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Industrial Utilization of Sorghum in India

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Abstract

Patterns of human consumption of sorghum are well documented. Much less is known about the industrial utilization of the crop and the market opportunities this presents for poor sorghum producers. This study documents the emerging patterns of industrial utilization and provides evidence that between 10–40% of rainy-season sorghum is used for nonfood uses. Postrainy-season sorghum utilization remains solely for food purposes as it is not price competitive as an industrial raw material. The main utilization sectors are the poultry feed sector (approximately 0.5 million t per year); the dairy feed sector (approximately 0.2 million t per year); and the grain alcohol sector (approximately 0.1 million t per year). In the most important utilization sector, poultry feed, sorghum utilization is related to the price of competing cereals, particularly maize. Sorghum is used when prices are 20–30% lower than that of maize. With the demand for poultry feed estimated to be 15% per year, and with limited opportunities for increased maize production, the demand for sorghum is likely to strengthen. However, the impact of trade liberalization and particularly maize imports will have to be considered. Institutional arrangements linking the key utilization industries and related public sector research have in the past been weak. Improving these linkages through public-private sector partnerships would help to further support private sector market development for a commodity produced by some of India's poorest farmers.

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Acronyms and Abbreviations

AIDA	All India Distillers' Association
AISMA	All India Starch Manufacturers' Association
AME	Apparent Metabolizable Energy
ANGRAU	Acharya N G Ranga Agricultural University
APEDA	Agriculture and Processed food products Export Development Authority
BCF	Balanced cattle feed
CBC	Crossbred cows
CFTRI	Central Food Technology Research Institute
CLFMA	Compound Livestock Feed Manufacturers' Association of India
DFID	Department for International Development
ENA	Extra Neutral Alcohol
ENS	Extra Neutral Spirit
FAO	Food and Agriculture Organization of the United Nations
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IMDA	Indian Maize Development Association
IMFL	Indian Manufactured Foreign Liquor
IMRB	Indian Market Research Bureau
KLPD	Kilo Litres Per Day
MSP	Minimum Support Price
NARS	National agricultural research system
NDDB	National Dairy Development Board
NRCS	National Research Centre for Sorghum
NRI	Natural Resources Institute
NSSO	National Sample Survey Organisation
RS	Rectified Spirit
SIF	Saccharification and Instant Fermentation
USDA	United States Department of Agriculture

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£1 = Indian Rupees 70

US$1 = Rs 42

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Summary

This study is based upon fieldwork undertaken in mid-1998 in the context of the project 'Sorghum in India: Technical, policy, economic, and social factors affecting improved utilization', which was funded by the Department for International Development (DFID) and jointly undertaken by ICRISAT, NRCS, and NRI.

The main industries using sorghum in India are the animal feed sector, alcohol distilleries, and starch industries.Only rainy-season sorghum is used for industrial purposes. Postrainy-sorghum is a highly valued foodgrain, and thus too expensive to be used as industrial raw material.

Animal Feed Sector

While discussing sorghum utilization for animal feed in India, one has to distinguish between poultry and dairy production. Although the latter has a solid foundation in the co-operative sector, the poultry industry appears to be more dynamic.

According to poultry producers and feed millers, very little sorghum was used in poultry feed in 1998/99 due to the availability of maize and its price advantage. Nevertheless, it was acknowledged that in the past, when maize was expensive, sorghum had been used at an inclusion rate of up to 10% in the case of broilers and up to 15% in the case of layers. Estimates of the industrial demand for sorghum are summarized in Table 1.

The demand for sorghum in poultry feed largely depends on the price of maize, which is the energy source preferred by poultry producers. According to industry sources, to make sorghum competitive, its price should be 20 – 30% lower than that of maize.

Table 1. Summary of industrial demand ('000 t) for sorghum in India.

Industry	1998[1]	2010[2]
Poultry feed		
Broilers	86–129	570–1150
Layers	312–468	1,100–1830
Others	20– 30	156–234
Dairy feed	160–240	290–570
Alcohol	90–100	200–500
Starch	50	30–80
Brewing	0	–
Food industry	0	0
Exports	0	–
Total	718–1017	2346–4364

1. These figures reflect the average utilization of sorghum during the 1990s, based on past inclusion rates and current requirements of raw material, rather than on specific data for 1998. The poultry and starch industries use sorghum only when maize is expensive or not readily available.
2. Figures are projections.

Despite the recession in the Indian economy which started towards the end of the 1990s, the poultry sector is expected to grow at a relatively high rate, i.e., 8 – 10% per annum in the case of egg production, and about 15% per annum in the case of broilers.

The resulting increased demand for poultry feed is expected to lead to a deficit in energy sources, in particular, owing to the limited supply of maize. Imports of the latter are being considered but are currently too expensive due to the lack of adequate port handling infrastructure and transport facilities. As a consequence, sorghum appears to stand a chance as an alternative raw material in this sector. However, it may face competition from imports in the medium to long term.

The limited inclusion of sorghum in poultry feed and its relatively low status as a raw material is partly due to perceptions and misconceptions surrounding the crop, such as:

- The level of tannin in Indian sorghum
- The level of mycotoxins in blackened (i.e., molded) grain
- Its energy value as compared to maize
- Difficulties in sorghum processing
- Lack of carotenoids for yolk pigmentation.

In this context, it appears that the industry could benefit from the availability of more accurate information on the feed value of the grain, and better linkages with sorghum researchers.

In the case of dairy feed, the co-operative sector readily acknowledges the inclusion of sorghum in their livestock diets, although not all co-op feed mills use it. In general, relatively less grain (about 10% depending on the type of feed) is used in dairy feed formulations. It is estimated that in 1998, approximately 50% of the commercial dairy feed producers (i.e., 4 million t in total) used sorghum at an inclusion rate of up to 10%.

According to feed millers, sorghum is included in feed rations mainly due to its cost, availability, and quality. According to some members of the industry, storage of sorghum poses a problem, particularly when the grain is used several months after harvest.

Although ruminants are less susceptible to partly damaged grain or the presence of tannin, it seems that private dairy feed millers in particular could benefit from more scientific information on the possibility of including sorghum in rations. This should also give sorghum a higher status as a feed ingredient. Animal feed specialists from NRI would be in a position to advise on this issue.

Apart from commercial feed manufacturers, small-scale dairy farmers are likely to consume substantial quantities of sorghum grain, particularly in regions where the crop is grown.

Alcohol Distilleries

Although the quantity of sorghum grain presently used by the alcohol sector is comparatively low, it seems to be the most "enthusiastic" user of the crop as an industrial raw material. With recent changes in government policies on licensing alcohol production and trade, the use of grains to produce potable alcohol is being promoted, thereby providing an opportunity for sorghum to gain greater acceptability as a raw material in the industry.

There are few complaints about sorghum, although some distillers indicated a preference for varieties with a higher starch content and less protein. Distilleries had no objection to using severely blackened grain as long as the starch content was acceptable.

In general, like most other industrial users, distilleries purchase rainy-season sorghum through traders or brokers in main producing centers. Though there were few complaints about this system, some distillers felt that brokers sometimes abused their position to "control" the market. In this context, contract farming may be an option providing better linkages between producers and industrial users.

Starch Industries

Some of the country's main starch manufacturers, who are primarily based in Ahmedabad, have used up to 50 000 t of sorghum in the past when maize was in short supply. Starch producers have even undertaken their own research into sorghum-based starch manufacturing technologies, and their conclusion was that sorghum was not a preferred raw material and would only be used if there were no alternatives.

In order to improve the supply of maize, the starch and poultry industries have formed an association with maize research institutes called the Indian Maize Development Association (IMDA).

Other Industries

Although beer brewers are aware of sorghum-based beer production in Africa, they prefer barley malt as the principal raw material. In addition, broken rice or flaked maize are used as adjuncts. However, one brewery (i.e., Hindustan Breweries in Mumbai) expressed interest in undertaking trials using sorghum as an adjunct.

With the exception of a small market for speciality breads in urban centers, sorghum is not accepted as a raw material for industrial food processing. Wheat flour or maize starch are the preferred ingredients. Composite flours do not currently appear to be an option in bread baking or biscuit manufacturing.

Export of sorghum does not appear to be an option for the time being. Moreover, Indian sorghum at present is not globally competitive and export quotas for coarse grains are usually taken up by maize.

Recommendations

The following initiatives may be considered to improve the prospects for industrial utilization of sorghum:

- **Applied research and extension involving the private sector.** A better link between institutions involved in sorghum research and industries should improve the status of the crop. For example, on-farm feed trials with poultry farmers could lead to more accurate information on Indian sorghum varieties and make them more acceptable as a raw material.
- **Breeding and/or distribution of varieties more appropriate for industrial use.** For example, the livestock feed industry would prefer varieties with higher levels of energy, while the alcohol industry would prefer a higher starch content. Since many varieties encompassing these characteristics are likely to already exist, emphasis should be placed on their identification and distribution.
- **Extension of better storage techniques.** This is required since the quality of sorghum stored 6 – 12 months after harvest suffers, causing problems when the grain is used for industrial purposes.
- **Encouraging dairy and poultry production in sorghum-growing areas.** Given sorghum's place in the livestock feed industry, its use by small-scale farmers is worth exploring. If generation of cash is the primary objective, then it goes without saying that marketing systems have to be in place (e.g., in the case of dairy production). The breeding of dual-purpose varieties (i.e., for fodder and feed grain) is an important element to be considered in this context.
- **Strengthening farmer-industries linkages.** Although many members of the industry seem to be happy with current sorghum marketing arrangements, there appears to be scope for certain forms of contract-farming and farmer associations to strengthen the link between sorghum producers and industrial users. Efforts towards this end vis-a-vis the supply of maize are already being undertaken by some members of the industry.

Introduction

Background

This study formed part of the project 'Sorghum in India: Technical, policy, economic, and social factors affecting improved utilization', which was DFID-funded and jointly undertaken by ICRISAT, NRCS, and NRI. Apart from production, human consumption, marketing, and policy issues, industrial utilization was identified as one of the key areas to be studied in determining the potential of sorghum in the semi-arid regions of India.

Given the limited prospects of human consumption of rainy-season sorghum, the study concentrated on documenting the current status of the crop as an industrial raw material, and projecting future trends. There have been few such studies in the past, partly due to lack of reliable data.

The purpose of this paper is to document facts based on extensive surveys and discussions with industries concerned, rather than to advocate the use of sorghum.

Methodology

The study was undertaken to test the following hypotheses:

- Due to economic and technical constraints, sorghum cannot compete with existing raw material in various alternate uses, and
- The elimination or reduction of these constraints would result in improved utilization of rainy-season grain, particularly that which has fallen out of the human food chain.

A two-week exploratory survey was undertaken during Apr-May 1998 to identify the key industries to be studied and to collect literature on the subject. This involved visits to Akola, Hyderabad, Mumbai, and Pune. Based on this, it was decided to confine the study to the animal feed, alcohol, and starch industries.

A postal survey of 40 animal feed manufacturers, 5 starch producers, and 7 distilleries was undertaken between May and Jul 1998. The survey was not intended for a statistical analysis, but to obtain more qualitative data on the subject.

The main survey spanned over four weeks in Aug and Sep 1998, with subteams visiting industries in Ahmedabad, Alwar, Anand, Bhilai, Delhi, Ghatabillod, Hyderabad, Mumbai, Nagpur, and Rohtak.

Global Sorghum Utilization

With an annual production of approximately 60–65 million t, sorghum is the fourth most important cereal produced in the world. The USA (17 million t produced in 1994) is its major producer (ICRISAT & FAO 1996). Most of the sorghum in industrialized countries is used as an ingredient in animal feed rations (Table 2). The production is highly commercialized with a good integration between farmers and utilizing industries. In Asia and Africa, a major part of sorghum is produced for human consumption and the production is largely based on small-scale farming.

Table 2. Sorghum utilization[1] in North America, Asia, and Africa between 1992 and 1994[2].

	North America		Asia		Africa	
User	m tonnes	%[3]	m tonnes	%[3]	m tonnes	%[3]
Direct food	0.1	1	13.3	64	12.8	74
Feed	11.1	97	5.6	27	1.3	8
Other uses[4]	0.3	3	2.0	10	3.2	18
Total utilization	11.5	100	20.9	100	17.3	100

1. Figures are the annual average.
2. Figures do not include exports (e.g., during 1992-94, USA exported 6.6 m t $year^{-1}$).
3. Figures may not add up due to rounding errors.
4. "Other uses" includes seed, manufacturing purposes, and waste.

Source: ICRISAT & FAO 1996

The Indian Sorghum Economy

India is the second largest producer of sorghum worldwide, and has the largest area under the crop. It occupies around 11 million ha in the semi-arid regions of the country and is the third most important food grain. Sorghum stover is widely used as fodder and it often gains importance over grain in certain regions, particularly where growing conditions are unfavorable.

Sorghum is grown both as a rainy-season (Jun-Oct) and postrainy-season (Sep-Jan) crop. The rainy-season crop is grown over about 53% of the area and it contributes about 65% of the total production. The postrainy-season crop covers the rest of the area and production. The major states growing rainy-season sorghum are Karnataka, Madhya Pradesh, and Maharashtra, which together share 63% of the area and 77% of the production (Figures 1 and 2, see Appendix). Maharashtra, Karnataka, and Andhra Pradesh together share 93% of the area under postrainy-season sorghum. While the rainy-season crop coincides with the main monsoon spell, postrainy-season sorghum is grown on residual soil moisture and scanty rain during the crop season.

Postrainy-season sorghum grain maturing under dry weather is of high quality, valued for food, and fetches a high price. The rainy-season production system is notable for its wide use of high-yielding hybrids, which occupy about 75-80% of the area. Hence, the productivity of rainy-season sorghum is about 60% higher than that of the postrainy-season crop. The highest rainy-season yield was recorded in Maharashtra at 1.7 t ha^{-1}, with some of its major districts yielding 1.9–2.6 t ha^{-1}. The sorghum varieties grown in India are predominantly white, and as a consequence, the tannin content is virtually zero.

The demand for rainy-season grain as food has declined over the last decade, mainly due to the deterioration in the apparent and actual grain quality as a result of rain-induced molding, increasing production of fine cereals (primarily wheat and rice), and public policies that make the latter accessible to the economically deprived. The per capita consumption of sorghum in rural India declined from 1.59 kg $month^{-1}$ in 1972 to 0.84 kg $month^{-1}$ in 1993 and from 0.71 kg $month^{-1}$ to 0.39 kg $month^{-1}$ in urban areas during the same period.

Due to molding, rainy-season grain fetches lower prices and is hence less profitable than other rainfed commercial crops. This has led to a reduction of about 42% in the area sown to rainy-season sorghum during the last three decades. It is believed that this decline may eventually stabilize around 5 million ha and production around 8 million t (NRCS 1997), depending on the promotion of its demand for nonfood uses. In this context, the lower price of rainy-season grain, in comparison to its competitor maize, is an advantage. During 1998, maize was available in adequate quantities and marketed at prices marginally higher than those of rainy-season sorghum. Comparative price trends of rainy-season sorghum and maize over the years, however, show that sorghum usually has a price advantage over maize ranging from 7-37%.

Given this situation the national agricultural research system (NARS) is contemplating an active strategy to promote the use of sorghum in different industrial uses and to work in tandem with these industries. However, there has so far been no interface with client industries to respond to their problems on grain utilization. The present study found that NARS has neither a database on the current industrial utilization of sorghum nor direct contact with most current and potential user industries. The technological suitability of the grain for the projected uses and the economic advantage of its use would essentially determine the flow of sorghum to industrial uses in India. There are also several opportunities to improve the grain yield at a more competitive cost of production. NARS is open to developing client-specific cultivars.

Animal Feed Sector

Increasing Demand for Livestock Products

Increasing purchasing power, population growth, and high income elasticities of demand will be the driving forces behind future increases in the consumption of animal products in India. It can be predicted that changes in India's food consumption patterns will be similar to those in countries such as Japan and Korea (McKinsey 1997). Although the patterns may differ from country to country due to sociocultural reasons, the trend will remain the same, i.e., cereal consumption declining and protein consumption increasing as per capita income increases. In fact, recent National Sample Survey Organisation (NSSO) data confirms this trend for both urban and rural India (Table 3).

Table 3. Changes (%) in food expenditure in India.

	1970-71	1983	1989-90
Urban India			
Cereals	36	33	26
Milk and meat	20	22	25
Rural India			
Cereals	54	50	37
Milk and meat	15	16	21

Source: McKinsey 1997.

According to the World Bank (1996), recent estimates of the expenditure elasticity for milk and dairy products are of the order of 1.14 – 1.47 in the case of rural households, and 0.61 – 1.09 for urban households. The demand for meat, fish, and eggs is also more elastic in rural households (0.92 – 1.18) than in urban households (0.54 – 0.88).

Although vegetarianism is widespread in India, a large majority of the population eats meat (i.e., primarily poultry, and mutton). According to the National Food Survey conducted by the Indian Market Research Bureau (IMRB), 74% of the urban population is nonvegetarian (Sachdev, personal communication 1997).

Although the consumption of animal products has increased over the last three decades in India, it is still "considerably lower than in industrial countries and in other developing countries" (World Bank 1996), particularly in the case of egg and meat (Table 4). According to the McKinsey report,

Table 4. Per capita consumption (kg year^{-1}) of livestock products in India and select countries, 1992.

Product	India	Other countries
Milk (liquid milk)	65.0[1]	China-3, Australia-104, USA-104
Eggs (pieces)	26.0	China-163, Japan-276, Australia-170, USA-181, Turkey-122
Poultry meat	0.5	Hong Kong-43, China-4, USA-40, Thailand-9

1. Milk equivalent.

Sources: World Bank (1996) and USDA 1995.

based on Dairy India 1997, average milk consumption in India is 183 grams capita day^{-1} as compared to a world average of 285 grams capita day^{-1}. The same source also states that "Urban India consumes about four times as much milk as rural India", and predicts that "the consumption of Indian dairy products is likely to grow fast - at an annual growth rate of over 20 per cent".

According to the World Bank (1996), "recent estimates of livestock product demand in the year 2020, assuming that the economy consistently grows at 5.5 percent per year, and population growth, price and income elasticities of the past ten years remain stable, indicate that demand for milk will increase by a factor of 10 to about 497 million t by 2020. Demand for eggs and poultry meat will increase by a factor of 7 to 7.21 and 1.35 million t respectively".

Although some of these growth rates may seem too optimistic, particularly in the light of a sluggish economy, it can be predicted that there will be a substantial increase in the demand for animal products, most likely driven by the fast growing middle class.

The growing demand for livestock products can either be met through imports or increased domestic production. Assuming the latter will continue, there will be an increased demand for animal feeds such as crop residues, forage crops, and feed concentrates such as grains and oilcakes. This study focuses on the concentrate feed industry, particularly on grains.

The Feed Industry

The feed industry can be broadly categorized into the:

- Organized sector, comprising the Compound Livestock Feed Manufacturers' Association of India (CLFMA), which includes both poultry and dairy feed manufacturers;
- Co-operative sector, (i.e., most of the larger co-operatives are also CLFMA members), which is responsible for approximately 50% of the commercial dairy feed rations; and
- Unorganized sector, which includes small-scale feed millers or commercial farmers mixing their own feeds for egg production, and who are not members of either of the first two sectors.

Figure 3 (see appendix) provides an overview of the feed production by CLFMA members. In 1996/97, the total feed production was 2.94 million t, with poultry feeds accounting for 1.36 million t and cattle and other feeds accounting for 1.58 million t.

The bulk of industrial poultry feed production takes place outside the organized sector. Egg producers mix their own layer rations on-farm, based on concentrates (excluding cereals) purchased from feed millers and cereals procured from elsewhere.

The success of the Indian dairy industry is largely due to the co-operative movement and Operation Flood, which was initiated in Gujarat. Apart from dairy processing and marketing, co-operatives also produce and supply dairy rations. Feed supply and milk marketing are often integrated. In fact, some of the biggest feed mills of the country belong to co-operatives (e.g., Amul and Kaira District Co-operative Milk Producers' Union Ltd).

The co-operative feed mills obtain advice on least-cost feed formulations and raw material supply from the National Dairy Development Board (NDDB). According to NDDB, the total feed milling capacity of the co-operative sector was of the order of 5040 t day^{-1} in 1998. This capacity was utilized at 55% in mid-1998, suggesting an annual production of approximately 1 million t.

Most of the larger co-operatives form part of CLFMA. As a consequence, it is estimated that in 1998 about 2 million t of commercial dairy feed were produced by the organized sector (i.e., CLFMA and co-operatives), and an additional 2 million t by the unorganized sector.

Table 5. Production, market availability, and demand (million tonnes) for feed ingredients by the livestock and poultry feed sector in 2000.

	1994			2000			
Feed item	Production	Market availability	Demand	Production	Market availability	Demand	Status
Energy sources							
Maize	10.50	1.05	5.20[1]	12.00	1.20	10.00[1]	Very acute
Sorghum and millets	21.00	2.10		23.00	2.30		Very acute
Cassava (tapioca)	5.30	2.65	0.65	6.00	3.00	1.25	Surplus
Milling byproducts		8.20	2.60		10.00	5.00	Surplus
Protein sources							
Oilcakes/meals	12.80	6.40	3.90	16.00	8.00	7.50	Adequate
Fish meal	0.15	0.15	0.52	0.20	0.20	1.00	Very acute
Total concentrates		20.55	12.87		24.70	24.75	Adequate
Total roughages		710.00	945.00		932.00	1306.00	Acute

1. Combined demand for maize, sorghum, and millets.

Source: CV Reddy, personal communication 1997.

Expected increases in consumption of animal products will inevitably lead to an increased demand for feed, which members of the industry forecast, will lead to severe shortages of raw materials, particularly carbohydrate sources such as coarse grains (Table 5). Although the figures on the availability of maize seem underestimated, it is apparent that the industry predicts an acute shortage of coarse grains for animal feed in the future.

Chaddha (personal communication 1998) predicts a shortage of grains for animal feed, based on a projected poultry feed production of 12.5 million t in 2000, and 58.5 million t in 2015.

The World Bank (1996) estimates the deficit in concentrate feed for all categories of animals (i.e., cattle and buffaloes, small ruminants, poultry, and pigs) at 2.6 million t and the deficit in roughage at 251 million t. It also points out that most national calculations show a deficit of 50 – 60 million t in concentrate feeds, which is mainly based on the assumption that 0.5 – 1.0 kgs of concentrate feed are consumed per day per animal (i.e., primarily bovines) in the traditional sector. Although this may correspond to the theoretical requirement, in practice a majority of the animals in the traditional sector (e.g., *desi* cows) are predominantly fed on roughage.

The Poultry Industry

Table 6 illustrates the development of the Indian poultry industry during the 1990s. Until 1997/98, the sector grew at the rate of 10 – 12% in the case of egg production, and 20 – 25% for broiler meat. According to the McKinsey Report on "modernising the Indian food chain", the poultry sector "is poised for dramatic growth" (i.e. in excess of 20% per annum over the next 10 years).

Such an expansion is likely to take place in the context of occasional fluctuations such as those experienced during 1997/98. The unexpected economic slowdown in India towards the end of the 1990s arising from global factors, led to a surplus production of broilers in particular, and subsequently falling prices.

Table 6. Main indicators of poultry development in India.

Indicators	1990	1996	1997	2000[1]	2015[1]
Egg production (million)	23 300	30 000	32 034	45 000	180 000
Broiler production (million)	190	510	630	1 085	6 000
Commercial layers (million)	76	103	110	155	700
Poultry meat production ('000 t)	412	870	1 050	1 200	9 000
Per capita availability year $^{-1}$					
Eggs (no.)	28	32	33	45	180
Poultry meat (gms)	494	917	1 100	1 200	9 000
Parent stock in production ('000 t)					
Layers	960	1 200	1 300	1 825	7 325
Broilers	2 000	5 600	6 800	10 000	55 300
Value of poultry products (million Rs)	37 490	81 000	98 500	111 075	562 500
Poultry feed production (million t)	4.3	6.8	7.6	12.5	58.5
Value of veterinary pharmaceuticals (million Rs)	2 000	4 400	5 000	7 000	32 000
Human population	834	948	953	1 000	1 040

1. Figures are projections.

Source: R. C. Chaddha, personal communication 1998.

In the medium to long term, however, growth is expected to pick up. It is projected that egg production will grow by about 9% per annum, and broiler production by approximately 15%. The feed required by parent stock and growers is expected to increase by 12% per annum.

The figures in Table 7 are based on findings of the survey undertaken in Apr and Aug 1998. Growers and parent stock consists of about 70 million layer growers, about 6 million broiler parents, and approximately 1.5 million layer parents. Also, the figures on feed intake do not always correspond to what is fed in reality (i.e., birds are often underfed).

Commercial poultry feed manufacturers primarily produce broiler feed. Layer feed rations, which form the bulk of poultry feed, are generally mixed on-farm, whereby egg producers purchase

Table 7. Estimated feed requirements by the commercial poultry sector in 1998 and 2010.

	Poultry population in 1998 (million)	Feed intake[1] (kg head^{-1})	Feed requirement in 1998 (million t)	Annual growth rates[2] (1998 – 2010) (%)	Projected feed requirement in 2010[3] (million t)
Layers	130.0	40.0	5.2	9%	14.6
Broilers	650.0	3.3	2.1	15%	11.5
Growers and parent stock			1.0	12%	3.9
Total			8.3		30.0

1. Feed intake in the case of broilers corresponds to lifetime intake (about 6 weeks) and in the case of layers to the actual laying period (about 1 year).
2. The growth rates chosen are lower than the figures published by the poultry industry, taking into account the recession in the Indian economy which started at the end of the 1990s.
3. Summarized feed requirements.

concentrates from feed millers and grains from their own sources. The figures in this study on the demand for feeds include on-farm mixing by commercial egg producers.

According to some poultry producers, the fact that egg production is partly shifting away from large urban areas such as Hyderabad to secondary centers such as Nizamabad, may be due to improved transport infrastructure, lower costs of production, and increased prevalence of contract farming in the industry.

Sorghum Use by the Poultry Feed Industry

According to the industry, substantial quantities of sorghum have been used in the past in poultry rations, especially when maize was not readily available or was too expensive. This, in addition to the fact that not all poultry producers/feed millers appeared perfectly open about their sorghum feeding practices, made data collection somewhat difficult. This lack of openness may have been influenced by the low status being given to sorghum as a raw material for feed.

As a result, information on rate of inclusion of sorghum varied. A typical response was, "Yes, we did include sorghum in our rations in the past but only up to 10% ". Table 8 indicates the extent of sorghum use in poultry rations in the early 1990s, although its 21% inclusion in layer mash appears to be somewhat on the higher side.

Rakshit and Rao (1997) used an energy value of 2645 kCal metabolizable energy per kg of sorghum to calculate least-cost formulations. A recent unpublished study conducted at the Project Directorate on Poultry, Rajendranagar, Hyderabad, reported the following Apparent Metabolizable Energy (AME) of major coarse grains: sorghum: 3631 kCal kg^{-1}, pearl millet: 3562 kCal kg^{-1} and maize: 3495 kCal kg^{-1}. The study also reported that the cost of a balanced poultry diet containing

Table 8. Composition (%) of broiler and layer feeds used on commercial farms[1] in 1993/94.

Ingredients	Broiler starter	Layer mash
Maize	53.5	34.0
Sorghum	7.0	21.0
Fish meal, 47%	4.0	3.0
Groundnut extract		3.5
Soybean meal, 47.5%	24.0	18.0
Sesame meal, 42%	5.0	
Sunflower meal extract		3.0
Rice polish	4.0	
Rice bran extract		10.0
Calcite/Sheil grit	1.3	4.5
Mineral mixture		3.0
Dicalcium phosphate	1.0	
Salt	0.2	
DL Methionine (g $tonne^{-1}$)	500	
Vit/Trace Min. Mix (kg $tonne^{-1}$)	2.5	
D.O.T. Pure (g $tonne^{-1}$)	125	
Furazolidone (V-Fur-200) (g $tonne^{-1}$)	250	

1. Since the original title of the table read "...feeds currently used ...", it was assumed that the period under consideration corresponded to 1993/94.

Source: Saxena 1994.

different coarse grains at the 58% level is most favorable when pearl millet and sorghum are used in comparison with maize or ragi and the cost of feed using maize was the highest (Dr G Syamsunder, personal communication).

Researchers at the Acharya N.G. Ranga Agricultural University (ANGRAU), who are also consultants for the poultry industry, recommend that not more than 30% of sorghum should be included in poultry feed due to uncertainties about tannin. In general, according to feed millers, more sorghum was used in layer rations, where energy matters less, than in broiler rations. During the second half of the 1990s it is reported that when maize was in short supply, average inclusion levels were of the order of 10% for broiler rations and 15% for layers. Grower rations tend to include less sorghum due to the risk of tannin.

Although sorghum grain is transported over long distances for feed production (e.g. from Maharashtra to Tamil Nadu or West Bengal), it is unlikely that the entire poultry sector included sorghum at the same level. Even when maize was in short supply, some producers would not prefer sorghum over other grains such as broken wheat or ragi.

The survey revealed a range of positive and negative perceptions which discourage the use or admission of sorghum in poultry rations. Overall, it became clear that sorghum is currently considered a second choice raw material for poultry feed.

Some of the issues highlighted in Table 9 appear to contradict each other. For example, according to the response to the survey questionnaire, availability was often stressed as an advantage while using sorghum. However, some producers clearly found it more difficult to obtain the grain. This may be due to location, lack of contact with sorghum traders/brokers or seasonal shortages.

The tannin content of sorghum grain, which is considered a disadvantage, is contentious. According to researchers at NRCS, Indian sorghum is predominantly white and virtually tannin-free. However, many poultry producers, including veterinary researchers from ANGRAU in Hyderabad are apparently not aware of this important fact. Inclusion levels may increase if producers know from

Table 9. Industry-perceived advantages and disadvantages of using sorghum in poultry feed.

Advantages	Disadvantages
• Low cost	• Lower energy content than maize
• Energy alternative to maize	• Risk of aflatoxins (often associated with blackened grain)
• Easy availability	• Risk of tannins
• Good pelletability	• Not always available
	• Problems with grinding: mash becomes powdery reducing feed intake by birds
	• Low palatability and digestibility
	• Varying quality; grain often infested with weevils, fungi, etc.
	• Sorghum lacks the carotenoid pigments present in yellow maize, which are necessary for egg yolk colour
	• Feed including sorghum is more difficult to sell
	• Absence of standard varieties in the market

Note: Apparent contradictions reflect information obtained during the course of the survey.

reliable sources that there is no risk of tannin in Indian sorghum, including the yellow varieties which are generally suspected for tannin content. On the other hand, according to NRCS experts, the Indian yellow sorghum's carotene content may impart a yellow color to egg yolk.

Researchers at NRCS clarified through past studies that blackened or molded grain does not normally contain aflatoxin. A post-graduate research study titled "Toxicopathological studies on feeding of black sorghum to broilers", undertaken in Akola[1], concluded that better performance was observed on a maize-based diet. Naturally infested black sorghum feed can be advocated in broiler rations to the extent of 75% (i.e., replacing maize up to 75%) without any adverse effect on body weight, hematological and biochemical parameters when compared with normal sorghum. Secondly, non-toxic effect was further confirmed from gross, histopathological and immune response studies (CMI & HI) in chicks. Severely damaged black sorghum, however, adversely affects all these parameters. Thirdly, washing and sundrying black sorghum improves all the parameters including humoral and HI response. It is therefore recommended that the use of black sorghum can be enhanced with this treatment prior to its use in broiler rations, in order to improve broiler performance. This methodology may prove useful in areas where black sorghum is consumed by the poor.

Although this study advocates the use of blackened sorghum in broiler rations, it also highlights some of the difficulties faced in classifying different degrees of damage due to blackening. Hence care during procurement is advised.

Opinions also differ widely on the amount of metabolizable energy in sorghum. Some see it as a good energy alternative to maize whereas others consider the energy level in sorghum too low (ranges between 2600 and 3100 kCal kg^{-1} of sorghum, as compared to 3300 kCal kg^{-1} in the case of maize). These disparities may be due to the quality of the sorghum examined, varietal differences, or the manner in which research was undertaken. More light needs to be shed on this issue and guidance provided to feed millers and poultry producers to promote the use of sorghum.

Table 10 shows the relative values (Indian Poultry Industry Yearbook, 1994) of grains used in animal feed. The criticism about lower energy in sorghum is countered with results of recent studies on AME at the Project Directorate on Poultry.

The perceived disadvantage in grinding sorghum is largely due to the use of hammer mills

Table 10. Relative value of grains used in animal feed.

Grain	Energy value (% value of maize)	Protein (%)	Palatability level	Fiber (%)	Protein balance	Beware of …
Maize	100	8.8	Very high	2.0	Good	High moisture Aflatoxin
Wheat	96	10.0	Very high	2.5	Excellent	New wheat
Sorghum	95	10.0	High	2.0	Fair	Tannin
Finger millet	95	6.0	High	3.0	Fair	Sand/silica

Source: Saxena 1994.

1. The study was undertaken by M R Joshi, under the supervision of Dr M V Joshi, in the Department of Veterinary Pathology at Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola. It led to a paper which was accepted for presentation at the World Poultry Conference in September 1996, New Delhi.

designed for grinding corn, which could be overcome by modifying the milling equipment. NRCS scientists also point out that when there is a steady demand for grain, farmers may grow standard varieties suited for feed, and variations in quality could be offset by contract farming.

These research findings on sorghum as feed for poultry have not found ready acceptance, which is an important reason for its poor reputation as a poultry feed ingredient, and its use only when maize is in short supply or too costly. At the same time, the quality of sorghum grain towards the end of the storage season (Jun to Aug) appears to be unfavorable due to its great vulnerability to damage during storage.

The Dairy Industry

According to McKinsey (1997), "dairy demand is poised for rapid growth". Table 11 shows some of the details of the bovine population in India, and the fact that the majority of the dairy herd is made up of indigenous cows and buffaloes [Figures in Dairy India (1997) are more than 10 years old]. The population of crossbred cows (CBC) is still comparatively small.

"Operation Flood", a very successful dairy expansion movement started in Kaira district, Gujarat, succeeded in linking and bringing together 8.4 million farmers in 200 districts into 70 000 milk societies (McKinsey 1997). In total, there are about 30 million small-scale dairy producers in India with an average herd size of 3.7 animals. Small and marginal farmers account for three quarters of the dairy farms and raise 60% of the cattle.

Table 12 highlights some of the dairy feeding patterns in the co-operative sector. It is noticeable that grains are consumed in small quantities, i.e., an average of about 220 grams day^{-1} crossbred cow^{-1}, 190 grams indigenous cow^{-1}, and 270 grams $buffalo^{-1}$. As a consequence, it can be assumed that on an average, about 200 – 250 grams of grain are consumed every day per head of dairy animal in India. It should also be noted that the consumption of grains for feed purposes is lowest in South India and highest in North India.

The 1987 dairy population in milk (53 million) and a daily consumption of 230 grams of grain per head would suggest a total consumption of 4.4 million t of grain per annum. However, this figure should only be used as an indicator. The consumption figures correspond to the results of a survey undertaken in the co-operative sector, and it can be expected that dairy animals outside this sector are

Table 11. In-milk and dry crossbred and indigenous cows and buffaloes, India, 1987 and 1982.

	Crossbred cows			Indigenous cows			Buffaloes			Total milch animals		
	In milk	Dry	Total	In milk	Dry	Total	In milk	Dry	Total	In milk	Dry	Total
Numbers ('000)												
1987	2 878	1 235	4 113	26 940	25 034	51 974	23 150	12 738	35 888	52 968	39 007	91 975
1982	1 762	915	2 677	24 827	26 275	51 102	17 998	12 052	30 050	44 587	39 242	83 829
Percentage of total milch animals												
1987			4.5			56.5			39.0			100.0
1982			3.2			61.0			35.8			100.0
Percentage growth in 1987 over 1982			53.6			1.7			19.4			9.7

Source: Dairy India 1997.

Table 12. Zonewise[1] feeding (kg day^{-1} $animal^{-1}$) of milch animals.

	Crossbred cows				Indigenous cows				Buffaloes			
Type of feed	E	N	S	W	E	N	S	W	E	N	S	W
Green fodder	3.64	13.65	5.40	6.08	2.97	5.63	4.03	3.69	5.87	11.36	4.18	5.50
Dry fodder	6.16	6.32	7.50	8.92	5.51	7.57	7.29	8.22	8.39	8.55	8.22	9.74
Grains	0.27	0.40	0.06	0.16	0.19	0.35	0.05	0.18	0.31	0.44	0.05	0.28
Oilcakes	0.67	0.66	0.64	0.53	0.46	0.31	0.28	0.32	0.51	0.53	0.24	0.36
BCF[2]	0.77	0.58	0.63	1.32	0.34	0.33	0.22	0.44	0.21	0.21	0.23	0.83
Others[3]	0.76	0.14	0.64	0.13	0.53	0.06	0.47	0.10	0.26	0.07	0.57	0.11

1. E = East, N = North, S = South, W = West.
2. BCF = Balanced cattle feed.
3. Includes pulses, bran, and cereal husk.

Source: Bhide and Chaudhari 1997.

fed less grain. At the same time, the dairy population has most likely increased. In fact, according to Dairy India 1997, the annual growth rate in milk production was about 5% during the 1980s and 1990s.

According to the 1998/99 estimate, approximately 4 million t of dairy feed is produced in India by the commercial sector (i.e., about 1 million t by nonco-operative CLFMA members, 1 million t by the co-operative sector, and 2 million t by the unorganized commercial sector).

The survey revealed that relatively little grain is used in dairy feed rations, which can be classified into standard feed, bypass feed, and high-energy feed. Manufacturers prefer to market more than a dozen feed formulations at a cheaper price for higher marketability. Standard dairy rations, which comprise the bulk of commercial feed, include approximately 10% grain; the bypass feed about 5 – 10%, and the high-energy feed about 20%. As a consequence, it is assumed that dairy rations include, on an average, about 10% grain, which would correspond to a total use of about 0.4 million t per annum by the industrial dairy sector.

Assuming an annual growth rate of 3%, based on the findings of the survey, it is predicted that commercial production of dairy feed will touch 5.7 million t in the year 2010. Though a conservative estimate, it reflects the views of the industry surveyed in mid-1998. Going by this projection, grain demand for dairy feed in 2010 could be about 0.57 million t. It must be mentioned here that an unestimated quantity of grain, whether partly damaged or not, is directly fed to animals at the farm level.

Sorghum Use by the Dairy Feed Industry

The cooperative dairy sector as a whole is very open on the utilization of sorghum. According to animal nutritionists of NDDB, the inclusion rate of sorghum in commercial dairy feed is of the order of 10%, and sorghum is the main cereal used, followed by maize, damaged wheat, and pearl millet. Computerized least-cost formulations are used to calculate the exact proportions of the ingredients.

The Amul feed mill at Kajari-Boriavia (in the Kaira District Co-op Milk Producers' Union, Anand), with an installed capacity of 600 t of feed per day and the largest feed factory in India, regularly uses sorghum in its feed production. During 1998, for the production of bypass protein rations, it followed an inclusion level of 2–5% (Jan–Mar 1998 2%; Apr–May 1998 5%). Demand for dairy feed rations is higher between Oct and Mar, when less green fodder is available. Therefore, the demand for grain too is higher during this period.

Table 13. Nutritional value of grains for dairy cattle and buffalo.

Grain	Dry matter (%)	Protein Total (%)	Protein Digestible (%)	TDN (%)	Energy (per kg) Digestible (Kcal)	Energy (per kg) Metabolizable (Kcal)	Ca (%)	P (%)
Barley	90	8.7	6.9	79	3483	-	0.06	0.33
Pearl millet	89	11.9	5.1	61	2665	2185	0.12	0.46
Sorghum	87	15.2	7.3	86	3772	3093	0.12	0.44
Maize	89	8.9	6.8	81	3571	2928	0.02	0.31
Oats	89	11.8	8.8	68	2998	2458	0.10	0.35
Wheat	89	13	10.1	78	3449	2820	0.50	0.40

Source: Dairy India 1997.

During 1998, Amul paid between Rs 3800 and 4000 per t of sorghum (landed factory). The main supplier was in Maharashtra (Jalgaon, Akola, etc). According to Amul, Rs 3200 could be considered a low price, and Rs 4200 the maximum they are prepared to pay. It was also noted that sorghum is not always available between Feb and Sep. Given its price range and ready availability, the cooperative feed sector is highly satisfied with sorghum as a feed component. In this context, the observation by Dr Amrita Patel, Managing Director, NDDB, on the need to develop satisfactory and safe storage techniques for sorghum grain is very pertinent.

Table 13 shows the nutritional values of various grains. According to it, sorghum is ahead of other grains in most nutritional categories. Feed experts at Amul mentioned that up to 5% tannin in grain may not adversely affect animal production. However, the non-co-operative commercial feed millers often have different views on sorghum grain. This may be related to the market perception on the image of sorghum grain, which in turn may be influenced by the moldy or blackened state in which it is often sold in the market, rather than on its feed value and economic advantage.

Table 14 summarizes the advantages and disadvantages of using sorghum in dairy feed, as expressed by dairy feed millers during the course of the survey. They are quite similar to the ones expressed by the poultry industry.

Table 14. Industry-perceived advantages and disadvantages of using sorghum in dairy feed.

Advantages	Disadvantages
• Low cost	• Presence of tannins
• Good energy source	• Discoloration of grains
• No problems with processing, if appropriate equipment is used (e.g., Amul)	• Deterioration of quality during storage (due to mould and insects)
• Good availability	• Moisture content is sometimes too high
• Traditionally fed to cattle in rural areas	• Not always available round the year
	• Low palatability and digestibility
	• Customer resistance if sorghum is included in feed (although manufacturers usually do not disclose raw materials used)
	• Absence of standard varieties in the market

Note: Apparent contradictions reflect information obtained during the course of the survey.

Sorghum Price Paid by the Feed Industry

Table 15 shows the indicative all-India average price of raw materials provided by the feed industry. As far as sorghum is concerned, since the prices quoted are far higher than those normally prevalent, they should be treated with caution. Sorghum prices are usually, 5–15% lower than the maize price, while a price differential of 10–15% was also admitted by a few feed millers.

According to literature, and given its nutritional value as a feed ingredient, the price of sorghum should be about 85–90% that of maize (John Wood, personal communication). At the same time, it may also be possible that this scenario partly reflects the feed value of sorghum varieties grown in the United States, which are specifically bred for industrial use; moreover the grain is also free from damage by mold.

A majority of feed millers surveyed in India stressed that sorghum should be either 20–30% or cheaper by about Rs. 1000 per t than maize to make it an attractive raw material.They have come to this conclusion due to the low apparent quality of sorghum in the market, as compared to maize. Parts of the industry purchase sorghum when maize is in short supply. However, the quality of sorghum grain suffers due to inadequate storage, reflecting on the prices paid during the lean season. The average price paid for sorghum by the feed industry around mid-1998 ranged between Rs 3500 and Rs. 4000 per t (landed cost).

Table 15. Indicative, all-India price of raw materials used in animal feed.

Raw material	1993/94	1994/95	1995/96
Rice bran	3020	5250	5260
Rice bran extract	1580	2520	2680
Maize	2370	4980	5130
Sorghum	2020	4730	4680
Groundnut cake	4180	6250	7290
Groundnut extract	3970	5150	6230
Soyameal	6120	7050	8270

Source: CLFMA 1997.

Potential Demand for Sorghum

Based on the preceding discussion, the calculations presented in Table 16 show the potential demand for sorghum to be of the order of 2.9 million t. It is expected that due to better quality and more information on the feed value of this grain, a greater number of feed producers would include sorghum at higher levels as compared to 1998. Though this level of demand may occur, given the actual and projected feed deficit in the Indian animal feed industry, it is assumed that maize will not be able to fill this gap alone due to its higher cost and limitations for potential expansion in production.

Figure 4 demonstrates the potential sorghum demand at different inclusion levels in the main feed categories in 2010. It was assumed that 50% of the respective feed industries would include sorghum in their rations at the inclusion rates shown.

At this point it may be appropriate to reiterate that future demand for sorghum in feed rations is a function of its price, regular availability, and quality. Particularly in the case of poultry feed, sorghum has to compete with maize on these aspects.

Table 16. Potential demand for sorghum in commercial animal feed.

	Feed demand in 1998[1] (million t)	Annual growth rate (%)	Projected feed demand in 2010 (million t)	Sorghum inclusion rates (by 50% of industry in 2010)	Potential demand for sorghum in feed in 2010 (million t)
Poultry industry					
Layers	5.2	9%	14.6	20%	1.46
Broilers	2.14	15%	11.4	15%	0.86
Growers and parent stock	1.0	12%	3.9	10%	0.19
Dairy industry	4.0	3%	5.7	15%	0.43
Total					2.94

1. It is estimated that layer rations contain 15% sorghum, broiler rations 10%, grower and parent stock rations 5%, and dairy rations 10%. It is assumed that by 2010, due to better quality sorghum and improved information, these inclusion levels will have increased to the rates shown. The figures in Table 1 are based on the assumption that 40% (low scenario) to 60% (high scenario) of the respective feed industries include sorghum at these inclusion rates.

Alcohol

The Industry

While discussing the potential for using sorghum in alcohol production, one must keep in mind that in India, molasses (a byproduct of sugar manufacture using sugarcane) constitutes the most important raw material in this industry. It is estimated that about 95% of the alcohol manufactured in India is from molasses and the rest comes from grains, and roots and tubers.

According to the All-India Distillers' Association (AIDA), alcohol production during 1997-98 was 1100 million liters. In general, 47% of this was redistilled as extra neutral spirit (ENS) for potable alcohol and 53% used for industrial purposes. In Maharashtra, the largest alcohol producing State, this ratio is 35% for human consumption and the rest goes for industrial use.

Molasses-based ENS is being used to develop several exotic formulations under local brands which are generally known as Indian Manufactured Foreign Liquor (IMFL). The manufacture of grain-based alcohol began in India only in the 1990s with the entry of Scotch whisky manufacturers and distributors. As a result, the local molasses-based potable alcohol industry has been facing competition from international Scotch whisky producers or importers. According to the Scotch Whisky Association, though the current Indian market for its product is very limited for different reasons, with increasing purchasing power, consumers will shift to more expensive products, and as a consequence, higher demand for grain-based alcohol and foreign liquor such as Scotch whisky is expected. These liquors are qualitatively superior to molasses-based IMFL.

At the same time, the supply of and demand for alcohol are highly influenced by Government policies which have an impact on:

- licensing of alcohol factories
- trade and taxation laws affecting the supply and costing of raw materials
- the level of duties and levies on potable ENA
- ban on alcohol production and consumption (prohibition) in some states; and
- the restriction on international companies to use only grain-based potable alcohol.

Granting licenses to alcohol factories is the State government's prerogative. In some states (e.g., Maharashtra) no new licenses for molasses-based potable alcohol industries have been issued. The Government of India favors restrictions on licensing due to production-related environmental pollution and the low quality of molasses-based alcohol which may contain harmful aldehydes and sulphates.

In June 1993, the Central Molasses Board, which controlled the price of molasses was dissolved and the policy on its pricing was delegated to State governments. This resulted in varying spurts in prices across the country – from Rs 150 per tonne (regulated price) to between Rs 800 and Rs 2500 (landed cost) – depending on the season and location of the factory. As a result, the cost of producing molasses-based alcohol went up, making it nonviable for factories with outdated production technology, and those with production levels far below installed capacity, and an increased interest in alternate raw materials, particularly cheaper coarse grains.

Production of sorghum-based alcohol was not encouraged in the past keeping in mind food security, since it is the third most important foodgrain in India. However, with decreasing per capita consumption of sorghum and greater availability of rice and wheat, rainy-season sorghum is gaining popularity as a raw material for industrial uses.

Duties and levies on potable alcohol include central excise duty, state taxes, and duties on inter-state movement. According to AIDA, the retail price of potable alcohol constitutes 75% excise duty, 10 – 15% marketing margin, and 10% producer's price. Maharashtra levies an export pass fee of Rs 10 per liter of rectified spirit (RS) leaving the State. This fee is not levied in other States like Madhya Pradesh, highlighting how complex and different the system is across the country.

Gujarat, Andhra Pradesh, and Haryana are the States where complete or partial prohibition was introduced in the recent past. It was subsequently lifted in Gujarath. According to AIDA's newsletter (1998), the Centre is considering scrapping the law, "which empowers the union and state governments to ban the movement of and trade in alcoholic products and impose prohibition in any part of the country". Frequent policy changes on prohibition and other legislation affecting the production, transport, trade, and consumption of alcohol make business planning difficult for companies active in this field.

When multinationals entered the alcohol trade in India, they were required to confine themselves to production and marketing of grain-based alcohol. This has to be seen in the light of the Government of India's policy not to issue more licenses for the production of molasses-based potable alcohol. However, according to distillers, some multinationals have entered into joint ventures with domestic companies having licenses to produce molasses-based alcohol.

Production of Grain-based Alcohol

Towards the end of the 1990s, about 13 multinationals had been licensed to produce and/or market grain-based alcohol. According to Praj Industries, Pune, a leading group which provides processing engineering, and turnkey plant erection facilities for the production of RS and extra neutral alcohol (ENA) from molasses and nonmolasses raw material, there are at least seven distilleries with an installed capacity of 224 KLPD (kiloliter per day) alcohol from grain. Of these, about six started production (some of them were visited during this survey), and another one at Nasik, Maharashtra, was in preproduction stage in mid-1998. These plants even use damaged grain sold by the Food Corporation of India (FCI), broken rice, barley, and coarse grains such as pearl millet and sorghum, which are locally competitive. According to an article in Business Line (7 Feb 1997), the total licensed capacity of nonmolasses-based alcohol is 100 million liters per year, working out to about 9% of 1100 million liters of RS produced in 1997/98 as reported by AIDA. There is reason to believe that 50% of the installed nonmolasses-based alcohol production is currently underway. This may constitute about 4.5% of the total alcohol produced.

On the basis of an annual production of approximately 50 million liters of rectified grain alcohol, one can assume that about 143 000 t of grain could have been used in 1998.

Grain-based alcohol is more expensive to produce than molasses-based alcohol, due to the high cost of raw material and additional processing costs (for coal/steam, and enzymes). During mid-1998 in eastern Maharashtra, the cost of producting ENA from molasses varied from Rs 13 to 16 per liter, and that from grain from Rs 21 to 27 per litre depending on raw material cost and alcohol recovery.

Due to the current excise duty formula which is based on production costs, grain-based alcohol is "penalised" for its higher cost of production. The Excise Commissioner of Maharashtra, Ajit Kumar Jain, aware of this disadvantage, suggested the possibility of a change in the duty structure to boost the production of grain-based alcohol. According to him, the Maharashtra Government was in favor of promoting grain-based alcohol production to create a demand for rainy-season sorghum. It must be remembered in this context that rain-damaged or blackened sorghum could be a favorable raw material for alcohol production because of its lower market price. Maharashtra, the main producer of rainy-season sorghum, regularly faces the problem of finding suitable users of blackened sorghum which constitutes 40-60% of its produce, depending on the rainfall pattern during grain maturity.

Alcohol from Sorghum

Rainy-season sorghum is the major raw material preferred by the alcohol industry. In general, this survey found the industry "enthusiastic" about using sorghum. Some of the distilleries near Nagpur, Bhilai, Ghatabillod, Cuddalore, and Bulandshahr were found using sorghum (nearly 40 million liters) either completely or partially for alcohol production. While this information is not exhaustive, there is sufficient reason to conclude that in 1998, about one lakh t of sorghum was used to produce alcohol.

Praj Industries highlights the suitability of their alcohol distillation technology for blackened sorghum under their slogan "Even with damaged grain Praj improves the health of your distillery". This group offers the HIFERM-NM process (Figure 5, see Appendix) for grain route distillation system for alternate production using molasses as well as grain/starch as raw materials. For distilleries operating with molasses, Praj Industries has developed a dual route module that allows switching to starch-based raw materials when required.

While distilleries utilizing grain use modern technology, there area a few using outdated plants and technology. The latter reported difficulties in grinding the grain as the plants did not have their own grinder, and lumping of grain residue led to choked of drainage pipes. On the contrary, distilleries using modern technology faced no such problems. Sorghum, whether molded or not, is a welcome raw material, and the major considerations are the landed price of the grain and its availability round the year. In this context, storability, particularly of the blackened grain, is important.

Like most other industrial users, distilleries purchase rainy-season sorghum through traders or brokers in main production centers such as Latur and Akola. Though there were few complaints about this system, one distiller in Madhya Pradesh felt that brokers sometimes abused their position to control the market. Some distilleries are even envisaging a form of contract farming involving the supply of seeds.

Distillers reported that they bought sorghum at a price (landed cost) ranging between Rs 3500 and 4200 per tonne. Prices are the lowest soon after harvest from Nov to Feb. The quality of grain suitable for alcohol production could even be inferior to that used for cattle feed. Hence, the price of grain used for alcohol could not be higher than that used for feed.

Some distilleries indicated a preference for sorghum varieties with a higher starch content (close to 70%) and less protein. However, they had no difficulty using severely blackened grain as long as the starch content and cost were acceptable. According to scientists at NRCS, several popular high-yielding hybrids have a starch content of 70% and above, and the starch content in molded grain may be less varying between 5% and 12% depending on the severity of damage.

Seagram, the principal trader of grain-based alcohol in India, has recently opened a research laboratory in Pune. As a consequence, it seems important for NRCS to stay in touch with such agencies using grain for alcohol production. An exchange of ideas regarding processing technology and varietal improvement of sorghum could be beneficial to producers and users.

When it came to trading, one of the distilleries mentioned difficulties in selling grain-based alcohol because of the adulteration of grain-based whisky with molasses-based alcohol, leading to

Table 17. Advantages and disadvantages of using sorghum in alcohol production.

Advantages	Disadvantages
• No major technical constraints with modern technology • Causes least pollution • Good quality alcohol free from sulphates and aldehydes present in molasses-based alcohol • Can create demand for damaged grain • Possible regular sourcing of grain from rainy-season crop • Byproduct of grain alcohol production can be used as animal feed	• Sorghum is a foodgrain, and may not be available for alcohol production in times of food shortages • Some producers in Maharashtra face difficulties in selling grain-based alcohol, largely due to the State-imposed export pass fee. This difficulty is localized. • Cost of production of ENA is higher than that from molasses.

lower demand. Table 17 summarizes the advantages and disadvantages (as perceived by some members of the industry) of using sorghum as a raw material in the alcohol industry.

Prospects

Distillers generally expected the grain-based alcohol market to grow. Asked about the impact of recession, a distiller felt that it could lead to increased demand. The grain-based alcohol market is expected to grow by about 5%. This would mean a total production of about 90 million liters of RS corresponding to a raw material requirement of about 260 000 t of grain in 2010.

However, given the overall economic climate, governmental policies, and the existing spare capacities in the industry, it is unlikely that new factories will be commissioned in the short to medium term. If government policies on grain-based alcohol become more favorable, there is a possibility of growth rising beyond 5%. Based on current use and projected growth rate, the demand for sorghum in the alcohol industry is expected to be between 0.2 – 0.5 million t in 2010.

Starch Industry

An Overview

According to sources in the starch industry, it was estimated that 0.6 million t of starch (including downstream products) were produced from maize, and 0.1 million t from cassava (tapioca) during 1998. According to the All India Starch Manufacturers' Association (AISMA), Mumbai, the per capita consumption of starch in India was 0.59 kg in 1994, compared to a global per capita consumption of 6.50 kg and 64.25 kgs in the USA. In the mid-1990s, the average growth rate for starch demand was 5% in India, compared to 12% globally. Figure 6 compares starch consumption patterns in India and the USA.

Figure 7 provides an overview of the downstream products and byproducts from maize-based starch by wet milling. According to a major starch industry source, some of the byproducts, like liquid glucose, are derived directly from wet milled grains.

Maize is the preferred raw material in the starch industry. The average landed cost of maize during 1998, according to industry sources, was between Rs 4000 and 5100 t^{-1}. The average starch price was Rs 7.35 kg^{-1} in 1991 and Rs 9.20 kg^{-1} in 1995. Grades of starch required for major and minor uses vary and so do their prices.

Maize starch prices (per kg) around mid-1998 were Rs 10 for textile grade raw starch, between Rs 13 and 15 for paper manufacture-grade starch, and between Rs 10 and 15 for food processing-grade starch.

Some of the downstream products such as dextrose and sorbitol fetch considerably higher prices. According to industry sources, if sorghum starch was available, it could have been sold largely for textile use at about Rs 8 kg^{-1}, a 20% reduction in price compared to maize starch of similar user grade.

Despite complaints by members of the industry about the general recession in the economy, reduced exports due to the economic crisis in Southeast Asia, and level of competition in the industry, starch demand can be expected to grow by 5% per annum in the medium to long term in India. The demand for starch appears to be saturated in the textile sector, whereas the paper manufacturing or food processing industries which traditionally did not use much starch, are likely to generate high growth rates (10% and above).

Increasing demand for maize from the feed sector is reported to be causing an increase in prices and a shortage of grain to the starch industry. In this context, the formation of the Indian Maize Development Association (IMDA) is expected to improve its supply.

Sorghum as a Raw Material

Some of the country's main starch manufacturers who are based in Ahmedabad, Gujarat, have used up to 50 000 t of sorghum per annum in the past (1994/95 and 1997/98) when maize was in short supply. However, due to the availability of maize and its relatively low prices in 1998, no sorghum utilization was observed when this survey was underway.

Indian starch producers (particularly Anil Starch, Ahmedabad) have undertaken research into sorghum-based processing technologies. According to them, there was only one starch factory using sorghum in the USA (established around 1980), and it too had stopped production after about five years. Overall, the conclusion was that sorghum was not a preferred raw material but would only be used when there were no other alternatives. The constraints perceived by the industry in the use of sorghum are low starch recovery rate, processing difficulties when maize-based technology and machinery are used, low yield and low quality of byproducts, and poor quality starch fetching a low price.

Despite the industry's knowledge of sorghum processing, starch recovery rates are about 4% lower compared to maize (i.e., sorghum = 61 – 62%, maize = 65 – 66%). This could be to the physicochemical nature of the sorghum grain (sorghum fiber retains more starch) or the processing machinery and technology which are basically designed to use maize.

Among the difficulties experienced during processing are increased wear and tear of grinding equipment due to the more abrasive nature of sorghum grain, and the occurrence of 'gelling' in postwet mill flow line causing clogging and related mechanical problems.

Both the yield and quality of byproducts (oil and gluten) from processed sorghum starch are low compared to maize. Apart from the lower recovery rate, customers prefer maize oil, which has a more appealing color. Maize gluten is preferred by the poultry industry due to its yellow color (which in turn produces a more yellow egg yolk). The difference in oil yield has a significant impact on the cost effectiveness of sorghum as compared to maize.

The quality of plain sorghum starch is considered inferior due to its off white color, making marketing more difficult. As a consequence, members of the industry who use it as a raw material are not always very open about their practices. On the other hand, downstream products from sorghum starch, such as liquid glucose, are easier to market as they are not visually different from similar products of maize. One industry member said he would purchase tapioca starch to produce downstream products if maize was short in supply. He would only consider sorghum if neither maize nor tapioca were available.

In order for sorghum to be used as an alternative raw material in the starch industry, it would have to be considerably cheaper than maize. The price differential is of the order of Rs. 1000 – 1200 t^{-1} of grain. This compares to a maize price of Rs 4000 – 5100 in Gujarat in 1998. According to a starch manufacturer near Delhi, the average annual maize price (landed factory) in 1997/98 was about Rs 4650 t^{-1}. In 1998, the price differential was not attractive enough for starch manufacturers to use sorghum as a raw material.

Prospects

Sorghum can only be used by the starch industry if maize is in short supply. Yet, starch manufacturers were eager for more information on the technical aspect of separating sorghum starch and its byproducts. In this light, the NRCS could keep in touch with AISMA and its members who have used sorghum in the past (mostly Gujarat-based companies) and, in consultation with starch manufacturers, conduct studies to improve the prospects of this grain.

Given these factors, it is difficult to forecast the demand for sorghum in this sector. Some starch processors may always be tempted to use sorghum as soon as maize prices begin to rise. In particular, low quality textile starch and some downstream products are likely to be sorghum based. Interaction between the industry and research institutions could promote these uses. As a consequence, the demand for sorghum in 2010 is projected between 30 000 – 80 000 t.

Other Industries

Brewing

Although beer brewers are aware of sorghum-based beer production in Africa (South Africa and Nigeria), they prefer the easily available barley malt as the principal raw material. In addition to barley malt which constitutes about 40–60% of the ingredients, broken rice or flaked maize are commonly used as adjuncts. According to the industry, sorghum is not currently used for beer production in India either as malt or as an adjunct. Therefore, it is difficult to judge the extent to which it might be adopted as a raw material. It appears this may largely depend on the availability of barley malt and adjuncts, and their prices.

Table 18 provides an overview of the production of barley, malt, and beer in India. There has been a steady decline in area sown to barley due to pressure to increase wheat production. However, this decline has not been reflected in a significant measure in the production. In the long run, barley production in India is expected to fall significantly. The demand for malted foods and beer on the other hand is rising rapidly. The average annual growth rates for malted foods and beer were 15% and 51% between 1995 and 1998 and 8% and 32% between 1990 and 1998 respectively. In 1998, off-take of barley by the malted food sector was estimated at only about 5-6% of total production. However, if sorghum malt or flaked grain could be available at more competitive prices, barley malt could be partly substituted and the adjunct completely replaced, helping reduce the cost of production of beer. Research into this area, could be jointly undertaken by interested breweries and the NRCS.

Hindustan Breweries in Mumbai, visited during this survey, expressed interest in undertaking such experimental trials using sorghum as an adjunct. However, the brewer was not clear where flaking of sorghum would take place and what quality of grain would be required for it. This is because the brewers have no working experience with sorghum, as compared with broken rice.

Given this scenario, one cannot forecast the quantity of sorghum that may possibly be used by the brewing industry in 2010.

Table 18. Production of barley, malted food, and beer in India.

Year	Area under barley ('000 ha)	Barley production ('000 t)	Malted food ('000 t)	Beer (million liters)
1990-91	962	1632	14.5	203.2
1991-92	954	1699	15.6	213.6
1992-93	916	1512	11.6	223.3
1993-94	794	1313	10.7	305.3
1994-95	891	1283	35.5	277.8
1995-96	884	1654	58.2	370.0
1996-97	760	1435	59.1	425.5
1997-98	-	1670[1]	79.7	433.1

1. Forecast.

Sources: CMIE 1997; CMIE 1998.

Industrial Food Processing

Sorghum is currently not used in the manufacture of bread and biscuits. Since India is one of the world's largest producers of wheat, which is in sufficient supply, there is no perceived need to look for alternative raw materials.

According to the manager of one of the largest bakeries in Mumbai, the problems associated with sorghum in bread manufacturing arise due to the absence of gluten, poor acceptability due to color and taste, and customer awareness/psychology discouraging its use.

During the 1970s, when there was a shortage of wheat in India, the Government tried to encourage the use of composite flours, which, however, failed. The Central Food Technology Research Institute (CFTRI) at Mysore carried out extensive research on the constitution of composite flours and their suitability for different uses in the food industry.

Sorghum finds disfavor in biscuit manufacturing, due to the easy availability of commonly preferred and industry familiar ingredients such as wheat flour and maize starch rather than the lack of gluten. In addition, it was mentioned that a certain level of wheat gluten is important in the process. Therefore, the nonuse of sorghum by these industries is not due to the lack of research information. As a consequence, the prospects of sorghum entering this industry are not very bright. Speciality bread manufacturers in urban centres ('seven-grain-bread' sold in Mumbai) seem to be the only users in the food industry.

Sorghum Milling

Sorghum milling and the equipment used were not covered in the survey. However, it was indicated by food processors that the setting up of small- and medium-scale sorghum mills in main producing regions could reduced the drudgery women face with household sorghum processing. This could possibly also promote its use by urban households traditionally used to this grain, but who are avoiding it due to processing problems.

Exports

Indian sorghum is slowly becoming competitive in the international market, largely due to the depreciation of the Rupee over the US$. Table 19 gives a comparison of the government-supported Minimum Support Price (MSP) of sorghum and the international price. Comparing the grain produced during rainy- and postrainy-seasons, the latter is highly priced in the domestic market because of its high quality for food use. Hence only rainy-season grain could emerge as a possible choice for export.

However, the quality of this grain doesn't measure up to international trade standards due to molding and other postharvest handling problems. Hence the Agriculture & Processed food products Export Development Authority (APEDA) has banned its export. Moreover, the Government of India fixes an annual quota of coarse grains meant for export (50 000 t in 1997/98 and 23 900 t in 1998/99) which is invariably availed by maize.

Between 1993 and 1995, small quantities of sorghum ranging between 3 100 and 71 900 t were exported, mostly to the Gulf. With research directed at upgrading grain quality, lowering production costs, and providing better storage and transport infrastructure, Indian sorghum could enter international markets in the coming years, depending on government policies and international prices.

Table 19. Comparative prices of sorghum in Indian and international markets.

Year	International price (US$ t^{-1})	Price equivalent in Rupees	Minimum support price (Rupees)
1990	103.9	1859.8	1800
1991	105.1	2564.4	2050
1992	102.4	2693.1	2400
1993	99.0	3078.9	2600
1994	103.9	3324.8	2800
1995	107.1	3641.4	3000
1996	150.0	5332.4	3100
1997	109.7	4071.0	3600
1998[1]	102.0	4163.6	3800
2005[2]	155.0	6975.0	5000

1. At the average international price and exchange rate up to Sep 1998.
2. At the assumed international price, exchange rate of Rs 45 = 1 US$, and MSP projected on the basis of past increases.

Source: NRCS.

Maize, Industrial Sorghum's Main Competitor

Maize is sorghum's main competitor in its industrial utilization. Although maize is also used as a foodcrop in India, its industrial use is very substantial. Table 20 shows how maize production increased from about 10 million t in 1992/93 to 11.2 million t in 1997/98. Figure 8 shows fluctuations in the price of maize in the Nizamabad wholesale market as compared to the total Indian production. It would be useful to analyze the factors behind this increase. Increased production has largely come about from increase in production rather than an increase in the area sown to the crop. However, productivity rose by only about 6% from 1992 to 1997.

This scenario is encouraging some members of the poultry feed industry to favor maize imports, notwithstanding IMDA's primary goal of promoting increased maize production at lower cost. According to Blue Cross Consultants, Delhi, who have a link with the US Feed Grains Council, there is zero duty on maize imports.

However, there are nontariff stipulations which make imports difficult (e.g., maize has to be declared not fit for human consumption; this is not done in the USA). In addition, imports are currently too expensive due to the lack of adequate port handling infrastructure and transport facilities. According to Blue Cross Consultants, in mid-1998, the international FOB price per tonne of maize (No. 2, US Gulf) was $92, freight and insurance charges were $25, on-sea bagging cost $6, and transport in India was about $3, leading to an overall price of $126 or about Rs 5300 (landed at factory gate). At the same time, in mid-1998, factory prices of Indian maize ranged between Rs 4000 and 5100 in different regions. Hence, import may not always be cost effective. Therefore, the availability of maize may largely depend on how effectively its productivity increases.

In conclusion, it can be said that sorghum appears to stand a chance as an alternative raw material in this sector. However, it is likely to face competition from imports in the medium to long term when India develops better port and handling facilities.

Table 20. Area, production, and productivity of maize in India.

	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98
Area (m ha)	5.9	6.0	6.1	6.0	6.3	6.3
Production (m t)	10.0	9.6	8.9	9.5	10.6	11.2
Productivity (kg ha^{-1})	1676	1602	1570	1448	1698	1775

Source: Government of India 1998.

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Appendix

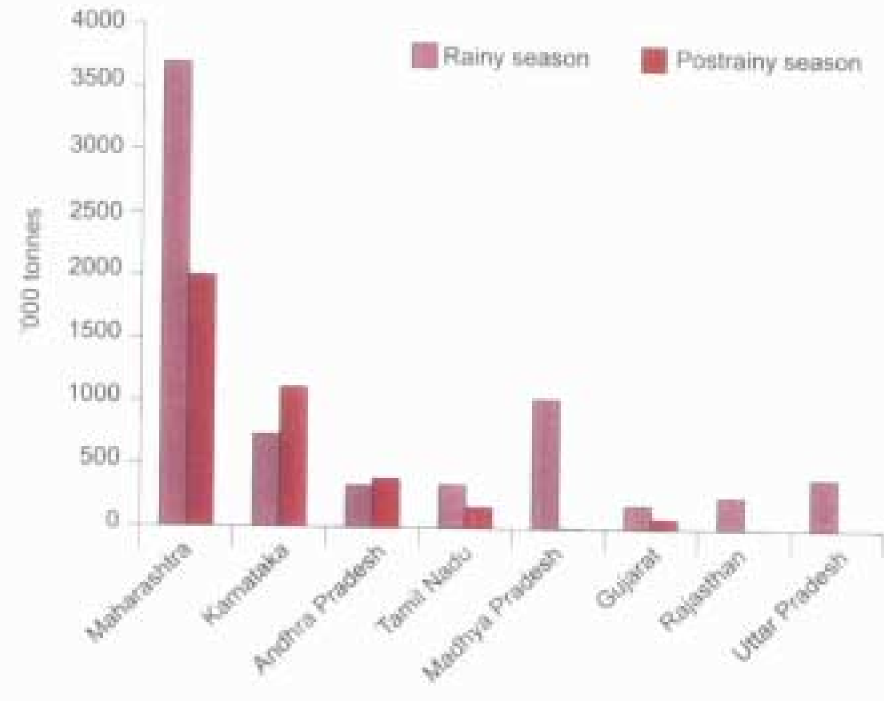

Figure 1. Sorghum production in major states of India in 1995-96 (Source: NRCS).

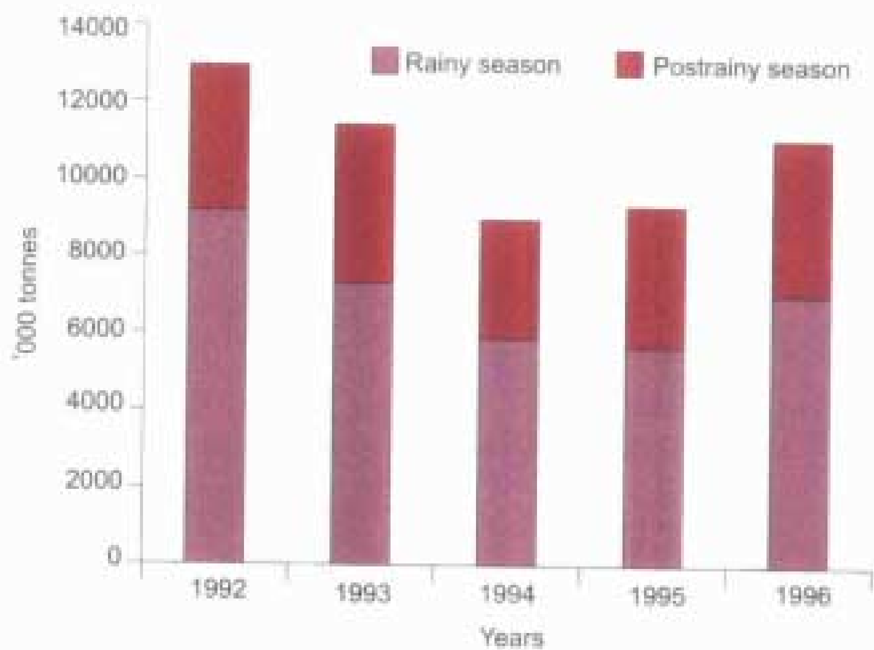

Figure 2. Sorghum production in India between 1992 and 1996 (Source: NRCS).

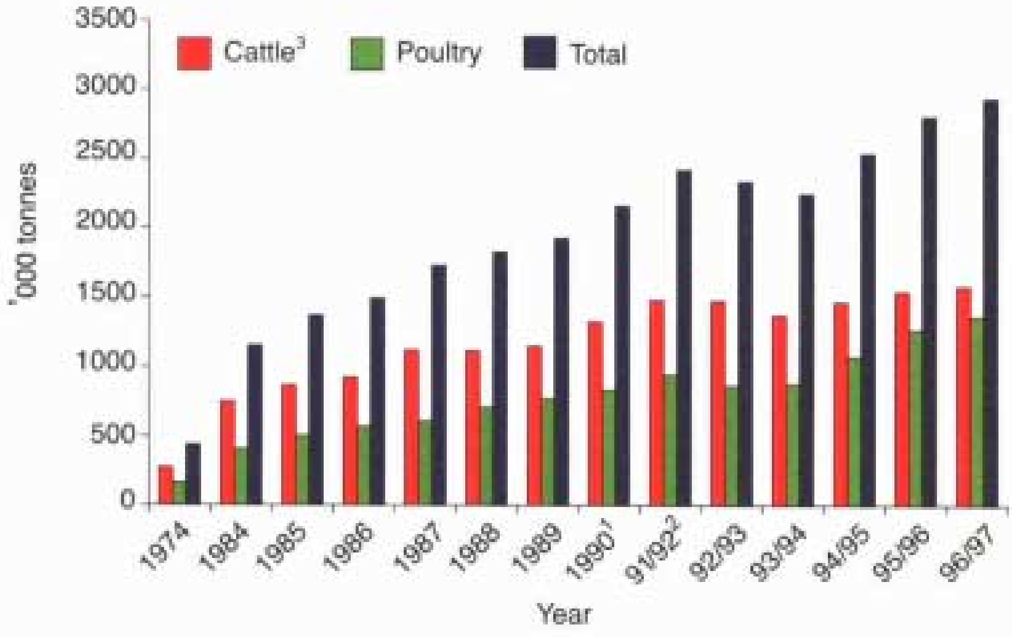

Figure 3. Compound animal feed produced by members of CLFMA (Source: CLFMA).

1. Figures until 1990 are based on the calendar year.
2. Figures are from April to following March.
3. Cattle feed includes 'other feed', which accounted for about 15 000 t in 1992/93 and about 30 000 t in 1996/97.

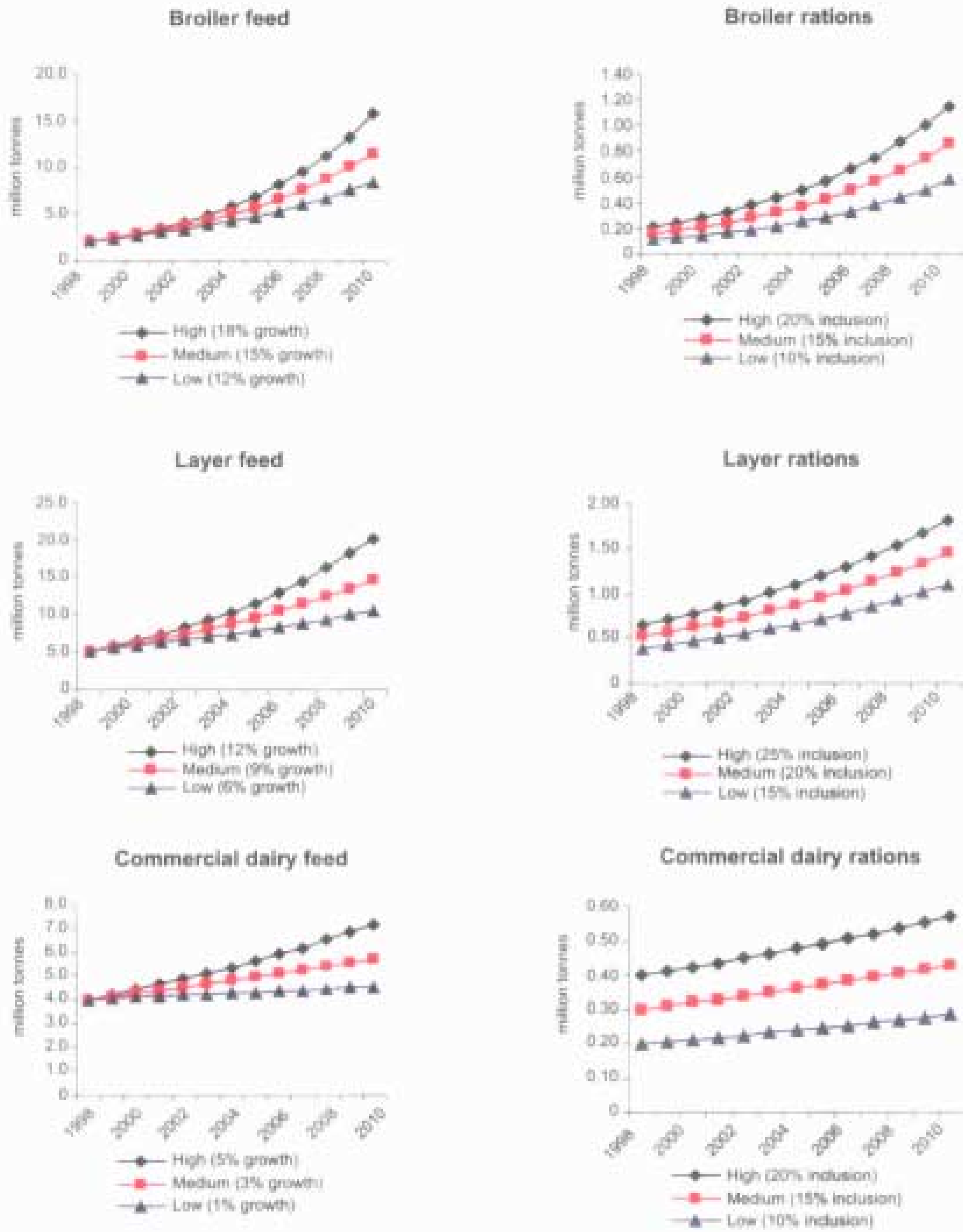

Figure 4. The potential demand for sorghum in the animal feed industry.

Note: Medium growth rates have been used to calculate the potential demand for sorghum.
It is assumed that 50% of the respective feed industries would include sorghum in their rations at the inclusion rates shown

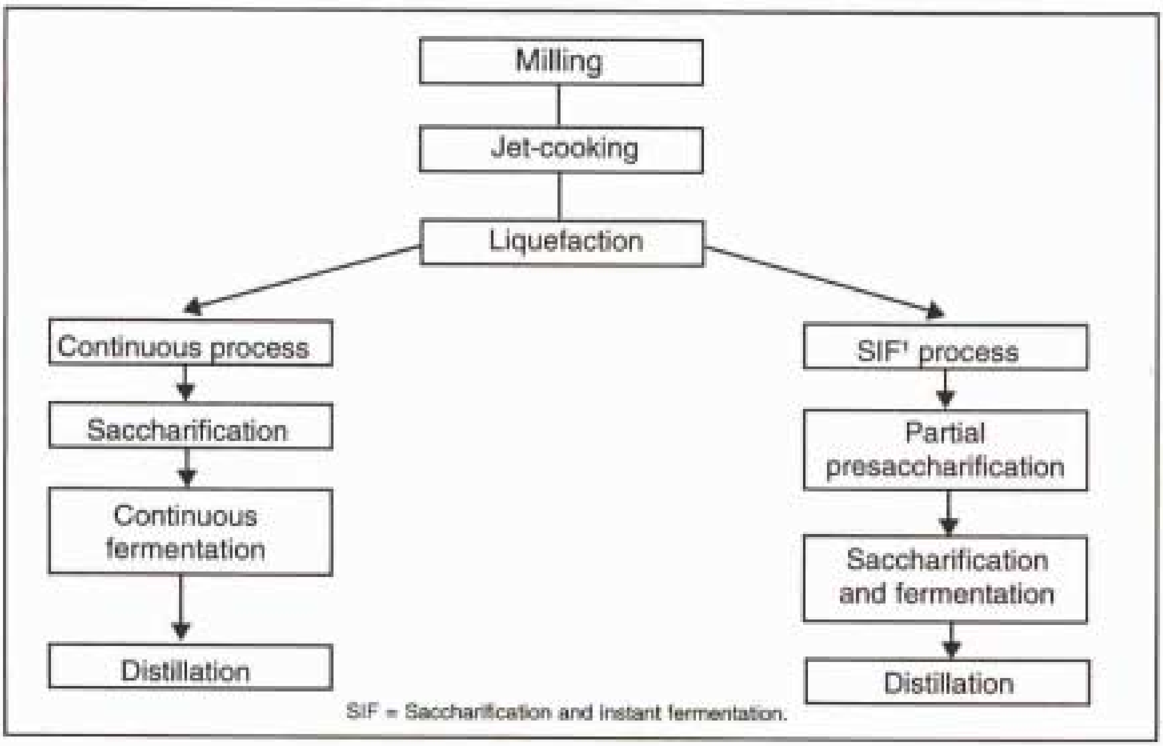

Figure 5. Praj Industries' HIFERM-NM process to convert starch into alcohol (Source: Praj Industries Ltd., Pune).

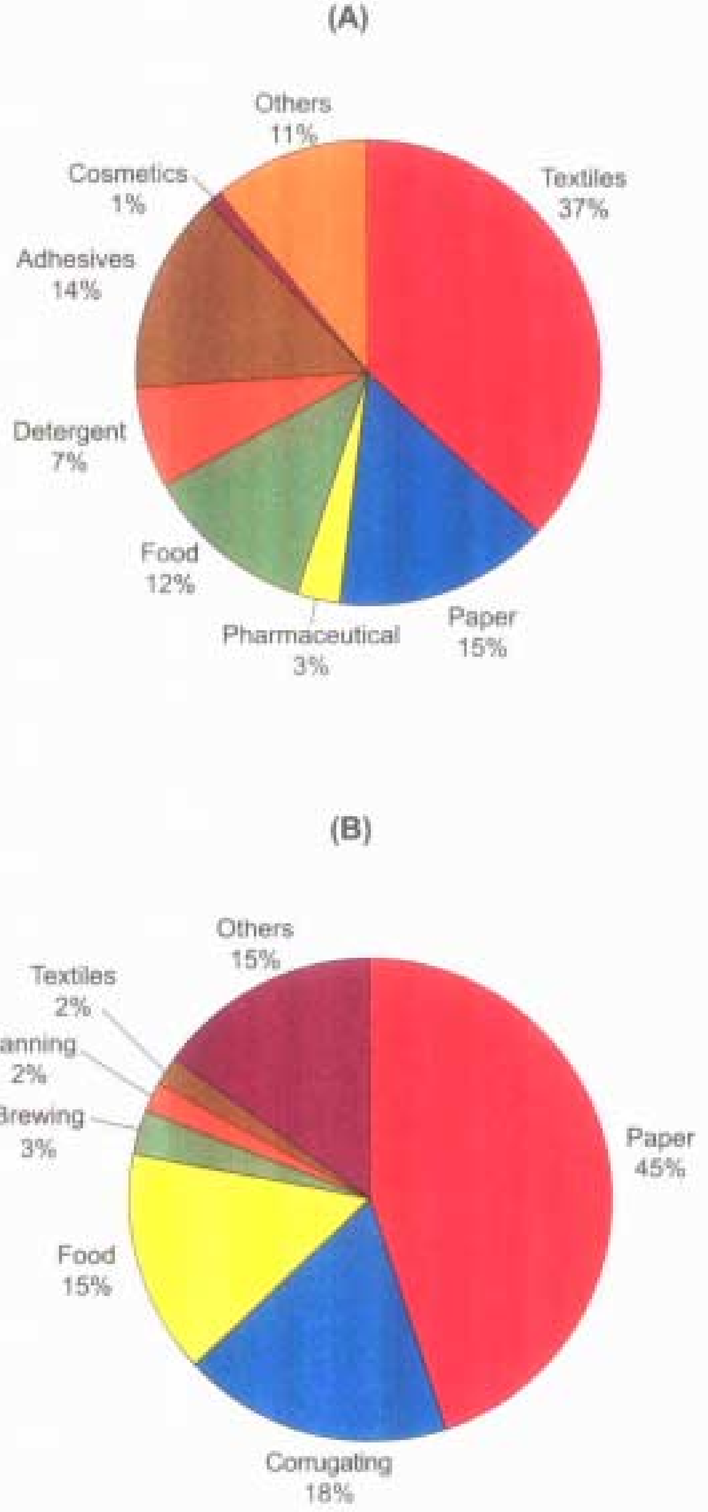

Figure 6. Consumption patterns of starch in India (A) and the USA (B).

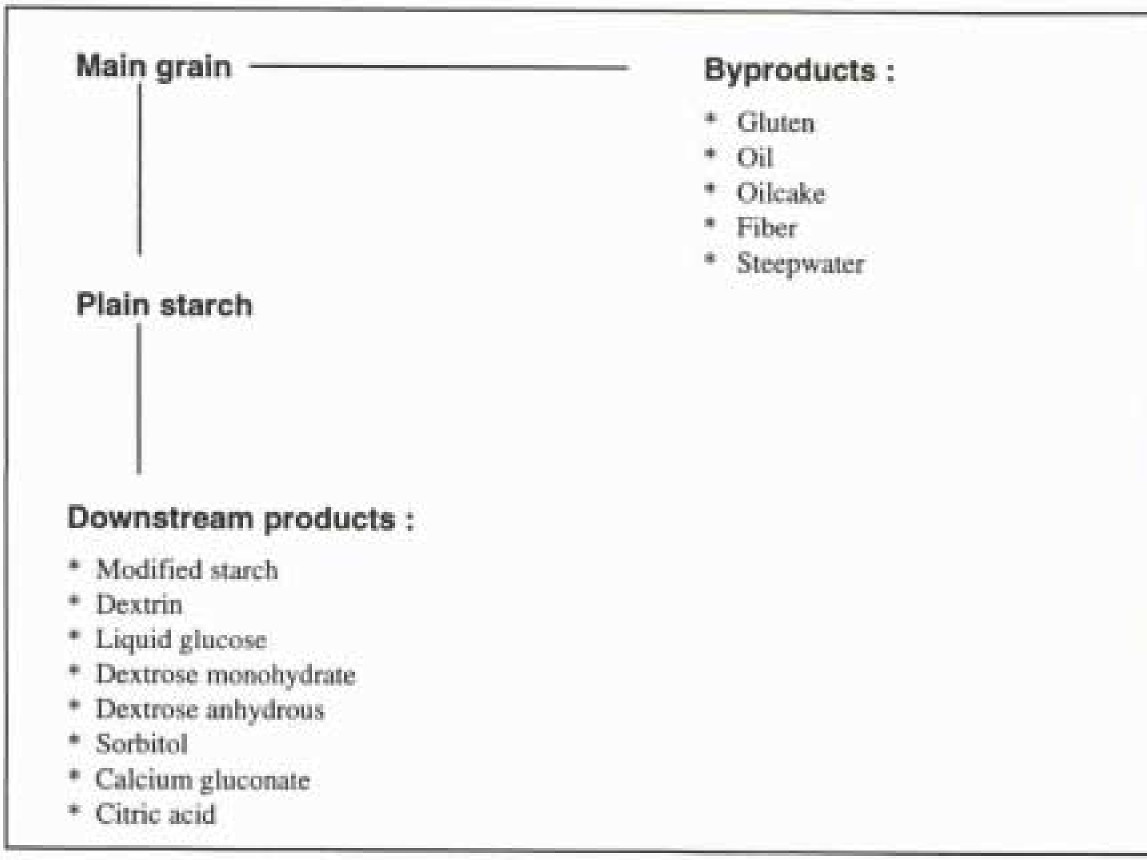

Figure 7. Downstream products and byproducts from the maize-based starch industry.

Figure 8. Production and wholesale prices of maize.

Note: The production figures are all-India figures, assuming the bulk of the harvest takes place around September. The monthly prices are from the Nizamabad wholesale market.

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 semi-arid tropics. ICRISAT's mission is to conduct research which 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.

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