4.0	4.6	4.3	4.2
ISS	Cattle	2.0	2.8	2.4	3.5	3.0
	Buffalo	0.9	1.4	1.2	1.9	1.7
	Total	3.0	4.2	3.7	5.3	4.7
Difference (Census–ISS)	Cattle	0.4	–0.2	0.6	–0.6	–0.1
	Buffalo	0.2	0.1	0.3	–0.4	–0.4
	Total	0.7	–0.2	0.9	–1.0	–0.5
% difference	Cattle	17.9	–8.0	19.8	–22.8	–2.8
	Buffalo	21.0	3.6	19.1	–25.9	–28.6
	Total	18.8	–4.0	19.6	–23.8	–10.9

Source: (i) Livestock Census, Tamil Nadu, 1966, 1977, 1982, 1989, and 1994.
(ii) Integrated Sample Survey Reports, various years.

To obtain a comparable unbiased estimate of milk production, the data on the number of milch animals that were lactating were taken from Livestock Census reports. The average yield per lactating animal from ISS reports and the total milk production in the state were estimated for the Census years. Table 9 shows the revised estimates of milk production in Tamil Nadu.

Total milk production in the state had increased from about 1.0 million tonnes in 1966 to 2.4 million tonnes in 1982. The rates of growth of milk

Table 9. Revised estimates of milk production in Tamil Nadu: Trends and composition.

	Milk production (thousand tonnes)			Composition of milk production (%)		
Year	Cattle	Buffalo	Total	Cattle	Buffalo	Total
1966	531.9	491.9	1024	52.0	48.1	100
1977	937.1 (6.9)	786.9 (5.5)	1724.0 (6.2)	54.4	45.6	100
1982	1301.1 (7.8)	1046.3 (6.6)	2347.4 (7.2)	55.4	44.6	100
1989	1759.3 (5.0)	1191.1 (2.0)	2950.4 (3.7)	59.6	40.4	100
1994	2199.3 (5.0)	1193.4 (0.04)	3392.7 (3.0)	64.8	35.8	100

Note: Figures in brackets indicate annual average growth rates.

production were found to be much faster from the mid-1970s than earlier. Since the early 1980s growth rate has begun declining. The growth rate of buffalo milk production was lower than that for cattle.

A structural change in the composition of milk production has taken place. In the mid-1960s, the share of cattle and buffalo milk to the total milk production was almost equal. Over time, this composition changed significantly in favor of cattle. Comparison of the trends in the composition of the milch animal population and milk production provides significant insights. In the mid-1960s, the number of milch buffalo was only about 25% of the total milch bovines, but it contributed about 50% to the total milk production. By the 1990s, the number of milch buffalo had increased to 31% of the total, but the share in milk production declined to 35%.

During 1966–77, the share of cattle milk to the increase in total milk production was 57.9 %, which increased to 67.0% during 1977–89 (Table 10). Obviously, the relative contribution of buffalo had declined steadily, while the contribution of cattle had increased.

In this context, it is important to examine the contribution of technological change to growth in milk production. This growth could be influenced either by an increase in the milch animal population, or productivity, or both. The additive decomposition model developed by Minhas and Vaidyanathan (1965) has been used to analyze the relative contribution of these factors to the growth in total milk production:

$$M_t - M_{t-1} = (P_t - P_{t-1})Y_{t-1} + (Y_t - Y_{t-1})P_{t-1} + (P_t - P_{t-1})(Y_t - Y_{t-1})$$

‘M’ refers to total milk production of a species
‘P’ refers to in-milk population
‘Y’ refers to average yield of in-milk population
‘t’ and ‘t-1’ refer to the terminal and base years respectively.

Table 10. Contribution of cattle and buffalo to the increase in milk production.

	Increase in total milk production (%)	
Year	Cattle	Buffalo
1966–77	57.9	42.1
1977–89	67.0	33.0
1989–94	99.5	0.5
1966–94	70.4	29.6

The left-hand side of the equation refers to the growth in milk production. The right hand side of the equation has three terms. The first term refers to the population effect, the second refers to the yield effect, and the last term refers to the interaction effect. By population effect we mean the contribution of changes in the milch animal population to the growth of milk production while the yield level is assumed unchanged. The yield effect refers to the contribution of changes in the yield while the population is assumed to remain unchanged. The interaction effect refers to the contribution due to changes in both population and yield. The results are given in Table 11.

The dominant factor contributing to the growth in milk production was the productivity of the milch animals. About 52% of the growth in bovine milk production between 1966 and 1994 was due to yield effect, 22% to population growth and the remaining due to their interaction. The dominance of the yield effect was observed in the case of both cattle and buffalo.

A comparison of the relative contributions of the sources of growth in the production of cattle and buffalo milk revealed that, although yield was the major contributing factor to the growth in milk production during 1966–77, a differential pattern was seen over time. In the case of cattle milk production, yield was the major contributing factor during 1966–77, but declined in subsequent periods, while the population effect kept on strengthening. In the case of buffalo milk, the contribution of yield consolidated over time and the population effect weakened.

There was a boom in the spread of AI in the 1980s, which slowed down in the following decade. A decrease was seen in the dependence on grazing and a shift in feeding practice from grazing to stall-feeding. A marginal change took

Table 11. Relative contribution (%) of different factors to the growth of milk production.

Output	Source of contribution	1966–77	1977–89	1989–94	1966–94
Bovine milk	Population effect	25.5	28. 6	44.8	21.9
	Yield effect	63.4	59.4	51.8	51.8
	Interaction effect	11.1	12.1	3.5	26.3
Cattle milk	Population effect	18.2	24.2	62.4	19.0
	Yield effect	71.9	62.5	32.6	50.8
	Interaction effect	10.0	13.3	5.1	30.2
Buffalo milk	Population effect	39.6	36.7	-	25.0
	Yield effect	48.8	53.2	-	55.3
	Interaction effect	11.6	10.0	-	19.7

place in the breed composition of milch animals towards crossbred animals, indicating the slow diffusion and partial success of crossbreeding technology in the state. Distribution of animals shifted from low to high milk yield levels, and from animals of higher orders of lactation to lower orders of lactation. The productivity of milch animals witnessed a steady increase during the period, reflecting the positive contribution of technological change to milk output growth.

Alhough milk production had shown a steadily increasing trend from the early 1980s to the mid-1990s, the growth rate had reduced sharply. A structural change in the composition of milk production had taken place in the state. The dominant factor contributing to the growth in milk production was the productivity of the animals. The relative contribution of population effect on the growth of cattle milk production increased and that of yield declined over time. On the other hand, in buffalo the contribution of population showed a steady decline and that of yield an increase over time. These trends could largely be attributed to changes in the breeding and feeding technologies.

References

Dhas, A.C. 1990. Structure of Milk Production in Tamil Nadu: An Analysis of Trends and Sources of Growth. *In* Resources, Institutions and Strategies: Operation Flood and Dairying. (Doornbos and Nair, eds.). Indo-Dutch Studies on Development Alternatives-4, Sage Publications, New Delhi.

Government of Tamil Nadu. Various years. Livestock Census Reports. Directorate of Economics and Statistics, Government of Tamil Nadu, Chennai.

Government of Tamil Nadu. Various years. Report on the Integrated Sample Surveys. Directorate of Economics and Statistics, Government of Tamil Nadu, Chennai.

Kalamani, A. 1984. Comparative Efficiency of Milk Production of Crossbred and Nondescript Cows and Murrah Graded in Sulur Block, Coimbatore District. M.A.Thesis (unpublished) Department of Economics, PSG College of Arts and Science, Coimbatore.

Minhas, B.S., and Vaidyanathan, A. 1965. Growth of Crop Output in India (1951–52 to 1958–61): An Analysis by Component Elements. Indian Journal of Agricultural Statistics 17(2).

Singh, D. et al. (undated). Sample Survey for Estimation of Milk Production and Study of Bovine Practices. Report of a survey conducted in Tamil Nadu state during 1965–66. Institute of Agricultural Research Statistics, New Delhi.

Impact of Mechanization on Draught Animal Power Use in Agriculture

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Before the introduction of new technologies (modern seeds, chemical fertilizers, and pesticides) in the mid-1960s, draught animals (particularly male cattle) were the major source of motive power (tractive and rotary) for Indian agriculture. Increasing use of new technologies led to expansion of area under crops and intensive use of land. This demanded more draught power to ensure timeliness in field operations. The draught animals were not capable of meeting the increased demand and thus machines were introduced/used to fill the gap. Machines subsequently replaced the draught animals for various farm operations such as irrigation and threshing (Singh 1992 and 1996). Further, with increasing subdivision of land holdings, maintaining draught animals became an uneconomical proposition for small landholders. These farmers therefore prefer custom hiring of tractors, threshers, and power tillers to maintaining draught animals. Custom hiring of tractor-drawn tillage equipment is now an accepted practice in many parts of the country. This paper investigates the trends in use of draught animal power vis-à-vis mechanical power in Indian agriculture.

The Process of Mechanization

During the last thirty years the net cultivated area has remained more or less stagnant (138–142 million ha), while the gross cropped area has increased to 189 million ha. The average size of holdings is 1.6 ha, with 79% of holdings below 1.3 ha. Indian farmers have been dependent on draught animal power for irrigation, threshing, transport, tillage, sowing, and cultivation. As cropping intensity has increased, animate power has been found inadequate to maintain schedules, and has been supplemented by mechanical power sources (tractors,

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Table 1. Trends in the numbers of bullock-drawn implements.					
Implements	1971–72	1976–77	1981–82	1986–87	1991–92
	....	....	(millions)	....	....
Wooden plow	39.3	41.0	43.0	43.0	39.6
Steel plow	5.4	6.5	6.7	8.9	9.6
Disc harrow	–	–	3.4	1.2	2.3
Cultivator	–	–	4.3	5.0	5.3
Puddler	1.7	2.1	2.3	3.3	2.4
Sowing devices	4.1	4.9	5.6	6.5	6.7
Leveling karaha	4.0	9.0	10.5	8.7	9.6
Olpad thresher	–	–	0.4	0.4	0.3
Cane crusher	0.7	0.8	0.7	0.7	0.8
Persian wheel	0.6	0.6	0.5	0.3	0.2
Bullock cart	13.0	12.7	13.7	14.4	13.4
Sprayer and duster	0.4	1.6	1.6	1.7	2.6

Source: Livestock Census, 1977, 1982, 1987 and 1992.

engines, and electric motors). Tillage, irrigation, and threshing operations, which require higher energy and are arduous to perform, are gradually being performed using mechanical power. Small farmers in agriculturally backward regions are still using the traditional animal-operated country plow.

Table 1 shows trends in the numbers of bullock-operated implements such as steel plow, puddler, disc harrow, sprayer and duster, spring tine harrow, and sowing devices since the early 1970s. The numbers of traditional implements such as wooden plows, cane crushers, Olpad thresher, Persian wheels, and bullock carts have either remained almost unchanged or decreased marginally, while those of improved implements such as the steel plow and puddler have increased.

Human Power

Human power is predominantly used for sowing, transplanting, fertilizer application, harvesting, and digging. Use of human power is likely to continue in hilly regions, *diara* lands, smallholdings, and in areas where mechanization has not been adopted. The population of agricultural workers has grown from 97.2 million in 1951 to 186.5 million in 1991 (Table 2), so human power in agriculture is available in plenty.

Table 2. Population dynamics of agricultural workers.					
Type of workers	1951	1961	1971	1981	1991
Total population (millions)	361.1	439.2	549.0	685.2	846.3
Agricultural workers (millions)	97.2	131.1	126.0	151.7	186.5
Agricultural workers' power (mkW)	4.9	6. 6	6.3	7.6	9.3

Source: Agricultural Statistics at a Glance, 1995.

Note: Capacity: 0.05kW/person.

Draught Animal Power

Draught animal power (DAP) is used for crop production and transportation. Bullock and male buffalo over three years of age are the main draught animals for field operations. India possesses famous draught breeds of cattle such as Nagori, Khilari, Helikar, Amrit Mahal, Kangayam, Malvi, Hariana, Gir, Angol, Tharparkar, and Gaulao. Adult male and female camels are used for field operations and for transport, but their population is estimated at less than 1% of total draught animals. The population of draught animals declined from 80.8 million in 1971–72 to about 77.7 million in 1991–92 (Table 3). The power availability too declined from 20.2 mkW to 19.4 mkW during this period.

Tractors

There were only 8635 tractors in use in 1951. Local tractor production began in 1961–62 with 880 tractors. Today, India manufactures more than 265 000 tractors per year. Different sizes of tractors are manufactured in India, ranging from less than 15 kW to more than 37.5 kW, but the most popular range is 15–30 kW.

Table 3. Trends in the population of draught animals for field operations.					
Animal	1961–62	1971–72	1981–82	1986–87	1991–92
Total (millions)	77.8	80.8	68.4	70.4	77.7
Cattle (millions)	70.7	73.2	61.1	63.6	70.3
Buffalo (millions)	7.1	7.6	7.3	6.8	7.4
DAP (mkW)	19.5	20.2	17.1	17.6	19.4

Source : Livestock Census 1972,1982, 1987 and 1992.

Capacity: Bovine-0.25 kW/animal.

Power Tillers

Power tillers were introduced in the country in the 1960s, but did not become as popular as the tractor due to limitations in the field and on the road, and ergonomic weaknesses. Power tillers are presently used more in rice and sugarcane-producing areas of Tamil Nadu, Andhra Pradesh, Kerala, Karnataka, West Bengal, Orissa, Bihar, and Maharashtra. The annual production was about 14,000 units in 1999–2000. The potential power availability is estimated to be 0.66 mkW (Table 4).

Diesel Engines and Electric Motors

These are used for stationary operations, especially the lifting of water for irrigation and operating grain mills, oil *ghanis*, sugarcane crushers, power threshers, and chaff cutters. The number of irrigation pumps has increased from 0.11 million in 1951–52 to about 15.3 million in 1996–97. As a result, the gross irrigated area increased from 22.6 to 70.6 million ha. Government support through financial incentives for irrigation hardware has played an important role in this growth. The electric pumps are preferred in electrified areas due to lower recurring cost. In 1996–97 the number of electric motors used for irrigation was 9.7 million with potential power availability of 36.3 mkW, and that of diesel engines was 5.6 million with potential power availability of 30.2 mkW (Table 5).

Farm power per unit area is one of the parameters used for expressing the mechanization status. The total farm power availability in 1951–52 was 0.20 kW ha^{-1}, which increased to 1 kW ha^{-1} in 1996–97 (Table 6). Human and animal power contributed 60% of the total farm power in 1971–72 and

Table 4. Trends in mechanical tractive power.

Tractive power	1961–62	1971–72	1981–82	1991–92	1996–97*
Tractor (millions)	0.03	0.15	0.52	1.23	1.82
Power tiller (millions)	-	0.02	0.08	0.10	0.11
Total power (mkW)	0.70	3.44	12.18	28.4	41.70

Source: Livestock Census Reports.
Automobile Association of India.

* Estimated capacity: Tractor-22.5 kW, Power tiller-6.5kW.

Table 5. Trends in the number of irrigation pumps.

Mechanical power	1951–52	1961–62	1971–72	1981–82	1991–92	1996–97
Electric pump (millions)	0.02	0.1	1.6	4.3	8.9	9.7
Diesel pump (millions)	0.08	0.2	1.6	3.1	4.7	5.6
Power (mkW)	0.47	1.6	14.1	32.3	56.5	65.3

Source: Livestock Census Reports.

Capacity: Electric motor-3.73 kW, Diesel engine-5.2 kW.

Table 6. Farm power availability per unit net cropped area.

Power	1961–62	1971–72	1981–82	1991–92	1996–97
Total farm power (mkW)	28.3	44.1	69.1	113.6	136.3
Unit farm power (kW ha^{-1})	0.2	0.3	0.5	0.8	1.0
% draught animal power	68.8	45.8	24.7	17.1	14.1

Table 7. Share of farm power sources.

	Total power (mkW)	
Power source	1971–72	1996–97
Human	6.3 (14.2)	10.1 (7.4)
Animal	20.2 (45.8)	19.2 (14.1)
Mechanical and electrical	17.6 (40.0)	107.0 (78.5)
Total farm power	44.1	136.4

Note: Figures in brackets are percent of the total power.

mechanical and electrical together contributed only 40% (Table 7). In 1996–97 the contribution from human and animal power was reduced to 21%, and the contribution of mechanical and electrical power increased to 79%. However, in terms of area coverage, draught animals continue to dominate (Table 8). About 55% of the area is dependent on draught animals. One-fifth of the area uses mechanical power. The remainder, especially shifting cultivation, hilly land, and waterlogged areas is cultivated by human power.

Power source	Number (millions)	Unit command area (ha)	Area covered (%)
Draught animals	77.1	2	54.3
Tractors	1.8	155	19.2
Power tillers	0.1		0.4

Table 8. Share of coverage of net cropped area by different power sources, 1996–97.

Changes in Draught Animal Population

Zebu cattle (*Bos indicus*) and buffalo (*Bubalus bubalis*) are the main draught animals in India (Table 9). In most parts of the country only male bovines are used for draught purposes. Cows are generally not used due to social and religious considerations. From 1961–62 to 1991–92, the population of working bovines has remained constant. The ratio of males to females has declined from 1.2 in 1961–62 to 1.0 in 1992. A similar decline occurred in the case of buffalo. This shows a shift away from draught animals, which has been facilitated by rising mechanization of agriculture.

Camels are used primarily for transport and as pack animals, and are also used for tractive power in states such as Rajasthan, Gujarat, Haryana, and Punjab for field operations and for lifting of water from open wells. The total camel population has increased marginally from 0.9 to 1.0 million (Table 10). About 60% of the adults are used for tillage as well as transport.

Pack Animals

Camels, donkeys, mules, horses, ponies, yaks, and mithuns are used mainly as pack animals and to pull carts. The population of horses and donkeys decreased between 1961–62 and 1991–92 (Table 10). Camel and mule

Table 9. Trends in male/female ratios in bovines.

Year	1961–62	1971–72	1981–82	1986–87	1991–92
Cattle (millions)	175.6	178.3	189.9	195.9	204.7
Male/female ratio	1.2	1.2	1.1	1.02	1.0
Buffalo (millions)	51.1	57.4	69.8	76.8	84.2
Male/female ratio	0.4	0.4	0.3	0.3	0.3

Source: Livestock Census, various years.

Table 10. Changes in the populations of pack animals.					
Animal	1961–62	1971–72	1981–82	1986–87	1991–92
	....	....	(millions)	....	....
Horses	1.3	1.0	0.9	0. 8	0.8
Camels	0.9	1.1	1.1	1.1	1.0
Mules	0.1	0.1	0.13	0.2	0.2
Donkeys	1.1	1	1	1.0	1.0
Yaks	0.02	0.04	0.12	0.04	0.1
Total	3.4	3.1	3.2	3.0	3.0
For work	3	2.5	2.32	2.2	2.5

Source: Livestock Census, various years.

populations showed positive growth. The total population of adult pack animals for work in 1961 was 3 million, but this declined to 2.5 million in 1992. The farmers' preference for faster modes of mechanical transport such as tractor, *Maruta* (local improvised four-wheel transport), and the mini-truck for haulage is one of the reasons for a decrease in the population of pack animals.

Draught Animals and Size of Land Holdings

Table 11 shows the distribution of draught animals across size groups of land holdings. Although all groups of farmers possess draught animals, the area commanded by a pair of animals on semi-medium, medium, and large farm holdings is very large, indicating that owners of these holdings may not be in a position to perform farm operations on schedule. Marginal and small farmers have a lower area per animal pair, but the ownership of draught animals is limited.

Table 11. Distribution of draught animals according to size of farm holding, 1986–87.

	Farm holdings (ha)					
Inputs	Marginal <1	Small 1–2	Semi-medium 2–4	Medium 4–10	Large 10	All sizes
Draught animals (millions)	26.0	16.3	14.7	11.1	3.2	71.3
Ha animal pair^{-1}	1.6	2.9	4.6	7.9	15.8	4.1
Farmers possessing pair of animals (%)	23.1	45.5	55.6	70.2	84.4	36.7

Source: Input Survey 1987-88, Ministry of Agriculture.

Animal Energy Use in Crop Production

The animal energy used in crop production, computed from the information in the Cost of Cultivation of Principal Crops in India operated by the Ministry of Agriculture, Government of India, is shown in Table 12. There has been a decrease in use of animal energy for all crops since 1971–72. A maximum decrease of 5% per annum was recorded in wheat, 3% in sugarcane, and 2.8% in pulses. On average, there has been a gradual reduction in use of animal energy. It has been reduced from 159 pair hours ha^{-1} in 1971–72 to 109 pair hours ha^{-1} in 1991–92. This indicates that although the population of draught animals has not changed much over time, their utilization has declined considerably.

Conclusions

Male cattle and buffalo are the chief sources of DAP for field operations. Although use of mechanical and electrical power has increased, draught

Table 12. Trends in animal energy utilization.

Crops	1971–72	1975–76	1981–82	1986–87	1990–91
Paddy	197	197	198	188	157
Wheat	187	213	128	91	71
Sorghum	121	90	90	100	103
Pearl millet	71	65	61	51	103
Maize	146*	134	125	113	103
Gram	138*	138	108	102	83
Pigeon pea	146*	146*	146	87	83
Groundnut	122	131	135	123	93
Rapeseed and mustard	105*	105	88	75	93
Soybean	145*	145	109	108*	93
Sugarcane	135*	135	101	75	74
Cotton	113	101	90	101	62
Jute and mesta	241	235	203	203	229
Potato	162*	162*	162	120	n. a.#
Onion	173	173	191	127	n. a.#
Weighted average	159	147	139	123	109

Note: * Previous or following year's data used.

Data of all the crops not available.

Data for coarse cereal (103), pulses (83) and oil seeds (93) combined for the year 1990–91.

animals continue to be a major farm power source in India for small and marginal farmers, In 1991–92, the total DAP population for field operations was about 35.8 million pairs. As a result of the introduction of mechanical power in agriculture, use of DAP declined gradually. There has been a gradual increase in adoption of the improved bullock-drawn steel plow, cultivator, puddler, seed-cum-fertilizer drill and bullock cart in India, but most small and marginal farmers still use traditional implements for tillage and sowing.

References

Government of India. 1972, 1977, 1982, 1987, and 1991. Indian Livestock Census reports. Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, New Delhi.

Annual Reports of All India Coordinated Research Projects on Utilization of Animal Energy in Agriculture. Indian Council of Agricultural Research. 1990-1999. New Delhi.

Government of India. 1991. Cost of Cultivation of Principal Crops in India. Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, New Delhi.

Government of India. 1999. Agricultural Statistics at a Glance. Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, New Delhi.

Livestock Technologies for Small Farm Systems

H P S Arya, M P Yadav and R Tiwari[1]

India is endowed with huge livestock populations of various species. It has about 300 million bovines, which are used to produce milk, draught power, and dung manure. There are about 180 million small ruminants that provide meat and fiber. The animal productivity is, however, far below the world average. Malnutrition and poor health are the two most important constraints to raising animal productivity. Animals primarily feed on crop residues and common grazing lands. Supplementation with green fodder and concentrate feed is inadequate. Public sector animal health and breeding infrastructure has seen unrestrained growth, but the delivery of these services is poor. The emphasis in health services is on curative treatment rather than on preventive management. As a result, many fatal diseases that have been eradicated elsewhere in the world are rampant among Indian livestock. This indicates that there is considerable scope to raise productivity of Indian livestock through technological and policy interventions. Accordingly, the aim of this paper is to document the livestock technologies available for field applications.

Livestock Production under Small Farm Systems

India is predominantly a country of small farms, which account for nearly three-fourths of the total milk and meat production. More than 70% of rural households possess one or two large animals or 2 to 5 small animals such as the goat, pigs, and poultry. Animals are largely maintained on crop residues. Large animals are partially stall-fed and partly grazed on community land. Small animals are maintained solely on grazing. Their movements are not controlled and they are free to mix with other animals. Most small livestock holders do not have proper housing facilities for animals. The animals are either kept outdoors or indoors with the humans. Some farmers maintain thatched or *pucca* sheds for large animals.

Small holders rarely apply scientific technology for breeding, feeding, health care, or management. They are unable to isolate or suitably care for sick

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animals. Nor can the farmers control the feeding or movements of their animals. Thus, the animals are exposed to diseases and environmental stress.

Potential Livestock Technologies to Augment Productivity

Researchers have long been striving to produce technologies in the fields of animal health, feeding, breeding, and management relevant to small farm systems. Various institutes such as the Indian Veterinary Research Institute (IVRI), National Dairy Research Institute (NDRI), Central Sheep and Wool Research Institute (CSWRI), Central Avian Research Institute (CARI), Central Institute for Research on Goats (CIRG), Central Institute for Research on Buffaloes (CIRB), Indian Grassland and Fodder Research Institute (IGFRI), and State Agricultural Universities are engaged in developing technologies relevant to smallholders.

The Indian Council of Agricultural Research (ICAR) has sanctioned several coordinated research projects and specific problem-oriented research projects on various aspects of animal husbandry. The All-India Coordinated Research Projects (AICRPs) on Breeding of Cattle, Buffalo, Pigs, Sheep, Goats, and Poultry; Coordinated Projects on Economic Ration and Agro-Industrial By-products Utilization; and a number of other research projects/schemes have successfully evolved useful and adaptable technologies. These can be grouped into two broad categories: (a) technologies that can be used only by veterinarians (e.g. those related to disease diagnostic tests, preservation of semen and vaccines, and surgical treatment), and (b) those that can be adopted and used by farmers either on their own or with the help and guidance of field veterinarians (e.g. those related to cross breeding, vaccination, balanced ration, animal feed, improved management practices, and prophylactic measure against animal diseases).

Inventory Of Livestock Technologies

Tables 1–5 present an inventory of technologies related to breeding, nutrition, health, management and product processing along with their advantages and limitations.

Adoption of Livestock Technologies

Unlike agriculture, studies relating to adoption and impact of technologies in animal husbandry are limited and sporadic. Most of these are micro-level studies focusing on only a few technologies. This section reviews such studies.

Table 1. Breeding technologies.

Technology	Advantage	Remarks To be used by:
Artificial Insemination	Genetic improvement of animals to increase milk yields	Farmers with the help of veterinarians
Frozen semen technology	Semen of proven sires can be preserved for a long period, transported easily and utilized to upgrade Desi or nondescript animals	Veterinarians at their own level
Kool pack system to screen bulls for semen freezing under field conditions	Useful for veterinary practitioners	Veterinarians at their own level
Crossbreeding of Landrace and indigenous breeds of pigs with 50% exotic blood	Obtaining crossbreeds for higher production potential of the animal	Farmers
Crossbreeding zebu cows with exotic semen (Holstein Friesian, Brown Swiss, and Jersey breed) to obtain 50% exotic blood	Increased milk yield and other parameters	Farmers with the help of veterinarians
Inter se mating of 50% crossbred cows with progeny-tested halfbreed bulls	Increased milk yield	-do-
Selective breeding in buffalo with Murrah and Nili Ravi breeds	Increased milk yield	-do-
Treatment of chronic anestrus in animals	Makes useless animals reproductively useful	-do-
Treatment of chronic repeat breeding	-do-	-do-
Timely examination and treatment of subclinical reproductive inefficiency	Timely conception leads to higher production.	-do-
Pregnancy diagnosis within 60-90 days after insemination	Reduces the dry period	-do-
Service on 90-120 days after parturition	-do-	-do-
Insemination during mid-heat preferably twice during the same heat	Increased breeding efficiency	-do-
Observing animals for sign of heat	Timely conception	Farmers at their own level
Observing animals for symptoms of pregnancy after service/insemination	-do-	-do-
Feeding of green fodder and concentrates during advanced pregnancy	Improves animal health and production	-do-
Taking care of animals at the time of parturition	-do-	-do-
Parturition in a clean place	Maintaining hygiene leads to good animal health and production	-do-
Arranging materials at the time of parturition	-do-	-do-
Keeping watch on the dropping of the placenta	-do-	-do-
Disposal of placenta	Maintaining hygiene leads to good animal health	-do-
Drying the cows two months before parturition	Good animal health and production	-do-
Freezing of semen by "Tupol"	Effective semen freezing	Veterinarians
Superovulation of cows and goats to harvest large numbers of embryos	Large number of embryos per flushing	Scientists, breeders, and veterinarians

Table 2. Feeding technologies.

Technology	Advantage	Remarks To be used by:
Urea-molasses liquid feed (UMLF)	UMLF supplies 50-60% of protein and energy requirement of growing cattle and cows yielding less than 10 kg milk daily and buffaloes yielding less than 6 kg milk daily	Farmers
Enrichment of low-grade roughage with urea-molasses.	Economic gain of Rs 60/- to Rs 84/- per 100 kg of wheat straw.	-do-
Urea enrichment of straw	Increase in milk yield from 0.5-1.5 litres $animal^{-1}$ day^{-1}. Better growth performance and animal health	-do-
Urea-Molasses Mineral Block	Useful for feed-scarce areas	-do-
Urea-Molasses impregnated dry roughage	-do-	-do-
Balanced compounded animal feed	Improvement in animal health	-do-
Changing ration during pre- and postnatal periods	High production	-do-
Regular feeding of mineral mixture	Proper health, growth and production	-do-
Use of industrial by-products and crop residues as animal feed	Economy in input use	-do-
Year-round production and feeding of high quality green fodder.	Better health & economy in growth and production	-do-
Drinking water to animals from a hygienic source.	Better animal health and production	-do-

Studies reveal varying levels of different livestock technologies. Kakoty (1975) observed a very high adoption of improved breeding and disease control practices, while the adoption of feeding and management practices was low.

Several studies have reported that protective vaccination against contagious diseases, fodder feeding, clean watering, and proper shelter for animals are the technologies having the highest adoption percentages. AI has been partially adopted at some places and not at others. Practices such as dehorning calves, castrating young calves, use of improved fodder seeds, crossbreeding, balanced feeding, and scientific milking have had very low adoption levels. (Singh 1978; Halyal et al. 1980; Sohal and Kherde 1980; Ramkumar 1989; Singh 1989).

Furthermore, some technologies are suitable for smallholders, while others are more suited to the large farmers. Sohal (1976) reported that spacious housing and year-round fodder production are more likely to be adopted by resourceful dairy farmers. Practices like taking special care of the

Table 3. Health care technologies.

echnology	Advantage	Remarks To be used by:
ange Cure (1997)	Cheaper and more effective than other available drugs and recurrence of infection is negligible	Farmers
ANGOL (1997)	-do-	-do-
ingworm cure (1977)	Present formulation is more effective and cheaper than the available marketed preparations	-do-
urn ointment (1977)	More effective and cheaper than other available drugs. No scar formation if applied immediately after burn injury	-do-
nactivated oil-emulsified duck virus hepatitis vaccine (1988)	Useful if the disease is reported. No vaccine against the disease is available at present	Farmers with the help of veterinarians
evelopment of live attenuated cell-culture propagated accine strain against avian reovirus infections. (1988-89)	The vaccine developed from indigenous isolated virus and therefore more effective	-do-
nactivated oil-emulsified egg drop syndrome-76 (EDS-76) accine (1994)	Better protection against prevalent virus strains	-do-
nactivated oil-emulsified Ranikhet disease (RD) vaccine 1994)	Long immunity to the breeder flock, helps in checking egg production losses due to RD, and chicks hatched from eggs of vaccinated breeders are immune to field exposure	-do-
nactivated oil-emulsified infectious bursal disease vaccine 1994)	As the technology uses indigenous strains it provides better protection	-do-
evelopment of inactivated oil-emulsified vaccine containing riple antigens. (ND+EDS-76+IBD) (1994-95)	Since vaccine contains all the three indigenous strains, it would give better protection, being more closer/homologous to the prevalent virus	-do-
ndigenous drug formulation against skin diseases of animals 1996)	Cheap, effective, and convenient to use	Farmers
atex Agglutination test - for goat pox diagnosis (1996)	Disease confirmation can be done at farm site by a skilled farmer. Losses due to spread of disease can be controlled sooner	Veterinary practitioners and farmers

...continued

Table 3. *Continued.*

Technology	Advantage	Remarks To be used by:
Experimental kit for maintaining the immune response against Newcastle (Ranikhet) Disease vaccination in chicks (1994)	Centrifuge and electricity not required, hence most suitable for field conditions	Veterinary practitioners
Experimental kit for monitoring the immune response against infectious Bursal Disease vaccination in chicks (1994)	The plates can be prepared at the farm, hence most suitable for field conditions	-do-
Plant molluscicide for control of aquatic pulmonate snails (1987)	Eradication of intermediate snail host which results in eradication of diseases such as Fascioliasis and Amphistomiasis	Farmers
Rinderpest tissue-culture vaccine	Good protection against disease	Farmers with the help of veterinarians
Foot and Mouth Disease (FMD) tissue-culture polyvalent vaccine	-do-	-do-
Hemorrhagic Septicemia (HS) Oil-adjuvant vaccine	-do-	-do-
Anthrax spore vaccine	-do-	-do-
Black Quarter (BQ) vaccine	-do-	-do-
BPL inactivated rabies vaccine	-do-	-do-
Tissue culture sheep pox vaccine	-do-	-do-
Goat pox vaccine	-do-	-do-
Lungworm pneumonia vaccine	-do-	-do-
Contagious caprine pleuropneumonia vaccine	-do-	-do-
Vaccine against infectious bronchitis in poultry	-do-	-do-
Modified live virus Rabies vaccine - Flury LEP (CEO)	-do-	-do-
Vaccine against Marek's disease in poultry	-do-	-do-
Vaccine against infectious laryngotrachitis	-do-	-do-
Lapinised swine fever vaccine	-do-	-do-

...continued

Table 3. *Continued.*

Technology	Advantage	Remarks To be used by:
B. abortus strain-19 vaccine	-do-	-do-
Salmonella abortus equi vaccine	-do-	-do-
Enterotoxemia vaccine	Provides good protection against disease	-do-
Fowl Pox vaccine (Chick Embryo Living Virus)	-do-	Farmers with the help of veterinarians
Fowl Cholera vaccine	-do-	-do-
Theileria Schizont vaccine	-do-	-do-
Horn Plate for internal fixing of long bone fracture in animals	Effective and speedy healing of bone joint and wound	Veterinary practitioners
COFAL test kit for diagnosis of avian leukosis	Effective and speedy diagnosis of disease	-do-
ELISA kit for diagnosis of FMD Virus	-do-	-do-
Timely treatment of sick animals	Avoidance of economic losses through reduced morbidity and mortality	Farmers with the help of veterinarians
Identifying a sick animal	Timely treatment of animals leading to better animal health and productivity	Farmers
Isolating the sick animals	Preventing the healthy stock from disease and infection	-do-
Observing the ectoparasites in animals at regular intervals	Better animal health and production	-do-
Regular deworming of animals	Better animal health and production	-do-
Year of release in parentheses wherever available		

Table 4. Livestock products processing technologies.

Technology	Advantage	Remarks To be used by:
Use of rabbit meat to prepare different products (sausages, patties, meatballs, *kababs*)	Economic profitability since the technology offers delicacy meat products. Employment generation	Farmers
Boiling of milk	Kills germs and makes milk safe for human consumption	
Preparation of milk products (*paneer*, *ghee*, butter, *shrikhand*, cheese, *rabri*, *rasgulla*, *sandesh*, yogurt.)	Increased economic profitability leads to increased employment	-do-
Preparation of various mutton and buffalo meat products (*tikka, kabab*, meatballs, curry, *keema, samosa*, sausages.)	Increased economic profitability and employment generation	-do-
Tenderisation of buffalo meat	Increase in sale value of meat and meat products	-do-
Preparation of various chicken meat products (curry, *tandoori* chicken, butter chicken, fried chicken, cutlets, sausages.)	Increased economic profitability and employment generation	-do-
Preparation of various pork meat products (curry, mince, Hamburger patties.)	Increased economic profitability and employment generation	-do-
Preparation of various fish products (fish *papad*, pickle, dried fish, fish curry, fish cutlets, *pakora*, fried fish.)	Increased economic profitability and employment generation	-do-
Preparation of various egg products (egg roll, boiled egg, fried egg, egg pickle, cakes.)	Increased economic profitability and employment generation	-do-

calves and feeding of good quality grass during periods of scarcity have a better chance of adoption by smaller farmers. Some other technologies, such as AI and pregnancy diagnosis, are almost uniformly applicable to all categories of farmers. A study conducted in the Karnal district of Haryana found that “feeding rations for milk production” by landless agricultural laborers, marginal farmers, small farmers, and medium farmers was a highly suitable innovation. On the other hand, vaccination against hemorrhagic septicemia (HS), rinder pest (RP), foot and mouth disease (FMD), black quarter (BQ) and anthrax was found to be most suitable for adoption by large farmers.

Sohal (2000) identified a number of constraints related to the adoption of various livestock technologies. He reported that the presence of unimproved bulls, males of crossbreeds, poor conception rates, and unavailability of AI facilities on farm are all constraints to adoption of breeding technologies. Unavailability of fodder seed, mineral mixture, and compound cattle feeds at convenient places, and their high costs, are the constraints in

Table 5. Management technologies.

Technology	Advantage	Remarks To be used by:
Early colostrum feeding to calves	Reduces calf mortality	Farmers
Regular control of parasitic infestations	Increase in the number of healthy calves and adults	-do-
Milk feeding according to recommended schedules	-do-	-do-
Milk replacer feeding	Reduced cost of calf rearing	-do-
Spacious housing with proper drinking water facilities	Savings in labor and increased production	-do-
Periodical spraying of sheds against parasites	Better health, growth, and production	-do-
Cleanliness of animals, sheds, utensils and workers	Avoidance of infections and diseases	-do-
Culling of animals of lower productivity	Increased profitability	-do-
Crossbred bullocks for draught purposes	Low priced	-do-
Dehorning	Avoidance of injury and horn diseases	-do-
Proper record keeping	Economic efficiency ensured	-do-
Cleaning the nostrils and body of newborn calves	Reduces calf mortality and maintains health	-do-
Maintaining regularity in feeding and milking	Better animal health and production	-do-
Right method of milking (full hand milking)	Avoids injury to teats and leads to higher production	-do-
Castration of male calves	Higher productivity and easy to control	-do-
Weaning of cattle/buffalo calves	Clean milk production and profitability	-do-

adoption of feeding technologies. The unavailability and high cost of medicine and absence of precise advice on cheap and comfortable housing are the main constraints to animal health and improved management practices.

Livestock Technologies and Small Production Systems

A number of technologies that are technically feasible under experimental conditions do not find wide acceptance among the final users because a majority of the users is either unaware of the technologies or unable to meet the requirements to make the technologies a success. Technologists attribute non-adoption or poor adoption to the inability of the extension systems to transfer such technologies, while extension personnel argue that farmers do not adopt technologies because of the mismatch between resource requirements of the technologies and their availability to the farmers. This is particularly the case with small and marginal farmers. Tables 6 and 7 present an analysis of such constraining factors.

Table 6. Typical physical constraints to technology adoption on small farms.

Features	Research Experimental Station	Resource-rich, organized large farms	Resource-poor, small unorganized farms
Livestock shed	Isolated, covered, with required drainage	Isolated, covered, with required drainage	Mixed, open, diversified, no proper drainage
Mobility of livestock	Controlled	Controlled	Uncontrolled
Feeding system	Stall-fed	Stall-fed and controlled pastures	Partly stall-fed, free-grazing on nativel pastures/waste lands
Drinking water	Controlled, clean	Controlled, clean	Village ponds, rivers, unhygienic
Environmental stress	Controlled environment	Controlled environment	No control on environment; stress due to summer heat, winter cold and rains
Hazards	Nil	Usually controllable	More common – floods, droughts, epidemics, etc.
Size of management unit	Large, contiguous	Large or medium, contiguous	Small, scattered, and fragmented
Diseases and pests	Controlled	Controlled	Animals vulnerable to infestation
Breed of animals	Descriptive and defined	Descriptive, defined and improved	Nondescript, mixed, local and less productive
Health status	Good, productive; unproductive animals culled	Good, productive, unproductive animals culled	Mixed, both productive and unproductive animals

ote: Not all conditions apply all the time, but most apply most of the time.

Table 7. Typical social and economic constraints to technology adoption on small farms.

Feature	Research Experimental Station	Resource-rich, organized large farms	Resource-poor, small unorganized farms
Access to livestock feeds, medicines, etc.	Unlimited, reliable	High, reliable	Low, unreliable
Tested quality semen	High quality	High quality	Low quality, unreliable, lack of accessibility
Drinking water and grazing pastures	Fully controlled	Controlled	Uncontrolled or controlled by others
Access to credit/cash	Unlimited	Good access	Poor access and shortage when most needed
Labor	Unlimited	Limited, hired	Family labor, constraints on occasion
Prices	Irrelevant	Lower for inputs Higher for outputs	Higher for inputs Lower for outputs
Appropriateness of technology generated on research station	Very high by definition	High	Very low

Issues In Livestock Technology Generation and Adoption

Animal science research has generated a number of useful technologies that can be gainfully adopted by farmers. The adoption level of most of the technologies is very low. The major reasons for the low level of adoption are:

- High cost of available technologies.
- Lack of awareness among the users (farmers).
- Lack of training in the proper use of technology.
- Technology is not situation- or farmer-specific.
- Inadequacy of veterinary facility for livestock in rural areas.
- Lack of adequate, organized processing and marketing facilities for animal products.
- Side effects of technology.
- Absence of field-testing and refinement of technology.

This analysis has questioned the appropriateness of livestock technologies under small farming systems prevailing in India. The alternatives are either to change the conditions as per the requirement of technology, which of course is impossible, or to generate technology appropriate to the resource-poor, risk-prone, diversified, and scattered small production units.

Generation of technology appropriate to such conditions is possible only through two approaches:

- Generation of technology through on-farm experimentation at the site and on the animals under small farming system units – which is difficult and not always possible.
- Generation of technology at the research stations and its subsequent assessment and refinement through experimentation in collaboration with the farmers.

The lack of established and standardized methodology for assessment and refinement of livestock technology and for conducting experimentation at the unorganized scattered small farm units needs to be viewed seriously. Research needs to be diverted to the design and development of such methodologies and approaches under participatory modes. Proper recognition and necessary incentives to the scientists, as well as farmers, would encourage participatory research.

References

Halyal, K.G., Chetani, L.M., and Popat, M.N. 1980. Adoption of improved animal husbandry practices in ICDP of Junagarh district. Rural India 100:225-227.

Kakoty, H.N. 1975. A study on the impact of ICDP on adoption of improved dairy practices by farmers around Guwahati city. M.Sc. Thesis (Unpub.), Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur.

Ramkumar, S. 1989. Adoption pattern of selected animal husbandry practices by dairy farmers: An extensive study. Journal of Educational Research and Extension. 25(4):192-197.

Singh, J. 1978. A study of some selected factors affecting adoption of dairy innovation by different categories of dairy farmers in the milkshed areas of Ludhiana milk plant. M.Sc. Thesis (Unpub.) NDRI, Karnal.

Singh, S. 1989. A study of differential level of knowledge and adoption of adopted village of dairy extension division, NDRI, Karnal. M.Sc. Thesis (Unpub.), NDRI, Karnal.

Sohal, T.S. 1976. Dairy farming technology for small, marginal, and agricultural laborers. Paper presented at National Seminar on Agricultural Technology and Extension Strategy for Small and Marginal farmers, PAU, Ludhiana.

Sohal, T.S. 2000. Constraints in the transfer of technology in livestock sector. Paper presented in Summer School on "Animal Husbandry & Veterinary Extension Education", May 8-28, IVRI, Izatnagar.

Sohal, T.S. and Kherde, R.L. 1980. A study of dairy adoption behaviour of small and marginal farmers in Punjab. Indian Journal of Extension Education 16(142):84-88.

Technological Developments in the Poultry Subsector

Raj Vir Singh, V K Saxena, and D Sharma[1]

The emergence of the modern poultry industry in India has its roots in backyard poultry farming. It began with the introduction of scientific poultry farming by a few Christian missionary organizations towards the end of the nineteenth century with imports of some improved poultry breeds from their countries. However, systematic efforts to develop the poultry industry on scientific lines began postindependence. In the last five decades (1950 to 2000), egg production increased from 2.8 million to 30,000 million. Similarly, broiler production too witnessed considerable growth. The tremendous growth in the poultry subsector is a result of application of modern technologies and growth of commercial poultry farming. There are now 60 thousand poultry farms under modern intensive systems of management. The indigenous fowl, however continues to play the key role in backyard poultry, and more than 100,000 families have flocks ranging from 5–250 birds.

The per capita availability of poultry products is considerably low; 30 eggs and 500g meat per annum as against the requirement of 160 eggs and 10 kg meat per annum. The growing human population and sustained growth in per capita income will fuel higher growth in demand for eggs and poultry meat. There is thus a considerable potential for development of the poultry subsector in the country.

Extensive research has been carried out in various areas of poultry production such as breeding, nutrition, health care, and management. The paper briefly discusses the research achievements in the poultry subsector, and identifies future research thrusts to accelerate its growth.

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Development of the Poultry Industry

Commercial poultry farming began under the first Five Year Plan (1951–55) with the establishment of 33 extension centers for providing improved breeds to interested farmers. The second Five Year Plan gave further impetus to backyard poultry farming in rural areas and commercial farming in urban areas. In subsequent Five Year Plans poultry developments efforts were further strengthened with aid from foreign agencies such as United States Agency for International Development (USAID) and United Nations Development Program (UNDP), and collaborations with foreign hatcheries.

Research Infrastructure

Poultry research is conducted in both the public and private sectors. In the public sector, ICAR, the apex organization for agricultural research in the country plays the key role in poultry research and development (R&D) activities. Research is carried out through its institutes such as the Central Avian Research Institute (CARI) and Indian Veterinary Research Institute (IVRI), Izatnagar project directorate, and also through 26 State Agricultural Universities (SAUs), and two veterinary universities. Other public sector institutions that contribute are Central Poultry Breeding Farms (CPBF), Central Food Technology Research Institute (CFTRI), and Animal Husbandry Departments of state governments. In the private sector the research focus is on pure-line breeding of layers and broilers, development of compounded feed, vaccines, and biologicals. Various poultry equipment such as incubators, hatchers, and farm equipment are also manufactured by private sector agencies.

Technological Change

Development of Superior Germplasm

Commercial Layers and Broilers

Production of superior germplasm was the main focus of poultry development. Since the indigenous fowl was central to backyard farming, initial efforts aimed at genetically improving the indigenous stock. Later, the large-scale import of elite poultry stock as grandparents by the private sector, and as pure lines by the public sector, opened the way for commercial poultry farming. The incorporation of elite stock provided poultry breeders with a choice and resulted in a substantial increase in poultry meat and egg production. Initially, White Leghorn was imported for egg production, and the breed was further improved through the family-selection method.

Subsequently, Rhode Island Red (RIR) populations were imported and other criteria for selection such as part-period production and egg mass were used for improvement. Rock and Cornish breeds were imported for crossing and selection to improve broiler production. Multi-trait selection index procedures were also used for selecting the better genotype in layers and broilers. The specialized selection and breeding programs such as Reciprocal Recurrent Selection (RRS), modified RRS and diallele were employed for selecting parent lines suitable for hybrid production.

The Central Avian Research Institute (CARI) explored possibilities for bringing an overall improvement in poultry productivity. A number of pure breeding programs were established at CARI, at different centers of the All-India Coordinated Research Project (AICRP) on poultry and at SAUs for development of superior germplasm of layers and broilers. The pure lines were then used for production of high-yielding hybrids. High-performing synthetic broiler stocks were also developed at the Punjab Agricultural University, Ludhiana (PAU), and CARI. As a result different superior layer and broiler stocks evolved and were released for use by the commercial poultry industry (Table 1).

Backyard Poultry Farming

The indigenous poultry population is approximately 70 million, with annual egg production of 55-60 eggs per hen and egg weight of 40 g. Early efforts for improvement of the indigenous fowl failed due to the introduction of high-yielding commercial stocks. There is now a new concept of “Phenotypic replica of indigenous fowl” in backyard poultry farming for improving productivity. A number of crossbred stocks resembling indigenous fowls have been developed (Table 2). Also, CARI has contributed significantly to the conservation and improvement of indigenous germplasm.

Testing and Evaluation of Germplasm

The superior stocks developed have undergone intensive testing by poultry breeders, large private hatcheries, nongovernmental organizations (NGOs),

Table 1. Genetically superior germplasm developed in the public sector.

Name of commercial stock	Type of stock	Name of the Institute
LI 80 (white egger)	Commercial layers	CARI, Izatnagar
ILM 90 (white egger)	Commercial layers	Kerala Agricultural University, Mannuthy
ILR 90(white egger)	Commercial layers	Andhra Pradesh Agricultural University, Hyderabad
HH 260 (white egger)	Commercial layers	CPBF, Bangalore
BH 78 (white egger)	Commercial layers	CPBF, Bombay
Kalinga Brown (brown egger)	Commercial layers	CPBF, Bhubaneshwar
CARI Gold 92 (brown egger)	Commercial layers	CARI, Izatnagar
CARI-RAINBRO (B-77) (colored plumage)	Commercial broilers	CARI, Izatnagar
IBL 80 (colored plumage)	Commercial broilers	PAU, Ludhiana
IBB 83 (colored plumage)	Commercial broilers	University of Agricultural Sciences, Bangalore
CARIBRO-VISHAL (91) (white plumage)	Commercial broilers	CARI, Izatnagar
CARIBRO RANGEELA (multicolored Plumage)	Commercial broilers	CARI, Izatnagar
CARIBRO-MRITUNJAI (CARI Naked Neck)	Commercial broilers	CARI, Izatnagar

Table 2. Poultry germplasm in rural poultry production.

	Characteristics			
Name	Type	56-day body wt. (kg)	Feather color	Purpose
Vanraja	Breed: cross	1.4	Graded brown	Dual/meat
Giriraja	Breed: cross	1.5	Graded brown	Dual/meat
AVM colored	Breed: cross	1.1	Mixed	Meat
Croiler	Synthetic	1.2	Graded brown	Meat
Maines T	Synthetic	0.7	Mixed	Tandoori
Krishipriya	Breed: cross	0.9	Graded brown	Dual
Grampriya	Breed: cross	1.0	Wheatish brown	Dual
Krishna J	Synthetic	0.6	Mixed	Egg
CARI-Gold	Breed: cross	1.0	Brown	Dual

and different centers using random sample poultry performance tests (RSPPT). Most of the layer and broiler stocks developed at CARI and different centers of the AICRP on poultry have repeatedly given excellent performances at RSPPT and were found comparable to those of private sector hatcheries. The commercial broilers developed at CARI attained a body weight of 1700 g at six weeks and 2100 g at seven weeks of age in RSPPT. The CARI stocks also had maximum survival rate and ranked higher in competition. The superior layer stock developed at different institutions showed encouraging performance. CARI-Golden stock topped the brown egger entries with an egg production (HH) of 281and 283(HD) at random sample layer test (RSLT).

Required Inputs

To increase and sustain productivity of superior stocks, inputs such as quality feed, better health care, and a package of management practices need to be strengthened. The research and technological advancement in these areas are summarized below.

Nutrition and Feed Technology

Feed accounts for 70–75% of the total operational cost of poultry production. Therefore, improving feed efficiency is important in maximizing profitability. Poultry feed formulations were developed/revised for tropical climatic conditions and alternative and nonconventional feed resources were identified. Research proved the acceptability of de-oiled rice polish, sorghum, finger millet, pearl millet, and rice polish in poultry mashes and de-oiled sunflower cake, and ramtill cake as protein sources. The fishmeal was reduced and replaced by synthetic amino acids (lysine and methionine) and vitamins.

The nutrient requirement of different classes and age groups of birds were determined to optimize production. Methods for improving nutrient values (enzyme utilization) were evolved, nonconventional poultry feeds were identified, and procedures for detoxification and improving the quality of feedstuff were standardized. The important technological innovations and their utilities in the area of poultry nutrition are presented in Table 3.

Table 3. Important technological innovations in poultry nutrition.

Name of technology	Example	Utility
Low cost ration		
a. Use of agro industrial by-products	De-oiled rice polish, de-oiled sunflower cake, soybean meal, salseed cake	• Reduces cost without affecting nutritive value of feed
b. Alternative protein sources	Meat meal, silkworm pupae meal, Lucern meal	• Uses feed ingredients not used by humans
c. Use of by-products and wastes	Manure, mortalities and feather meal, hatchery waste	• Recycling of waste
d. Use of probiotics	Lactobacillus sp., Streptococcus sp., Pediococeies sp., Bacillus sp.	• Establishes favorable intestinal flora • Serves the function of antibiotic feed additive
e. Use of antibiotic feed additives	Zinc, Bacitracin, Oreomycin, Monnacin	• Promotes growth and feed conversion efficiency (FCE)
f. Use of feed grade enzymes	Hemicellulase, cellulase, amylase, tannase, phystase, proteinase	• Improves nutritive value and feed utilization • Improves body weight gain and FCE • Reduces volume of excreta
g. Feed processing	Pelleting /crumbing	• Improves growth and FCE by 10%-25% • Releases encapsulated nutrients • Improves digestibility of food • Reduces deleterious factors

Health Care and Biosecurity

High mortality and morbidity caused by various diseases have been the major handicap in poultry production in the past. The facilities for disease diagnosis and production of pharmaceuticals and vaccines were inadequate. However in the last three decades there has been a significant breakthrough in poultry disease control. At present there are about 250 diagnostic laboratories, 28 veterinary colleges, three major vaccine-producing projects in the private sector and 14 in the public sector. The advances in technologies such as Specific Pathogen Free (SPF) egg, monoclonal antibodies, rDNA and membrane antigen system are used for vaccine production. Research has generated effective diagnostic measures and vaccines against several killer diseases such as Newcastle Disease (ND), fowl pox (FP), Marek's disease

(MD), and Infectious Bursal disease (IBD). There is still, however, a lack of facilities for testing vaccine efficacy, spot diagnosis, and farmer-oriented health care in rural areas.

Uncontrolled movement of poultry and its products has further complicated the situation. The changing management practices have enabled pathogens to modify themselves and appear as new pathogens causing new diseases. There has been a re-emergence of old diseases such as ND, Avian Influenza (AI) and FP, and new disease problems such as leechi disease, Inclusion Body Hepatitis (IBH) and Egg Drop Syndrome (EDS) have also emerged. Variation of recognized diseases such as IBD, Infectious Bronchitis (IB), and MD and syndromes, resulting from the interaction of more than one pathogen, such as Swollen Head Syndrome (SHS), Blue Wing disease, and infectious enteropathies have also been observed. Biotechnological tools such as diagnostic probes and PCR-based DNA amplification have proved useful in proper diagnosis. Use of endogenous and thermostable microorganisms for vaccine development have proved efficient in controlling diseases in rural areas. The development of immunomodulators and pharmaceuticals has also contributed significantly.

Poultry Reproduction

Poultry reproduction technologies have contributed considerably towards increasing the use of superior germplasm. Advances in semen evaluation, semen diluents, and artificial insemination of poultry germplasm have all helped augment the production. A simple semen diluent has been developed that successfully preserves the fertilizing ability of chicken spermatozoa for 24 hours at low temperature. A technique for evaluating the fertilizing ability of male quail has also been developed.

Poultry Equipment

India has made considerable progress in manufacturing a wide range of housing, incubation, watering, and vaccination equipment. The automation and innovation in poultry-shed ventilation and environmentally controlled houses have been demonstrated widely. There has been a rise in the use of automated feeding and drinking systems, nipple and cup drinkers, mediators and dosers, electric time switches, manure drying and disposal machines, and beak trimming and mass vaccination equipment. The hatchery equipment segments are manufacturing large incubators.

Automatic small, broiler processing plants that meet local demand and export norms are the need of the new millennium. The quality of factory-dressed chicken, cut-up parts, and deboned chicken needs to be improved.

Potential Benefits

The superior stocks of broilers and layers have altogether revolutionized the poultry industry. In the 1950s a layer used to produce 200–220 eggs with an efficiency of 3.4–3.5 kg feed kg^{-1}egg., which has now increased to 290–300 eggs with efficiency of 2.5–2.6 kg feed kg^{-1} egg. Similarly, 30–40 years ago, broilers used to attain a body weight of 0.8 kg in eight weeks and approximately 3.2 kg feed was required per kg body weight. Now, average body weight reaches 1.7–1.8 kg, with feed efficiency of 1.8–2.0 kg feed kg^{-1} live weight at six weeks.

Adoption of Technologies

The level of adoption of technologies in the organized sector has been adequate. A large number of farmers and commercial poultry breeders have adopted many technologies related to poultry breeding, nutrition, health and management. However, in the unorganized sector, the adoption is slow due to several constraints. On average, more than one-third of the total poultry population in the country belongs to the improved category.

The dissemination and adoption of technologies take place via different pathways. In the public sector, the ICAR institutes such as CARI, Izatnagar and Project Directorate on Poultry (PDP), Hyderabad are the main centers that develop technologies and disseminate them among farmers, large private hatcheries and NGOs. The large commercial breeders and hatcheries in the private sector procure and develop the superior grandparent stock. The parent stocks are sold to the franchisees, which ultimately produce the commercial hybrids that are sold to end-users. Thus, there is a network of functionaries engaged in poultry farming.

The superior stocks require better feed, proper vaccination, medication, and a package of improved management practices. The main constraint in the adoption of technologies is higher cost of inputs resulting in low profitability. Fluctuating market trends in terms of seasonality in consumption of poultry products and their prices also restrict adoption. Various myths prevalent in Indian society were also responsible for the non-adoption of new techniques during the early years of introduction of improved poultry. These included the idea that the egg from the indigenous fowl is more nutritious than that of commercial hybrids, and that the same holds good for the meat. Illiteracy, lack of awareness, and religious taboos have also been major causes for slow adoption of poultry technologies. The myths are however on the wane and increasing literacy and easily available credit facilities are encouraging poultry farmers to adopt new technologies.

Other Poultry Germplasm

The chicken has been in the forefront of research because it accounts for more than 90% of the poultry population. Ducks come next and are popular in states such as Assam, West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala and Tripura. However, the research efforts on ducks are severely lacking.

Quail has enormous potential as a producer of meat of excellent quality, taste and delicacy. Quails were primarily imported as pilot animals in 1974 at the Poultry Research Division (now the CARI) of IVRI. The good qualities of quail include smaller gestation interval, small space requirement, and high productivity, making this species suitable for commercial exploitation. The research at CARI has led to production of superior stock (Table 4), as well as development of a package of practices for quail farming. Quail meat and eggs are now becoming popular in several parts of the country. Nevertheless, more research efforts are required to expand quail farming.

Research on guinea fowl was initiated about a decade ago. Selective breeding for juvenile weight and high immunocompetence has resulted in increased body weights (Table 4) and improved lifespan. Guinea fowl is popular for its excellent meat, foraging habits, inherent hardiness, and resistance to common poultry diseases. Recently, research on turkeys has also been initiated at CARI with the objective of developing an adaptable small turkey.

Emerging Technologies

Ex Vivo Embryo Culture, Chimera Production and Transgenesis

The advances in the areas of molecular biology and embryo manipulation have made it possible to transfer the gene of choice from a donor to a heterologous

Table 4. High-yielding germplasm (other than broiler and layer chicken) developed at CARI, Izatnagar.

Germplasm	Plumage color	Utility	Performance status
Desi type (Cross) Chicken			
CARI-Nirbhik (Aseel Cross)	Colored	Backyard	190 eggs $annum^{-1}$ and plentiful meat
CARI-Shyam (Kadaknath Cross)	Colored	Backyard	210 eggs $annum^{-1}$
UPCARI (Frizzle Cross)	Colored	Backyard	220 eggs $annum^{-1}$, and adapted to hot climates
HITCARI(Naked neck Cross)	Colored	Backyard	220 eggs $annum^{-1}$, and adapted to hot climates
Quail (Japanese)			
CARI-Shweta	White	Meat type	165g at 5 weeks, and 245 eggs $annum^{-1}$
CARI-Uttam	Wild	Meat type	182g at 5 weeks, and 285 eggs $annum^{-1}$
CARI- Ujjwal	White breasted	Meat type	167g at 5 weeks, and 270 eggs $annum^{-1}$
CARI-Pearl	Wild	Egg type	113 g at 5 weeks, and 280 eggs $annum^{-1}$
Guinea Fowl			
Guncari-Swetambri	White	Meat	863 g at 12 weeks
Guncari-Kadambri	Pearl	Meat	871g at 12 weeks
Guncari-Chitambri	Lavender	Meat	834 g at 12 weeks
Turkey			
CARI-Virat	White	Meat	1805 g, 5040 g and 6448 g at 8, 24, and 30 weeks, respectively

recipient to augment its production or to produce the pharmaceuticals/ protein of choice. The chick has become a classical model system in developmental biology, providing a vast amount of detailed morphological and descriptive data of the processes of growth and differentiation. Traditional work in chickens has also led to significant advances in the understanding of vertebrate immunology and physiology.

There has been excellent progress in the background techniques required specifically for poultry such as the double window ex vivo embryo culture system, single stage embryo-culture system, and ex vivo culture system for Guinea fowl and quail. The first millennium chick and the world's first guinea fowl keet using ex vivo embryo culture system were produced at CARI. These new techniques and modifications have improved embryo survival rate and enabled faster and easier application of microinjection, and blastodermal cell- and primordial germ cell (PGC) transfer procedures for production of transgenic poultry.

The stage X blastoderm cells collected from freshly laid eggs contain PGC and start to differentiate at around stage X from the pluripotent blastodermal cells. For transgenic chicken to be produced using blastodermal cell chimeras, techniques for in vitro genetic modification of blastodermal cells are required. Since chicken embryonic stem cell lines are currently unavailable and blastodermal cells capable of forming germline chimeras can only be maintained in culture for up to seven days, research to date has focused on the transfection of freshly isolated blastodermal cells.

Breeding for Tolerance to Climatic Stresses

Certain major genes, such as those for the naked neck and frizzle, contribute significantly to heat stress tolerance. These genes reduce the total feather cover and the feather structure of the bird to enable more efficient heat dissipation. Research has resulted in the production of a naked neck population (CARI-MRITUNJAI) that is better adapted to tropical climates. Naked neck stocks developed at CARI performed excellently when tested at different centers of RSPPT and in the field.

Molecular and Immunocompetence Investigations

Variability is one of the important tools for improving stocks. The variability investigated at genome level, through RAPD-PCR and DNA fingerprinting, enables selection of suitable parents for production of commercial hybrids. Research on these lines has generated a lot of data in layers and broilers. Molecular investigations may thus prove of immense value in augmenting production through production of further superior germplasm.

Genetic resistance to diseases has always been an important issue for poultry research. Several investigations have shown that indirect selection by incorporating immunocompetence traits into selection procedure is the best method for enhancing the bird’s overall resistance to diseases. Investigations have shown that commercial broilers have high immunocompetence levels. Further investigations through marking lines for immunological traits and studying the differences at major histocompatibility complex (MHC) region are under way in order to find suitable marker(s)/immunological trait(s) that can be used as selection criteria.

Future Perspectives

Although the poultry industry has grown tremendously on all fronts there is still scope for improving productivity. The explosion of knowledge in molecular biology will have profound impact on all branches of poultry science.

Molecular Genetic Mapping and Transgenesis

- Good progress has been made at integrating poultry maps, representing some 1400 loci so far. The average spacing between markers on the combined linkage maps is approaching 2 centiMorgans (cM), which is adequate for knowing the location of functional genes. Such a minimal genome map is normally a prerequisite for locating useful Quantitative Trait Loci (QTL) for subsequent marker-assisted selection (MAS). In the future, researchers will attempt to integrate MAS optimally with the conventional quantitative genetics approach to poultry breeding.
- Identification, localization, and cloning of useful candidate genes are prerequisites for their manipulation to produce transgenic chicken using the new rDNA technology
- There has been considerable progress in development of background techniques for producing transgenic poultry. Application of these could enable dramatic gains in egg and meat productivity, disease resistance, and production of human proteins in eggs.
- Transgenic poultry would help to give new insights into many areas such as immunology, cancer biology, developmental biology, and physiology. The production of transgenic chicken will give scientists a unique opportunity to investigate gene expression and function within the complexity of a living organism.
- The time scale of progress in molecular biotechnology is largely proportional to the resources made available for the necessary research and development. In the case of poultry biotechnology, the resources have been minimal and need to be increased substantially.
- Poultry biodiversity, i.e. the set of genetically diverse poultry resources, must be preserved and conserved to sustain agricultural development.
- Blastodermal cells, PGCs, DNA, and spermatozoa can be preserved in the form of genome banks storing these at -196 ^{0}C in liquid nitrogen.

Poultry Health

- The application of molecular biotechnology to produce improved diagnostic kits and vaccines is now well established and will continue to grow as a major component of disease control in the years ahead.
- Increasing the innate resistance of birds to infections and parasites can increase disease control.
- Significant progress has been made in recent years on many aspects of the immune system and MHC-related basic studies that will ensure practical industrial applications in the near future.
- Low-cost thermostable vaccines and effective disease control of poultry in rural small-scale poultry production are required.
- Disease surveillance and forecasting systems need further strengthening.

Poultry Nutrition

- Basic research in nutritional biochemistry and physiology requires attention so that future nutritional technologies can be more science-based and less empirical.
- Alternative and cheaper ingredients for poultry feed must be developed, preferably locally.
- Production of genetically modified feeds with higher nutritive value for poultry should also be looked into more seriously.
- The definition of specific nutrient requirements for new and specific strains of poultry should become a regular feature of applied nutrition research.
- Low cost feed supplements should be developed based on local ingredients not used for human consumption.

Poultry Reproduction

- The poor reproductive performance of broiler breeder females should be given priority in poultry reproduction research. Solving the problem will depend on a deeper understanding of the basic neuroendocrine mechanisms involved.
- A further area of research likely to yield practical applications is that of the genetics of sex determination and the possibility of manipulating the sex ratio, i.e., to maximize female chicks in commercial layer strains or male chicks in commercial broiler strains.

General Considerations

- Cost effectiveness of various technologies should be evaluated.
- Collaboration among institutes and with NGOs and related agencies should be encouraged.
- Superior genetic stocks should be imported as and when required for improving efficiency of breeding programs.
- Poultry science courses must be given more emphasis at graduate and post-graduate levels in all the veterinary colleges and universities.

Goats in India: Status and Technological Possibilities for Improvement

Shalander Kumar and K P Pant[1]

The goat is one of the most important species of livestock in India. It has short generation interval, high prolificacy, and is easily adaptable to a wide range of climatic conditions. These characteristics give it a greater relevance in the household economy of the poor, particularly in the marginal environments including arid, semi-arid, and mountain regions. In these environments rainfall is erratic and frequency of crop failure is high. The goat is capable of surviving on sparse vegetation and in extreme climates.

Goat meat is the most preferred meat in the country. Almost 95% of the goat meat produced in the country is consumed locally; though per capita availability is far below the requirement. The goat produces a variety of other useful products and by-products including milk, skins, fleeces, and manure. In hilly regions, goats are valued for both meat and fine fiber (pashmina) production.

The productivity of goats in India is low. The average carcass weight is only 10 kg, lower than the world average of 12 kg. The milk productivity is also low. One of the main causes of low productivity is lack of adoption of scientific methods of production, and limited commercialisation of goat keeping. Nevertheless, there is considerable potential to raise the productivity of goats and their economic and food security contributions, as India has a large number of important breeds of goat. This paper examines the population dynamics and contribution of goats, and identifies potential technologies for improving meat and milk productivity.

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Growth and Contribution

Goats constitute an important productive asset of the country that generates a flow of income and employment throughout the year, especially for the landless, marginal, and small landholders. These constitute about 85% of all households, but occupy only one-third of the total land in India. On the other hand, the distribution of livestock wealth, including sheep and goats is more equitable. These households maintain about 71% of the small ruminant population largely on common lands and harvested fields. Thus, they can be profitably raised with low investment in extensive and semi-intensive systems.

The goat population in India has increased faster than all other major livestock species during the last two decades (Table 1). From 1972–97, goats increased at an annual rate of 2.7%, despite nearly 41% of goats being slaughtered annually, and another 15.5% dying of natural causes.

The monetary contributions of goat to the Indian economy are given in Table 2. Meat contributes more than half of the total output of goats, followed by milk, by-products, skins, and manure.

Density and Distribution

Due to the goat's adaptability to a variety of agroclimates, the goat population is distributed widely throughout India. Yet there are marked variations in its distribution and density across states (Table 3). Livestock policy aimed to restrict the goat population to 40 million and increase the number of sheep to 70 million by 2000 A.D. (Govt. of India, NCA, 1976). Despite this, the population of goats rose to 115 million in 1992, whereas the population of sheep remained at 51 million. This reflects the socioeconomic relevance and wide adaptability of goats.

Table 1. Population growth rate of goats vis-à-vis other livestock species in India.

	Population (million)		Annual compound growth rate (%)				
Species	1951	1992	1972–77	1977–82	1982–87	1987–92	1972–92
Cattle	155.3	204.5	0.2	1.3	0.7	0.5	0.7
Buffalo	43.4	84.2	1.6	2.4	1.2	1.9	1.9
Sheep	39.1	50.8	0.5	3.5	–1.3	2.1	1.2
Goat	47.2	115.3	2.3	4.7	3.0	0.9	2.7

Source: Govt. of India 1972, 1977, 1982, 1987, and 1992.

Table 2. Contribution of goats to the Indian economy, 1994.

Product	Quantity (thousand t)	Value (million Rs)
Meat	470	27 360
Milk	2 200	11 000
Pashmina	0.04	20
By-products	-	3 650
Manure	18 790	1 879
Blood	46	46
Skin	-	3 283
Total		47 283

Table 3. The density and distribution of goats in India.

State	Population (million)	Density (goats km^{-2})
Andhra Pradesh	4.3	15.7
Assam	3.5	44.0
Bihar	17.5	100.4
Gujarat	4.2	21.6
Haryana	0.8	18.1
Himachal Pradesh	1.1	20.8
Jammu and Kashmir	1.8	8.0
Karnataka	6.3	32.8
Kerala	1.9	47.6
Madhya Pradesh	8.4	18.9
Maharashtra	10.0	32.3
Orissa	4.9	31.7
Punjab	0.5	10.8
Rajasthan	15.3	44.7
Tamil Nadu	6.3	48.8
Uttar Pradesh	13.1	44.5
West Bengal	14.2	159.7

Source: Govt. of India. 1972, 1977, 1982, 1987, and 1992.

Their population is concentrated largely in Bihar and West Bengal in the east; Rajasthan, Maharashtra, and Madhya Pradesh in the west; and Uttar Pradesh in the north. The density of goats is highest in West Bengal (160 goats km^{-2}), followed by Bihar. In Assam, Kerala, Madhya Pradesh, Rajasthan, Tamil Nadu and Uttar Pradesh there are 40–50 goats km^{-2}. The lowest density is in Jammu & Kashmir (8 goats km^{-2}), closely followed by Punjab.

Goats are often blamed for denuding the vegetative cover and causing desertification. If the density of goats is an indicator, the blame is unfounded. West Bengal and Bihar have the highest densities of goats, but there are no signs of desertification in these states. It is undoubtedly true that large populations of goats or any other livestock continuously grazing throughout the year in a small area would be extremely harmful to the growth of vegetation. Deforestation coupled with overgrazing by livestock will also have adverse consequences on the forests and wastelands (Acharya 1992). Therefore, in order to get the best from the system, the animals and common property resources (CPRs) must be properly managed.

Technologies for Enhancing Goat Productivity

The Central Institute for Research on Goats (CIRG), an offshoot of ICAR, is the main institute that conducts basic and applied research on goat production. The Institute has developed technologies and standardized methods for improving the productivity of goats. If effectively transferred to the goat farmers, these would go a long way in improving goat productivity. The rest of the paper deals with the technologies available for application in the field.

Genetic Improvement of Goats

There are twenty well-recognized goat breeds in India suited to different geographical and climatic conditions. Since 1971, systematic scientific efforts have been made to improve the genetic potential of goats in terms of increasing milk, meat, and fiber production. The superior germplasm, especially those of Barbari and Jamunapari breeds maintained at CIRG, could be used for breeding high-yielding animals.

Optimizing Survival of Goats

The well-managed goat is less likely to succumb to diseases. Those such as *peste des petits ruminants* (PPR), foot and mouth disease, brucellosis, and pustular dermatitis are widely prevalent in different regions. A number of research projects in the area of goat health have been successful to some extent in reducing mortality due to diseases. The CIRG has developed an annual goat health calendar for organized flocks (Table 4). Implementation of

Table 4. Annual preventive goat health calendar.

	Months											
Operations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vaccination												
Foot and mouth						+						+
disease (FMD)*						+						
Foot and mouth												
disease (FMD)**												
ET		+						+				
peste des petits ruminants (PPR)	+											
Sheep pox#											+	
Hemorrhagic septicemia (HS)						+	Or+					
Drenching												
Coccidiosis				+			+					
Parasites						+	Or+			+		
Dipping												
Lice				+						+		
Ticks					+	+	+					
Watch for												
Ecthyma				+	+					+		
Coccidiosis					+				+		+	
Tapeworm		+		+	+							
Haemonchus										+		
Ticks						+	+	+	+			
Wounds #						+	+	+				
Abortions	+						+	+				+
Pod-Toxicity						+	+	+				
Screen for												
Brucellosis				+	+						+	+
Johne's disease											+	

* Immunity 6 months ** Immunity one year # Only for sheep.

this calendar could help check the mortality and production losses due to diseases up to 70 percent.

Artificial Insemination

Limited access to good quality breeding bucks is one of the reasons for low productivity of goats. Artificial insemination, which has been standardized, could be used effectively as a breeding method for multiplication of superior quality animals. Semen production potentials have been worked out for breeds such as the Jamunapari, Baribari, Jhakrana, Kutchi, Marwari, and Sirohi. Studies have been conducted on sexual maturity and optimal age for semen production in different goat breeds. Bacterial load in buck semen has been worked out. A protocol for freezing buck semen has been developed that retains 50–55% motility and 40% fertility. The deep cervical insemination technique with freshly diluted semen has been standardized with a 75% fertility rate in goats. A fertility rate of 50% has been obtained with frozen semen using deep cervical insemination.

Structures and Appliances for Organized Goat Farms

Various structures and appliances for goat farms have been standardized that are essential for better management and the higher growth rate of goats. They also reduce contamination and wastage of feed.

Provision of optimum floor space in goat houses is essential for the comfort of goats and to maintain higher survival rates and minimize disease incidence. Goats need covered as well as open space (paddock), and the requirement for the latter was found to be different for different age groups. Table 5 shows the optimal floor space requirement for goats at different ages.

Ventilation Space

Proper ventilation provides enough oxygen for the animals, helps remove spent gases and moisture, and maintains a suitable vapor pressure in the shed. Ventilation also allows sufficient sunlight into the sheds. Ventilation of sheds affects the performance of goats and should be maintained at an optimum. In

Table 5. Optimum floor space requirement for goats.

Category/ age of goat	Floor space (m^2 $goat^{-1}$)	
	Covered	Open space
0 – 3 months	0.2 – 0.3	0.4 – 0.6
3 – 9 months	0.6 – 0.8	1.2 – 1.5
9 –12 months	0.8 – 1.0	1.5 – 2.0
Yearlings (above 12 months)	1.0	2.0
Adult bucks	1.5 – 2.0	3.0 – 4.0
Lactating does	1.5	3.0

hot dry periods a total ventilation space 70% of the floor area should be provided. In hot humid regions, two facing sides of the wall should be kept totally open. During cool weather, 2–10% ventilation is required, and during the rest of the year ventilation space should not be less than 25%.

A set of suitable feeders and watering mangers for goats of different age groups were developed for use in organized goat farms and villages to reduce contamination and wastage of feeds. Skilled and semi-skilled persons can fabricate this equipment in small workshops, using easily available materials such as angle iron, GI sheets, iron bars, and welding rods. The feeders and watering mangers were extensively tested and found suitable for use by both goats and sheep. The height of the feeding trough should be kept at the average shoulder point height of the animal for goats aged more than three months. For kids below three months the height should be 25% less than the average shoulder point height. The feeders developed were suitable for feeding of concentrate, pelleted feed, dry fodder (straw), green fodder, and silage. The wastage of feed materials was reduced drastically using these, and there was no contamination by goat feces and urine.

Grazing and Carrying Capacity

As grazing resources are shrinking, tree fodder will be an important alternative for feeding goats. Harvested dried leaves could form part of a complete feed (pellets). Some of the promising feeds are 1) 60% Anni (*Chlorodendron phlomides*) leaves, and 40% concentrate mixture (maize, barley, groundnut cake, sesame cake, mineral mixture and salt); 2) 40% Heens (*Capparis horrida*) leaves, 20% Arhar (*Cajanus cajan*) straw, and 40% concentrate mixture; and 3) 40% neem (*Azadirachta indica*) dry leaves (winter season), 30% arhar straw, and 30% concentrate mixture.

Urea treatment was found to be economical for improving poor quality straws. A complete ration was formulated using treated barley straw 47%, barley grain 32%, arhar straw 20% and mineral mixture with salt 1%, which can maintain adult goats.

Twenty percent subabul (*Leucaena* spp.) leaves in a complete feed yielded better growth and higher carcass production. Leaves of indigenous babul (*Acacia nilotica*) at 15% level in a complete feed were found to improve milk productivity. Subabul also has potential as feed for chevon production as it has no deleterious effect on various economic traits and carcass characteristics.

Value-added Products

Meat from Spent Goats

A nutrient dense shelf-stable dehydrated minced meat product (Chevon) has been prepared from spent (those animals that are no longer useful or productive) goats using 20% split dehusked lentil paste. Good quality chevon pickle with better shelf life at ambient temperature could be prepared using mustard oil, acetic acid, dry and green spices, and cane sugar (flavor enhancer). Curing and mechanical tenderizing of partially frozen meat chunks from spent goat carcasses helped overcome the problem of dark red color, strong flavor, and toughness. Good quality sausages with higher yield were manufactured from spent buck meat and have a shelf life of seven days under refrigeration.

Incorporation of 0.5% phosphate mixture in *shami kabab* formulation resulted in an improvement of organoleptic scores, and yield and retention of the product's organoleptic traits on cold storage. The major cause of spoilage was visible surface mold growth. The product could safely be preserved for 14 days under refrigeration. Good quality Chevon *samosa* may be prepared from spent goat meat using 10% cooked mashed potatoes. Goat stomach, often rejected by meat eaters, can be used to manufacture a crisp snack containing 55% protein.

Goat Milk Products

Good quality *paneer* could be prepared from goat milk using citric acid (0.15% w/w) and fermented *paneer* whey as coagulants. *Paneer* packed in polypropylene bags could safely be preserved for three days under refrigeration (4$\pm$1°C). Addition of 2.0–2.5% food grade gelatin was found beneficial for producing goat milk *shrikhand* of desired quality. The *shrikhand* could be preserved safely in glass containers for three days at ambient temperature and 30 days under refrigeration (4$\pm$1°C). Among the nonconventional milk coagulants used, *chhana* prepared using lactic acid was found superior to *chhana* prepared using hydrochloric acid solution, fermented *paneer* whey, and citric acid.

Conclusions

The technologies and methods discussed in this paper have the potential to enhance the productivity and thereby the profitability of goats. Although both small and large goat farmers could use these, technologies befitting small farmers are needed for development of these systems.

To ensure sustainable development of goat husbandry, the research and development efforts in the following areas should be given priority:

- Provision of good quality breeding bucks.
- Intensified efforts to prevent and control diseases, especially PPR and Johne's disease.
- Improvement of common grazing resources.
- Cessation of slaughter of underage animals.
- Commercialization and intensification of the goat enterprise.

References

Acharya, R.M. 1992. Pages 49-53 *in* Recent advances in goat production. Proceedings of the fifth International Conference on Goats, 2-8 Mar 1992, New Delhi, India.

Government of India. 1972, 1977, 1982, 1987, and 1992. Livestock Census. Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi.

Government of India. 1976. Report of the National Commission on Agriculture, Part VII, Animal Husbandry, Ministry of Agriculture and Irrigation, New Delhi.

Enhancing Productivity of Sheep: Technology Dimensions

B U Khan, A L Arora and R C Sharma[1]

Sheep husbandry is an important enterprise in the arid and semi-arid areas of India characterized by sparse vegetation, marginal land, and a high incidence of poverty. It is a low-investment sustainable enterprise yielding reasonably high rates of return. The sheep are valued for both mutton and wool production, although sheep productivity in terms of both is low. Wool yield in India is about 0.9 kg annum^{-1}, about 60% less than the world average. The mutton yield is about 12 kg annum^{-1}, compared to a world average of 15 kg annum^{-1}. The reasons for low productivity of sheep in India are poor exploitation of genetic potential of native stock, inadequate feed resources, nutritional deficiency, heat stress, poor health monitoring, and inadequate marketing and credit support to sheep owners.

Various breeding strategies have evolved for improving body weight, and wool production and its quality. The emphasis has been on improving the production and quality of apparel wool. Limited efforts have been made to improve the production and quality of carpet wool or mutton production. A number of sheep strains have been evolved in India through crossbreeding of indigenous sheep with superior temperate breeds such as Dorset, Suffolk, Rambouillet, and Merino. The developed genotypes have demonstrated their production potential under experimental conditions. This paper attempts to document the technologies that can be employed gainfully under field conditions.

Sheep Biodiversity

India is a rich repository of sheep genetic resources and diversity. Sheep diversity is related basically to the geography of the region, production system,

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ecological and environmental variations, and the genetic constitution of breeds. India has the fourth largest sheep population in the world, accounting for 4.6% of the global population. The country produces about 2% of the world's sheep meat, 0.8% of raw wool, and 1.1% of scoured wool. It is estimated that India produces about 169 million kg of mutton, 42.7 million kg of wool, and 40 million skins annually. The national sheep flock is worth Rs 24 billion producing an annual flow of outputs worth Rs 8 billion.

The sheep population remained almost static at about 40 million until the 1970s. In 1982, it increased to 49 million, and then declined to 45.7 million in 1987. In 1992, there was a subsequent increase to 51 million (Table 1). The decline in 1987 was due mainly to widespread drought in the country, which resulted in a higher slaughter rate in that year.

The four distinct sheep breeding tracts in the country are North Temperate (Himalayan region), Northwestern (Rajasthan, Maharashtra, Gujarat, Madhya Pradesh), Eastern (West Bengal, Bihar), and Southern Peninsular (Andhra Pradesh, Karnataka, Tamil Nadu). The regional distribution of sheep breeds is shown in Table 2. There are 57 breeds of sheep in India. Most of these are nondescript due to indiscriminate breeding and intermixing of breeds. They have evolved primarily through natural selection under the prevailing climatic conditions (usually harsh), migration, tropical diseases, poor nutrition, and shortage of drinking water. There are no breed societies or agencies that register animals of a particular breed, maintain flock books, or the purity of breed or type. The bulk of sheep is raised in the

Table 1. Sheep population trends.

Census year	Population (millions)	Annual growth rate (%)
1951	39.1	-
1956	39.3	0.1
1961	40.2	0.5
1966	42.0	0.9
1972	40.0	–1.0
1977	41.0	0.5
1982	48.8	3.5
1987	45.7	–1.3
1992	50.8	2.1

Source: AHS Series-6, Deptt. of Animal Husbandry and Dairying, Govt. of India, New Delhi.

Table 2. Sheep breeds and their distribution in different regions.

North temperate	Northwestern	Eastern	Southern peninsular
Gaddi (CW)	Chokla (CW)	Chhota Nagpuri (MCW)	Deccani (M)
Rampur Bushair (CW)	Nali (CW)	Shahbadi (M)	Bellary (MCW)
Poonchi (CW)	Marwari (MCW)	Belangir (MCW)	Nellore (M)
Karnah (AW)	Magra (CW)		Ganjam (MCW)
Mandya (M)			
Gurez (CW)		Jaisalmeri (MCW)	Bonpala (MCW)
Hassan (M)			
Kashmir Merino (AW)	Pugal (MCW)	Garole (M)	Coimbatore (MCW)
Changthangi (CW)	Malpura (M)	Tibetan (CW)	Nilgiri (AW)
Bhakarwal (CW)	Sonadi (MCW)		Ramnad White (M)
	Patanwadi (CW)		Madras Red (M)
	Muzaffarnagari (MCW)		Trichi Black (M)
	Jalauni (MCW)		Kanguri (M)
	Kheri (M)		Kilakarsal (M)
	Munjal (M)		Mecheri (M)
			Vembur (M)

Note: Figures in parentheses are the major products of each breed: AW = Apparel wool; CW = Carpet wool; MCW = Mutton and Carpet wool; M = Mutton.

northwestern arid and semi-arid regions. In the north temperate regions sheep are mainly raised for apparel wool. Sheep are raised mainly for mutton in the southern peninsular region. Management, husbandry systems and breeds, in each of these agroecological zones, are distinctly different.

Technologies for Improving Mutton Productivity

Several methods for increasing body weight of sheep have been tried by selection within the indigenous and crossbred populations. In mutton production programs, more emphasis has been given to six-month body weight than to greasy fleece. Since the characteristics related to mutton production (body weight gains, efficiency of feed conversion, and dressing percentage) are moderate to highly heritable, selection within indigenous breeds can bring about considerable improvement. Countries with developed sheep industries maintain special breeding flocks to supply superior germplasm to commercial flocks.

The performance of Indian indigenous and crossbred sheep with respect to growth, feed efficiency, and carcass traits is shown in Tables 3 and 4. Results on growth performance reveal that Malpura and Muzaffarnagari breeds of the northwestern region, and the Nellore and Mandya in the southern region have great potential for use as improver breeds for mutton production. New synthetics generally attain a live weight of about 30 kg at six months of age under intensive feeding conditions.

In crossbreeds, improvement in body weight up to six months of age over indigenous breeds is conspicuous. However, only marginal improvement is observed at 12 months of age. This indicates that crossbreeds/new synthetics require high levels of nutrition. If they are managed on the same feeding regime as the indigenous breeds, the differences that are conspicuous up to six months of age narrow gradually and become marginal at the age of one year.

Table 3. Comparative growth performance of native and crossbred mutton-type sheep.

	Weight (kg) at					
Breed/Genetic group	Birth	3 months	6 months	9 months	12 months	Source
Malpura	2.9	12.9	19.2	22.3	25.6	1
Sonadi	2.8	12.5	18.5	22.1	25.4	1
Avimaans/Mutton Synthetic	3.2	14.1	22.1	23.8	26.7	1
Mandya	2.2	13.5	17.3	20.1	22.9	2
Mandya Synthetic	2.6	14.9	22.2	22.2	25.1	2
Nellore	3.0	13. 5	17.8	21.2	24.5	2
Nellore Synthetic	3.2	14.8	21.0	23.3	26.4	2
Muzaffarnagari	3.3	14.5	19.7	23.9	28.0	2
Dorset × Muzaffarnagari	3.5	15.2	21.3	25.7	30.3	2
Suffolk × Muzaffarnagari	3.9	16.3	23.6	27.7	32.0	2
Deccani	2.9	12.6	16.7	18.8	22.2	2
Dorset × Deccani	3.5	13.8	20.3	22.1	25.1	2
Madras Red	2.2	9.0	12.5	15.3	16.2	2
Dorset × Madras Red	3.0	12.0	16.5	19.4	21.2	2
Awassi × Malpura	3.6	16.5	24.4	27.1	30.4	3
Avikalin	3.0	14.9	19.9	23.0	30.2	3
Avikalin × Avimaans	3.0	15.8	20.8	25.2	30.6	3

Source: 1. Final Report (Mutton unit), 1991. CSWRI, Avikanagar.
2. Final Report, 1993. Project Coordinator, Sheep Breeding (AICRP).
3. Annual Report 1996 CSWRI, Avikanagar.

Table 4. Feedlot performance of native and crossbred mutton-type sheep.

Breed/ genetic group	Initial weight dressing (kg)	Final weight (kg)	Average daily gain (g)	Feed efficiency (%)	Hot carcass weight (kg)	Dressing (%) Exotic wool breeds
Malpura	16.0	29.1	146	15.6	-	59.1
Avimaans	18.9	32.5	151	15.7	-	59.1
Mandya	10.2	18.1	87	13.5	8.5	54.5
Mandya Synthetic	13.9	23.8	110	14.5	10.6	55.2
Nellore	13.5	20.1	91	14.6	10.6	58.2
Nellore Synthetic	14.8	26.5	134	14.7	13.0	59.3
Muzaffarnagari	16.7	26.7	110	14.1	-	57.3
Dorset × Muzaffarnagari	18.6	32.3	152	19.5	-	58.8
Suffolk × Muzaffarnagari	13.3	26.4	145	23.6	-	56.9
Deccani	11.2	25.3	119	13.0	8.3	52.7
Dorset × Deccani	12.2	27.4	143	13.9	10.8	55.0
Madras Red	9.3	17.7	87	12.3	8.2	51.4
Dorset × Madras Red	12.0	26.0	123	14.1	11.1	57.5

Superior Germplasm for Mutton Production

Through selective breeding and intensive selection some of the important indigenous sheep breeds such as the Malpura, Sonadi, Muzaffarnagari, Madras Red, Mandya, Nellore, and Deccani have been improved.

Production of Fat Lamb

Production of fat lamb is a very promising commercial program. The major advantage of this technology is that sheep owners need rear the animals only for about three months. Further, the profit earned after three months is on a par with or more than that earned after rearing lambs for 12 months under extensive grazing. After considering all the inputs required for raising the lambs to finishing weight, a net profit of about Rs 316 per slaughtered lamb could be obtained (Table 5). In addition, this technology would help avoid mortality risk and the unnecessary expense of rearing lambs for the whole year.

Malpura, an indigenous sheep breed, is well adapted to harsh climatic conditions with good mothering ability and sufficient milk to sustain lambs. An elite Malpura flock has been developed through intensive selection.

Table 5. Economics of fattening lambs for mutton production.	
	Cost (Rs)
A. Cost items	
Approximate cost of 2 month old lamb (@ Rs 35 kg^{-1}) for weaning weight 11 kg	385
Fattening cost (i.e. 25 kg live weight)	276
Required body weight gain = 14.0 kg	
Average Feed Efficiency = 18.7% or 5.35 kg feed required for 1 kg gain in body weight	
Total feed required 14.0 $\times$ 5.35 (74.9 kg) (Cost of feed at Rs 368 per quintal)	
Labor cost (Rs 67 day^{-1} for 90 days, one laborer per 150 lambs)	40
Shearing cost	5
Health costs	10
Interest on investment per lamb	18
Total cost/lamb	734
B. Returns from meat production	
Meat yield (12.5 kg meat; dressing % = 50), @ Rs 72 kg^{-1}	900
Wool (400 g at Rs 35) and skin	90
Head, hooves, and offal	28
Manure	10
Stomach/Intestine	16
Lungs	6
Total returns $lamb^{-1}$	1050
Net returns $lamb^{-1}$	316

Note: 1 US $ = Rs 40.

Malpura weaner lambs (two months of age) are now capable of achieving a body weight of 25 kg at about five months of age.

Technologies for Improving Wool Productivity

Wool production increased from 27.5 million kg in 1951 to 45.6 million kg in 1992-93. The sheep population in India constitutes 4.6% of world population, but accounts for only 0.8 % of the world greasy and 1.1% of the scoured wool production. The quantity and quality of wool produced in different regions are shown in Table 6. About 65% of wool is produced the northwestern region, followed by the southern peninsular region (20%).

The average wool production per sheep is only 0.9 kg against the world average of 2.4 kg. The sheep of the northwestern region produce the highest

Table 6. Wool production and quality in different regions, 1992-93.					
Parameter	Northwestern	North temperate	Southern peninsular	Eastern	Total
Sheep population (million)	21.5 (42.2)	3.6 (7.1)	20.9 (41.1)	4.9 (9.6)	50. 9
Wool production (million kg)	29.8 (65.4)	4.8(10.5)	9.1 (20.0)	1.9 (4.2)	44.6
Yield (kg sheep^{-1})	1.40	1.32	0.44	0.39	3.6
Fineness (microns)	30-45	22-30	40-60	50-60	
Medullation (%)	30-80	05-15	60-80	80-90	
Bur content (%)	2-5	2-8	< 5	1-3	

Note: Figures in parentheses are percent of total.

yield (1.4 kg). The North Temperate region ranks next with an average yield of 1.3 kg. The sheep in the eastern and Southern Peninsular regions are poor yielders. The wool produced in the Northwestern and North Temperate regions is also of superior quality. As a result of poor productivity India imports about 50 million kg of wool (both apparel and carpet types) to meet the requirements of the industry. Efforts have been made to improve the genetic potential of sheep through crossbreeding of indigenous sheep with exotic breeds. Sheep strains evolved with improved wool quantity and quality are shown in Table 7.

While it may not be possible to produce apparel wool in the required quantity, the carpet wool requirement can be met easily with suitable and progressive development programs. India can make an impact on exports by marketing hand-knotted carpets, druggets, and hosiery items. Therefore, improving quantity and quality of carpet wool must be given due priority.

Carpet Wool Production

Almost all Indian wool types can be used for carpet manufacture if judiciously blended. However, the northwestern arid and semi-arid regions encompassing the states of Rajasthan, Haryana, Gujarat, Madhya Pradesh and plains of Uttar Pradesh, specifically produce good quality carpet wool. This region produces almost two-thirds of the total wool in the country. Excepting the wool produced from the Malpura and Sonadi breeds, the wool produced is of good carpet quality. Wool produced in the northern temperate region is suitable for apparel and finer carpets.

Table 7. Improved breeds/types of sheep.

New genotype / location	Parent breeds: Indigenous	Parent breeds: Exotic	Level of exotic inheritance (%)
Bharat Merino (CSWRI, Avikanagar)	Chokla, Nali	Rambouillet, Merino	75
Avivastra (CSWRI, Avikanagar)	Chokla, Nali	Rambouillet, Merino	50
Nilgiri Synthetic (SRRS, TNVASU Sandynallah)	Nilgiri	Merino	62.5/75
Patanwadi Synthetic (GAU, Dntiwada)	Patanwadi	Rambouillet, Merino	50
Avikalins (CSWRI, Avikanagar)	Malpura	Rambouillet	50
Avimaans (CSWRI, Avikanagar)	Malpura, Sonadi	Dorset, Suffolk	50
Indian Karakul (CSWRI, ARC Bikaner)	Marwari, Malpura, Sonadi	Karakul	75
Kashmir Merino (J &K State)	Gaddi, Bhakarwal	Delaine Merino Rambouillet, Soviet Merino	50-75

Names in parentheses indicate location of development of the genotype.

Superior Germplasm for Carpet Wool

Indigenous Sheep Breeds

Research efforts have been made to improve wool yield and its quality among indigenous breeds through selective breeding and selection. Since the characteristics connected with carpet wool production (greasy fleece yield, fiber diameter, medullation, and staple length) are heritable, selection within the indigenous breed can bring about considerable improvement. Promising Indian sheep breeds that produce carpet wool are the Chokla, Magra, Nali, Patanwadi, Marwari, Jaisalmeri, Pugal, Bhakarwal, Gurez, Gaddi, and Rampur Bushair.

New Types

Avikalin. Much research has been conducted on improving carpet wool production and quality through crossing the extremely coarse and hairy Malpura breed with exotic fine wool breeds such as the Rambouillet. The half-breeds from such a crossing yield about twice as much wool as the indigenous breed, which is of excellent carpet quality. The Avikalin strain evolved from Rambouillet × Malpura halfbreeds has been evaluated for its carpet wool quality the wool produced by this strain is superior to the carpet wool from all indigenous breeds.

Under field conditions, with the use of superior Avikalin rams, there was an increase of about 15–20% in wool quantity in addition to an increase in body weight. The quality of wool was also better. Avikalin can be used as an improver breed for crossbreeding with the coarse wool breeds of sheep to increase carpet wool production. This breed is thus suitable as a dual-purpose type for carpet wool and mutton production.

Fine Wool Production

Attempts to crossbreed native sheep with exotic fine wool breeds for increasing wool production and quality were made even during the pre-independence period. The major emphasis was to enhance fine wool production. As a result of crossbreeding experiments a few new fine wool sheep types were developed in the country and the wool characteristics of these are depicted in Table 8.

Bharat Merino

The Bharat Merino breed was developed at the CSWRI, Avikanagar by crossing Rambouillet/Russian Merino with native Chokla, Malpura, Nali and Jaisalmeri ewes and stabilizing exotic inheritance at a level of 75 percent. The breed produced annually 2.5–2.8 kg greasy fleece of 20µ fiber diameter,

Table 8. Fleece characteristics of developed types of sheep in India.

Breed	Greasy fleece weight (kg)	Average staple length (cm)	Average fiber diameter (cm)	Medullation (%)
Hissardale	1.5 – 2.7	5.5 – 6.2	21.5 – 24.5	0.0 – 0.6
Kashmir Merino	2.5 – 2.8	4.8 – 5.6	20.4 – 20.9	0.0
Nilgiri	0.2 – 1.4	7.0 – 8.7	21.6 – 27.4	8.4 – 18.0
Deccani Merino	1.5	5.8	22.1	1.6
Nilgiri Synthetic	1.0 – 1.5	4.6 – 5.0	20.6 – 21.6	1.0 – 3.2
Patanwadi Synthetic	1.2 – 1.7	4.6 – 5.2	19.3 – 23.2	9.0 – 20.8
Bharat Merino	2.6 – 2.8	2.9 – 9.4	17.6 – 20.2	1.0 – 1.1
Avivastra	1.9	3.5	21.6	7.6

medullation of less than one percent, and a staple length of 4–5 cm. Since 1987, a part of the flock is being performance tested under the subtemperate climate of the Kodai hills. The performance has been very satisfactory.

This is a promising substitute for fine wool sheep that are imported as improver breeds. The shorter staple length and lower greasy fleece weight under semi-arid conditions are attributed to climatic constraints and the inadequate availability of grazing and feed resources. The performance of the Bharat Merino at the CSWRI regional station at Mannavanur has been encouraging. Since it has not been possible to get fine wool with desirable staple length from the higher crosses in the arid and semi-arid regions, apparel wool production can be intensified only in temperate areas such as the northern temperate hilly region and Nilgiri/Kodai hills in the southern region. In these areas three-fourth crosses of the Rambouillet or Merino, including the Bharat Merino can be propagated and annual clips obtained to meet the requirements for apparel manufacture.

Kashmir Merino

The Kashmir Merino breed was developed at the Government Sheep Breeding and Research Farm, Reasi (Jammu) using the foundation population produced by mating ewes of Kashmir valley, Gaddi, Bhakarwal, and Poonch breeds with exotic rams of Delaine Merino, Rambouillet and Soviet Merino breeds. The present population of this breed that has 75–82% exotic genes exceeds one million. This was achieved after sustained use of the genetic technique over 20 years. Inter se mating and rigorous selection has been followed for improving the fleece characteristics and body weights in Kashmir Merino. Due to the involvement of a number of native and exotic breeds, the Kashmir Merino sheep are highly variable in their morphological and production performance characteristics.

Feeding Management

There has been a continuous decline in availability of grazing areas for livestock due to increased population, urbanization, industrialization, and use of fallow lands for cultivation and other activities. It is, therefore, important to develop and use the remaining lands for pasture development and tree plantation. The border areas under farms or defence artillery ranges can be developed as pasture and used for grazing sheep. Agroforestry, silvipasture, and hortipasture should be popularized. Forest areas, after initial protection for three years, could be used for controlled grazing. The system of extensive grazing should be modified to semi-intensive system. It may be possible to introduce the feedlot system in states such as Punjab, Haryana, and Andhra Pradesh where surplus broken grains and crop residues for feeding lambs are more readily available at competitive rates. Identification of new sources of protein or cheaper sources of compound animal feeds and fodder is also necessary. Utilization of by-product and nonconventional feed resources and enrichment of low-grade feeds is desirable.

Health Management

Diseases in sheep adversely affect the production performance of the animals and, in turn, the net profit. Prophylactic health measures against prevalent diseases and antihelminthic drenching against internal parasites are the important health practices that must be strengthened in farmer's flocks to minimize losses and increase the productivity of sheep. Effective vaccines in adequate quantities against diseases such as enterotoxemia, hemorrhagic septicemia, foot and mouth disease (FMD), and sheep pox.are essential. Effective control measures against emerging diseases such as Blue Tongue and *peste de petite ruminantes* (PPR) must be developed. There should be effective arrangements for storage and transport of vaccines for which a proper cold storage infrastructure must be developed. It is important to control development of drug resistance. Hence, a proper drenching strategy must be developed to control this problem.

Conclusions

- Potential mutton-type breeds such as the Malpura, Sonadi, Muzzaffarnagari, Madras Red, Mandya, Nellore, Deccani, Mecheri, and Ganjam should be restricted to selective breeding by using superior rams for enhancing mutton production.
- Carpet wool producing breeds such as the Nali, Chokla, Patanwadi, Marwari, Magra, Pugal, Gaddi, and Jaisalmeri should be further improved through selective breeding by distribution of good quality rams of the respective breeds. Wool quality traits of these breeds better meet the carpet wool requirements of industry.

- Efforts should be made to introduce luster in indigenous carpet wool breeds to gain maximum returns through sale of quality carpet wool.
- Apparel wool production should be intensified only in temperate areas such as northern temperate hilly region and Nilgiri/Kodai hills in the South. In these areas three-fourth crosses of Rambouillet or Merino, including the Bharat Merino, could be propagated and annual clips obtained to meet the requirements for apparel manufacture.
- Crossbreeds could be tried in areas where adequate feed resources are available.

References

Central Sheep and Wool Research Institute. 1991. Final Report. AICRP on Sheep Breeding and Mutton Unit, CSWRI, Avikanagar, Rajasthan-304501, India.

Central Sheep and Wool Research Institute. 1993. Final Report. AICRP on Sheep Breeding, CSWRI, Avikanagar, Rajasthan-304501, India.

Central Sheep and Wool Research Institute. 1996. Annual report. CSWRI, Avikanagar, Rajasthan-304501, India.

Central Sheep and Wool Research Institute. 1998. Annual report. CSWRI, Avikanagar, Rajasthan-304501, India.

Central Sheep and Wool Research Institute. 1998. Transferable Technologies. CSWRI, Avikanagar, Rajasthan-304501, India.

Government of India. 1997. AHS Series-6, Department of Animal Husbandry and Dairying, Ministry of Agriculture, New Delhi.

Conservation of Farm Animals in India: Challenges and Strategies

R Sahai[1]

The term sustainable management has several definitions or connotations. The World Commission on Environment and Development defines sustainable management for development as a type of development that meets the needs of the present generation without jeopardizing its ability to meet the requirements of future generations. In the economic context, sustainable development means that the number of users and quantity of products/goods are maintained or made on some constant level, which is ecologically non-destructive or depletive over time. It should also meet at least the basic needs of all segments of the population.

At present, sustainable management is a subject of serious debate. One school of thought proposes that sustainability and continuous development are contradictory terms. The process of development involves an increase in entropy and therefore, cannot remain sustainable ad infinitum. Alternate resources or production systems must replace the original one after some time.

Exploitative production systems have depleted resources at an alarming rate in recent times. Modern production systems depend heavily on a few strains, breed types or crosses, in plants and animals. The local breeds or strains have therefore been neglected. Low economic viability has also contributed to endangerment and degeneration leading to extinction of certain forms of genetic resources.

Sustainable management assumes special importance with respect to domestic animals as they are vital sources of milk, meat, hides, fiber, draught power, and manure. With the application of biotechnology, genetic resources have been increasingly used for obtaining value-added products such as

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biochemicals, pharmaceuticals, and other genetically engineered substances. Thus, sustainability should be determined on the holistic value of domestic breeds, though this is seldom done.

Conservation in its broadest sense comprises judicious management of a resource to derive full benefits for the present and ensuring that it retains productivity potential so as to meet the needs of the future. Although conservation of animal genetic resources is known to be essential, overriding economic considerations often jeopardize the attempts to preserve them. New biotechnological approaches have the potential for the conservation of genetic resources in the form of sperm, embryos, oocytes, isolated chromosomes, genomic DNA libraries, and isolated genes. Some of these technologies are still in the experimental stage but hold promise for the preservation of animal germplasm, which cannot be retained in situ due to poor production.

Conservation of Domestic Animal Biodiversity

Conservation of animal biodiversity is of the utmost importance because:

- Domestic animals are a part of global biodiversity and heritage of mankind and should be appropriately conserved and utilized.
- Human societies all over the world have developed social and cultural bonds with certain species or breeds of animals. Numerous religious rituals, festivals, and folklore are interwoven with native domestic animals. In some societies ownership of certain breeds is a status symbol.
- Animal production in the future will require new gene combinations. Only conservation of biodiversity can provide genetic variability and material for genetic engineering and developing more productive forms.
- Many minor breeds have not been exploited owing to their poor economic value and are rapidly decreasing in number. Minority breeds are also valuable reserves of genetic diversity and should be adequately recognized and exploited.
- Unplanned breeding has led to genetic erosion, dilution, and degeneration of some established breeds. Conservation becomes a vital necessity in such situations. Conserved germplasm can be used for reintroduction and revival of lost breeds.
- India is among the countries that have signed the 1992 Global Convention on Conservation of Biological Diversity. This places the onus for the conservation of all forms of biodiversity on the country of origin and use. Thus, conservation has become a national commitment.

Issues in Sustainable Management

Evaluation of Breeds vis-à-vis Economic Viability

Barring sporadic studies on a few breeds reared on organized farms, domestic animals have not been evaluated systematically for their total utility and economic viability. The production systems adopted by rural farming communities are radically different from those of organized farms. Therefore, information on productivity of breeds in organized farms cannot be extrapolated to farmer's herds. Improved breeds with high production potential require special care and quality inputs for better performance. For native breeds, strategies for production improvement are urgently needed to ensure their conservation.

Population and Production Paradox

The animal genetic resources scenario in India is a strange paradox of prosperity and poverty. Farm livestock populations are exceedingly high in relation to the land area, while the productivity of the animals is much lower than in Europe, America, and Australia. The high livestock population density leads to diminished availability of inputs as well as poor maintenance, causing deterioration in the quality of animals. Thus, conservation in India should also include measures to prevent dilution in qualitative terms in livestock breeds.

Authentic information on population and status of various breeds of farm animals is scanty. Farm animals have been enumerated in each successive livestock census on the basis of species with no reference to breed. An attempt has been recently made to separately catalogue crossbred cattle. It is thus difficult to infer the status of a breed as threatened or endangered. The problem is further compounded by the fact that a number of breeds have not been accredited and characterized.

Dilution, Decline, and Degeneration

Between 60–80% of farm animals fall into the nondescript category. Barring a few organized farms which still maintain small nuclear herds of pure breeds, there is unrestricted interbreeding. Furthermore, breeding plans recommended by Central and various state governments are seldom followed rigorously.

Impact of Crossbreeding on Conservation

Breed substitution or modification by crossbreeding gained prominence in cattle and some other domestic species from the early 1960s. These strategies enhanced production but could not attain the established long-term goals. Originally, it was envisaged that the advent of high yielding farm animals would include the concurrent elimination of low producers. It was hoped that the livestock population would stabilize and later decline with the increase of population of more efficient animals as in Europe and America. However, this did not happen. Effects of these developments per se on native breeds have not been analyzed meticulously, but these are among the causal factors responsible for endangerment of native germplasm.

Process of Endangerment

The process of endangerment in livestock begins when the economic returns from a breed progressively decline or are not commensurate with the inputs. Effective and timely conservation measures can retrieve the breed from extinction. Incentives and subsidies for upkeep and alternate usage should be considered to address the problem. The eventual solution would lie in the improvement of production in the breed to make it sustainable.

Population Benchmarks

The International Union for the Conservation of Nature (IUCN) has given definitions for the rarity of species related to their chances of survival. However, considerable ambiguity exists in the terminology and population benchmarks for domesticated species for being declared endangered. Table 1 shows the divergent views on this.

Table 1. Criteria for inclusion in endangered category (numbers)

Cattle	Sheep	Goats	Pigs	Horses
750[1]	1500	500	150	1000
7500[2]	15000	5000	-	5000
1000[3]	500	200	200	-
10000[4]	10000	10000	10000	10000

Source: 1. Alderson 1981, 2. Simak 1991, 3. Maijala 1982, 4. FAO.

In developing countries, the risk of population/breed loss due to disease, adverse climatic conditions, and drought are high. Therefore, population size of domesticated breeds of various species from the standpoint of vulnerability should be much higher than those suggested by various experts.

Survival Value of Breed for Conservation

Progressive improvement in the production potential over a period of time is an in-built security for the survival of breeds. It has been contended that exotic breeds with superior productivity or crosses are less adaptable than the indigenous breeds; yet they have better survival value in the production system owing to higher monetary return. The majority of indigenous livestock breeds have genetic attributes like better capacity to withstand drought, superior resistance to tropical diseases, and better capacity to utilize coarse forages. Despite this, low productivity diminishes their survival value necessitating conservation.

Herd Books of Animal Genetic Resources

The creation of herd books in the 1940s was the first meaningful attempt to register animals conforming to certain well-defined genetic attributes and production traits. The aim was to identify promising animals and ensure their optimal utilization particularly in improving the production level of the breed. So far, Haryana, Gir, Kankrej and Ongole cattle, and Murrah and Surti buffalo have been included in registration programs. Additional breeds such as Rathi, Nagori, and Khillari cattle will soon be included. No scheme for other livestock breeds exists at present.

Participation of Farming Communities in Conservation

The Convention on Biological Diversity recognizes that the local communities are the real custodians of biological diversity and have vital stakes in conservation. They should thus be involved fully in conservation programs. Farming communities should also share the benefits from sustainable utilization. At present, many financial institutions provide incentives and loans for the rearing of exotic or high-yielding crossbreeds, but do not provide similar assistance for indigenous stocks. Encouraging the propagation of native breeds will progressively increase their sustainability and they will be automatically conserved.

Legal Framework - a Gray Area in Conservation

The new patent laws and issues relating to intellectual property rights have neither been properly understood nor assessed in relation to their impact on domestic animal genetic resources. The laws on domesticated animals are inadequate and are not strictly observed in the absence of stringent punitive measures. These laws should cover all aspects of conservation such as benefit sharing, transfer, acquisition, accession, generation and sharing of information, and misuse and abuse of domestic animals. Currently, misuse, overexploitation, and non-judicious utilization of genetic resources are rampant. The following aspects require examination from the legal standpoint:

- Laws regarding trusteeship/ownership of animal genetic resources in gene banks outside the country.
- Laws prohibiting/permitting use of genetic resources/material, and punitive measures for infringements.
- Terms, conditions, rights, and obligations in such transactions involving third parties and further transfer of genetic resources.
- Transfer of genetic resources for commercial use and research – rights and obligations, and benefit sharing.
- Laws on the piracy and acquisition of classified data on animal genetic resources.
- Regulations on networking with global agencies.
- Legal guidelines on negotiations for bilateral agreements.
- Legal frameworks for the establishment and working of databanks.
- Laws regarding benefit sharing by parties and local communities.
- Rules and monetary obligations of nongovernmental organizations (NGOs) handling animal genetic resource conservation programs.
- Laws covering breed registration societies and other similar organizations.

Vistas of Conservation

The vistas of conservation and utilization in the Indian context are multifaceted and complex. These should cover the following aspects:

- Judicious and scientific management of livestock breeds to progressively enhance their sustainability.
- Strategies for the preservation of less productive breeds with adequate genetic variability and distinctive characteristics as a part of genetic security.

- Development of technologies for enhancing sustainability. Alternate uses of the breed may at times ensure conservation.
- Establishment of in situ and ex situ gene banks.
- Establishment of informatics system having data banks with interactive networking with other organizations and global agencies.
- Development and progressive upgrading of software and hardware for computerized inventory systems.
- Building of regional level Livestock Conservation Boards/Conservation Units. Attempts should be made to enlist services of avid conservationists and committed NGOs in such ventures.
- Formulation of breeding policies with well defined objectives consistent with the economic conditions of the farmers, and ethos of conservation;
- Formulation of livestock population policy to ensure that animal populations are consistent with the carrying capacity and environmental management;
- Steps for people's participation in conservation programs through Breed Societies, Associations, Breed Survival Trusts and NGOs.
- Enactment of laws pertaining to data banks, gene banks, transfer/movement of genetic resources, patenting of genetic resources, prohibitive and punitive laws for preventing abuse, and misuse.
- Development of financial and institutional mechanisms that are mandated to support conservation of domesticated animals.

It is obvious that sustainable management, coupled with enhancement of the economic returns are key elements for conservation. However, less viable breeds should be supported being a part of the genetic heritage of mankind as well as to maintain genetic diversity.

References

Alderson, L. 1981. The conservation of animal genetic resources in U.K. FAO Animal Production and Health Paper 24, Rome, Italy, pp.53-76.

Maijala, K. 1982. Preliminary report of the working party on animal genetic resources in Europe. *In* Conservation of animal genetic resources, Session 1. Commission on Animal Genetics, EAAP, GI, Leningrad, Russia.

Simak, E. 1991. The conservation of rare breeds of West Germany. Pages 65-69 *in* Genetic Conservation of Domestic Livestock (Alderson, L., ed.). CAB International, Wallingford, UK.

Potential of Nutritional Technologies in Improving Livestock Productivity

Khub Singh and C S Prasad[1]

Adequate nutrition is important for maintenance, growth, and reproduction of animals. Indian livestock are underfed and undernourished. India is short of dry fodder by 31%, green fodder by 23%, and concentrate feeds by 47% (World Bank, 1996). This is due per se to the huge numbers of animals in relation to available feed and fodder resources. Animals largely derive their feed requirements from crop by-products and grazing on common lands. Further, a majority of livestock is owned by small landholders and the landless, who often face acute shortage of feed and fodder.

Animal science research has yielded a number of biochemical and mechanical technologies that, besides improving the nutritional quality of feed, also help avoid wastage of these resources. The efficacy of many of these techniques has been proved, yet their adoption has remained restricted and sporadic due to a number of operating constraints. This paper describes different nutritional technologies and attempts a subjective assessment of their adoption and impact.

Chopping Green Fodder

Chopping of green fodder and unthreshed straws/stovers is a simple but effective technology. This has developed gradually from use of various hand-operated chaffing blades to power-operated mechanical mega-chaff cutters of varying capacities. Residues of crops such as rice, millets, and maize are long and need chopping before being fed to livestock.

Ruminants reduce feed particle size by chewing. Energy spent on chewing reduces the amount of metabolizable energy (ME) used for

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production, and can thus have a substantial negative effect on productivity. Feeding of chopped roughage reduces the energy wasted while chewing. Chopping green fodder, straws and stovers helps in adopting strategic supplementation, improves the palatability of less-preferred roughages by mixing with highly palatable fodder, improves digestibility, and reduces wastage. The net biological value of the feed also improves.

Chaffing of all varieties of green fodder including sugar tops, straws, and stovers such as rice, maize, pearl millet (*bajra*), and sorghum (*jowar*) is practiced in most of northern India.

Wetting and Soaking

Wetting and soaking of roughage and concentrates is also a simple and age-old technology. The straws, stovers, and concentrates (ingredients or mixtures) are either soaked in water or moistened just prior to feeding. This hydration of the particles facilitates their digestion in the rumen.

Soaking of concentrate mixtures or ingredients is a common practice followed in most parts of the country. Soaking or wetting of straws and stovers is however not as common. During the hot-dry periods in some parts of the country the wheat straw (*bhoosa*) is soaked/wetted before feeding to ruminants.

Addition of soaked concentrate mixture or ingredients such as cakes, bran, chuni, and flour to chopped straws and stovers improves their palatability and the total dry matter intake of basal diets comprising dry roughage. Mixing of high density concentrates and low density roughages results in even distribution of nutrients and facilitates better microbial and enzymatic action in the rumen.

Soaking or wetting of straws helps remove some of the undesirable elements such as excess oxalate in rice straw. Soaking roughage and concentrate is common where animals are fed a gruel. Soaking of straws or stovers for long periods however may result in the loss of some soluble nutrients, so care must be taken that the soaking is only for very short periods.

Grinding and Pelleting

Grinding and pelleting involve physical treatment that enhances the utilization of fibrous feed stuffs by ruminants. Grinding decreases particle size and increases the bulk density of leaf and stem fraction of forages. Ground roughage is further processed by pelleting or cubing before feeding to the animals. Pelleting helps increase the bulk density and decrease dustiness. This is a common practice wherever concentrates are fed.

Commercial feed-manufacturing mills/factories pellet the concentrate mixture for different species of livestock. Preparation of a complete feed comprising of concentrate and roughages has not been adopted by commercial feed manufacturers mainly because of the high processing costs.

Grinding and pelleting of roughages increase feed intake and reduce feed:gain ratio. Digestibility of ground and pelleted roughages is generally low compared to the original material fed in either long or chopped forms due to a reduction in fiber digestion. However, grinding and pelleting of forages dramatically reduces the time that ruminants spend on chewing the long coarse material, resulting in the increased availability of digestible energy for production. Although the performance of animals improves with processed feeds, net energy (NE) content of poor quality roughages still remains poor. Furthermore, the process of grinding and pelleting is energy dependent and, hence, the technology has not received much attention.

Conservation of Feeds and Fodder

Seasonal feed deficits can be reduced considerably or overcome through conservation and storage of feed resources during surplus seasons for use in lean periods. During the monsoon, plenty of green fodder is available in fields, on bunds, roadsides, and under forest covers. These can be profitably conserved for feeding. The surplus fodder can be conserved as hay in a dry form or as silage in a wet form.

Haymaking

This involves reducing the moisture content of green forages to less than 15%, so that they can be stored without spoilage or further nutrient loss. Green forages with 80–85% dry matter preserve most of their nutrients. Crops with thin stems and more leaves are better suited for haymaking as they dry faster than those with a thick, pithy stem and small leaves. Leguminous fodder crops should be harvested at the flower initiation stage or when crown buds start to grow, while grasses and other fodder crops should be harvested at the pre-flowering stage. They should preferably be harvested when air humidity is low.

The harvested forage is spread in the field and raked a few times for quick drying. The dried forage is then collected and baled when the moisture concentration is low (<15%) which helps storage and requires less space. Crops with thick and juicy stems are dried after chaffing to speed up the drying process and to prevent loss of nutrients.

Field curing is conducted during bright sunny weather but may result in bleaching of the forage and loss of leaves due to shattering. To avoid this, drying can be done in barns by passing hot air through the forage. Although artificial drying produces hay of good quality, it is expensive and beyond the reach of small and marginal farmers.

The technology of haymaking is fully standardized and can be easily applied under favorable conditions. However slight carelessness could result in loss of quality or even complete spoilage. Conservation of fodder is not undertaken routinely by the average Indian farmer.

The reasons for the low adoption of this technology are:

- Lack of knowledge of the benefits of fodder conservation.
- High losses due to incorrect harvesting time and weather conditions.
- Lack of interest and skills for proper preservation and storage.
- Losses due to shattering and dropping of leaves, especially in legumes.
- Losses of soluble nutrients due to leaching caused by rain during the drying period.
- Storage of hay with high moisture content resulting in mold growth.
- Extra expenditure in terms of labor and materials for the processing of green fodder.

Haymaking is one of the best methods of preserving forages. Feeding hay to livestock helps reduce the amount of concentrate feeding, and thereby, the cost of feeding. The low moisture content of hay considerably reduces costs and efforts involved in transportation and handling. The surplus green grasses available during the monsoon in the forest go unused and could be put to the best possible use by this process.

Silage Making

Silage is the product of controlled fermentation of green fodder retaining high moisture content. Naturally produced organic acids, chiefly lactic acid, preserve the green fodder. Silage making involves selecting crops and plant materials rich in soluble sugars with dry matter concentration of about

15–30%. The material is stored in pits under anaerobic conditions. Chaffing of the material for ensiling increases the compactness. The silo should be airtight after filling. Fermentation begins within hours of closing the silo and accelerates in the next two to three days. Molasses or jaggery is added to increase the fermentation. Organic acids (primarily lactic and acetic acid), ethanol, and gases such as carbon dioxide (CO_2), methane (CH_4), and ammonia (NH_3) are produced during the fermentation process. The pH of the biomass is reduced to below 4.0, resulting in the termination of all biological activities. The material remains conserved. This method preserves the forage material for a long period with minimal nutrient loss.

Crops rich in soluble carbohydrates, such as maize, oats, sorghum, pearl millet, and cultivated grasses are most suitable for ensiling. During abundant green fodder availability they can be converted to silage and stored for use in times of scarcity. The crops should contain about 30–35% dry matter at the time of ensiling. Sorghum and oats should be harvested at the flowering stage while maize has to be harvested at the milk stage.

Large quantities of sugarcane tops rich in soluble carbohydrates are available in sugarcane growing areas during the crushing season. Only 30% of the available sugarcane tops is used for animal feeding as fresh feed and the rest is partly used as fuel. Conversion of these to silage would provide sufficient wet fodder during summer.

Tall varieties of rice are grown in some traditional rice-growing areas in India. They are susceptible to lodging under conditions of high fertilization, to avoid which, one-third of the top portion is removed during the vegetative stage. Fresh straw of many dwarf varieties is quite succulent at maturity and contains about 50–65% moisture at harvest, making it suitable for ensiling. Silage making is not an established practice in most parts of India due to reasons such as:

- Lack of surplus forage during the rainy season.
- Labor requirement for cutting, raking, collecting, chopping, pit construction, and materials (polyethylene, molasses) are a problem in some areas.

Some of these problems may be overcome if the milk cooperatives and state animal husbandry departments prepare large silos. Preparing silage near reserve forest areas by harvesting the forest grasses at a proper stage and ensiling them, rather than drying and burning, would be useful.

Urea-Ammoniation of Straws

Urea treatment of straws is so far the most accepted chemical treatment. Urea (fertilizer grade) available in all parts of the country is relatively safe, easy to store, and dissolves easily in water. Urea treatment is more feasible in tropical climates because it breaks down quickly into ammonia under higher ambient temperatures. The treatment is quite flexible, as it can be adapted to local conditions and preferences. Of all treatments the economics of urea treatment is best understood.

The treatment process is simple, and 4 kg urea is the optimal amount to treat 100 kg of air-dried straw. Water is essential as it helps in the hydrolysis of urea and also acts as a carrier for the ammonia to penetrate the cell walls of the plant material. The moisture level is not very critical to the process but a 30–40% moisture level gives the desired effect. The total cost for treating one tonne straw is Rs 800/-. Feeding livestock with urea-treated straw can result in saving of concentrates to the extent of 1.5 kg animal^{-1} day^{-1}.

The key factor that determines the economics and practicality of urea treatment is the method of storage. Cemented storage structures are ideal but not practical in the field. Pits or mud structures may also be used. Covering the stack is important and can be achieved by using polythene sheets, empty urea bags stitched together, or even dried grass/leaves to keep it airtight.

This technology is most likely to work when:

- Plenty of dry, slender straw is available.
- Straw is cheap compared to other feeds.
- There is a shortage of grasses or other green fodder.
- Water is freely and conveniently available.
- The price of urea is not prohibitive.
- The cost of polythene covering is low.
- Labor is easily available

Microbial growth in the rumen depends on the nitrogen supply, rumen-digestible energy, and sources of phosphorus and sulfur. The efficiency of microbial production depends on the amount of microbial biomass produced per unit of adenosine triphosphate (ATP) during fermentation of carbohydrates in the rumen to volatile fatty acids (VFAs). Cell wall carbohydrates are the major source of energy for rumen microbes on a straw diet. Insufficient energy from cell wall-rich crop residues is often a limiting factor to ruminant productivity in the tropics. Urea ammoniation, apart from being a source of nitrogen for microbial synthesis, also provides additional energy due to the weakening/loosening of the lignocellulose bonds in the treated straw.

Urea-treated straw feeds save on concentrate feeding, increase milk yield by 1–2 litres animal^{-1} day^{-1}, reduce the land area required for green fodder production, and offer better economic returns to the farmer. Treated straw can be fed to growing, lactating, and pregnant cattle and buffalo. The feedback from farmers who have adopted this technology indicates:

- Increase in straw consumption.
- Better growth performance.
- Improvement in health.
- Increase in milk yield ranging from 0.5–1.5 litres animal^{-1} day^{-1}.

Despite acknowledging the benefit of the technology during demonstrations, farmers have not enthusiastically continued urea treatment. The most important reason for this is that in most cases the returns are marginal. Other constraints are:

- Production of sticky dung complicates the preparation of dung cakes.
- Pungent smell of ammonia.
- Spoilage of straw in open stacks.

Urea-Molasses Treatment

Molasses is used to improve the palatability of the basal feed or as a source of readily fermentable energy, which may stimulate microbial fermentation in the presence of other nutrients such as nitrogen (urea) and phosphorus (phosphoric acid). Spraying of straw with 10% molasses and 2% urea is found to improve intake and digestibility of the basal roughage. Urea provides an additional source of nitrogen.

A urea-molasses-mineral block (UMMB) has been developed recently, which contains soluble and fermentable nitrogen from urea, highly fermentable energy from molasses, and essential minerals. Natural protein sources such as groundnut extract and cottonseed extract have also been added to provide preformed peptides and amino acids.

The field application of urea-molasses by spraying is limited owing to difficulty in handling of the mixture and toxicity in cases of uncontrolled intake. The high cost of molasses is also a limiting factor. The method is particularly useful in situations where there is plenty of straw, medium to low animal production, and limited access to other supplements. The UMMB technology has been tested on-farm in Gujarat and was more popular with farmers maintaining buffalo. Modifications have been made to improve the nutrient balance and consistency for better acceptance by farmers.

Supplementation of UMMB has been found to improve the dry matter intake of the basal roughage and the feed digestibility. The nutrients from the block are well utilized by the animals and UMMB supplementation improves reproductive performance of cows due to enhanced availability and utilization of nutrients, particularly micronutrients.

Calf Starter/Milk Replacer

Calf starter is a balanced concentrate mixture fed to calves from the 10^{th} day of age to supplement the nutrients and raise them on a limited milk intake. This provides a balanced diet to the calf and cuts down the cost of milk feeding. Generally 16% digestible crude protein (DCP) and 70% total digestible nutrients (TDN) in the calf starter are sufficient for a satisfactory growth. The protein quality is important during the pre-ruminant stage. The calf starter should contain a major proportion of grains to provide readily soluble carbohydrates, protein-rich sources such as cakes, fat sources, and mineral mixture. The constituents of the calf starters can be altered according to the feed availability. Ingredients such as barley/oats/millet grains, groundnut cake/linseed oil meal/soybean oil meal, wheat bran/rice bran, fishmeal, and mineral supplements can be used to make a good quality calf starter. Good quality hay or leguminous green fodder given in addition to calf starters has been found to encourage the early development of rumen functions.

The adoption of this technology has been limited because of the following reasons:

- The farmer feels that he is unethically depriving the calf of milk.
- There is a lack of awareness of the technology.
- There is a (wrong) perception that the health of the calf would be affected.

Bypass Nutrients

Bypass nutrients are fractions of the nutrients that are fermented to a comparatively lower degree in the rumen. They then become available intact at the lower part of the gastrointestinal tract for subsequent digestion and absorption. The approach envisages minimization of ruminal fermentation losses and better utilization of the nutrients after their digestion and absorption in the small intestine. There are three types of major nutrients that could bypass rumen fermentation to a certain degree. These are proteins/ amino acids, starch/glucose, and fats/fatty acids.

Slowly degradable or bypass nutrients may occur in feeds in their natural form. Alternatively, feeds that are highly degradable in the rumen can also be manipulated to restrict their degradation.

Bypass Proteins

A high proportion of the soluble plant protein from roughage-based diets is deaminated and lost as ammonia during digestion in the rumen. This is because the rate of protein degradation is faster than the utilization of nitrogen for microbial growth. Thus, if part of the protein is not degraded in the rumen it can be utilized more efficiently in the small intestine.

Several feed ingredients have been screened for their bypass protein value. Some of them such as cottonseed cake, fishmeal, solvent-extracted coconut cake, subabul leaf meal, soybean extract, sunflower extract, and maize gluten meal have bypass characteristics in their natural form. However feeds such as groundnut cake, wheat bran, gingelly cake, and horse gram have to be manipulated to reduce their rumen degradability for optimization of ratios between degradable and nondegradable fractions in the diet.

Chemical- or heat treatments are the main methods used for protecting proteins. Heat treatment of groundnut cake at 130°C for two hours or formaldehyde treatment at 1% of crude protein (CP) significantly increases the bypass protein of the cake (up to 50%).

Feeding bypass protein to high yielding animals (about 10 litres day^{-1} or more) and fast growing calves (500 g day^{-1}) would offer better economic returns to farmers by way of increased milk production/growth rate. Lactating cows yielding 8 litres and above require about 50% of CP in the feed in the form of bypass protein particularly when fed on straw based diets. The economic returns of feeding bypass protein to animals are quite substantial because of increased production (1.5 kg animal^{-1} day^{-1}).

Use of bypass protein feeds by farmers is limited. Lack of awareness is a major constraint. In some parts of the country the farmers use natural high bypass protein sources and even heat treatment to a limited extent.

Bypass Starch and Bypass Fat

Starch can be protected from ruminal hydrolysis with formaldehyde- or ammonia treatment. Encapsulating fats/lipids with formaldehyde-treated protein is an effective method of protection against ruminal hydrolysis and biohydrogenation of lipids. However, the method has its limitations due to the use of formaldehyde. A simpler approach is the conversion to calcium salts of free fatty acids removed from edible oils during refining. These are protected against rumen degradation.

Feeding bypass starch reduces excess production of lactic acid in the rumen, which otherwise inhibits digestion of fiber. The starch left unfermented in the rumen is digested in the small intestine, producing glucose which, after absorption, is more efficiently used as an energy source by the animals.

Feeding protected fats to high-yielding animals that receive low fat density diets increases milk yield and also efficiency of energy utilization. Providing higher fat supplements without protection affects the utilization of fiber in the rumen. Providing bypass fat is necessary to meet the energy requirements of high-yielding cows, especially in early lactation.

Both the technologies are useful only for high yielding animals and thus have limited level of adoption. The technology is being commercialized.

Mineral Supplementation

Although minerals are required in only small quantities, mineral deficiency can have a marked effect on productivity, reproductive performance, and health. Under farming systems, where straws/stovers form the major source of roughage, the role of minerals becomes more pertinent as these roughages are low in many minerals and contain certain antinutritional factors such as oxalates, tannins, and silica, which may affect mineral utilization. Mineral imbalances depend on the type of feed and where it is grown. Mineral needs depend on animal output and supplements are particularly important for high-yielding animals.

Feeding of formulated mineral mixtures or pure ingredients, although simple, is not a cost-effective method. Besides, the bioavailability of minerals is greater from organic than inorganic sources. Selection is therefore based on the biological availability or release and absorption coefficient. In areas of acute mineral deficiency or where animals exhibit chronic symptoms of deficiency, providing chelated organomineral complexes with high bioavailability is a better approach. Providing region-specific mineral supplements based on mineral mapping is an alternative cost-effective approach. The best way of providing mineral supplements is through the feed or fodder/top feed sources, which are rich in minerals, without affecting the feeding practices followed by the farmers. Few farmers use mineral supplements, except on the advice of a veterinarian.

Supplementation of the diet with a mineral mixture is an effective way of overcoming most reproductive problems such as repeat breeding, low fertility, infertility, delayed postpartum estrus, and silent heat. It is also essential for optimum level of production whether it be milk, meat, egg, or wool production.

Strategic Supplementation

Feeding only straw does not provide sufficient nutrients to maintain the animals, although coarse straws (millets, sorghum, maize) give better results than slender straws (rice, wheat, barley). Feeding straw for a short period may be good for survival or for dung production, but to achieve higher levels of milk, meat, or draught power, straw must be either treated or supplemented with better feeds. Supplementation can be made with concentrates, roughage, or both.

Supplementation of straws with deficient nutrients such as nitrogen and minerals to improve straw intake and digestibility is called catalytic supplementation. Use of small amounts of concentrate supplements, licks, kitchen waste, or green fodder may achieve this objective. Supplementation for increased straw intake is achieved through improved rumen function. The amount of supplement is small in this case, since higher levels of supplementation decreases straw intake through a substitution effect, which may be inevitable when feeding high-producing animals as the level of supplement required is very high.

Farmers generally feed cakes/bran or grass to their productive stock along with straw. This technology is viable and sustainable and does not greatly interfere with the existing farming system. Technical information available on

Table 1. Screening of supplementation strategies for three hypothetical and simplified farming systems.

	Urban dairies	Village conditions	Survival feeding; plenty of low quality roughage	Survival feeding; no roughage available
System characteristics				
Cost ratio (supplement/roughage)	Low	High	Very high	Not available
Price ratio (milk/supplement)	High	Low	Very low	Very low
System objectives	Milk	Milk, dung, draught	Survival	Survival
Supplementation strategies				
Catalytic	Not relevant	Not very relevant	Very relevant	Not relevant
Strategic	Not relevant	Sometimes relevant	Relevant	Not available
Substitutional	Very common	Not common	Irrelevant	Not available

Source: Handbook for straw feeding systems (Singh , K. and Schiere, J.B. 1995).

Note: This screening is an approximation.

the nutritive value of supplementary diets and strong extension support are required for increased adoption of this technology.

For an animal to maintain body weight and produce 2–3 litres of milk day^{-1} catalytic supplementation (provision of urea, small amounts of cake, bran, or green fodder) is recommended. For higher levels of productivity supplementation with concentrates, green forages, or compound feeds is required. The level and type of supplementation depend on the availability of supplements, their prices, and the desired level of production. For supplementation to be economically attractive, the value of increased output has to be greater than the cost of the supplement.

The addition of small amounts of supplements increases the intake of poor quality roughage. Supplements such as urea, oil cakes, or green fodder improve the intake of crop residues by providing a more favorable rumen environment. Straw sprayed with 2% urea improves straw intake by about 10%; just enough for an animal to achieve maintenance. Groundnut cake fed at a rate of 20% of straw dry matter intake (finger millet straw-based diets) improves dry matter intake and digestibility. Furthermore, supplementing a diet of finger millet straw and wheat bran (75:25) with groundnut cake improves nutrient digestibility. Use of legumes or top feeds (*Sesbania*, *Gliricidia*, *Leucaena*) which supply nitrogen and minerals increases straw intake. Mixing local grasses/top feeds/green fodder with straw during chopping will enhance intake and digestibility and also helps in producing good quality dung. This technology is suitable where straw is cheap, supplements are expensive, and where only low production/growth is achievable.

Probiotics / Growth Promoters

Antibiotics and antimicrobials when used in low quantities (subtherapeutic) as growth promoters, increase feed and reproductive efficiency, and reduce mortality. However, their use has created much controversy on the possibility of drug residues in animal products that may be toxic to humans. The antibiotics are pure chemical compounds and are absorbed in the digestive tract. They improve growth and feed efficiency but can cause mutation of other microorganisms.

Most probiotics are specific in their action and are used to improve feed utilization, uptake of nutrients, or feed efficiency by altering the rumen fermentation and/or improving feed conversion efficiency. The most commonly used probiotics are yeast cultures (*Saccharomyces cerevisae* and *Aspergillus)* and bacteria (*Lactobacillus spp., Bacillus subtilis, Streptococcus spp*.), which are available commercially in the form of water-soluble powders, liquids, or as feed additives. In addition to bacteria and yeast, some enzyme cultures are also being used as additives for improving the nutritional efficiency of feedstuffs.

Some enzymes when added to the feed increase the availability of polysaccharides (starch) and proteins, partially hydrolyze viscous carbohydrates (beta-glucans, arabinoxylans) present in some grains, supplement the animal’s endogenous enzymes, and hydrolyze fibrous materials that are not hydrolyzed by the endogenous enzymes. These effects are generally more evident in young animals whose digestive systems are not completely developed.

Several manufacturers are now adding probiotics to their compound feed. The use of probiotics by farmers themselves is negligible due to prohibitive cost, lack of awareness, and inconsistent results.

Manipulation of the Rumen Ecosystem

Increasing digestion of fiber by manipulating rumen microbes is being experimentally tested. The types and numbers of fiber-degrading microorganisms in the rumen have been identified under varying feeding conditions. Knowledge of the genetic diversity and number of these organisms at the species and strain level is lacking. The identification of specific populations of rumen microorganisms in their natural environment is likely to improve due to molecular techniques based on 16S rDNA sequences that can phylogenetically identify these organisms. Further studies may also demonstrate the possibility of ascribing activity to organisms on a phylogenetic basis.

The enzymes reintroduced into the dominant rumen bacteria have been primarily cellulases, xylanases, and more recently, esterases. However mechanisms involved with the binding and presentation of rumen bacteria and enzymes to cellulose (e.g. cellulosome complex) are still poorly understood, impeding the ability to manipulate a rate-limiting step in the kinetics of ruminal fiber digestion. Recent studies have demonstrated that the genus *Ruminococcus* is very diverse in both genotype and fiber-digesting ability and may therefore be amenable to manipulation. The technology has not been perfected so far and efforts in this direction are continuing.

Non-genetic manipulation of the protozoa in the rumen by chemical and biological means has been tried. Although the balance of nutrients available to the animal may improve, treatment of ruminants with defaunating agents to remove ciliate protozoa from the rumen had a secondary effect on population of rumen fungi and bacteria. This technology has thus not been accepted as an effective approach.

Genetic Manipulation for Improvement in Nutritive Value of Straws/Stovers

The nutritive value of crop residues can be improved by genetic manipulation. Genetic manipulation has been used to increase grain production, resistance to disease, and drought resistance in crops. Some of the attributes incorporated in this process might adversely affect the quality of crop residues. High silica and lignin for example could be protective for the plant but adversely affect the nutritive value of crop residues. Genetic manipulation for improvement in quality and/or quantity of straws and stovers, without negatively affecting the grain yield, could resolve many problems in mixed crop-livestock farming systems. Not much emphasis has been laid in the past on genetic manipulation of crops for improvement in quality and/or quantity of straws and stovers.

Recombinant DNA technology is being used to produce transgenic subterranean clover (*Trifolium subterraneum*) and lucerne with increased concentrations of proteins that are resistant to rumen degradation and are hydrolyzed rapidly by intestinal proteases. These forage legumes have been transformed with genes encoding for the sulfur amino acid-rich proteins sunflower albumin and ovalbumins, which are degraded slowly by rumen microorganisms. Improving forage protein quality through genetic manipulation is promising but progress is relatively slow.

The adoption of this technology does not require much effort. However, the relative contribution of genetic and environmental effects needs to be better studied. This requires a coordinated approach by the plant breeders, geneticists, animal nutritionists and physiologists. Controlled experiments leading to a better understanding of the effects of environmental factors on plant physiology and straw quality such as leafiness, translocation of cell solubles from stem to grain, hemicellulose-cellulose ratio, lignification of cell walls, and digestibility need to be conducted.

The ultimate decision to adopt a particular technology depends to a great extent on the farmer's perceptions about the technology attributes and their socioeconomic relevance. There is a growing concern among researchers, extension personnel, and policy makers to include farmers' perceptions in generation and adoption of technology. Lack of coordination among various agencies has often resulted in delay or failure in the accomplishment of the goals. There is an urgent need to work out possible feed options, utilizing feed resources available to farmers in different agroecological zones of the country, to match the nutrient requirements of the animals. This is a gigantic but necessary task that should not be delayed any further.

References

Singh, K. and Schiere, J.B. (eds.) 1995. Handbook for straw feeding systems: principles and applications with emphasis on Indian livestock production. Indo-Dutch Project on Bioconversion of Crop Residues.

Oilseed Cakes for Improving Animal Nutrition

D M Hegde[1]

Improving efficiency of feed use is critical to raising the productivity and profitability of animal agriculture. The cost of feed accounts for 50–60% of the total cost of production in ruminants and 65–80% in nonruminants under intensive production systems. The significant impact of improved nutrition on animal productivity in the developing countries has repeatedly been highlighted (ILRI 1995). Crop residues and other cellulosic materials are staple ruminant feeds in India. The low nitrogen and mineral content, along with high lignin and silica contents of roughage, lead to its low digestibility. To achieve productive levels in the animal consistent with their genetic make-up, the straw-based rations need protein-rich oilseeds and oil cakes as supplements. This is important in countries such as India that have enormous livestock populations and shortages of feed in relation to requirements. The objective of this paper is to assess the oil cake availability for feed use and its contribution towards improving the nutritional security of livestock by examining various oil cakes for their nutritional attributes.

Oilseed Meals and Cakes

India is the third largest producer of oilseeds after the USA and China. It accounts for 8.8% of world oilseed production and 7% of world oil meal production (Tables 1–2). It has about 27 thousand ha under oilseeds, producing about 25000 tonnes of oilseeds. The major oilseeds cultivated in India are groundnut, rapeseed-mustard, soybean, sunflower, sesame, linseed, castor, and niger. The yield level of most of these oilseeds is below the world average. For some crops such as soybean, sunflower, rapeseed-mustard, and linseed the yield levels are about 50% of the world average.

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Table 1. Area, production, and yield of oilseeds in India ,1998–99.

Oilseed	India Area ('000 ha)	India Production ('000 t)	India Yield (kg ha^{-1})	World Area ('000 ha)	World Production ('000 t)	World Yield (kg ha^{-1})
Groundnut	7572	9163	1210	23799	30972	1301
Rapeseed-mustard	6598	5774	875	24987	33568	1343
Soybean	6309	6942	1100	70690	158327	2240
Sesame	1673	555	332	6706	2292	342
Sunflower	2004	1170	584	21251	24942	1174
Safflower	529	324	614	1121	947	845
Linseed	798	275	344	3520	2653	754
Castor	689	842	1221	1290	1189	922
Niger seed	538	164	304	-	-	-
Total	26711	25211	944	153364	254890	1662

Table 2. Oil meal production in India and the world.

Oil meal	India 1997–98	India 1998–99	World 1997–98	World 1998–99
	('000 t)			
Soybean	3682	4141	104440	105421
Cotton	3052	3213	15553	15200
Groundnut	2253	2281	6415	6796
Sunflower	503	481	10327	11003
Rapeseed	2699	3015	19079	20700
Sesame	253	240	905	912
Palm kernel	-	-	2628	2810
Linseed	169	163	1361	1442
Copra	265	256	1815	1625

Oilseed meals are rich in protein and other valuable feed nutrients for livestock (Table 3). Oil is extracted from oilseeds by using pressure to force out the oil, or by using an organic solvent, usually hexane, to dissolve oil from the seed. Seeds such as groundnut, cottonseed, and sunflower have a thick coat or husk, rich in fiber and of low digestibility, which lowers the nutritive value of the material. This husk may be completely or partially removed by cracking and riddling, the process being known as decortication. Removal of the husk lowers the crude fiber content (Table 3) and improves the apparent

Table 3. Chemical composition of oilseed cakes.				
Cake	Crude protein	Oil (%)	Crude fiber	General remarks
Groundnut cake				
Expeller-pressed	48.0	8.0	7.0	Low in lysine, arginine, histidine, and S- containing amino acids
Solvent-extracted	51.0	1.0	10.0	
Rapeseed-mustard				
Expeller-pressed	37.0	5.0	10.0	Palatability problems due to pungent odor
Sesame cake				
Expeller-pressed	40.0	8.0	7.0	-
Linseed cake				
Expeller-pressed	29.0	8.0	10.0	-
Solvent-extracted	33.0	1.0	9.0	
Cottonseed cake (Decorticated)				
Expeller-pressed	41.0	5.0	12.0	Low in Ca, Zn, Mn
Solvent-extracted	42.0	1.5	16.0	Effect of gossypol is greater in monogastric animals
Safflower cake (Decorticated)				
Expeller-pressed	48.0	5.0	15.0	-
Coconut cake				
Expeller-pressed	22.0	6.5	12.0	-

Source : AICRP on agricultural by-products and industrial wastes for livestock and poultry feeding. ICAR, New Delhi.

digestibility of the other constituents. Generally, the residual oil content of the cakes is higher in screw-pressed cakes than in solvent-extracted meals.

India also has many unconventional oilseeds of which only a small proportion is presently exploited (Table 4). They are also rich sources of protein and other nutrients, but their use in the livestock industry is limited by the presence of one or more undesirable nutritional factors (Table 5). These, however, can be used in concentrate mixtures in varying proportions depending on their chemical composition.

The quality of a protein in a particular oilseed is relatively constant, but may vary in the cake or meal, depending on the technique employed for the

Table 4. Unconventional oil meals/cakes available for animal feed.

Source	Availability of oilseeds	By-product availability	Extraction rate (%)	By-product
	................('000 t)	....		
Sal seed meal	5504	4806	88	Meal
Mahua seed	2176	1414	65	Cake
Neem seed	418	334	80	Cake
Rubber seed	336	117	35	Cake
Karanj	111	81	73	Cake
Kusum	105	70	67	Cake
Khankan, Undi, Nahar, Tobacco seed	102	59	40-75	Cake
Mango seeds	1000	500	50-55	Meal/Kernel

Source: AICRP on agricultural by-products and industrial wastes for livestock and poultry feeding, ICAR, New Delhi.

Table 5. Chemical composition, toxic factors, and safe level of inclusion in the concentrate mixture (CM) of unconventional oil cakes.

Extractions	Crude protein	Crude fiber	TDN	Toxic factors	Level of inclusion in diet
	....	(%)	....		
Mahua seed cake	20	13	50	Mowrin (19%)	20% in CM of crossbred calves
Karanj cake	34	4-5	62	Karanjia, Pongamol, glabrin	15% in CM of growing and lactating cows
Kusum seed cake	22	5-7	79	HCN (2.4 mg/100 g DM)	35% in CM of crossbred calves and 17% in broiler chickens
Sal seed cake	9-20	2-4	40-58	Tannic acid (8-10%), glucosides (3.83%)	10% in CM of milch cattle
Kokam cake	16	4	70	-	15% in CM of crossbred calves
Castor cake	35	33	-	Ricin (0.22%)	Only detoxified meal at 10% in CM of sheep
Neem seed cake	17	42	57	Nimbia, Salamin	Only detoxified cake at 10% in CM of adult animals

Source: AICRP on agricultural by-products and industrial wastes for livestock and poultry feeding, ICAR, New Delhi.

extraction of the oil. As mentioned earlier, generally, the residual oil content of the cakes is generally higher in screw-pressed cakes than in solvent-extracted meals. High temperatures and pressures of expeller processing may result in the lowering of the nutritive value. For ruminants, such denaturation may be beneficial, owing to an associated reduction in degradability. High temperatures and pressures also degrade some deleterious substances such as gossypol. Solvent extraction does not involve pressing, temperatures are comparatively low, and protein value of meals is almost the same as that of the original seed. The oilseed cakes may make a significant contribution to the energy content of the diet, particularly when the oil contents are high.

Antinutritional Factors

Some oil meals contain certain antimetabolites or other antinutritional factors which when consumed may be toxic to animals. Table 6 shows some of the important antinutritional factors found in different oilseed cakes/meals. These factors may affect the absorption of dietary nutrients in the digestive tract as a result of toxic action on some organ or tissue, or production traits. Detoxification of some factors is possible by treating a particular ingredient.

Table 6. Antinutritional factors in oilseeds/plant protein meals.

Meals	Antinutritional factors
Soybean	Protease inhibitors*, allergins*, oligosaccharides, phytin, lipoxygenase*, lectins*, saponin, hemagglutinins, citrinin
Rapeseed	Erucic acid, glucosinolates, sinapine, tannins, pertins, oligosaccharides
Canola	Glucosinolates, sinapine, pectins, oligosaccharides
Cottonseed	Gossypol, tannins, cyclopropenoid fatty acids
Sunflower	Chlorogenic acid, high fiber, achratoxin
Groundnut	Mycotoxins, tannins, oligosaccharides, protease inhibitors*
Copra	Fiber, mannans
Palm kernel	Fiber and sharp shells, galactomannans
Sesame	Phytase, oxalate
Sal seed	Tannins
Linseed	Prussic acid

* Destroyed by heating.

Some of these treatments are simple whereas others are cumbersome. It is, however, necessary that whenever such ingredients containing toxic factors are mixed in the feed, their inclusion levels should be such that an animal can tolerate them. Toxic factors can be of two types, intrinsic and extrinsic. Intrinsic factors are usually of plant origin such as tannins, trypsin inhibitors, goitrogens, cyanogenetic glucosides, saponins, hemagglutinins, gossypol, lathyrogens, and nimbin and its derivatives. Extrinsic factors are those produced by the attack of pathogens on feed ingredients, e.g. *Aspergillus* spp., causing aflatoxicosis.

Critical Amino Acids in Oilseed Meals

Oilseed cakes and extractions are the most important sources of essential amino acids. In general, oilseed proteins have low cysteine and methionine content and a variable but low lysine content (Table 7). As a result, these cannot adequately supplement the cereal proteins with which they are commonly used. The gross protein value of some oilseed such as cotton, groundnut, and soybean is high; their chemical composition does not favor their greater use. Cottonseed meal also has the disadvantage of a low cysteine, methionine, and lysine contents, with lysine being the first limiting amino acid.

Different oilseed meals are degraded at varying rates in the rumen of livestock. Since high-yielding dairy cattle and fast-growing goats and sheep need higher levels of undegradable dietary protein, it is possible to select desirable components of protein meals and formulate rations for differential levels of productivity (Sudhakara Rao et al. 1992).

Table 7. Important limiting amino acid contents of commonly-used oil meals.

Source	Arginine	Lysine	Tryptophan	Methionine	Cysteine
			(%)		
Groundnut	4.4	1.3	0.4	0.6	0.7
Soybean	3.0	2.6	0.5	0.8	0.7
Sesame	3.7	1.2	0.6	1.4	0.4
Safflower	3.8	2.0	0.6	1.6	0.7
Cotton seed	3.4	1.4	0.5	0.8	1.0

Limitations to the Use of Oilseed Cakes

The problem of aflatoxins in animal feeds is being debated at length. The use of groundnut meal, which is very susceptible to fungal infection and aflatoxin contamination, has drastically decreased recently despite the superiority of its proteins. Improper harvesting, transport, processing, and storage all contribute to aflatoxin contamination. Preventive measures during crop production and postharvest handling of seeds would greatly reduce the level of contamination in feeds. Creating an awareness among farmers about aflatoxins would help increase groundnut meal use in animal feeds. While soybean meal is not normally found to contain detectable amounts of aflatoxins, the incidence of these metabolites has been on the rise recently.

Sunflower meal is very rich in many essential amino acids, but its use has been restricted owing to its high fiber content. Decorticating the sunflower seeds prior to expelling/solvent extraction produces oil with less gum content, better clarity, and a meal with lower fiber. However, the economic viability of the process has yet to be established. Similar problems limit the use of other meals such as safflower meal, and niger seed meal in animal feeds.

References

International Livestock Research Institute (ILRI). 1995. Global agenda for livestock research (Gardiner, P. and Devendra, C., eds.). Proceedings of a consultation, ILRI, Nairobi, Kenya.

Sudhakara Rao, M., Krishna, N. and Prasad, A. 1992. Determination of effective protein degradability of some unconventional protein sources in cattle by nylon bag technique. Indian Journal of Agricultural Sciences 52:280-281.

Status of Forage Breeding Technologies in India

N P Melkania and G P Shukla[1]

The availability of feed resources in India improved considerably after the introduction of Green Revolution technologies in the mid-1960s, but the gains remain largely confined to irrigated regions. At an all-India level, the deficit is estimated at 31% for dry fodder and 23% for green fodder. The deficit in green fodder is due to low priority accorded to fodder crops in research and development efforts compared to food crops. The share of fodder crops in total cropped area has remained stagnant during the last two decades. In recent years India has enlarged its food buffer stock considerably and thus it is expected that the policy emphasis will shift from foodgrains to fodder crops in view of the growing demand for livestock products. The increase in area under forage crops particularly leguminous crops, besides alleviating fodder constraints would impart sustainability to agricultural systems by improving soil fertility and contributing towards increased production of sequential crops. Fodder breeding research efforts have generated a number of high yielding fodder cultivars that can be profitably cultivated under field conditions in different agroecological conditions. The purpose of this paper is to document the varieties of different forage crops and identify constraints to their adoption by farmers.

Trends in the Area under Fodder Crops

During the triennium ending (TE) 1992–94, about 8.5 million ha of land were under fodder crops, comprising only 4.6% of the gross cropped area.[2] This includes area under guar crop, which is grown for fodder as well as grain production in Rajasthan, Gujarat, and Haryana. The total area under fodder crops has been increasing steadily at an annual rate of 1.3% (Fig. 1 and Table 1), mainly due to an increase in area under irrigated fodder that grew at a much faster rate of 2.2% per annum (Kelley and Parthasarathy Rao 1994).

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1. All India Coordinated Project for Research on Forage Crops, Indian Grassland and Fodder Research Institute, Jhansi—284 003, India.

2. Data on area and production of specific fodder crops is difficult to obtain, although some information is available from State Departments of Agriculture.

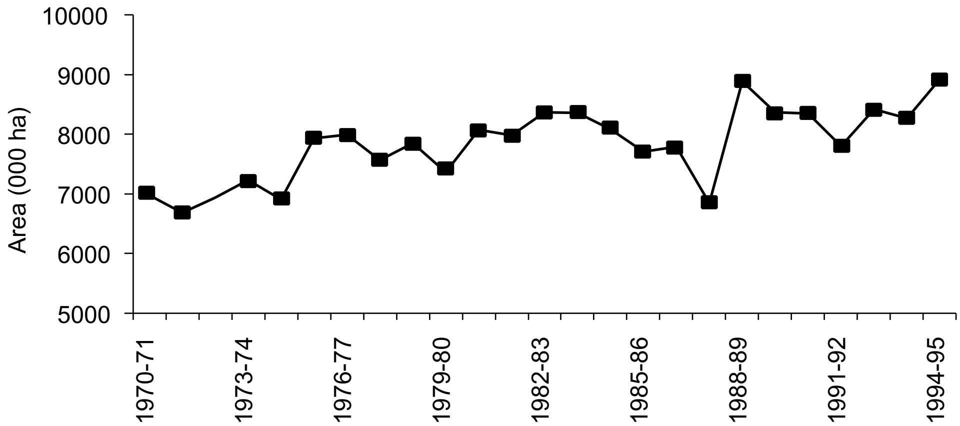

Figure 1. Trends in the area under fodder crops in India.

There is considerable regional variation in the area in fodder crops (Table 1). Fodder crops are relatively more important in the states of Rajasthan, Punjab, Haryana, and Gujarat, where they account for about 10% of the gross cropped area. In Madhya Pradesh, Maharashtra, Tamil Nadu, and

Table 1. Area under fodder crops in selected states of India, 1992–94.

State	Fodder area (thousand ha)	Share in gross cropped area (%)	Compound growth rate (%) (1984–94)
Andhra Pradesh	152.0	1.2	–0.1
Assam	9.0	0.2	12.0
Bihar	15.0	0.2	1.3
Gujarat	1205.0	10.7	4.6
Haryana	545.0	9.3	–1.8
Himachal Pradesh	4.0	0.4	–14.9
Jammu & Kashmir	42.0	3.9	4.1
Karnataka	77.0	0.6	–0.4
Kerala	2.0	0.1	-
Madhya Pradesh	805.0	3.3	–1.2
Maharashtra	860.0	4.0	2.0
Punjab	770.0	10.1	0.1
Rajasthan	2850.0	14.3	1.9
Tamil Nadu	188.0	2.7	5.6
Uttar Pradesh	1003.0	3.9	1.6
West Bengal	3.0	neg	-
All India	8535.0	4.6	1.3

Uttar Pradesh fodder crops account for 3–4% of the total cultivated area. In other states it rarely exceeds 1% of the total cropped area.

Changes in area under fodder at state level have been dynamic despite the stagnancy at national level (Table 1). In Assam, the fodder area expanded at a rate of about 12% a year, followed by Tamil Nadu, Gujarat, Jammu and Kashmir, Maharashtra, Rajasthan, and Uttar Pradesh. The area under fodder crops showed a negative growth in Haryana, Himachal Pradesh, and Madhya Pradesh. In other states it has been either marginally positive or negative.

Improved Forage Cultivars/Varieties

A number of institutes under the Indian Council of Agricultural Research (ICAR) and the State Agricultural Universities (SAUs) conduct research on forage crops. The ICAR has generated a number of improved forage varieties through the All-India Coordinated Project for Research on Forage Crops (AICRP-FC) in collaboration with State Agricultural Universities (SAUs), nongovernmental organizations (NGOs), and ICAR institutes. Besides, the Indian Grassland and Fodder Research Institute (IGFRI), an offshoot of ICAR, has also contributed significantly towards development of improved fodder production technologies.

The forage variety improvement program under AICRP-FC and the All-India Coordinated Sorghum Improvement Programs released 54 different varieties of forage crops during the last decade. A few important characteristics of these cultivars/varieties include their wide adaptability and resistance to major insect pests and diseases. Some of them can be grown throughout the country, and others are suited to specific agroclimates.

An important aspect was the development of forage sorghum hybrids with multiple improvements in yield in irrigated multicut systems. Varieties resistant to *Maydis* blight and downy mildew in pearl millet have also been released for cultivation. The oat improvement program also led to the evolution of multicut and more productive varieties. Good varieties of Napier x Bajra hybrid have broken the yield plateau of the traditional variety NB-21 (Tables 2 and 3). A notable breakthrough was the genetic improvement of *Trifolium* and *Medicago*. In *Trifolium,* a diploid variety resistant to *Rhizotonia* and *Fusarium* root rot and *Sclerotinia* stem rot with high dry matter content was released as Bundel Berseem-2. A tetraploid variety with multiple gene resistance and gigantic plant type has been released recently. Besides, UPB-

Table 2. Forage crop varieties (cereals) released during 1989–2000.

Crop	Variety	Year of release	Green forage yield (t ha^{-1})	Target domain	Specific features
Jowar-Sorghum (*Sorghum vulgare*)	GFS-1	1990	32–50	Gujarat	Single- to double-cut variety; resistant to major foliar diseases
	Pro-Agro chari	1991	60–90	Throughout the country	Multicut (3–5 cuts); resistant to various foliar diseases and insect pests
	Pant Chari-3 (UPFS-23)	1991	35–45	Uttar Pradesh	Single-cut; resistant to major stem and foliar diseases and insect pests
	Gujarat Forage Sorghum-1 (AS-16)	1992	40–70	Gujarat	Multicut (2–3); resistant to foliar diseases
	MFSH-3	1993	50–85	Throughout the country	Multicut (3–5); resistant to major foliar diseases
	Punjab Sudex (Hybrid)	1994	60–95	Punjab	Multicut; resistant to foliar diseases, and fairly tolerant to major insect pests
	Hara Sona (Hybrid)	1995	60–90	Throughout the country	Multicut (3–5); resistant to various major foliar diseases
	HC-308	1995	35–55	Throughout the country	Single-cut; fairly tolerant to major foliar diseases
	CSV-15	1996	40–60	Sorghum growing tract	Multicut; fairly resistant to major foliar diseases and insect pests
	CSH-13	1997	60–90	Sorghum growing tract	Multicut; fairly resistant to major foliar diseases and insect pests
	PCH-106 (hybrid)	1996	65–90	Throughout the country	Multicut (3–4); resistant to leaf spot and stem borer
Bajra-Pearl millet (*Pennisetum typhoides*)	Rajbajra chari-2	1990	30–45	Bajra growing tract	Resistant to all major diseases including downy mildew, and insect pests
	Fodder Kumbu-8 (TNSC-1)	1993	27–40	Bajra growing tract	Resistant to all foliar diseases and insect pests
Makka-Maize (*Zea mays*)	J-1006	1993	35–45	Punjab	Resistant to *Maydis* blight and brown striped downy mildew and stem borer
Jai-Oats (*Avena sativa*)	Bundel Jai-822	1989	35–40	Throughout the country	Multicut; resistant to all major diseases, and insect pests
	UPO-212	1990–91	37–52	Throughout the country	Multicut; resistant to all major diseases and insect pests
	OL-125	1994	35–48	Throughout the country	Multicut; fairly tolerant to major diseases and insect pests
	Bundel Jai-851	1997	40–62	Northern and Northwest regions	Multicut (3–4 cuts); resistant to major diseases and insect pests

Table 3. Forage crop varieties (grasses) released during 1989–2000.

Crop	Variety	Year of release	Green forage yield (t ha^{-1})	Target domain	Specific features
Bajra × Napier Hybrid	PBN-83	1989	125–170	Punjab	Resistant to major diseases and insect pests
	CO-2	1995	120–180	Tamil Nadu and other southern states	Resistant to major diseases and insect pests
	CO-3	1997	130–200	Southern states	Resistant to major diseases and insect pests
	PGG-101	1995	80–145	Punjab	Free from all major diseases and insect pests
	PGG-518	1997	120–130	Irrigated conditions of Punjab	Apomictic, perennial, multicut summer fodder; resistant to insect pests and diseases
	PG-616	2000	20–120	Irrigated conditions of Punjab	Apomictic, perennial, multicut summer fodder; resistant to insect pests and diseases and lodging
Anjan-Buffalo Grass (*Cenchrus ciliaris*)	Neela Kolu Kattai (CO-1)	1991	28–47	Tamil Nadu and other southern states	Perennial; free from major diseases and insect pests
	Blan Buffel (FS-391)			Tamil Nadu and other semi-arid areas	Perennial; free from major diseases and insect pests
Guinea grass – Green Panic (*Panicum maximum*)	PGG-19	1989	75–130	Punjab	Free from major diseases and insect pests
	PGG-101	1995	80–145	Punjab	Free from major diseases and insect pests
	PGG-518	1997	120–130	Irrigated conditions of Punjab	Apomictic, perennial, multicut summer fodder; resistant to insect pests and diseases
	PG-616	2000	20–120	Irrigated conditions of Punjab	Apomictic, perennial, multicut summer fodder; resistant to insect pests and diseases
Nandi grass (*Setaria sphacelata* cv. nandi)	PSS-1	1990	75–110	Subtemperate and hill areas	Resistant to major diseases and insect pests
Tall Fescue (*Festuca* spp.)	Him-1	1997	40–45	Himachal Pradesh	Suitable for cultivation in temperate and subtemperate regions; resistant to major diseases and insect pests

110 has broken climate boundaries and performs reasonably well in the temperature range of 10–20°C. In *Medicago*, Anand-3 was adapted to high elevation and low temperatures below 0°C during crop growth. Another variety, RL-88, appears to behave as a self-pollinated crop and does not get contaminated at short to medium isolation distances (Table 4).

Other noteworthy developments in forage research include production of hybrids in forage sorghum and pearl millet (Table 2), contraclimatic adaptive varieties in berseem (*Trifolium alexandrinum*) and *Medicago sativa*, highly productive Napier × Bajra hybrid materials, and highly adaptive disease resistant multicut varieties in oats. Additionally, the breeding program paved the way for developing exploitable varieties of nontraditional crops such as ricebean, gobhi sarson, and metha (*Trigonella foenum graecum*) (Tables 4 and 5). Advances were also made with the temperate forages. Promising varieties of Persian clover and Tall Fescue have been developed. The selection and improvement of forage varieties for desert and drought-prone areas is a major breakthrough. The improved varieties of *Cenchrus ciliaris* are also worth a mention.

Adoption of Improved Varieties

Unlike food crops, where considerable information has been generated on area under high-yielding varieties, there are few if any statistics available to indicate the area under various fodder crops and adoption of improved varieties. This is because not much importance has been attached to the livestock sector and thereby fodder crops in the process of agricultural development. The general observations indicate that although farmers are aware of the benefits of feeding green fodder to animals, a majority of them do not grow fodder crops or grow them only on a small fraction of their land (Prasad et al. 1995, Rai et al. 1995). A review of literature indicates the following limitations to adoption of fodder crops/varieties:

- Average size of land holding is small and is the main limitation to shifting area away from food to fodder crops.
- Livestock production is subsistence-oriented, and a major part of the feed consumption is derived from crop residues and grazing lands. Fodder markets are not developed and are fragmented because of lack of commercialization of livestock production. Thus, the market signals to bring greater area under fodder crops are not encouraging.

Table 4. Forage crop varieties (legumes) released during 1989–2000.

Crop	Variety	Year of release	Green forage yield (t ha^{-1})	Target domain	Specific features
Cowpea (*Vigna unguiculata*)	Gujarat Lobia-3	1990	25–40	Gujarat	Growing upward at 27 to 32^{o}C; resistant to major diseases and insect pests
	UPC-4200	1991	27–42	Northern & Eastern regions	Resistant to cowpea mosaic virus, *Pythium* and *Rhizoctonia* root rot
	Bundel Lobia-1 (IFC-8401)	1992	25–32	Throughout the country	Tolerant to cowpea yellow mosaic virus, flea beetle and semi-looper insect pests
	Lobia-88	1992	25–35	Punjab	Highly resistant to cowpea mosaic virus and anthracnose; fairly tolerant to semi-looper and leaf minor pests
	Bundel Lobia-2 (IFC-8503)	1995	22–35	Northeastern regions	Fairly resistant to cowpea mosaic virus and anthracnose
	UPC-8705	1997	30–42	Throughout the country	Resistant to dry root rot and collar rot
	Haryana Lobia-88	1997	28–35	Northwestern regions	Resistant to cowpea mosaic virus
	UPC-9202	1999	35–42	Sub-tropical to temperate conditions in the central zone of the country	Biomass stays green after pod maturity even during Oct.–Nov., resistant to yellow mosaic virus disease, root and stem rot, anthracnose and wilt diseases, pod borers, aphids, and leaf hopper; pods tolerant to seed shattering, fodder-cum-grain type
Guar-Cluster bean (*Cymopsis tetragonaloba*)	Bundel Guar-1 (IGFRI-212-1)	1993	22–35	Northwest regions	Resistant to *Xanthomonas* and *Alternaria*, and fairly tolerant to insect pests
	Guara-80	1994	30–45	Punjab	Tolerant to bacterial leaf blight
	Bundel Guar-2 (IGFRI-2395-2)	1995	28–40	Guar growing tract	Resistant to foliar diseases including *Xanthomonas*; good seed producer
	Bundel Guar-3 (IGFRI-1019-1)	1999	26–30	Guar growing tract	Resistant to lodging, free from pod shattering and highly responsive to fertilizers; dual purpose, moderately resistant to drought, bacterial blight powdery mildew diseases and major insect pests; high in vitro dry matter digestibility (71.2%)

...continued

Table 4. *Continued.*

Sem-Hyacinth bean (*Lablab purpureus*)	JLP-4	1993	22–35	Throughout the country	Resistant to all major diseases and insect pests; suitable for rainfed and drought-prone areas
Berseem-Egyptian clover (*Trifolium alexandrinum*)	UPB-110	1993	50–65	Southern zone	Tolerant to major diseases and insect pests in field conditions
	Bundel Berseem-2	1997	58–85	Central and Northwest zones	Resistant to *Rhizoctonia* and *Fusarium* root rot, *Sclerotinia* stem rot, lodging, shattering, and major insect pests
	Bundel Berseem-4	2000	50–60	Northeastern region	A tetraploid variety with broad leaves, vigorous plant type; multiple resistance to root rot, stem rot, and major insect pests
Rijka-Lucerne (*Medicago sativa*)	Anand-3	1994	60–90	Himachal Pradesh	Resistant to powdery mildew, other major diseases, and insect pests, suitable for cultivation in temperate zones at higher elevations, ranging from 1200–2500 m above sea level; temperature 0°C and below during growth period
	RL-88	1995	70–100	Throughout the country	Perennial; resistant to major diseases and insect pests, behaves as if self pollinated, and requires less isolation distance for maintenance
Shaftal-Persian clover (*Trifolium resupinatum*)	SH-48	1994	80–105	Himachal Pradesh	Free from major diseases and insect pests; highly resistant to *Sclerotinia* stem rot in wetland and damp conditions; suitable for cultivation in acidic soils after harvest of rice crop
	SH-69	1995	75–110	Punjab	Free from major diseases and pests, highly resistant to *Sclerotinia* stem rot in wetland and damp conditions, suitable for cultivation in acidic soils after harvest of rice crop
Rice bean (*Vigna umbellata*)	RBL-1	1994	25–40	Punjab	Resistant to major diseases, and insect pests; basically a pulse crop but also proved its worth as a forage crop
	RBL-6	1997	22–45	Punjab	Resistant to major diseases, and insect pests; basically a pulse crop but also proved its worth as a forage crop
	Bidhan-1 (K-1)	2000	25–50	Northeast, Southwest and South-central regions	Resistant to major diseases and insect pests, flourishes well at high humidity, and survives well at low soil pH

Crop	Variety	Year of release	Green forage yield ($t\ ha^{-1}$)	Target domain	Specific features
Gobhi Sarson (*Brassica* sp.)	GSL-1	1994	25–35	Punjab	Comparatively tolerant to major diseases and insect pests including aphids; basically oilseed crop but also proved its worth as a fodder crop
	Sheetal (HPN-1)	1995	18–30	Himachal Pradesh	Comparatively tolerant to major diseases and insect pests including aphids; basically oilseed crop but also proved its worth as a fodder crop
Metha (*Trigonalla foenum-graecum*)	ML-150	1995	27–35	Punjab	Highly resistant to powdery mildew and stem rot diseases

Table 5. Other forage crop varieties released during 1989–2000.

- Farmers lack orientation in cultivation of green fodder, and transfer of technical information related to different fodder crops to farmers is inadequate. Lack of seed availability is another major limitation.
- Availability of timely irrigation is an important requirement, particularly for multicut fodder crops.

Conclusions

Breeding research has developed a number of forage cultivars that grow under varying agroecological conditions. Their adoption, however, has been slow as is indicated by the sluggish growth in the area under fodder crops. Appropriate incentives to farmers to grow fodder crops, strengthening information flow on fodder cultivation practices as well as livestock feeding practices, and expansion of fodder markets would help alleviate the fodder scarcity and contribute towards improving animal productivity.

References

Kelley, T.G. and Parthasarathy Rao, P. 1994. Trends in cultivated green fodder crops in India. *In* Proceedings of the workshop on variation in the quantity and quality of fibrous crop residues, 8-9 February 1994, (Joshi, A.L., Doyle, P.T., and Oosting, S.J., eds.) Bharatiya Agro Industries Foundation, Pune, Maharashtra.

Prasad, C.S., Subba Rao, A., Sitaramaswamy, J., Dixit, P.K., Ranganathan, K., Krishnamurthy, C.S., Ramanand, and Vasantha, G. 1995. Rapid rural appraisal on fodder production and feeding practices in Banagalore district. *In* Farming Systems Research for Improving Livestock Production and Crop Residue Utilization (Singh, C.B., Rao, S.V.N., and Jain, D.K., eds.). Indian Council of Agricultural Research, New Delhi, and National Agricultural University, The Netherlands.

Rai, S.N., Singh, C.B. and Sohi, D.S. 1995. Rapid rural appraisal in problem identification and technology targeting. *In* Farming Systems Research for Improving Livestock Production and Crop Residue Utilization (Singh, C.B., Rao, S.V.N., and Jain, D.K., eds.). Indian Council of Agricultural Research, New Delhi, and National Agricultural University, The Netherlands.

Potential Technological and Management Interventions for Improving the Productivity of Grasslands

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India is a country with tropical monsoon climate where most of the rains occur between June and September. Thus, the active growth period in rainfed areas is 3–4 months. In this climate the native vegetation comprises different types of woodland. Seminatural grazing lands grow only on clearing of the wood bunds. Grazing lands are controlled by the degree of grazing. Pastures are not maintained due to the prevalent ecoclimate and exist only at high altitudes in the Himalayas beyond the tree line.

The total area of grazing lands in India is about 86 million ha (Pandeya 1986). This, together with crop residues and by-products, supports India's entire livestock population. The total arable land in the country is about 147.4 million ha. Assuming that croplands donate one-tenth of production as fodder, the total arable land supporting livestock feed would be about 14.7 million ha, thereby increasing the potential grazing area to about 100 million ha. Taking the average potential above-ground net primary productivity as 500 g m^{-2} yr^{-1}, the total fodder production is 501.5 million t of dry fodder yr^{-1} for 239 million animals, excluding sheep, goats, horses, camels, and donkeys. Also, assuming that a normal healthy cow consumes 7 t dry herbage yr^{-1}, the annual consumption is 1673 million t yr^{-1}. The net primary production level of Indian grasslands is thus far below the total requirement. The overgrazing and continuous degradation of grazing lands, along with loss of fertility, is further decreasing their productivity (Pandeya and Jain 1979). The problems of grazing lands are related to ecological and socioeconomic causes (Pandeya 1986). In arid areas water is the limiting factor; in semi-arid areas improper land utilization and excessive grazing are the main problems; and in the high rainfall zones the low nutritive value of the herbage is a constraint. Another serious problem is the low legume component of the grasslands.

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This paper analyzes the capability of grassland technologies to improve grazing capacity of Indian rangelands and its implications for animal production.

The Present Scenario

Over the past 40 years while the net area sown increased by about 20%, the gross cropped area increased by over 40%, implying an increase in the cropping intensity from 1.1 in 1950–51 to 1.3 in 1992–93 (Table 1). Although the area under forests shows an increase, the area under the tree canopy has decreased drastically. The area under pastures, cultivable waste, fallow, and barren lands has also decreased. Thus, common grazing lands have declined in area, both quantitatively and qualitatively.

The fodder demand and supply position has always been considered in relation to the grazing animal population and the area under forage crops. Estimates show a deficiency of feed and fodder (Singh and Majumdar 1992). A different feeding strategy and feed quality are required for different animal species. Buffalo and cattle require stall feedng. Small ruminants need a greater fodder supply from tree leaves besides grazing/browsing in forests. Also, there are large areas facing land degradation, which progressively reduces the productivity of the grasslands (Table 2).

Table 1. Land use in India.

Category	Area (million ha)		% change
	1950–51	1992–93	
Geographic area	284.3	305.0	7.3
Forests	40.5	68.1	68.1
Unavailable for cultivation / non-agriculture / barren land	47.5	41.3	–13.1
Pastures	26.5	15.0	–43.4
Cultivable waste	22.9	14.6	–36.2
Fallow land	28.1	23.6	–16.0
Net area sown	118.7	142.5	20.0
Gross cropped area	131.9	185.5	40.6
Cropping intensity	1.1	1.3	17.1
Net irrigated area	20.9	50.1	139.7
Gross irrigated area	22.6	66.1	192.5

Source: Agricultural Statistics at a Glance 1996.

Table 2. Severity and extent of soil degradation.					
	Severity of degradation (million ha)				Total area (million ha)
Type of degradation	L	M	H	VH	
Water erosion	5.0	24.3	107.2	12.4	148.9
Wind erosion	-	-	10.8	2.7	13.5
Chemical deterioration	2.8	2.0	9.0	-	13.8
Physical deterioration	6.4	5.2	-	-	11.6
Total	14.2	33.2	124.3	16.1	187.8

L = Low, M = Medium, H = High, VH = Very High

Indian Grasslands - Types, Production, and Potential

The Grass Cover of India

A survey of the grasslands of India conducted between 1954 and 1962 revealed five major grass covers (Dabadghao and Shankarnarayan 1973). These were *Sehima-Dichanthium*, *Dichanthium-Cenchrus-Lasiurus*, *Phragmites-Saccharum-Imperata*, *Themeda-Arundinella*, and Temperate Alpine associations.

Sehima-Dichanthium

This cover type spreads over the whole of peninsular India, including the Central Indian Plateau, the Chhota Nagpur Plateau and the Aravali Ranges with a potential coverage of approximately 1.74 million km^2. It is represented by dominant perennial grasses such as *Dichanthium annulatum, Sehima nervosum, Bothrichloa pertusa, Chrysopogon fulvus, Heteropogon contortus, Iseilema laxum, Themeda triandra, Cynodon dactylon, Aristida setacea,* and *Cymbopogon* spp. Important associated species are *Apluda mutica, Bothrichloa intermedia, Arundinella nepalensis, Desmostachya bipinnata, Eragrostis,* and *Eragrostiella* spp.

Dicanthium-Cenchrus-Lasiurus

This type is associated with subtropical arid and semi-arid regions comprising the northern part of Gujarat, the whole of Rajasthan, excluding the Aravalli Ranges in the south, western Uttar Pradesh, Delhi, Punjab, and Haryana with a potential area of more than 0.44 million km^2. The principal perennial grass species are *Cenchrus ciliaris, C. setigerus, Dicanthium annulatum, Cymbopogon jwarancusa, Cynodon dactylon, Eleusine compressa, Lesiurus sindicus, Sporobolus marginatus, Dactyloctenium sindicum,* and *Desmostachya bipinnata*. Important associated species are *Chloris dolichostachya, Heteropogon contortus, Saccharum bengalense,* and *Vitevaria zyzanioides*.

Phragmites-Saccharum-Imperata

This association occurs throughout the Gangetic Plain and the Brahmaputra Valley and extends into the plains of Punjab. The area covers approximately 2.8 million km^2 in the northeastern states, West Bengal, Bihar, Uttar Pradesh, Punjab, and Haryana. The principal perennial species in drier regions are *Imperata cylindrica, Saccharum arundinaceum, S. spontaneum, Phragmites karka,* and *Desmostachya bipinnata*. Other important species are *Bothrichloa intermedia, Vitevaria zizanioides, Imperata cylindrica, Chrysopogon aciculatus,* and *Panicum notatum*.

Themeda-Arundinella

This association occurs in the entire northern and northwestern mountain tract, in an approximate area of 230 thousand km^2 in the northeastern states, West Bengal, Uttar Pradesh, Punjab, Haryana, Himachal Pradesh, and Jammu and Kashmir. This type is associated with undifferentiated forest and hill soils, and also with undifferentiated forest submountain regional soils. The principal grass vegetation is represented by *Arundinella bengalensis, A. nepalensis, Bothrichloa intermedia, Chrysopogon fulvus, Cymbopogon jwarancusa, Cynodon dactylon, Heteropogon contortus, Themeda anathera, Eulaliopsis binata,* and *Ischaemum barbatum*. Associated perennial species are *Apluda mutica, Arundinella khaseana, Pennisetum flaccidum*, and *Chloris dolichostachys*.

Table 3. Production levels of various grass covers in India.

	Harvestable biomass (t ha^{-1})	
Grass cover	Actual	Potential
Sehima - Dichanthium	3.5	6.0
Dichanthium - Cenchrus - Lasiurus	3.3	5.0
Phragmitis- Saccharum - Imperata	5.0	5.0
Themeda - Arundinella	2.2	4.0

Temperate Alpine

These grasslands occur on the high hills of Uttaranchal, Jammu and Kashmir, Himachal Pradesh, West Bengal, and the northeastern regions. They differ from the *Themeda-Arundinella* type in that they essentially occur at higher elevations beyond the tree line, approximately above 3000 m in the west and above 2000 m in the east. The principal perennial species are *Agropyron conaliculatum, Chrysopogon gryllus, Dactylis glomerata, Danthonia cachemyiana, Phleum alpinum, Carex nubigena, Poa pratensis,* and *Stipa concinna.* Associated species are *Poa alpina, Festuca lucida, Eragrostis nigra,* and *Bromus ramosus*.

Research on Grassland Improvement

Grassland improvement is possible through various ecological approaches such as protection of grassland for recovery of vegetation, removal of unwanted bushes, reseeding, application of fertilizers, and better management. These improvement techniques are discussed below:

Protection from Grazing

Overgrazing results in degradation of grasslands with sparse vegetation and dominance of unpalatable and noxious vegetation. Increased protection through fencing can improve vegetation recovery. Grazing lands can be protected with barbed wire/chicken wire or chain links supported by angle iron/cement/stone/wooden poles or by fencing with unpalatable bushes. A review of the efficacy and cost effectiveness of various kinds of fencing (Kanodia and Patil 1982) indicated that living fences were most cost effective for protecting large areas. Species suitable for live hedges are *Pithecelobium dulce, Carissa carandas, Agave sisalana, Agave Americana, Opuntia ficus-indica, Zizyphus nummularia, Jatropha curcas, Parkinsonia aculeata,* and *Lawsonia inermis*.

For grazing lands in the hills, Tandon et al. (1982) recommended five years' protection to improve the degraded low-altitude grazing areas. Effective fencing for 5 years with no improvement measures could increase herbage yield from 0.9–3.0 t ha^{-1}. Closing these grazing lands not only improves forage quantity but also its quality (Table 4). A stone wall (1 m high and 45 m wide) supported by live hedges of *Agave americana*, *Barberis,* and *Yucca* sp. was found to be economically and ecologically viable.

Table 4. Effect of closure on the average herbage production, number of species, and nutrient content of grasses in the hills of Uttar Pradesh.

Management type	Herbage production ($t\ ha^{-1}\ yr^{-1}$)	Number of species	Crude protein (%)	P (%)	K (%)
Open grazing lands	0.9	13.0	3.2	0.2	1.1
Two year closure	2.4	21.0	3.7	0.2	1.2
Five year closure	3.0	25.0	3.7	0.2	1.2

Table 5. Effect of protection on species composition on a rocky site.

	Plants per m^2				
Plant groups Years:	1	2	3	4	5
Perennial grasses	11	28	43	182	397
Annual grasses	1023	204	150	142	85
Legumes	111	81	148	190	65
Forbs	444	116	148	46	33

Studies revealed an increase in the herbage yield from 0.1 to 3.5 t ha^{-1} within 3 years of protecting degraded grazing lands. The plant population of desired perennial grasses increased from 11 plants m^{-2} to 397 plants m^{-2} and that of undesirable forbs decreased from 444 plants m^{-2} to 33 plants m^{-2} (Table 5) during a period of five years on semi-rocky land (Trivedi and Kanodia 1982). After two years of protection, the forage yield increased by 148% in 'poor', 92% in 'fair', and 116% in 'good' condition classes of rangelands in tropical arid regions with sandy to sandy loam soils (Paroda et al 1980).

Bush Clearing

Heavy infestation of bushes in grazing lands adversely affects the availability of open space for growing grasses and forage. Studies conducted at the Indian Grassland and Fodder Research Institute (IGFRI), Jhansi (Table 6), and elsewhere in arid regions (Table 7), reveal the adverse effect of high bush density on forage yield. The standard practice of bush clearing involves either manual or mechanical felling and removal of stumps, or application of selective herbicides on the cut stumps to prevent them from coppicing. Those trees providing fodder, however, should be maintained in the grazing lands as feed reserves.

Table 6. Bush density and dry forage yield of a semi-arid *Sehima-Heteropogon* grassland.

	Bush density (number ha^{-1})	Forage yield (t ha^{-1})
Protected grassland	0	4.2
	1450.0	1.1
	2175.0	1.3
	3775.0	0.6
Unprotected grassland	1300.0	0.1

Table 7. Bush density–dry forage yield relationship in desert grazing lands.

Bush density (% canopy cover)	Yield of leaf fodder	Yield of grass	Combined yield
	....	(kg ha^{-1})	....
18	150	545	695
14	125	875	1000
11	105	770	875

A certain ratio could be maintained between the bush cover and the grass cover. Kaul and Ganguli (1963) recognized three density classes of the bushes of *Zizyphus nummularia* in the grazing lands of the Indian deserts, where yields of grass and leaf fodder are influenced by varying densities of bushes (Table 7). A medium density level of 14% of the land area covered by shrubs is considered optimal for high forage and leaf production.

Reseeding

To improve the productivity of deteriorated rangelands, low-yielding annual grasses must be replaced by reseeding with high-yielding perennial grasses adapted to the prevailing conditions. Tropical grasslands usually have grasses of lower quality (low in protein content) than temperate grasslands. Introduction of suitable pasture legumes rectifies this to some extent. Studies have shown that planting legumes can add 40-50 kg N ha^{-1} to grassland soils. Legumes also influence total dry matter production and crude protein yield (Table 8).

Cenchrus ciliaris is the most suitable grass for arid and semi-arid zones, *C. setigerus* for sandy loam soils, *Chrysopogon fulvus* for red-gravelly/sloping lands, *Lasiurus sindicus* for extreme arid conditions, *Panicum turgidum* for

Table 8. Effect of range legumes on dry forage yield of natural grasslands (t ha^{-1}) and the organic carbon in soil.

Treatment	Dry matter yield (t ha^{-1})	Organic carbon (%)
Control (No legume, no fertilizer)	3.3	0.6
Fertilizer (40 kg N/ha)	4.6	0.7
Legume introduction		
Alysicarpus rugosus	4.2	0.6
Atylosia scarebaeoides	4.1	0.7
Clitoria ternatea	4.4	0.6
Dolichos lablab	4.7	0.8
Desmodium tortuosum	4.2	0.7
Neonotonia wightii	3.8	0.7
Macroptelium atropurpureum	4.1	0.6
M. lathyroides	4.9	0.8
Mimosa invisa	3.7	0.7
Stylosanthes guianensis	4.2	0.8
S. humilis	4.0	0.6
Sesbania sesban	4.1	0.6

sand dunes, *Dichanthium annulatum* for moist loamy soils, and *Iseilema laxum* and *Panicum maximum* for clay soils with higher moisture contents (Kanodia 1987 and 1988; Yadav 1987). In sandy or sandy loam soils with rainfall up to 750 mm, suitable legumes are *Stylosanthes hamata, Alysicarpus rugosus,* and *Lablab purpureus*.

Fertilizer Application

Application of nitrogen can considerably improve forage production and quality of grasses in terms of crude protein. Application of 40–60 kg N ha^{-1} and 20–30 kg P ha^{-1} could increase pasture production by 50–100% (Table 9). Increases in pasture production due to the application of P_2O_5 are of a lower order compared to nitrogen application. No significant effect on pasture production is observed due to potash application (Shankarnarayan et al. 1973, Shankarnarayan and Rai 1975a, Shankarnarayan et al. 1975b). However, potassium is important for the long-term maintenance of pastures. In north-west Himalayan grazing lands Sharma and Koranne (1988) have shown increase in forage yield on application of N and P (Table 10).

Table 9. Effects of fertilizers on dry matter yields in major range grasses.							
Treatment	*S. nervosum*	*C. fulvus*	*B. intermedia*	*C. ciliaris*	*C. setigerus*	*L. laxam*	*H. contortus*
	($t\ ha^{-1}$)						
N ($kg\ ha^{-1}$)							
0	3.9	4.4	2.5	2.7	2.6	4.4	3.5
20	-	-		-	-	5.3	4.7
30	-	6.8	3.1	4.0	4.2	-	-
40	-	-	-	-	-	6.4	5.6
60	6.1	8.3	3.3	4.7	5.3	-	-
90	-	10.0	3.3	5.6	6.2	-	6.4
P ($kg\ ha^{-1}$)							
0	4.5	6.4	2.3	3.6	4.0	5.1	4.1
20	4.7	7.9	-	-	-	5.7	5.0
30	-	-	3.5	4.3	4.2	5.7	-
40	5.7	7.8	-	-	-	-	6.7
60	-	-	3.6	4.9	5.1	-	-

Source: IGFRI, Jhansi

Table 10. Effect of N and P fertilization on forage production ($t\ ha^{-1}$) in the northwest Himalayan grasslands.

N levels ($kg\ ha^{-1}$)	P levels ($kg\ ha^{-1}$)			
	0	30	60	Mean
0	1.8	2.3	3.2	2.4
30	3.4	4.3	5.3	4.3
60	4.7	5.5	7.0	5.7
Mean	3.3	4.0	5.2	

The use of nitrogenous fertilizers on grasslands is expensive. Therefore, introduction of legumes into native grasslands is a cheap alternative due to their nitrogen-fixing capacity.

Cutting Management

The ultimate objective of pasture management is to provide maximum digestible dry matter per unit area per growing season through a series of harvests. Table 11 shows that harvesting at 60 day intervals at 15 cm above the ground level gave the highest forage yield. However, crude protein content has been found to be higher at shorter cutting intervals.

Table 11. Effects of cutting intervals on forage yield (t ha^{-1}) and crude protein content (%) in different grasses.

	C. ciliaris		*C. setigerus*		*S. nervosum*		*C. fulvus*		*D. annulatum*		*I. laxam*	
Treatment	DM	CP	DM	CP	DM	CP	DM	CP	DM	CP	DM	CP
Cutting intervals (days)												
10	0.3	11.7	0.4	12.9	0.8	11.1	0.7	11.5	0.9	7.3	0.4	9.9
20	0.7	9.5	1.0	10.5	1.6	8.9	1.5	9.9	1.7	8.8	0.7	7.9
30	1.0	8.1	1.1	8.6	2.1	7.6	2.2	8.7	2.0	8.5	1.0	6.9
60	2.0	6.3	2.2	7.4	4.1	6.5	4.2	7.0	2.8	7.3	1.5	5.0
Cutting height (cm)												
5	0.8	8.9	1.1	10.0	1.8	8.4	0.9	9.3	1.6	8.9	0.8	7.5
10	1.0	9.0	1.2	9.6	2.2	8.6	2.3	9.1	1.9	8.4	1.0	7.4
15	1.2	8.8	1.5	9.9	2.4	8.5	2.3	9.2	2.1	8.2	1.0	7.8

DM – Dry matter

CP – crude protein

Grazing Management

The greatest single factor responsible for deterioration of grasslands is overgrazing. While grazing, animals tend to favor certain grasses and avoid others. Desirable species thus become depleted much faster than species that are less palatable. Most perennial grasses utilize the reserve food material stored in the underground parts to produce new shoots. When overgrazing occurs the reserve food material is lost faster, and perennial grasses are unable to regenerate due to a continuous drain on food reserves. A certain period of rest is thus essential for perennial grasses to recuperate and rejuvenate. Based on these considerations the following types of grazing systems are recommended:

- Continuous grazing
- Deferred grazing
- Rotational grazing
- Deferred-rotational grazing

In the continuous grazing system the grassland is not divided into compartments or paddocks and animals are free to move in the whole area. Continuous grazing with high stocking rates can lead to a deterioration in composition and production of good forage grasses and an increase in unpalatable ones. It also affects soil fertility levels and exposes the area to runoff and soil loss. In the deferred system, the grazing area is divided into compartments and at least one of these is rested until seed setting. In rotational grazing compartments are grazed in rotation for a specific duration. The deferred rotational grazing system is a mix of the latter two types and is considered the best system of grazing because (1) the same grassland supports a greater number of grazing days, (2) proper vegetation composition is maintained through self seeding, (3) health of the sward is maintained as the optimum utilization of biomass takes place and a period of rest is available to grasses, (4) soil fertility is maintained, and (5) potential erosion hazards are avoided.

In *Sehima*-dominated grasslands, the deferred rotational grazing system is superior to the continuous system (Upadhyay et al. 1971). For arid rangelands, there was an increase of 22% in dry matter yield of *Cenchrus* species under deferred-rotational grazing and an increase in carrying capacity from 0.49 to 0.73 sheep ha^{-1}. Under continuous grazing only 0.53 sheep ha^{-1} were carried. In the *Lasiurus*-dominated grasslands in western Rajasthan, the deferred-rotational grazing system is superior to the continuous grazing system in terms of average body weight gain of Tharparker heifers. The calving rate was also higher (26%) under a deferred-rotational grazing system compared to the continuous system (Shankarnarayan et al. 1981).

Animal Production

Animal production based on pastures and the silvipastoral system has been less studied. Upadhyay et al. (1980) compared two grass species for growth and milk production under grazing conditions, but found no significant differences. Other studies have shown that animal productivity can be sustained with proper management with improved vegetation in a multi-tier system. Rai et al. (1987) reported higher weight gains in animals grazed on leguminous mixed pastures compared to native grasslands.

Silvipastoral Systems

The silvipastoral systems involve the establishment of multipurpose trees in existing pastures/grazing lands or wastelands, with grasses, legumes or cereals planted between the lines of trees. The pastures are used for cut and carry or in situ grazing. During the initial years of tree establishment and growth, the grasses and legumes are harvested as hay, and the area is maintained as a seasonal hay plot followed by grazing in a rotational or deferred rotational grazing system. The technique seems simple but the land area, soil type, topography, natural vegetation, local socioeconomic conditions, stocking rates, rainfall, temperature, and wind are some of the important factors that determine its success (Pathak and Roy 1994; Pathak et al. 1995).

Forage Production

Depending upon the land capability, soil type, and its fertility, forage production rises from the first year and peaks in the 2nd or 3rd year. Forage production of up to 7.9 and 7.4 t ha^{-1} could be easily harvested depending on the choice of grass. The canopy of different trees did not make a significant difference to grass growth. Thus, depending upon the soil moisture and nutrients, yield differences of 2–10 t ha^{-1} yr^{-1} could be obtained from the grasses (Muthana and Shankarnarayan 1978, Prajapati 1979).

Firewood

Four to six t ha^{-1} yr^{-1} of firewood can be expected from short rotation species on degraded lands at a tree density of 500 plants ha^{-1} in a 10-year cycle. Annual lopping when trees are 6–7 years old has been found to give 2.3–3.5 t ha^{-1} fodder and 4.5–6.5 t ha^{-1} firewood. Thus, combining the forage and top feed yield, the system could easily produce 5.3–9.5 t ha^{-1} forage and 5 t ha^{-1} firewood or 10–14.5 t ha^{-1} total biomass. With the correct plant species, geometry, and management it might be possible to raise this to12–15 t ha^{-1} yr^{-1}.

Grazing

The stubble after the grass harvest can be grazed by different species of animals from the 4^{th} year onwards between December and June. The productivity of grasses during the next monsoon is not affected. The leaf litter of the trees, the legume component in the pasture, and occasional lopped tree leaves provide a balanced ration.

Seed Production

The production of grass, legume, and tree seeds is a profitable enterprise. On slightly better sites, in a rotation of 5–6 years at the time of system renewal a crop of pigeon pea or cowpea could be obtained. Good production of these crops has been obtained in many situations (Deb Roy et al. 1978; Muthana and Shankarnarayan 1978).

Hortipastoral System

Dryland fruit crops such as *Zizyphus mauratiana*, custard apple, and *Emblica officinalis*, when grown in a hortipastoral system with grasses and legumes, provide early income from fruits, firewood from prunings, and forage from the grasses and legumes. These systems have been found to provide an annual forage yield of 4–6 t ha^{-1}. The presence of *Stylosanthes hamata* helps to increase fruit production.

Techniques and Choice of Species for Different Types of Degraded Lands

Table 12 shows the techniques and choice of species for rehabilitating different types of degraded lands to optimize land productivity. Species such as *Acacia nilotica* and *Dalbergia sissoo* account for 86% and 84% interception of seepage. Trees interplanted with Napier grass are more efficient at intercepting seepage (Patil et al. 1994).

Grasses and legumes can provide early colonization of mine overburdens. Species such as *Stylosanthes hamata, Clitoria ternata,* and *Macroptilium atropurpureum* produce poor root/shoot ratios but are desirable as colonizing and nitrogen-fixing species. Grasses such as *Bothrichloa intermedia, B. pertusa, Cenchrus setigerus*, and *Chrysopogon fulvus* colonize early with high production but poor root/shoot ratios.

Soil Productivity

Six years after silvipasture establishment, nitrogen, phosphorus, organic carbon, and potassium levels have been found to increase with time even when grasses are harvested and removed every year (Singh et al. 1977; Misra et al. 1982).

Socioeconomic Implications of Silvipastoral Systems

Privately owned land improves and appreciates when managed well. However, common property resources are highly susceptible to degradation due to a lack of responsibility sharing. In such situations, institutional arrangements to suit local/regional problems and policies are required to protect and improve the degraded resources. Production-related activities having direct impact on

Table 12. Techniques and choices of species for the rehabilitation of degraded lands.

Degraded lands	Mechanical	Trees	Grasses/legumes
Waterlogged areas	Creating drainage facilities, leveling, bunding and lining of canals to check seepage	*Eucalyptus robusta, E. hybrid, Casuarina equisetifolia, Pterospermum acerifolium, Sesbania sesban, S. macrocarpa, S. aculeata, S. rostrata, Terminalia arjuna, Acacia nilotica*	*Brachiaria mutica, B. brizantha, Echinochloa colona, Iseilema laxum, Dichanthium annulatum*
Barren and fallow lands	Proper leveling and drainage in the watershed concept to ensure application of water and nutrients. Breaking hard pans of calcium carbonate nodules. Applying gypsum/ pyrite/ lime/ manure to balance the nutrients or adding some essential nutrients through chemical fertilizers.	*Acacia nilotica, Albizia lebbeck, A.amara, A.procera, Dalbergia sissoo, Leucaena leucocephala, Hardwickia binata, Melia azedarach, Azadirachta indica,* Bamboo	*Cenchrus ciliaris, C.setigerus, Chrysopogon fulvus, Sehima nervosum, Panicum maximum, Pennisetum pedicellatum, P. polystachyon, Stylosanthes hamata, S. guanensis, Macroptelium atropurpureum*
Ravines	Depending upon the suitability for a specific purpose, bulldozing, leveling and bunding the shallow ravines to grow crops. Providing mild soil and water conservation treatments to medium and deep ravines	*Acacia nilotica, A. tortilis, A.farnesiana*, *Prosopis juliflora, Dichrostachys cinerea, Albizia lebbeck*	*Cenchrus ciliaris, C. setigerus, Dichanthium annulatum, Bothrichloa intermedia, Stylosanthes hamata, Macroptilium atropurpureum*
Alkaline/Saline sodic lands	Scraping surface salts, flushing with water to wash excess salts, impounding water to leach injurious salts, trenching and flushing to remove surface salts, providing subsurface drainage, pumping water to lower the water table, deep plowing /breaking deep hard pan layers to remove hard pan. Adding gypsum, pyrite, sulfur, manure, growing green manuring crops, adding crop residues	*Acacia nilotica, A. tortilis, Prosopis juliflora, Casuarina equisetifolia, Azadirachta indica, Sesbania sesban*	*Brachiaria mutica, Bothrichloa intermedia, Panicum maximum, Dichanthium annulatum, Desmanthes virgatus, Stylosanthes hamata*

natural resources need to be analyzed in an economic framework including non-monetary costs.

The production from degraded lands has been analyzed financially. Gupta and Mohan (1982) reported the merit of silvipastoral and hortipastoral systems indicating the high benefit/cost (B/C) ratios with higher employment potential and environmental benefits. In another study on the sub-Himalayan boundary degraded lands, Dhruvanarayana and Ram Babu (1984) reported a B/C value of 3.43 under *Acacia catechu* plantation with bhabar grass (*Eulaliopsis binata* (Retz) Hubbard). They observed that silvipasture or silviculture of fast-growing species in ravines was the best option with a B/C ratio of 1.9. They observed that on good lands, hortipastoral systems gave a B/C ratio of 3.2, while on highly degraded lands silvipastoral systems gave a B/C ratio of 1.8 (Dhruvanarayana and Ram Babu 1990). On highly degraded rocky and gravelly areas or ravines in the central Indian semi-arid zone, silvipastoral, energy plantations, and hortipastoral systems provided the most viable option of land use and land cover. Several studies by Pathak (1991), Pathak and Khan (1990,1992), and Pathak et al. (1995) reported very high B/C ratio and internal rates of return (IRR) on energy plantations and silvipastoral systems (Table 13).

Future Thrust Areas

- The grassland cover survey carried out during 1954 needs updating.
- Changing land use and land cover demands reinvesting in proper land use decisions for degraded lands where silvipastoral systems are most ideal. Habitat-specific studies are required to optimize forage supply from such lands.
- System synthesis for producing diversity in the components, and designs for optimizing yields are needed for different types of degraded lands.

Table 13. Present and expected returns from a silvipastoral system on degraded land.

Products	Present		Expected	
	Productivity ($t\ ha^{-1}\ yr^{-1}$)	Production ($M\ t\ yr^{-1}$.)	Productivity ($t\ ha^{-1}\ yr^{-1}$.)	Production ($M\ t\ yr^{-1}$)
Forage	0.5 –1.0	25–50	4.0–5.5	200–275
Topfeeds	Negligible	-	1.6–2.5	80–125
Firewood	Negligible	-	2.0–3.0	100– 150

- Research and development emphasis is required on high altitude pasture management systems.
- Grazing management is needed to sustain productive grasslands and improved animal productivity.
- Grass densification (baling), storage, and improved transport efficiency to deficit zones in the country during adverse weather.
- Socioeconomic analysis and interventions for optimizing pasture productivity and sustenance through participatory management on common property resources, and through Joint Forest Management, need urgent attention.

References

Dabadghao, P.M. and Shankarnarayan, K.A. 1973. The grass covers of India. Indian Council of Agricultural Research, New Delhi.

Debroy, R., Patil, B.D., and Pathak, P.S. 1978. Silvipastoral farming for amelioration and increased land productivity of the arid and semi-arid regions. Proc. International Symposium on Arid Zone Research and Development, 345-350.

Dhruvanarayana, V.V. and Ram Babu. 1990. Social and economic considerations in the management of soils of hilly regions. Pages 273-284 *in* Technologies for Wasteland Development. (Abrol, I.P. and Dhruvanarayana, V.V., eds.). ICAR, New Delhi.

Dhruvanarayana, V.V. and Ram Babu. 1984. Economic viability of tree/grass crops on highly eroded soils. Pages 37-45 *in* (Sharma, K., ed.) Economics of Wastelands Development, SPWD, New Delhi.

Gupta, R. K. and Rao, D.L.N. 1994. The potential of agroforestry for sequestering carbon in wastelands and mitigating climatic change. Pages 90-95 *in* Agroforestry Systems for Sustainable Land Use. (Singh P., Pathak P.S. and Roy, M.M., eds.). Oxford & IBH Pub. Co. Pvt. Ltd., New Delhi

Gupta, T. and Mohan, D. 1982. Economics of Trees vs. Annual Crops on Marginal Agricultural Lands. Oxford & IBH Pub. Co., New Delhi.

Kanodia, K.C. 1987. Forage resources of heavy rainfall areas in western India with special reference to grassland amelioration. Pages 153-163 *in* Forage Production in India (Singh, P., ed.) RMSI, IGFRI, Jhansi, India,.

Kanodia, K.C. 1988. Production potentials of grazing lands and their management strategies. Pages 58-65 *in* Rangeland Resource and Management (Singh, P. and Pathak, P.S., eds.) RMSI, IGFRI, Jhansi, India,

Kanodia, K.C. and Patil. B.D. 1982. Pasture development. Pages 263-305 *in* Desert Resources and Technology (Singh, A., ed.) Scientific Publishers, Jodhpur, India.

Kaul, R.W. and Ganguli, B.N. 1963. Fodder potential of *Zizyphus* in the shrub grazing lands of arid zone. Indian For. 39:623-630.

Mimeograph, National Wastelands Development Board, New Delhi.

Misra, S.M., Patil, B.D. and Pathak, P.S. 1982. Comparative differences in soil properties as a result of growing different grass, legume, and tree combinations. Indian J. Range management 3(1 & 2) :71-74.

Muthana, K.D. and Shankarnarayan, K.A. 1978. The scope of silvipastoral management in arid regions. Arid Zone Research in India, Souvenir, Silver Jubilee, CAZRI, Jodhpur.

Pandeya, S.C. 1986. Impact of human activities on the organic productivity of seminatural grazing lands: from arid to dry subhumid areas of western India. Final Report, Department of Environment Project, Department of Special Assistance in Biosciences, Saurashtra University, Rajkot, 499 pp.

Pandeya, S.C. and Jain, H.K. 1979. Pages 630-655 *in* Tropical Grazing lands Ecosystems (UNESCO) A State of Knowledge Report, Natural Resources Series XVI.

Paroda, R.S., Mann, H.S. and Verma, C.M. 1980. Management of Indian arid rangelands. Tech. Bull. No.4. Central Arid Zone Research Instt., Jodhpur, India.

Pathak, P.S. 1991. Economic analysis of silvipastoral systems. Pages 41-51 *in* Forestry Economics Research in Asia, (Thammincha, S. L. Puangchit and Woods, H. eds). Ka Setsart University Bangkok and IDRC, Canada.

Pathak, P.S. and Roy, M.M. 1994. Silvipastoral Ststem of Production, Bulletin, IGFRI, Jhansi.

Pathak, P.S. and Khan, T.A. 1990. Silvipastoral systems in economic framework. *In* Silvipastoral systems in India, 1981-1989. (Pathak, P.S. and Singh, P. eds.). Range Management Society of India, IGFRI, Jhansi.

Pathak, P.S. and Khan, T.A. 1992. Economics of minirotation energy plantations on moist wastelands. Pages 1-8 *in* Economics of Energy Plantation (Mathur, A.N., Hussain, I. and Rathore, N.S., eds.). Himanshu Publications, Delhi.

Pathak, P.S., Gupta, S.K. and Singh, P. 1995. IGFRI Approaches to rehabilitation of degraded lands, IGFRI, Bulletin, Indian Grassland and Fodder Research Institute, Jhansi, 23 pp.

Patil, S.G., Manjunatha, M.V., Hebbara, M., Kuligod, V.B. and Gupta, R.K. 1994. Evaluation of tree species for their biodrainagability in irrigation commands. Pages 35-56 *in* Agroforestry Systems for Degraded Lands, (Singh, P., Pathak, P.S. and Roy, M.M., eds.). Oxford & IBH Pub. Co, (Pvt.) Ltd., New Delhi.

Prajapati, M.C. 1979. Silvipastoral system of production in ravines. Proc. Summer Instt. on Silvipastoral Production, IGFRI, Jhansi 28- 40 pp.

Rai, P. and Kanodia, K.C. 1981. Effect of split application of nitrogen on the quantity and quality of *Sehima-Heteropogon* grasslands. Forage Res.7:8385.

Rai, P., Kanodia, K.C., Patil, B.D., Velayudhan, K.C. and Agrawal, R. 1980. Nitrogen equivalence of range legumes introduced in natural grasslands. Indian J. Range Mgmt.1:97-101.

Rai, P., Kanodia, K.C. and Upadhyay, V.S. 1987. Role of range legumes in sheep production. Indian J. Range Mgmt. 8(2):113-115.

Rai, P., Velayudhan, K.C., Shankarnarayan, K.A. and Kanodia, K.C. 1981. Effect of neem cake blended urea and its time of application on quality and quantity of *Sehima-Heteropogon* grasslands at Jhansi. Ann. Arid Zone 29:107-116.

Ranjhan, S.K. 1994. Availability and requirements of feed and fodder for livestock and poultry. Report, Department of Animal Husbandry, Government of India, New Delhi.

Shankarnarayan, K.A. and Rai, P. 1975a. Effect of fertilizer application on dry matter production in *Iseilema laxum* grassland at Jhansi. *Forage Res.* 1:155-157.

Shankarnarayan, K.A., Dabadghao, P.M., Rai, P., Upadhyay, V.S. and Maurya, R.K. 1973. Fertilizers for the grasslands of *Heteropogon contortus* in Jhansi. Indian J. Agric. Sci. 43:562-566.

Shankarnarayan, K.A., Kacker, N.L. and Mertia, R.S. 1981. Productivity of large herbivores, cattle and sheep productivity of arid grazing land ecosystem., Monograph No. 19. Central Arid Zone Research Instt., Jodhpur, India.

Shankarnarayan, K.A., Dabadghao, P.M., Upadhyay, V.S. and Rai, P. 1975b. Note of the effect of NPK on Sehima grasslands. Indian J. Agric. Sci. 45:383-386.

Sharma, B.R. and Karanne, K.D. 1988. Present status and management strategies for increasing biomass production in northwestern Himalayan rangelands. Pages 138 -147 *in* Rangeland Resource and Management (Singh, P. and Pathak, P.S., eds.). RMSI, IGFRI, Jhansi, India.

Singh P. and Mazumdar A.B. 1992. Current status of feed and forage management of livestock in India. Agricultural Situation in India 47(5):375 – 382. Directorate of Economics and Statistics, Department of Agriculture and Co-operation, Ministry of Agriculture, New Delhi, India.

Singh, D., Mannikar, N.D., Srivas, N.C. and Saxena, D.C. 1977. Changes in soil fertility under long term cultivation of fodder crops and grasses. J.Indian Soc. Soil 25:28-32.

Tandon, J.P., Melkania, N.P. and Singh, S.P. 1982. Herbage production, structure and possible measures for improvement of mid-Himalayan grasslands. Indian J. Range Mgmt. 3:21-27.

Trivedi, B.K. and Kanodia, K.C. 1982. Succession of grassland vegetation on semi-rocky substratum at Jhansi. Indian J. Range Mgmt. 3:1-10.

Upadhyay, V.S., Dabadghao, P.M. and Shankarnarayan, K.A. 1971. Annual Report. Indian Grassland and Fodder Res. Instt., Jhansi.

Upadhyay, V.S., Rai, P. and Patil, B.D. 1980. Comparison of two tropical grass species for growth and milk production in dairy cattle under grazing conditions. Indian J. Range Mgmt. 1(2):129-136.

Yadav, M.S. 1987. Reseeding arid rangelands with improved pasture grasses. Pages 149-152 *in* Forage Production in India (Singh, P. ed.). RMSI, IGFRI, Jhansi, India.

Conversion from Free Range Grazing to Managed Feeding: Technological and Institutional Issues

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The study examines technological and institutional issues in conversion of free range grazing to managed feeding in the semi-arid Bundelkhand region of central India. The region is spread over 72 000 km^2 and supports a population of 12 million humans as well as 10 million cattle and buffalo. Growing human and animal populations have resulted in an increased pressure on the land, which has in turn led to a decline in the productivity and availability of grazing lands (natural grasslands, wastelands, and forests). The region thus suffers from a serious shortage of livestock feed for most of the year, leaving many farmers with little option but to allow their animals to graze freely. Such practices damage cropped fields and discourage farmers from growing crops in the summer season.

The intensification of livestock production is often considered a solution to the problems arising from free-range grazing. The farmers may replace their current large numbers of free grazing, low-productivity animals with smaller numbers of stall-fed, more productive animals. In an effort to stimulate this change, technologies have been developed for fodder production from irrigated, rainfed, and rehabilitated lands; the latter including grasslands, wastelands, and forests. Although technically sound, most of these technologies have not been adopted by the local farmers. This study is an attempt to address such issues. The study was conducted in 1998 with the specific objectives of:

- Determining the reasons for the persistence of free grazing;
- Identifying constraints and opportunities for conversion from free grazing to managed feeding systems; and
- Identifying context-specific and client-oriented technologies required for managed feeding systems.

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Methodology

The traditional view of technology transfer is that it is a linear process, from research institute to extension department to farmers. The feedback, if any, is limited and informal and thus, researchers have limited contact with the farmers. This approach focuses only on the technology without considering the socioeconomic environment in which the farmer lives and works.

The study uses Agricultural Research for Development (ARD) approach which is wider in perspective, focuses on participatory technology development, and takes into account the indigenous knowledge of farmers and their requirements. Table 1 highlights how this approach compares with the conventional approach to research.

Table 1. Comparison of ARD and conventional research approaches.

ARD approach	Conventional approach
• Research is based on the needs identified by the beneficiary	• Researcher driven technology; formulation of problems and agendas based on the area of interest of the researchers
• Participatory technology development: involving the end users as partners rather than recipients	• Continuous interaction and frequent feedback between farmers and researchers
• Linear technology transfer with research providing the solution to the recipient farmer	• Specialized approach to planning and implementing R&D; consultation across disciplines normally occurs with comparison of research results
• Interdisciplinary approaches in planning and implementing research and development (R&D) at the institutional level	

The steps followed during the course of the study were:

- Reconnaissance surveys to understand the geographical, social and economic context in which free grazing operates.
- Analysis of block level secondary data to identify criteria for zoning.
- Zoning of the Bundelkhand region to identify relatively homogeneous subareas with regard to factors or criteria relevant to the study, and select sites for an in-depth study.
- In-depth study of eight selected villages in four blocks using Participatory Rural Appraisal (PRA) methodology employing tools such as semi-structured interview, transect walks, social and natural resource mapping,

seasonal calendars, analysis of agricultural knowledge and information system (AKIS), and problem identification and ranking.

Table 2 lists the sites selected for the in-depth study.

Table 2. Site selection criteria and sites selected for in-depth study.

		Proportion of land covered by forest and wasteland (%)	
		Low	High
Proportion of land covered by crops	Low	Zone 1 Block: Babina Villages: Ghisauli, Simariya	Zone 2 Block: Datia Villages: Baghavali, Bajni
	High	Zone 3 Block: Konch Villages: Gorakaranpur, Virasani	Zone 4 Block: Sagar Villages: Guraiya, Menpaani

The villages were selected based on the probability of existence of free grazing/managed feeding systems. Ghisauli, Bajni and Guraiya villages had a watershed project in each. Baghavali and Bajni had Joint Forest Management (JFM) projects. These villages were selected to see if these projects had any influence on the feeding systems being followed in the village. Simariya was a village where the villagers realized the ill effects of free grazing and were making conscious efforts to arrest the practice. Gorakaranpur and Virasani fell in the area that was supposedly following a high degree of managed feeding. Menpaani had a large buffalo population and there was a high degree of stall-feeding, with all the feeds being bought.

Conditions that Favor Free Range Grazing or Managed Feeding

Free range grazing and managed feeding were not mutually exclusive but were found to coexist at zonal, village, and household/herd level. However, the relative importance varied at different levels. At block level, the relative importance of free range grazing or managed feeding depended mainly on the availability of fodder from crop residues versus fodder from natural grasslands, wastelands, and forests. The major factors that influenced the relative importance of free grazing or stall-feeding included:

- Cropping intensity: In zones and villages with high cropping intensities, the amount of crop residues was high, while natural grazing resources were limited. In these areas, stall-feeding was relatively important. The reverse held for zones and villages with a low cropping intensity.
- Proximity to forests, wastelands, and fallow lands: Villages nearer to these areas had a high proportion of free range grazing.
- Access to land: Smallholders and the landless practiced free range grazing even in irrigated (high fodder producing) areas.
- Access to markets for milk and fodder: Villages with access to milk and fodder markets had a higher proportion of stall feeding than those in remote and inaccessible areas.

Economic Rationale for Free Grazing or Managed Feeding

Before designing or recommending new technologies, it is important that scientists understand the farmer's viewpoint. Stall-feeding is assumed to be economically better than free grazing. This is because stall-fed animals are usually of better genotype, and produce more milk than free grazing animals. In this sense, improved breeds are considered to be more productive.

On the other hand, the decisions of farmers are based on the output per unit of capital (and labor), and influenced by their resource endowments, and the constraints/ opportunities existing in the surroundings. For example, an investment of Rs 20 thousand to buy 20 local cattle that are free grazed at limited labor costs may well be only as productive as spending the equivalent amount on the purchase of one buffalo. Although the latter yields more milk per head than the local breed, it may not be as profitable as 20 local cows.

Farmers may practice free grazing only because they have the opportunity to do so. They are not interested in more productive animals except for a few that they can feed with their home-produced crop residues. Low productivity becomes a problem when local animals can no longer be free grazed, and farmers are forced to stall-feed them. The breed then does not perform well enough and farmers replace these animals with buffalo.

Stall-fed, high-producing breeds are not necessarily always more profitable economically than free range grazed, local breeds. Farmers might opt for a system with a high degree of stall-feeding because it is economically more productive than free grazing (a positive choice) or because the circumstances preclude the option of free grazing (a negative choice). Also, farmers who practice free grazing might do so because they have no other option (a negative choice), or because they have nothing to gain from converting to a stall-feeding regime (a positive choice for free grazing).

The labor requirement for the livestock subsector shows considerable variation between villages and households where free range grazing prevails and those where stall-feeding is predominant. In free grazing, labor is required for supervision of grazing during the winter and monsoon seasons and is usually drawn from the family. One person can supervise a large herd. In the villages and households practicing stall-feeding one of the setbacks of the system is that labor is required on a continuous basis. Children are sometimes kept away from school to keep up with the high labor requirements.

A detailed partial budgeting analysis was carried out with three types of farmers practicing various degrees of stall-feeding to examine the profitability of free grazing vis-à-vis stall-feeding. These three types were:

1. *A farmer with a herd of six cows and buffalo and an irrigated land area of 9 ha.* The grazing practice varied according to the season. During summer, all animals were on unsupervised grazing for the whole day. In winter, non-lactating animals were grazed under supervision in the morning and evening. In the monsoon, all animals grazed unsupervised in the farmer's grassland during the morning and evening. In the afternoon, they were grazed under supervision on the common lands. The farmer gave a concentrate mixture of linseed, cotton seed cake, barley flour, and gram flour to both lactating and dry cows and buffalo three times a day during winter and summer. Only the lactating buffalo were given concentrates during the monsoon. The herd was fed with wheat straw every day during summer and winter. The farmer used 30 man-days of hired labor and 16 man-days of family labor animal^{-1}yr^{-1}.
2. *A system where there was no land available for grazing and a system of dairying largely based on stall feeding with purchased inputs and minimal free grazing.* Wheat straw was provided to the animals for 10 months. Concentrates were fed for eight months (during the lactation period). On average, a farmer used nine man-days of family labor animal^{-1} yr^{-1}. Replacement of stock was done every three years. The herd size ranged from 4–60 ruminants per household.
3. *A commercial, peri-urban dairy farmer with an average herd of six cows and 10 buffalo practicing a totally stall-fed system without any grazing.* All inputs were purchased and wheat straw and concentrates provided to animals throughout the year. Twenty-six man-days of hired labor and 11 man-days of family labor animal^{-1} yr^{-1} were used. Stock was replaced every two years.

The best estimates of major variables were used to determine the gross margin. These estimates were based on information collected from the farmers, direct observations, the literature, and expert knowledge. Tables 3 to 6 give the best estimates of the gross production value, gross costs, and gross margins for the above three systems as well as a completely free grazing system on a per animal basis, and an estimate of the cash inflow and outflow. The latter excludes the imputed costs incurred in milk production or 'costs' that do not require cash payments, such as the imputed values of farm-produced fodder and crop by-products, interest on own capital, and family labor. The tables also show household cash income from the different systems under varying assumptions of herd sizes. The household cash income was based on herd size x cash flow per animal, minus the value of home-consumed milk at 0.6 l day^{-1}. For large herd sizes (that exceeded the number that could be fed with the crop residues of a large nine ha farm, or that could be managed with family labor of 547.5 man-days per year), the additional costs of fodder and labor were also deducted from the herd size x cash flow per animal to obtain the net household cash income. The cash flow figures for the free grazing and mixed systems are based on the best estimates of

Table 3. Gross production value, costs, and gross margins for a free grazing system for indigenous cows.

	Rs animal^{-1} yr^{-1} (indigenous cows)			
	Minimum	Best estimate	Cash flow	Maximum
Fresh milk	600	1845	1845	4020
Manure	150	150	150	150
Sale of calves (imputed)	300	500	0	600
Gross production value	**1050**	**2495**		**4770**
Total cash flow			**1995**	
Labor (hired+family)	1200	1200		1800
Concentrates	0	0	0	0
Other feeds	0	0	0	
Veterinary services	0	0	0	0
Interest on capital (24%)	168	168		600
Depreciation	80	50	50	75
Transportation (imputed)	0	0	0	0
Gross costs	**1448**	**1418**		**2475**
Total cash outflow			**50**	
Gross margin	**(398)**	**1077**		**2295**
Net cash flow			**1945**	

Note: 1 US $ = Rs 40.

Table 4. Gross production value, costs, and gross margins for a mixed system.

	Good quality indigenous cow				Buffalo (local breed)			
	Mini-mum	Best estimate	Cash flow	Maxi-mum	Mini-mum	Best estimate	Cash flow	Maxi-mum
	.... (Rs animal^{-1} yr^{-1})							
Fresh milk	3120	5355	5355	14280	3780	9360	9360	17100
Dung	300	300	300	300	300	300	300	300
Sale from calf (imputed)	400	500	500	800	400	600	600	800
Gross production value	**3820**	**6155**		**15380**	**4480**	**10260**		**18200**
Total cash flow			**6155**				**10260**	
Labor (hired+family)	2550	2550		3375	3450	3450		4388
Concentrates	506	2205	2205	3600	759	2940	2940	4500
Other feeds	0	5340		8380	1825	7215		10500
Veterinary services	250	250	250	250	250	250	250	250
Interest on capital (24%)	480	480		2400	1080	2400		6000
Depreciation	229	260	217	750	700	1400	1400	1500
Transportation (imputed)	48	210	210	240	60	210	210	240
Gross costs	**4063**	**11295**	**2882**	**18995**	**8124**	**17865**	**4800**	**27378**
Total cash outflow								
Gross margin	**(243)**	**(5140)**		**(3615)**	**(3644)**	**(7605)**		**(9178)**
Net cash flow			**3273**				**5460**	

Table 5. Gross production value, costs and gross margins for a stall-feeding system with minimal free grazing, and all inputs purchased

	Good quality indigenous cow				Buffalo (local breed)			
	Mini-mum	Best estimate	Cash flow	Maxi-mum	Mini-mum	Best estimate	Cash flow	Maxi-mum
	.... (Rs animal^{-1} yr^{-1})							
Fresh milk	3120	5355	14280	14280	3780	9360	17100	17100
Manure	500	500	500	500	500	500	500	500
Sale from calf (imputed)	400	500	500	800	400	600	800	800
Gross Production Value	**4020**	**6355**		**15580**	**4680**	**10460**		**18400**
Total cash flow			**15280**			**18400**		
Labor (hired+family)	2550	2550		3375	3450	3450		4388
Concentrates	506	2205	2205	3600	759	2940	2940	4500
Other feeds	0	5340	5340	7300	1825	7215	7215	10500
Veterinary services	400	400	400	400	400	400	400	400
Interest on capital (24%)	480	480		2400	1080	2400		6000
Depreciation	229	260	217	750	700	1400	1400	1500
Transportation (imputed)	60	210	210	240	60	210	210	240
Gross costs	**4225**	**11445**		**18065**	**8274**	**18015**		**27528**
Total cash outflow			**8372**				**12165**	
Gross margin	**(205)**	**(5090)**		**(2485)**	**(3594)**	**(7555)**		**(9128)**
Net cash flow		**6908**			**6235**			

Table 6. Gross production value, costs, and gross margins for a system based on total stall feeding and all inputs purchased.

	Buffalo (good breed)			
	Minimum	Best estimate	Cash flow	Maximum
	.... (Rs animal^{-1} yr^{-1})			
Fresh milk	6300	14910	29040	29040
Manure	600	600	600	600
Sale from calves (imputed)	700	800	1000	1000
Gross production value	**7600**	**16310**		**30640**
Total cash flow			**30640**	
Labor (hired+family)	3600	3600		4725
Concentrates	911	2940	2940	5625
Other feeds	1825	8415	8415	11700
Veterinary services	250	250	250	250
Interest on capital (24%)	2400	4320		15000
Depreciation	2933	3500	3500	4750
Transportation (imputed)	72	240	240	300
Gross costs	**11992**	**23265**		**42350**
Total cash outflow			**15345**	
Gross margin	**(4392)**	**(6955)**		**(11710)**
Net cash flow			**15295**	

production value and gross cash costs, whereas the cash flow for the two stall-fed systems are based on maximum estimates of production value, and best estimates of gross cash costs. Only then do the latter two systems seem to produce a positive cash flow. The assumption seems justified, moreover, that these stall-feeding systems yield closer to the maximum estimates than mixed feeding systems.

Analysis of the results suggests that:

- In real economic terms, i.e., when all the costs (including costs that do not require cash payments, such as the imputed values of farm produced fodder and crop by-products, imputed interest on own capital, and family labor) are taken into account, free grazing would be the only viable system. All other systems would produce negative gross margins.
- The positive household cash incomes for the mixed and stall-fed systems would only be obtained when imputed costs of household labor, capital involved, and crop residues are not considered. The comparison of the household cash income for the two herd sizes (3 cattle + 1 buffalo vs. 7 cattle + 3 buffalo) of the mixed system suggests that, in areas where there

is no land for free range grazing, increasing the herd beyond the size that can be supported by farm-produced crop residues is not an economically viable option.

This comparative economic analysis suggests that, if economic costs are considered but environmental and social costs to the community ignored, free grazing is the only system that gives a positive gross margin. Stall-feeding is only sustainable when farmers disregard the cost of own labor, capital, and crop residues. The analysis suggests that gross margins and cash flows drop dramatically when herd sizes are extended beyond the numbers that farmers can feed with their own crop residues, and they have to purchase fodder to cover the deficit. The economic analysis suggests that farmers who practice free range grazing may do so because it is the best allocation of their capital, while those who practice complete stall-feeding or mixed systems (involving some purchased inputs) may only do so because there is not enough land to graze their animals.

The potential for further intensification of livestock production and the technologies required must, therefore, be looked at in relation to the resource availability at zonal, household, and village level. At current prices, a high dependence on stall-feeding is unlikely to become a viable option unless the quality and quantity of homegrown crop residues can be increased substantially on a year-round basis at low or no additional cost, and the conversion efficiency of animals considerably increased through low-cost genetic improvements.

Marketing Systems

Market access is necessary for the application of systems involving a high degree of stall-feeding. The fodder market found in the region had three features:

- In most of the villages studied, the most readily available fodder consisted of crop by-products, especially wheat straw. The price of fodder fluctuated considerably, i.e., low immediately after harvesting and increasing as the season advanced. The highest price was during winter. The farmers in Gorakaranpur reported that they bought dried wheat straw from their neighbors at Rs 100 to Rs 150 per 100 kg. Farmers who could afford it and had storage space usually bought fodder just after the harvesting season.

- Farmers living in villages with Joint Fodder Management (JFM) activities did sell some of the fodder harvested from the protected forests. They did this due to lack of storage space or because it was a means of earning some ready cash.
- Some buyers of fodder guaranteed their supply through an arrangement where a farmer raised a fodder crop on their request. The purchaser collected fodder and weeds from the designated plot. This was supposedly cheaper than purchasing the fodder from the market. However, when comparing the costs incurred this seemed doubtful. The buyer got about 500 kg of green sorghum from a plot of 46.45 m^2 at a cost of Rs 900, while 100 kg of green fodder could be bought in the market for Rs 100. The only advantage was that the farmer could collect other grasses and weeds from the field as well. The same field produced 350 kg of *Berseem* during winter.

Knowledge and Information System

Zonal variations must be taken into account when developing technologies. Links between farmers and technology sources tend to be limited. Farmers who want to use forest resources without restriction often clash with the Forestry Department, which has a legal enforcement role. JFM is a more viable alternative as it creates opportunities for better collaboration. Farmers should be made aware of the long-term benefits of the approach instead of looking only at short-term benefits such as free fodder and employment in trench digging.

Furthermore, farmers are not interested in taking an active role in the sustainable use of natural resources, if these do not belong to them and they do not have a stake in the benefits.

Farmers appreciate contacts with extension staff. However, the technological training of the latter is limited to technology transfer, and they are rarely capable of providing organizational and leadership training to farmers.

The researchers have even less contact with farmers. Due to the absence of good mechanisms for dissemination, the technologies do not reach the farmers, leaving a big gap in terms of flow of information and feedback from both researchers and farmers.

Nongovernmental organizations are other potential collaborators in the dissemination of technologies. They have the advantage of a more appropriate approach in mobilizing people.

Policy Influences

Central and state government policies also influence the choice of free grazing or stall-feeding. Agriculture is a state subject, yet the central and state governments have control over various issues related to forest and wastelands. Different governments control different categories of land e.g. revenue land, and protected/unprotected forests. The lack of co-ordination among various agencies is a hindrance to implementing the wasteland development projects. Some issues in this regard are now mentioned.

Land Ceiling Act

The ceiling of irrigated land in Uttar Pradesh and Madhya Pradesh is 7.3 ha for two crops a year, and 10.9 ha for one crop a year. The ceiling for dry land is 18.3 ha in Uttar Pradesh and 21.9 ha in Madhya Pradesh. Many large landowners do not want to opt for a second crop, as that will reduce the amount of land they can own. According to government officials this failure or reluctance to have a second crop leaves a lot of land area uncultivated and promotes free grazing. However, the Ceiling Act is not a major factor, as only a few farmers possess more than 7.3 ha of land. Irrigation facilities have been designed for *rabi* (dry season) crops only. Another reason is failure to popularize short duration *kharif* (wet season) crops. The lack of fodder in summer due to nonproduction of *zaid* (summer) crop is mainly due to a lack of irrigation. At present, only small areas of vegetables are grown during summer, which do not provide any crop residues.

Forests and Wasteland Policy

Increasing the productivity of wastelands and forests, which are categorized as revenue lands, protected, unprotected, and grazing lands is complex as different government departments and ministries control these. Grass plantations can be harvested legally by community organizations in the absence of formal lease deeds. Various authorities are permitted to lease out different categories of lands. Lack of coordination and information on land ownership often causes delays in obtaining the lease. For example, a District Collector in Rajasthan leased some revenue land to a tree growers' co-operative. Five years into the project it was realized that the land was reserve forest, which can only be leased by the central government. The deed was cancelled and the project had to be rolled back (Mishra 1998). Due to encroachment, and state government policy to distribute common lands to landless people, the area under village common land in the country has been reduced by 41–55% (Jodha 1985).

Before the New Forest Policy of 1988, the community rights for ownership of pasture and share of forest produce were not recognized. The Government of India issued guidelines in 1990 for participation of the people in the management and sharing of forest produce, with emphasis on non-timber forest products (Saigal et al. 1997). This concept is in its pilot phase and, presently, does not induce true participation.

Fodder Policy

The National Commission on Agriculture (NCA 1976) emphasized that feeding is of crucial importance. The NCA recommended identification of grass species suitable for wastelands and development of technologies for improving productivity of such lands. The Commission observed that high-yielding nutritious fodder crops should compete favorably with any food or cash crop. This policy was not coupled with similar suitable policies (such as credit facilities and provision of bulls in the villages for crossing) in other departments for replacement of unproductive livestock by high-yielding breeds. The government put much emphasis on artificial insemination programs to produce high-yielding animals, but farmers refuted the program for many valid reasons. The NCA did not at the time realize the importance of crop residues that can be used for fodder.

Grazing Policy

There is presently no national grazing policy, although it is in the process of formulation. Madhya Pradesh has a grazing policy, which imposes several restrictions and grazing fees, but does not discuss pasture development. In the absence of a grazing policy, only forest regulations cover grazing restrictions, and these often contradict the fodder policy. All these factors lead to an imbalance between grazing pressure and carrying capacity of grazing lands.

Industrial Policy

The significant influence of industrial policy on free grazing was observed in Jalaun district. A multinational soybean-processing company popularized soybean cultivation in the area, distributed minikits and bought back the soybeans at good prices. Farmers accepted the technology because of its profitability. Now, many farmers grow soybean as a second crop during the *kharif* season. However, the free grazing is restricted. In some of these villages, farmers now use soybean straw as fodder.

Technology Needs and Recommendations

A number of technologies have been developed to address the issues of fodder shortages and overgrazing. Approaches have included wasteland rehabilitation schemes coupled with grassland/silvipasture development, development of improved varieties of fodder grasses and legumes, and identification of species resistant to grazing pressure. The main aim has been to provide farmers with sufficient fodder for managed feeding systems (which may include stall feeding as well as rotational grazing), thereby reducing the widespread degradation of forest and grasslands due to free range grazing.

The wide range of farm types in the region means that solutions need to be tailored differently depending on whether the farmers own large or small holdings, or are landless. The landless animal owner, for example, would benefit from the increased employment opportunities and the increased fodder availability provided through wasteland rehabilitation and grassland management schemes. Provision of improved fodder crop varieties and improved cropping schemes (fodder/food intercrops), and improved animals could be targeted at large-scale farmers. The smallholder would benefit from dual-purpose (food and fodder) crop varieties, enabling maximum use of the limited land available.

Table 7 shows the technological and strategic interventions recommended for various zones.

Availability of water can solve the problem of free grazing, as it is the main reason for the severe shortage of fodder, especially during the summer months. This problem affects on-farm crop production and also the productivity of forests and grasslands. In areas where water conservation methods are used, the land is more productive; the grasses produced often being ‘cut and carried’ for use in stall feeding systems. Water conservation schemes need to be coupled with grassland management projects.

A major problem faced by small farmers in the study area was the shortage of land for crop production. Farmers with access to irrigation and

Table 7. Zone-wise major problems and related technological and strategic recommendations.

	Zone 1	Zone 2	Zone 3	Zone 4
Characteristics	§ Low animal pressure § Rainfed cropping (37%) § Wasteland (18%) § Free grazing on degraded grasslands	§ Low animal pressure § Forest (45%) § Rainfed cropping (26%) § JFM projects provide cut & carry fodder and fuel wood § Majority of animals free grazed	§ High animal pressure § Rainfed cropping (48%) § Wasteland (15%) § Severe shortage of fodder	§ High animal pressure § Irrigated cropping (40%) § Wasteland (11%) § Free grazing on common property resources (CPRs) § Food crop residues provide fodder for stall-feeding
Problems	§ Low fodder availability § Lack of water harvesting infrastructure § Limited food crop residues	§ Forest degradation § Low crop residue production § Lack of water harvesting infrastructure	§ Low fodder production § Low food crop residue production § Lack of water harvesting infrastructure	§ Insufficient fodder production § Low fodder quality § Limited fodder markets
Technological and strategic recommenda-tions	§ Grassland development (silvipastures, agroforestry, wasteland rehabilitation) § Wasteland rehabilitation (check dams, staggered trenching, emphasis on organizational and managerial aspects) § Participatory project planning, implementation, and management	§ JFM development (including social, organizational and managerial aspects) § Wasteland rehabilitation § Participatory project planning, implementatio nand management	§ Selection and breeding of dual purpose (food/fodder) crops for rainfed conditions § Development of food/fodder intercropping systems § Water harvesting – on farm (ridging, bunding, tied ridging) § Distribution of improved bulls § Wasteland rehabilitation § Grassland development § Participatory project planning, implementatio, and management	§ Selection and breeding of dual purpose (food/fodder) crops for irrigated conditions § Improved marketing systems to distribute fodder § Distribution of improved bulls § Development of fodder processing § Techniques for improved nutrition § Participatory project planning, implementation and management

thus the potential for high crop yields, tended to grow only food crops. Less than one percent of the land was put to fodder cultivation. The development of dual-purpose crops (food/fodder) is almost certainly the only practical solution to the fodder shortages of the area.

A number of watershed projects in the area, although technically sound, failed to adequately involve the local people. For example, in Guraiya and Ghisauli villages, watershed projects were seen more as an employment opportunity than for the increased land productivity. This was because the people did not have a sense of project ownership, nor were they fully aware of the advantages of sustaining the project once the implementing agency had left.

This shows that technological experiments need to be conducted in combination with social experiments to find the most suitable match of technology and the form of organization to manage a common property. Parallel or separate experiments may not be successful as social organizational constraints may well rule out the use of certain technologies despite their relative merits. For example, it may prove that cut and carry is the only technology that can be controlled or managed, given the constraints of the organization concerned, although other technologies (rotational grazing or deferred rotational grazing) may well produce higher quantities of biomass. The technical optimum is not necessarily the most feasible social solution. Research should then focus on optimizing cut and carry systems, despite the lower biomass production of this technology.

References

Jodha, N. S. 1985. Population, growth, and decline of common property resources in Rajasthan, India. Population and development Review Vol. 2(2).

Mishra, V. K. 1998. Legal, administrative and procedural hassles in greening of wasteland in India. Wasteland News 13(2): Nov 97-Jan 98.

Government of India. 1976. Field Crops. National Commission on Agriculture. Ministry of Agriculture Vol. 15

Saigal et al. 1997. Food and fuel wood. NTFP can sustain JFM. Wasteland News 3(1) Aug-Oct:46-55.

Food Processing Technologies for the Sustained Growth of Dairying

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The importance of the dairy subsector in the Indian economy is reflected by the fact that it is the second largest contributor to the gross value of output of the agricultural sector, after rice. Milk production has grown at an annual growth rate of 4.1% between 1980–81 and 1998–99. The annual per capita availability of milk in the country has increased at an average annual growth rate of 2.5% during this period. As a result, India's import dependence has reduced. At present, almost the entire milk demand is met through domestic supplies. Various agencies such as the National Dairy Development Board (NDDB), Dairy Cooperatives, National Dairy Research Institute (NDRI), and other research and developmental institutions have contributed to this phenomenal growth.

The remarkable growth in dairying achieved over the last few decades needs to be sustained in an efficient and economic manner so as to ensure adequate returns to investments at farm and industry levels, and the continued availability of milk and milk products at economical rates to consumers. This would be possible by developing vertical linkages between producers and consumers with the processing sector in between. This paper first examines the prospects of value addition to milk and then identifies efficient value added technologies.

Prospects for Value Addition

Of the total milk produced in the country, about one-third is retained by the producers for personal consumption, and the rest finds its way to the market. There is little information on the utilization pattern of milk; yet the bulk is consumed as whole milk and/or as ghee and curds. Available statistics indicate that only about one-fifth of the total milk produced is processed into products

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such as cheese, butter, whey, and sweetmeats. (Dairy India 1999). This is due to the lack of processing and associated infrastructures. Nevertheless, there is a huge potential for development of the market for processed milk food. Several factors underline this proposition. First, India's huge population itself is a source of demand for processed milk products. However, the effective demand is constrained due to the low per capita income of the majority of the population. The rapid growth in per capita income in recent years indicates the gradual emergence of an upwardly mobile middle class, which because of its nouveau riche behavior, is expected to be a great source of demand for processed foods. Second, a large part of the demand comes from the urban population, which has been growing rapidly in recent decades. Third, India's present share in world exports of dairy products is miniscule. This is because of higher domestic demand for milk and lack of competitiveness in the world market due to high levels of support to producers, industry and exporters of milk and milk products in Europe and the USA. With the implementation of the WTO agreement the cost of milk production, as well as processing, is expected to rise in major exporting countries. This is to the advantage of many developing countries including India. Furthermore, processing costs in India are also high for a number of reasons. The application of improved processing technologies would help reduce processing costs.

Dairy Production Technologies

Improving Quality of Raw Milk

Lactoperoxidase System for Preservation of Raw Milk

Refrigeration of raw milk in rural areas is difficult because of the inadequacy and frequent breakdown of power supply, voltage fluctuations, and high cost of refrigeration equipment. Thus, an alternative method for preservation of milk, known as the lactoperoxidase (LP) system, has been developed.

The advantages of this method are:

- LP is a naturally occurring antimicrobial agent in bovine milk, which can be harnessed for effective preservation of raw milk.
- LP can be activated with an exogenous dose of thiocyanate and hydrogen peroxide within 2-3 hours of milk production.
- Milk remains in a good condition up to 30 hours at 37°C.
- The cost of preservation is low.

Technologies for Process Upgradation of Traditional Milk Products

The sector engaged in the preparation of a wide range of indigenous milk products lacks organization and requires modernization. Intensive scientific, research/development (R&D), and financial inputs are necessary to develop industrial manufacturing and packaging systems. Significant work has been done to this end; some of the new processes are discussed here.

Khoa Powder

Khoa cannot be stored for more than five days at room temperature without spoiling. Addition of preservatives to *khoa* is illegal in India. Thus, in many parts of the country, *khoa* production is banned during summer. Unfortunately this is the time when the demand for *khoa* is invariably at its peak. The cost of packaging and transportation of *khoa* is also high due to its bulk. The technology developed for manufacture of *khoa* powder would help eliminate these problems. Standardized buffalo milk is vacuum concentrated to the desired level and heated to accentuate flavor prior to drying. Antioxidants and free-flowing agents are added to improve the chemical and physical properties.

The advantages of the new process are:

- About 14 kg of *khoa* powder is obtained from 100 liters of standardized buffalo milk. On reconstitution with water, this quantity produces about 21 kg of *khoa*.
- *Khoa* powder can be used directly for the preparation of various sweets (*burfi, milk-cake, kalakand,* and *gulab jamun*). The quality of sweets made from *khoa* powder is highly acceptable.
- With appropriate preservative techniques *khoa* powder can be stored up to 10 months at 30°C.

Instant Kulfi Mix Powder

Kulfi is a popular frozen milk product. The chemical and organoleptic qualities of commercially sold *kulfi* vary and tend to be of inferior microbial quality. A technology has been perfected for the manufacture of *kulfi* mix powder by spray drying. The mix is formulated from milk fat, milk solid not fat (MSNF), sucrose, and isabgol (*Plantago psyllium)* husk. The concentration of solids in the mix is adjusted and only 25% of the total sugar required added before drying. The mix is homogenized and heat-treated in a tubular heat exchanger, then spray dried. The remaining sugar is powdered, dry blended with the mixture, and packaged in tin cans. The approximate chemical composition of *kulfi* mix powder is: fat 25.4%, MSNF 37.0%, isabgol 0.5%, sugar 34.7%, and moisture 2.5%.

The advantages of the new process are:

- The product has a shelf life of seven months at 30°C in tin cans.
- The cost of production of *kulfi* mix powder at current prices works out to Rs 90 per kg; much lower than that from regular processes.
- *Kulfi* mix powder can be instantly reconstituted and frozen to get *kulfi* of consistently good quality throughout the year at an affordable price.

Gulab Jamun Mix Powder

Gulab Jamun is traditionally prepared from a mixture of *khoa*, bleached wheat flour (*maida*), and baking powder. There are wide variations in the chemical composition, flavor, and texture of *khoa*; these affect the final quality of *gulab jamun*. The shelf life of traditionally prepared *Gulab Jamun* is about one week at ambient temperatures. Refrigeration adversely affects its texture and quality. The instant *Gulab Jamun* mix powder overcomes these problems, with several additional benefits.

Gulab Jamun mix powder is formulated from milk powder, vanaspati oils, *maida*, semolina, baking powder, and ground cardamom. Two different formulae have been developed for spray and roller-dried skimmed milk. The product can be packed and sold in a metallized polyester laminate.

The steps involved in *Gulab Jamun* preparation such as making the dough, deep fat frying, and soaking of balls in sugar syrup were standardized for the mix powder. One kg mix powder yields about 150 *gulab jamuns* of average size (25 g each).

The advantages of the new process are:

- *Gulab Jamun* mix powder packaged in metallized polyester laminates without preservatives remains fit for use for up to eight months at 30°C.
- The cost of *Gulab Jamun* mix powder formulated from roller dried skimmed milk is estimated to be Rs 70 per kg; the spray-based mix formulation is slightly costlier (Rs 75 per kg).
- The technology is simple and the product convenient to use.

Instant Kheer Mix

Kheer is a dessert popular throughout India, but has limited life even under refrigeration. In the past, several unsuccessful attempts have been made to extend the shelf life of *kheer*. Rice *kheer* produced in a dry form suitable for ready reconstitution has overcome the problem of a limited shelf life.

The process for an instant rice-based *kheer* mix consists of separate instantization of the milk and rice phases of the product employing two-stage spray-bed and fluid-bed drying systems. Appropriate compositional and process manipulations ensure a high product quality. The two-phase product comprising powdered liquid/milk fraction and a particulate (rice) fraction is packaged bag-in-bag, a small polyethylene pouch of rice being carried in a bigger bag containing the powder. The mix packaged in metallized polyester/ LDPE pouches has a shelf life of at least six months at 37°C. Reconstitution involves rehydration of instant rice in boiling water for 10 minutes followed by dispersal of the powder into the rice-water mixture. The reconstituted product can be suitably flavored and enriched with dry fruits if desired, and is very close to conventional *kheer*.

The advantages of the new process are:

- The shelf life of *kheer* is enhanced to six months compared to 1-2 days for the conventional product.
- It is of considerable convenience to consumers – no sourcing of raw materials is required.
- Cooking time is reduced to 10 minutes as compared to one hour in conventional process; therefore there are savings in terms of fuel.
- The cost of manufacture is low.

Paneer and Related Products

Paneer is prepared by acid and heat coagulation of milk. Traditionally, small dealers or the consumers themselves have produced it in very small quantities. Commercial production of *paneer* helps dairies utilize surplus milk during the flush season and provides an outlet for relatively inferior quality milk. The limitations of *paneer* production on a large scale are lack of improved technology of manufacture and limited shelf life.

The advantages of the new process using buffalo milk are:

- Higher yield and improved rheology achieved by incorporation of hydrocolloids.
- Improved rheological characteristics by proper pH and temperature control.
- Economical production through use of low cost unconventional coagulants.
- Savings in energy and water requirement.
- The simplified manufacturing technique makes the process more suitable for mechanization.

UF - *Paneer*. Membrane technology has been used for the manufacture of *paneer*. The process involves standardization and heating of milk followed by ultrafiltration (UF) whereby lactose, water, and some minerals are removed. The concentrated mass is cooled, acidified, and then placed in suitable containers. This is followed by texturization using microwave technique. The resulting product has typical characteristics of normal *paneer*. The process also helps increase the shelf life.

The advantages of this technique are:

- Uniformity of production.
- Improved shelf life and increased yield.
- It is a nutritionally improved product.

Long Shelf-life *Paneer* in Retort Pouches. The traditional technology is suitable for batch operations and handling of milk from 5 to 10 thousand liters in batches, but has certain limitations. Nearly half the milk solids are lost in whey. It has a limited shelf life and production is labor intensive. Proper packaging and quality assurance systems are lacking. The new process achieves the in-package sterilization and texturization of *paneer* in retort pouches.

The advantages of the new process are:

- The product yield is almost doubled.
- Whey solids are retained in the product and there is no problem of whey disposal.
- The product has a shelf life of three months at 30°C.
- Various unit operations are integrated fully with mechanized energy-efficient equipment.
- An appropriate packaging system is available.
- Cost of manufacture is low.

Technologies for Manufacture of Cheese and Related Products

Accelerated Ripening of Cheese

The traditional process of manufacturing ripened varieties of cheeses such as Cheddar and Gouda takes a long time to yield the product. The long-time curing is cumbersome, labor intensive, energy consuming, and expensive. This problem is aggravated further in the case of Cheddar cheese production from buffalo milk. Technologies have been developed that accelerate the ripening process of cheeses, thus saving on refrigeration and labor.

The new process involves standardization of buffalo milk, relatively higher heat treatment, addition of a higher rate of starter culture and microbial rennet, and cooking at lower temperature. Supplementing the starter culture with adjunct bacteria, addition of exogenous free enzymes, such as lipase and protease, and microencapsulated enzymes, and partial curing of cheese at elevated temperatures accelerates the rate of ripening. Supplementation of buffalo milk with goat milk also improves the flavor, and the development of body and texture.

The advantages of the new process are:

- Buffalo milk can be used to manufacture good quality Cheddar cheese.
- Supplementation with goat milk provides a profitable outlet for using goat milk.
- The process saves a considerable amount of labor, space, and energy and curtails the amount of money tied up in cold storage.
- It reduces the total ripening costs to about 20–27% of the original.

Cheddar Cheese Flavor Base

A process technology for Cheddar Cheese Flavor Base (CCFB) in a paste and spray-dried form has been developed. This form has 15 to 20 times more intensity of flavor and is a cheap and convenient substitute for matured natural Cheddar cheese, which is used conventionally for flavoring different food products.

The CCFB is made by incubating young cheese slurry and exogenous enzymes at elevated temperatures under controlled reaction conditions. Cheddar cheese flavor develops within hours. All the critical control points of the process are standardized to obtain a uniform product. The flavor components are retained during spray drying using microencapsulation techniques. The shelf life of spray dried CCFB packed in metallized polyester laminate pouches is more than eight months at 15°C.

The advantages of the new process are:

- Production costs are reduced by as much as 40–80%.
- Production capacity is increased and product stability enhanced
- There is improved consistency and batch-to-batch product uniformity.
- There is better control in the development of new products.

Technologies for Manufacture of Fermented Milk Products

Mishti dahi

Mishti dahi is a popular traditional fermented milk product from eastern India. Since the manufacturing conditions are not controlled, the quality of each lot of *mishti dahi* is different. A standard method has now been developed, which is also suitable to large-scale production.

Skimmed milk is concentrated into known total solids employing a vacuum process. Cream is added to adjust fat in the partially concentrated milk. The standardized concentrated milk is heated and homogenized, followed by addition of sugar. The sweetened milk is heated to generate the characteristic caramel flavor, cooled to 30°C, and inoculated with LF-40 starter culture (1% by weight of milk). It is then filled in pasteurized polystyrene cups and incubated at 30°C for seven hours.

UF-Shrikhand

Shrikhand is an indigenous fermented milk product presently being manufactured by conventional methods. The conventional method allows the whey proteins to drain along with whey during *chakka* (curd cheese) making. The yield of skimmed milk *chakka* is about 18% by the conventional method.

A new method of skimmed milk *chakka* manufacture has been standardized that gives 23% extra yield (due to the recovery of whey proteins) using an UF technique. The quality of *shrikhand* made from UF-*chakka* has been found to be excellent.

Coagulated skimmed milk is concentrated by ultrafiltration using a mineral membrane module so as to recover whey proteins in the form of UF-retentate (*chakka*). Cream and sugar are added to the retentate. The minimum shelf life of the product is two weeks under refrigeration.

Technologies for Manufacture of Formulated Foods

Bifidus-containing Infant Formula

Existing infant formulae being marketed currently in India do not offer the bioprotective features essential to protect the health of bottle-fed babies. Higher instances of diarrheal diseases are reported among bottle-fed babies.

The advantages of the new technology are:

- The ratio of whey protein: casein:fat:carbohydrate:mineral is similar to that of human milk.
- Essential nutrient and caloric content conform to WHO/FAO, *Codex Alimentarius* Commission standards
- The product contains 1.2 x 10^5 cfu per gm of *Bifidobacterium bifidum* suitable for intestinal implantation in babies.
- Nutritional/biological adequacy has been established through feeding trials carried out under pediatric supervision.
- The cost of manufacture is 40% lower than that of conventional formulae.

Low Fat Spread

Butter is one of the most consumed dairy items. However, very few of those who would like to eat butter can afford to buy it. When refrigerated, butter becomes hard and brittle and loses its spreading consistency. When left at ambient temperature, it loses its plasticity.

It is therefore necessary to provide a product that is acceptable in all respects including spreadable consistency at ambient and refrigerated temperatures. An attempt was made to develop a low-fat, low-cholesterol, and low-cost spread, which could serve as a substitute for butter.

Low fat spreads usually have about 40% moisture content. Consequently, its shelf life is slightly less than that of conventional butter that has only 15-16% moisture. The butter-flavored spread is prepared with skimmed milk powder, a blend of hydrogenated fat and refined soybean oil, carrageenan, trisodium citrate, common salt, diacetyl, glycerol monostearate, and annatto butter color. The cheese-flavored spread can be prepared in the same way except that part of the skimmed milk powder is replaced with ripened Cheddar cheese to impart the typical flavor.

The advantages of the new process are:

- Butter-flavored spread packaged in polystyrene cups (100 g) can be stored for six weeks at 5°C.

- Butter-flavored low-fat spread costs only 58% the price of conventional butter, whereas the cheese-flavored product is slightly more expensive being 70% the cost of butter

Low Lactose Milk

Per capita consumption of milk, which is low in India, is expected to rise with an increase in milk production in the near future. Nearly 62% of the Indian population cannot digest lactose in milk. The incidence of lactose intolerance varies from region to region. The problem can be overcome by conversion of the lactose in milk into glucose and galactose by the enzyme ß-galactosidase. Since lactose in milk is converted into these monosaccharides in the human body following ingestion of milk, consumption of low lactose milk prepared by treatment of milk with ß-galactosidase will overcome lactose intolerance without any side effects.

The critical factor in preparation of low lactose milk is the enzyme ß-galactosidase. A number of microorganisms have been screened and identified as suitable sources for the enzyme. Strains of the yeast *Kluvyeromyces fragilis* and bacterial strains of *Streptococcus cremoris, S. thermophilus, Lactobacillus bulgaricus*, and *Leuconostoc cremoris* are all suitable for production of the enzyme. Whey (a by-product of the cheese industry) supplemented with a nitrogen source serves as the medium for the propagation of the organism.

The enzyme is also commercially available. The quantity of the enzyme is expressed in terms of enzyme units; one unit being equivalent to hydrolysis of 1.0 µmole of lactose into glucose and galactose in one minute. The advantage of the new process is that low lactose milk has the same shelf life as nonhydrolyzed milk.

Technologies for the Manufacture of Dairy By-products

Whey Powder

Whey is the by-product obtained during the manufacture of cheese, *paneer*, *chhana*, casein, and other coagulated products. The growing demands for cheese and increasing industrial production of casein and other coagulated products have generated enormous quantities of whey. On average, about 800 million kg of whey are produced annually as a by-product, with about 52 million kg of nutritious whey solids. Unfortunately most of this goes waste.

Besides being nutritious, whey solids possess excellent functional attributes such as solubility, emulsifying and foaming property, gel-formation, water binding property, flavor, and viscosity. Whey is rich in organic matter. The BOD (Biological Oxygen Demand) of whey is as high as 35–50 thousand mg O_2 L^{-1}. Disposal of untreated whey can therefore be harmful to the environment and human health. Thus, recovery of whey solids offers dual advantages. A technology has been developed for the manufacture of whey powder, whey protein concentrate, and lactose using membrane technology, which is less energy intensive and more cost effective.

The method of production of whey powder involves clarification of whey, its partial concentration employing reverse osmosis, followed by vacuum concentration, precrystallization of lactose using alpha-lactose monohydrates as seeding material, and finally spray-drying and packaging.

Whey Protein Concentrates

Whey protein concentrates (WPC) are used mainly as ingredients in non-dairy products, but also to some extent in dairy products such as infant and weaning foods. Additionally, they can be utilized for designing speciality food products, such as health food, hospital meals, fruit juices, and beverage mixtures.

The process for WPC manufacture involves pretreatment and ultrafiltration of whey, followed by spray drying of the UF-retentate. The pH of whey obtained from buffalo milk Cheddar cheese is adjusted to 7.2 prior to heating. Whey is cooled to 50°C before ultrafiltration. The retentate is spray dried using 180°C inlet and 80°C outlet temperatures. Whey protein concentrate powder thus obtained is cooled to room temperature, and packaged in polyethylene or metallized polyester laminates.

The advantages of the new process are:

- Energy requirements of membrane processes are low compared to evaporation processes.
- Adoption of membrane technology has distinct advantages in terms of improved yield and enhanced nutritive value.
- The product is stable for six months at room temperature.

Acido Whey - A Whey Drink

A process has been developed to prepare a palatable soft beverage utilizing whey that has been named 'Acido-whey'. Acido-whey is a noncarbonated drink, fermented with a selected strain of lactic acid bacteria and retaining all the nutrients of the whey intact. No preservative or synthetic color is added. It is highly refreshing, therapeutic in nature, and costs less compared to other beverages. The process is commercially feasible and economical to those dairy industries that are engaged in simultaneously processing fluid milk and manufacturing *paneer* and cheese.

Technologies for Use of Probiotics in Dairy Products

Probiotic Cheese

The tremendous growth of the market for probiotic food in Japan, Europe, the USA, and Australia are indicative of a trend that could be emulated by the dairy industry in India. A process was standardized for manufacturing Edam cheese containing an adequate number of viable cells of the probiotic microorganism *Bifidobacterium bifidum* (ATCC 15696). This cheese was comparable to the conventional product in its organoleptic and physicochemical characteristics. The efficacy of the probiotic characteristics imparted to the cheese was demonstrated through animal bioassays, i.e. intestinal implantation, antagonism towards colonic coliforms, and reduction in b-glucuronidase activity. The cheese also contains physiologically active peptides that augment its functional value. It is expected that the implantation of this health-promoting strain in the human intestine will lead to the manifestation of the probiotic attributes in the human system. This needs to be further investigated through clinical trials.

The advantages of the new process are:

- Product diversification and value addition.
- Added therapeutic and physiological benefits in the cheese.
- Distinct anticarcinogenic properties besides antagonism towards enteric coliforms, thus reducing the risk of gastrointestinal diseases.

Technologies for Manufacture of Dairy Equipment

Continuous Butter Melter

The melting of butter is an important unit operation that precedes the use of the continuous ghee-making system. Butter is received from cold storage in the form of large slabs normally at 4°C, and melts in jacketed tanks very slowly due to poor heat transfer coefficient. The melting operation has to be started in advance to keep the system in operation. The handling of large bricks of butter is also difficult. Continuous butter melters are not manufactured in India.

The continuous butter melter consists of a tank type heat exchanger with a rotor comprised of three components: a cutter, a conveying and turbulence generator, and a retainer disc to disintegrate butter lumps.

The advantages of the new process are:

- Quick operation: The melting capacity of 600-1000 kg/h is obtained with a heat-transfer surface area of only 0.72 m^2. The initial temperature of butter is 12–14°C and temperature at the outlet is 55–65°C.
- It is a safe and convenient way of handling butter.
- The heat transfer coefficients are high.
- Less energy is required compared with that in the jacketed kettle. Approximately 50 kJ kg^{-1} butter can be saved.

Continuous Ghee-making Machine

Ghee is currently manufactured by a batch process, which suffers from many disadvantages:

- A low heat transfer coefficient and unhygienic method of operation.
- An excessive strain on the operator due to the heat and humidity.
- Problems of severe scaling and foaming leading to inefficient utilization of the heat transfer surface and product loss.
- A high energy requirement.

A new process has been designed on the principle of heat transfer and hydrodynamics in a horizontal thin film-scraped surface-heat exchanger with a specific rate of water evaporation of 75 kg h^{-1} m^2 at 3.5–4.0 atm. steam pressure.

Continuous Khoa *Making Machine*

Khoa is an important ingredient in the manufacture of milk-based sweets. Presently, *khoa* is made primarily in jacketed kettles, which have the following disadvantages:

- They are unhygienic to operate.
- The heat transfer cannot be controlled and optimized
- An excessive strain on the operator due to the heat and humidity.
- Handling of large volumes is cumbersome.

A cascade system comprising two horizontal straight-sided thin film-scraped surface-heat exchangers has been fabricated to manufacture *khoa* from standardized buffalo milk. The rotor of the first heat exchanger is provided with four variable clearance blades and rotated at 3.3 rps. In this heat exchanger, milk is concentrated to about 40% total solids, which then flows into the second heat exchanger by gravity. The rotor of this heat exchanger has two helical conveying ribbons in addition to two variable clearance-scraping blades rotated at 2.5 rps.

The advantages of the new process are:

- The heat transfer rates are high.
- Cleaning is easy due to the absence of fouling.
- There is a negligible hold-up volume as the product remains in the form of a thin film.
- The product is of uniform quality.

India has undoubtedly made tremendous progress in dairying, but this is more quantitative than qualitative. What India now requires is a qualitative improvement in the entire food chain so that the country can establish itself as a reliable supplier of dairy products conforming to international standards and the quality assurance systems as envisaged under WTO agreements. Fast urbanization, increased purchasing power, nutritional awareness, and demand for region-specific milk products require new technologies to be developed for tailormade products.

ICAR-ICRISAT Collaborative Workshop on "Documentation, Adoption, and Impacts of Livestock Technologies in Mixed Crop-Livestock Farming Systems in India"

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About NCAP

The National Centre for Agricultural Economics and Policy Research (NCAP) was established by the Indian Council of Agricultural Research (ICAR) with a view to upgrade agricultural economics research through the integration of economics input in the planning, design, and evaluation of agricultural research programs, and to strengthen the competence in agricultural policy analysis within the Council. The Centre is assigned a leadership role in this area, not only for various ICAR institutions, but also for the State Agricultural Universities. In order to make agricultural research a more effective instrument for agricultural and rural change and to strengthen policy-making and planning machinery, NCAP undertakes and sponsors research in agricultural economics relating to problems of regional and national importance.

About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the SAT. ICRISAT's mission is to conduct research that can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

About the SLP

Poverty, food insecurity, and a deteriorating environment threaten the livelihoods and even the lives of millions of rural people in developing countries. Smallholder farmers in these countries have few resources or opportunities to improve their situation, but one option *is* widely available: by integrating crop and livestock production, farmers can improve their farm productivity while protecting their natural resources.

Linking the livestock-related research of its partners worldwide, the Systemwide Livestock Program of the Consultative Group on International Agricultural Research (CGIAR) is a unique vehicle for enhancing the contribution of animal agriculture to the CGIAR's objectives of increasing food production, eradicating poverty, and protecting the environment.

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