



Vision 2030

National Dairy Research Institute

Karnal-132001, India

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Foreword



The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climate change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science. In this endeavour, all the institutions of ICAR, have revised and prepared respective Vision-2030 documents highlighting the issues and strategies relevant for the next twenty years.

India ranks first in the milk production, but Indian dairy is a classic example of production by masses rather than mass production. The nation's milk supply comes from millions of small producers, dispersed throughout the rural areas. These farmers maintain, on an average, a herd of only two-three milch animals, comprising cows and/or buffaloes. With an overall achievement of 112.0 million tonnes of milk in 2009-10 from cattle, buffaloes and goats and a per capita milk availability of 263 g/day, an anticipated 116 million tonnes of milk production in 2011, the Indian dairy scenario is constantly looking ahead & promises to take greater strides in making dairying more remunerative to the farmer. However, with the ever increasing population, it is estimated that the total milk production should be around 200 million tonnes by the year 2030 to meet the demand. National Dairy Research Institute is the premier Institute for R&D and Human Resource Development (HRD) in the country. The Institute's endeavour to conduct frontline research on all aspects of dairying, to develop new technologies for increasing milk productivity have contributed significantly in ushering the "White Revolution" in the country.

It is expected that the analytical approach and forward looking concepts presented in the 'Vision 2030' document will prove useful for the researchers, policymakers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.



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Director General, Indian Council of Agricultural Research (ICAR)
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Dated the 2nd August, 2011
New Delhi

Preface

National Dairy Research Institute is the premier institution of dairying in Asia. The Institute had its origin from Imperial Institute of Animal Husbandry and Dairying, which was established in Bangalore in 1923. In 1936, it was expanded and renamed as Imperial Dairy Institute. In 1955, its Headquarter was shifted to Karnal and the institute was renamed as National Dairy Research Institute. The Southern Regional Station at Bangalore and the Eastern Regional Station at Kalyani in West Bengal are providing the region specific R&D support for dairy development. For further strengthening of academic programmes of human resource development, status of Deemed University was conferred to the Institute in 1989.

The Institute undertakes research, teaching and extension activities towards dairy development in the country. It also conducts basic and applied research with the objective to enhance animal productivity, develop new products and practices for the benefit of millions of farmers and consumers. Over more than eight decades of its existence, the Institute has shown remarkable development and expertise in different areas of Dairy Production, Processing, Management and Human Resource Development.

With expanding population, growing urbanization and increasing purchase power, the demand for milk and milk products is expected to go up and we have to catch up with the daunting challenge to produce more milk and convert it efficiently into value added products. Global trend in animal production also indicates a rapid and massive increase in consumption of livestock products. In India, it is expected that milk consumption will grow at 3-4% per annum. The total projected demand of milk by the year 2030 would be about 200 million tonnes, which amounts to an annual increase of around 4 million tonnes during the next two decades. To meet this demand we have to accelerate our growth rate in milk production. One of the biggest strengths of Indian Dairy sector is mega biodiversity and large livestock population. Presently, India is holding about 200 million cattle and 105 million buffaloes. To enhance the production and productivity, on one side, by applying all advanced reproductive technologies, we have to increase the number of animals, with superior germplasm, however, on the other side, equally or even more important, the number of non producing and less producing animals has to be

reduced. It is essentially required to reduce the competition of animals on limited feed and fodder, health coverage and services.

Further our research priorities will also have the focus on functional dairy foods, composite dairy food, fortification, value addition, quality assurance and food safety. The present document *NDRI Vision 2030* articulates the strategies not only to undertake this daunting task but also to ensure that the milk produced is clean, safe, wholesome for the consumer, and remunerative for the economic well being and livelihood security of dairy farmers.

I would like to express my gratitude to Dr. S. Ayyappan, Secretary, Department of Agricultural Research and Education (DARE) and Director General, Indian Council of Agricultural Research for his inspiration and encouragement in preparing *NDRI Vision 2030*.

The valuable comments and inputs received from the Hon'ble members of the Research Advisory Committee of NDRI and Mr. Animesh Banerjee, Former President IDA & Former Executive Director NDDB have helped greatly in fine-tuning the document. I am certain that *NDRI Vision 2030* will provide our worthy scientists the necessary direction for harnessing science for meeting the challenges and expectations of the dairy farming community.



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Preamble

Dairy farming has remained a very important component of the traditional farming system of the country, and is one of the most important means of providing livelihood and nutritional security to the vast majority of rural masses. The most prevalent dairy production system is under mixed farming system integrating crop and livestock production in a synergistic manner. The milk productivity of bovines is, by and large, low because of poor genetic make-up, shortage of feed and fodder and inadequate health cover. This is because our production systems are not intensive commercial systems, but subsidiary and supplemental systems as part of the overall land use system where crop production dominates the scene. A wide range of milk producers (around 70 million rural households) viz. landless labourers, marginal, small, medium and large farmers are engaged in dairy farming in India.

From traditional dairying, however, the country with its vast dairy animal resources is poised to become leading player in the world arena particularly after its emergence as world's leading milk-producing country accounting for 15.6% of the estimated 671.3 million tonnes of the world milk production in the year 2007.

The National Dairy Research Institute (NDRI) has an important role to strengthen dairy industry through innovative technologies and human resource development in the years ahead. There is a growing demand for safe, nutritious, health promoting convenience milk products calling for value addition, product diversification and complete quality assurance. This warrants formulation of policies and programmes to control cost of milk production and processing, facilitate flow of milk to the organized sector and strengthen the legitimate interests of various stakeholders in dairy sector at national and international level. In the years to come, commercialized agriculture will become a reality because of requirement of high materials, monetary, scientific and technological inputs and dairying will be expected to play an increasingly major role in the global market. Although, the volumes are small, now India has its presence in the world markets and regularly exports milk products to countries in West Asia, South-East Asia, South Asia and North America.

The emerging scenario in dairy sector has necessitated a relook at the priorities and fine-tuning of research agenda in the form of NDRI Vision 2030. The first systematic effort by the NDRI was made in this direction by preparing 'Vision 2020'; the next attempt was after five years by preparing 'Perspective Plan 2025' to address the changes that had taken place and to articulate new challenges that had emerged. The present document attempts to identify the constraints / bottlenecks/ challenges in the development of dairy industry and suggests appropriate strategies and a roadmap for shaping the future of the dairy research in the country for ensuring dairy food, nutritional and environmental security and emphasizes to exploit the emerging domestic and global opportunities.

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Dairy Scenario

Dairy sector is economically and socially very significant in India due to the multi-functionality of dairy animals performing output, input, asset and socio-cultural functions. According to the 2007 Livestock Census, there are 166 million indigenous cattle, 33 million crossbred cattle and 105 million buffaloes in India. In this, the proportion of adult milch females is 19, 43 and 46 %, respectively. The decade-wise trend in livestock population (1997-2007) shows a distinct shift in composition of dairy animal stock in favour of buffaloes and crossbred cattle, as their numbers increased by 5.91 and 6.05 million, respectively, while that of indigenous cattle declined by 1.8 million.

India is the top milk producing nation in the world contributing about 15% to the global milk pool. The decade-wise rate of growth in milk production in India (3.6%) is substantially higher than the world average of 1.5 %. The turmoil in the feed input-milk output prices, a part and parcel of the recent economic crisis has affected the milk production in the leading milk producing countries in the world. However, in India, the production of milk remained more or less resilient to these economic developments. Due to lower level of market orientation of dairy production system in the country, the responsiveness of milk production to price signals is weak.

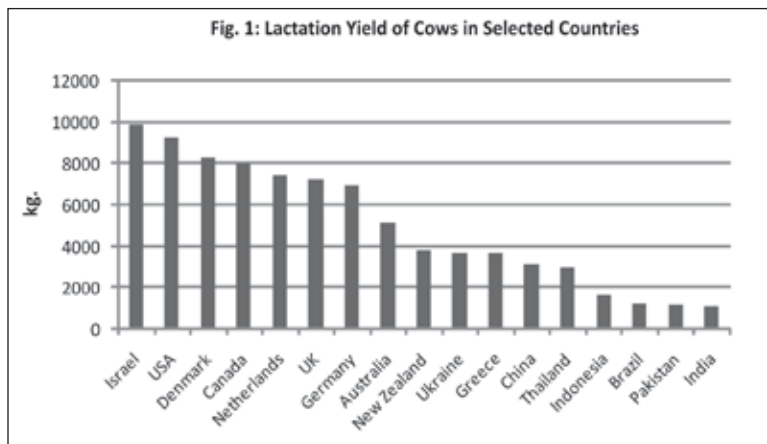
Low scale of production

The low level of commercial orientation in milk production is reflected in the small scale of milk production for a majority of households. Empirical evidence based on the large sample surveys (NSSO, 2005) indicate that level of milk production for 36 % households is only ≤ 500 litres/annum and for another 27 % between 500-1000 litres /annum. Such a tiny scale can provide some nutritional benefits to the family, but not enough surpluses for the market. Only 15 % households produce >2000 litres/annum and contribute 50 % to the total milk production. Interestingly, although the scale of dairy production is positively associated with land ownership, a considerable proportion of small landholders take up dairying as a commercial activity. Among the households producing more than 5000 litres of milk/annum, 54 % belong to marginal and small landholders, suggesting that

with efficient input and output support services, dairying can be a vital economic activity for the economic upliftment of these small landholders.

Low Milk Productivity

Despite of holding the number one position in milk production in the world for over a decade, the milk productivity in the country remains one of the lowest as compared to the many leading countries of the world (Fig. 1). In India, the average milk productivity of crossbred cows, indigenous cows and buffaloes is only 6.44, 1.97 and 4.3 kg/day respectively (GOI, 2009). Further, there are wide inter-state and inter-district variations in the milk yield and hence, the yield-gaps even compared to these low- productivity levels are profound. For instance, Punjab has the highest productivity of crossbred cows and buffaloes, and Haryana is the top-ranking state in terms of the milk productivity of indigenous animals. The milk yield of dairy animals in states like, Jharkhand, Orissa, etc. is far below the productivity levels in dynamic milk regions of Punjab and Haryana. The average performance of these states is the best among all the states in India; however, there are huge yield gaps at the district level within these states, ranging from 10-25% in comparison to the best performing district within each state.



Source: FAOSTAT

Availability of Inputs and Services

Feed is the major input in livestock production. In value terms, it accounts for about 80-90 % of the variable cost of milk production. The feed and fodder in India mostly consists of crop by-residues that depend on the regional cropping pattern.

Two essential sources of nutrients to realize the genetic potential of animals, viz. green fodder and concentrates, particularly in the form of balanced compound animal feed are in short supply. The area under fodder crops in India has stagnated at about 8.5-9.0 million hectares during the past decade and accounts for only about 4.6% of the total cultivated area. Fodder cultivation for livestock is a common practice in only selected regions that are more advanced milk production/ milk shed areas such as Punjab, Haryana, Western Uttar Pradesh and parts of Gujarat and Rajasthan. With the production of about 491 million tonnes of green fodder as against an estimated requirement of nearly 648 million tones, there is more than 27% deficit in green fodder. Also, there is a 35% shortfall in availability of concentrates in the country (GOI, 2007).

The breeding and veterinary health care services are available to the dairy farmers through network of over 56000 AI centres and about same number of veterinary institutions, mostly functioning under the aegis of State Animal Husbandry Departments (AHDs) (GOI, 2009). In recent years, there has been notable growth in coverage of non-departmental AI centres, particularly in Andhra Pradesh, Karnataka, Tamil Nadu and West Bengal. The total artificial inseminations performed by all the agencies in the country in 2007-08 are reported to be about 30 million. Considering an average number of 2.5 services per conception, the AI services cover only about 11% of the dairy animal population, indicating the extremely low coverage of breeding services. The outreach of veterinary health care services is also low. On an average, each centre operated by the public sector caters to about 5500 cattle and buffaloes, and the non-government enterprises in the provisioning of veterinary services are very limited. The incidence of diseases and epidemics is very high in the country. The poor status of animal health stems from the extremely limited attention paid to preventive health care services and inefficiencies in provision of curative health services.

The credit facilities to the dairy farmers are available in the form of term loans from the banks and other financial institutions. But, primarily due to lack of commercial orientation towards dairy farming, the share of the livestock sector in total term loans to the agriculture sector is less than 10% (GOI, 2007), although the value of output of the livestock sector accounts for more than one quarter of the total agricultural output. In recent years, a few new models of delivering credit services to the animal husbandry sector have been initiated, such as finances under the Rural Infrastructure Development Fund (RIDF) to establish veterinary

dispensaries and livestock aid centres and the Venture Capital Fund for dairy and poultry sector to promote new entrepreneurs in these two areas and the National Credit Fund for Women. There are also a large number of micro credit institutions that have emerged, but there is no umbrella scheme to promote micro finance in the livestock sector.

The public extension services delivery system for technology and knowledge transfer in the livestock sector has been weak. The extension activities related to the livestock sector are, by and large, entrusted to the State Animal Husbandry Departments and the evolution of a comprehensive nationwide extension service in the livestock sector has not been attempted.

Processing and Value Addition

India has a unique pattern of production, processing and marketing/consumption of milk, which is not comparable with any large milk producing country. About 35 % of milk produced in India is processed. The organized sector (large scale dairy plants) processes about 13 million tonnes annually, while the unorganized sector (halwais and vendors) processes about 22 million tonnes per annum (CII, 2009). In the organized sector, there are over 1000 dairy plants in the cooperative, public and private sectors, registered with the Government of India and the State Governments. The market size of processed products in the organized and unorganized sector (at 2003-04 prices) is estimated at Rs 255 billion and Rs 906 billion, respectively. There is a huge potential for processing and value addition, particularly in ethnic Indian products, which are largely sold in unbranded form in the market.

Domestic Consumption

On an average, the foods of animal origin in Indian diet account for about 10-11% of the total consumption expenditure (NSSO, 2010). Milk is the most preferred item, claiming 70% of the expenditure on livestock based foods. The per capita consumption of liquid milk has been around 55 liters during 1993/94 to 2003/04, but the demand for value added dairy products has increased at about 7.6 % per annum, registering a higher growth in urban than in rural areas (CII, 2009).

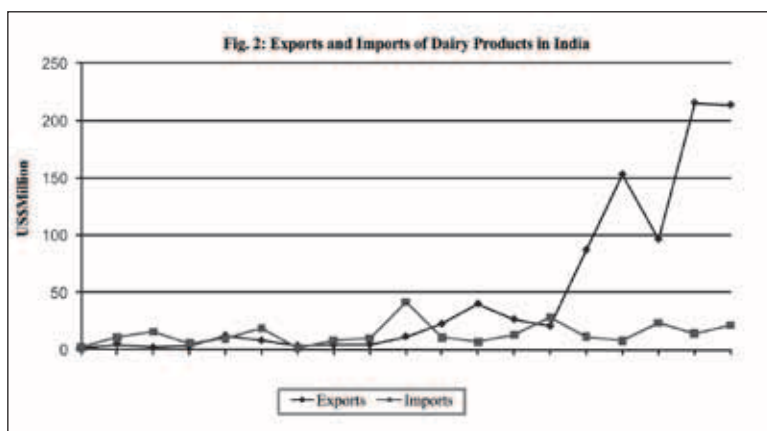
Trade

India has negligible share in the world dairy exports (0.2%), partly due to low exportable surplus of value added dairy products and partly because the world dairy

markets continue to be highly protected. In the recent decade, dairy exports have gained ground (Fig. 2) and the share of dairy exports in total exports of livestock products has for the first time reached double digit (13.5%). Skim milk powder and whole milk powder are the most important items for exports. Another important tradable dairy product is butter and similar high-fat milk products like, butter oil and dairy spread etc. In the recent years, the export earnings from yoghurt and buttermilk, whey and whey-based products and cheese and curd have increased due to shifting consumer preferences towards low fat based dairy products. The new products that have entered in the export basket, include, milk & cream of low fat content (<1%), curdled milk & cream, kephir, fermented & other acidified milk and whey (Hazra and Sirohi, 2007). Also, the exports of cheese, specially fresh and processed cheese, have shown increasing trend although in volume terms the exports of these products is still very small.

Asian countries are the major markets of Indian dairy products accounting for nearly 82% share in total dairy exports from the country. Among the non-Asian countries, USA is one of the top 10 destinations of Indian exports during TE 2002/03 and TE 2007-08. USA is importing milk powders, fermented milk products, whey based items and few cheese products from India. Whey and products consisting of natural milk constituents produced by Indian dairy industry have also been able to make inroads in Korea, Japan, Germany and Canada.

On the import side, due to opening up of the domestic dairy industry to private players and resulting increase in production of dairy products, the value of dairy



Source: Directorate General of Foreign Trade

imports has declined substantially during the 90's. Our principal suppliers of dairy products have been the European nations, USA and Oceania.

Indian Dairy Sector: SWOT Analysis

The main strengths of the Indian dairy sector are its diverse bovine population, increasing availability of milk for value addition and processing, low cost of milk production in comparison to leading milk producing nations in the world, growing organized sector and presence of niche R&D and educational institutions to train the technical manpower for all levels to support & industry operations.

The increasing demand for convenient and hygienic foods at both, domestic and global level and availability of technology for processing of by-products, offer immense investment opportunities in the Indian dairy sector. The realization of the potential opportunities would be instrumental in enhancing livelihood security of the millions of dairy farmers in the country.

The R&D efforts for overcoming the weakness of the dairy production system (such as, low productivity of animals, lack of commercial orientation among milk producers, low awareness among producers about scientific dairy farming, clean milk production and value chain) and dealing with the threats posed by extinction of indigenous breeds, increasing incidence of adulterated milk, climate change have to be intensified for multidimensional growth of dairy sector in the country and linking the smallholder dairy producers to the buoyant domestic and global markets of dairy products.

Indian Dairy Sector: Futuristic Outlook

The anticipated dynamism in the global and domestic economic environment would bring about far-reaching changes even in the dairy sector. These changes include, emergence of large scale (more than 200 animals) commercial dairy farmers in several more regions other than in Punjab, Andhra and Maharashtra, where some such commercial farms are presently located. Also, further spread of information and communication technology would facilitate de-intermediation of milk marketing bringing about transformation of the prevalent traditional unorganized milk marketing system into a modern organized milk processing and marketing system.

The preliminary estimates of the scenario planning in India carried out at NDRI show that the share of buffalo based production system in total milk production will increase from current level of 44% to about 49% by 2035 (Table 1). In the buffalo dominant and cow dominant production systems, the supply of milk would either exceed its demand or be able to meet the rise in economic demand for milk and milk products, as the economic forces coupled with development initiatives in these regions would lead to enhancement of the productivity of dairy animals. However, in the mixed production systems, viz. where both, cows and buffaloes are reared in 40:60 or 60:40 ratio, the demand for milk would far-outstrip its supply, as in the absence of clear focus of the dairy development agenda in the region, the increase in productivity of dairy animals is likely to be of lower magnitude.

Table 1: Anticipated Demand Supply Scenario of Different Dairy Production Systems in 2035

Dairy Production Systems	Milk Supply (MT)	Nutritional demand (MT)	Economic demand (MT)	Surplus/deficit (MT)
Buffalo Production System	111.890 (49.36%)	38.990	96.051	+15.839
Cow production system	71.730 (31.64%)	61.361	72.426	-0.696
Mixed production system	43.070 (19.00%)	34.605	62.703	-19.633
All-India	226.69	134.956	231.18	-4.49

NDRI 2030

The National Dairy Research Institute is moving forward with missionary zeal to tackle the constraints and challenges in dairy development so as to ensure optimum returns to consumers and dairy farmers in the dairy value chain. The efforts would be to assume a lead role in the dairy sector in the world and build-up an organizational climate that is responsive to the needs of various stakeholders.

Vision

Ensure availability of quality milk and milk products at affordable cost, livelihood security to the producer and profitability to the dairy industry through adoption of appropriate technologies.

Mission

Provide R&D support towards generation and dissemination of knowledge towards improved national milch herd for milk production enhancement, greater productivity of dairy industry and management aspects of the dairy profession leading to the social, economic and environmental benefits to the Nation as well as contribute towards manpower development programmes.

Mandate

The National Dairy Research Institute, therefore, has the following mandate:

- Conducting research in the areas of Dairy Production, Processing and Marketing.
- Demand driven 'Human Resource Development' to meet the requirements of Dairy Industry & R&D Institutions.
- Dissemination of innovative dairy production and processing technologies for socio-economic transformations.

Focus

To accomplish the vision, mission and mandate of the NDRI, the R&D and HRD initiatives would concentrate on the following key areas:

- Strengthen the availability of superior germplasm of cattle and buffalo bulls and improving genetic base of Sahiwal and Karan Fries cattle and Murrah buffaloes.
- Improving utilization of feed resources for higher milk production.
- Enhancing fertility of dairy animals through biotechnological augmentation of reproduction.
- Developing climatic stress amelioration strategies/ techniques for dairy animals.
- Innovations to enhance value addition, processing efficiency, quality and safety dairy products.
- Promote dairy enterprises through transfer of technology and improved supply chain management for socio-economic transformations.
- Develop reliable database for strategic planning at national and international level.
- Strengthen higher dairy education in the country, develop human resources and capacity building for R&D institutes in dairying.
- Documentation of research findings for wider circulation and peer review.

Harnessing Science

Dairying in our country is recognized as an instrument for social and economic development. There has been a consistent growth in milk production over the last few decades at a consistent rate of around 4%. The National Policy on Agriculture also advises farmers to diversify their risks by avoiding mono-cropping and take up animal husbandry, dairy, horticulture and other similar business. The nation's milk supply comes from millions of small producers, dispersed throughout the rural areas. These farmers maintain on an average a herd of two-three milch animals, comprising cows and/or buffaloes. The animals' nutritional requirements are largely met by agricultural waste and by-products. Improved buffalo and zebu production could significantly enhance the economy and living standards of farmers in India. There are at least 30 different zebu breeds in Indian subcontinent alone: Tharparkar, Sahiwal and Red Sindhi, Gir, Rathi are the predominant dairy breeds. The average lactation yield of these breeds is around 1800 litres in a 305 days period. However, most of the cattle in India are of the nondescript types which yield very little milk. The adaptation of buffalo and zebu to tropical climates ensures their place in the future of world agriculture. Unlike agriculture, dairying has a distinct advantage as it provides a stable, year-round income – an important economic incentive for the small farmer to take to dairying as a profession. It would, therefore, be the Institute's endeavour to conduct frontline research on all aspects of dairying to develop new technologies not only for increasing the quantity of milk / animal but also to ensure that the milk and milk products produced carry the brand value of our country in terms of meeting quality standards, with a vision to fulfill the aspirations of the people. The Institute will, therefore, strive with a single-minded purpose to make livestock rearing a profitable venture for the dairy farmer. Unfortunately, the dairy scenario at present has to undergo a sea change for making this dream come true. NDRI is committed to bring about this transformation in all the three major facets of Dairy development viz. Dairy Production, Dairy Processing and Dairy Extension, Economics and Marketing.

Dairy Production

Breeding strategies for enhancing milk production in the country is the need of the hour. Keeping in mind the resource position of the farmers, which is, by and large, poor; it is important that breeds are developed for high milk production that can be reared under the rugged Indian conditions where fodder scarcity, heat and humidity are a reality. The Institute undertakes the challenge to evolve various breed improvement programs of cattle (Sahiwal, Tharparkar and crossbreds) and Murrah buffaloes to meet these challenges.

Anestrous and repeat breeding in buffaloes and bovines are two of the most serious reproductive problems affecting 30-40% of the total cattle and buffalo population. On a conservative estimate, the country is losing 20-30 million tonnes of milk annually on account of anestrus and repeat breeding in cattle and buffaloes, which translates to a loss of nearly Rs. 40-50000 crores annually. At a micro level, each missed heat is a missed opportunity. For each heat missed, the farmer incurs a loss in the productive life of the animal by 21 days. The Institute takes up the challenge to solve the problems of infertility in the Indian livestock by evolving cost effective simple technologies in nutrition, physiology and biochemistry. Identification of fertility markers in farm animals can help in defining cattle and buffalo population, which can be maintained on balanced feed. Other aspects connected to animal productivity are assisted reproductive technologies, improved semen extenders, understanding of gene regulation to improve fertility. The knowledge of these aspects will help in harnessing science for sustained and profitable livestock rearing.

It is strongly being realized that gradual stress induced by global warming and climate change is also influencing fertility and productivity of livestock directly, and, through reduction in fodder production indirectly. Milk production of high producing European, crossbreds and buffaloes is reduced when the Temperature Humidity Index (THI) of the region exceeds 75. On an average THI exceeds 75 at 75-80% places in India throughout the year. Majority of places in India observe THI > 75 and more than 85% places in India experience moderate to high heat stress during April, May and June and THI range of 75 to 85 at 2.00 PM. This situation is likely to worsen in the years to come. All THI maps for baseline and 2030 indicates a temperature rise and change in THI in Uttar Pradesh, Madhya Pradesh, Gujarat, Rajasthan and other states of India based on the regional climate model PRECIS A1B scenario. Changes in productivity are also linked

with changes in expression of different genes. The Institute, therefore, envisages undertaking studies to understand as to how changes in gene expression occur during different patho- physiological conditions and develop suitable remedies to overcome ill effects of stress.

It has been well documented that proper feeding is by far the most important factor hampering the productivity of Indian ruminants. There is a need to optimize the use of available feed resources and enhancing the bioavailability of nutrients from these feed resources. Strategic supplementation of limiting nutrients and area specific nutritional interventions are some of the approaches, which are to be pursued for enhancing productivity. Biotechnological interventions, modeling of rumen fermentation and nutrient utilization for reducing enteric methane production to improve metabolizable energy utilization of feeds are to be harnessed for combating the adverse effects of climate. Nutritional genomic studies to identify efficient feed utilization needs to be taken up. There is also a need to explore newer feed additives to improve the rumen fermentation, minimize wastage of nutrients and increase productivity from dairy animals.

Designing strategy for bringing in improvement of economic traits in milk producing animals will depend on identification of new target molecules, adoption of which as the selection criteria will drastically affect the performance of animals in terms of higher yield and better fertility. However, most often these phenotypes in higher mammals represent the complex interplay of a cascade of physiological processes working in synergy in the context of whole animal's functioning. Thus, it remains a challenge to dissect out these processes in molecular terms and identify which molecule/ pathway could be exploited as a key target to improve these traits *per se*. Advent of high throughput genomics and proteomics tools in recent time offer opportunity to look at collective behaviour of a large number of genes under a given situation, be it the influence of a particular genetic group, nutritional plane or climatic condition. Discovering novel genes/ regulation mechanism of these genes, hitherto unknown, will remain another objective of the genomics research. A sustained research effort in this direction for relatively unknown species like buffalo will pave way for innovation of accurate manipulation strategies, management decisions and drug targets towards better animal productivity.

Biotechnology as applied to agriculture implies increased productivity from animals. One of the main objectives will be to harness maximum from the animals, by not compromising with the health/fertility of the animal. This,

therefore, demands research in the frontline areas, so that superior germplasm can be multiplied at a faster rate. Various embryo biotechnologies have potential for this, like stem cell research, transgenesis and cloning etc. But to gain maximum advantage from these technologies, the research efforts need to be focused both on basic research to understand the mechanisms and pathways regulating these mechanisms and also on applied research to get direct benefits. In Indian context, the buffalo will remain main focus of research in these areas.

The milk producing ability of animals is related to the expression of various genes and proteins in the mammary gland apart from the hormonal regulation. Similarly, the reproduction potential of the farm animal is dependent on the expression of genes and proteins in the reproductive systems. 1) Proteomics is an upcoming area wherein the detailed proteome analysis of the systems as a whole, will help us understand the gene network pathway of production and reproduction traits. 2) Bovine genome has been recently annotated and the annotation of buffalo genome is under progress by various groups. Many of the annotated genes have been categorized as pseudo and hypothetical genes. Therefore there is a need to annotate the genes at the protein level by proteomic approaches. 3) Generation of voluminous data from genomics and proteomics approaches from farm animals needs further validation in terms of their structure at molecular level. Therefore, there is a need to characterize the proteins at molecular level by X-ray crystallography to make a data base of animals' proteins leading to structural genomics of farm animals.

Clean milk production is an essential pre-requisite for making milk and milk products to the satisfaction of not only Indian consumers but also for promoting exports. The vision of the Institute would be to develop a sustainable, scientific, environment friendly and animal welfare oriented dairy animal management system based on principles of clean, green and ethical animal production. To accomplish the vision, the Institute will focus on strengthening the research base & human resource capacity, and infrastructure facilities including modernization of the existing amenities to become a front runner in the area of state-of-the-art dairy animal production and management with the aim to evolve an efficient dairy animal production and management system to produce quality milk that could compete in the global market.

In the quality control program, the application of advanced techniques such as analytical nanotechnology will be applied for detection of contaminants and adulterants in milk and milk products such as melamine using chemical

sensor and biosensor. Lateral flow assays (LFA), which are also called immunochromatographic strip tests will be used for the specific qualitative or semi-quantitative detection of many analytes including antigens, antibodies, and even the products of nucleic acid amplification tests. Further, the development of rapid methods and validation of methods for detection of adulteration in milk and milk products will be done.

Dairy Processing

Foods with functional benefits such as hypocholesterolemic, anti-carcinogenic, anti-ageing effects are being preferred by consumers and it is possible to pass on these health benefits to the consumers through functional dairy foods. In this area of functional dairy foods, research will be conducted towards generation of bioactive peptides from milk proteins, for the production of functional foods to either enhance their bioavailability from their natural source or create novel foods via the addition and/or fortification of isolated or enriched fractions of bioactive peptides. Novel functional product categories such as antioxidant enriched, omega-3 fatty acids enriched, low cholesterol dairy products, herbal dairy products, low calorie indigenous dairy foods and minerals and vitamins fortified functional dairy products and low cholesterol dairy foods will be evaluated. Application of nanotechnology will be explored in the development of novel functional food with special reference to encapsulated bioactive components. For commercial exploitation of the value added dairy foods, extension of shelf-life assumes greater importance. In this regard, High Hydrostatic Pressure (HHP), Pulsed Electric Field (PEF), Ohmic Heating and Membrane Technology as also packaging interventions involving nanotechnology are the emerging technological options with promising future applications on industrial scale. These alternative technologies have great potential not only in improving energy and processing efficiencies but also for maintaining the “wholesomeness” of the processed products. There is a need to understand the mechanisms involved during the processing through such novel technologies in various categories of dairy products to bring out the desirable characteristics. It will also assist in optimizing the processing conditions and up-scaling the technologies.

In dairy microbiology, the Institute envisages to contribute in the development of functional fermented dairy foods and other nutraceuticals for better human health. This would be made possible through the use of modern biological tools and techniques developed during the last two decades. The development of innovative

dairy foods would be possible through further exploitation of the different kinds of organisms (dairy starters, probiotics etc.). The value addition of the dairy foods through the development of newer biotechnological and micro & nanotechnological approaches would bring in a new era of foods that would address the future needs of the mankind. Studies on the diversity of the micro-organisms would further help in developing novel dairy foods with enhanced health attributes. There is an urgent need for developing rapid and reliable techniques for monitoring quality and safety management of dairy foods. This can be made possible through the development of biosensors and bioassay techniques. Also innovations in molecular biology would greatly help in achieving the objectives of quality and safety of dairy foods. Further challenges in the areas of science can only be met through human resource development of high calibre and state-of-the-art infrastructure.

Traditional Indian dairy products (TIDPs) will continue to be one of the major areas of focus in research as this segment is economically most relevant and offers enormous opportunities for growth particularly in the organised sector of the dairy industry. Shelf life enhancement employing novel processing and packaging options will be critical to address the issues of production of quality products for wider marketing network. Newer healthful and functional ingredients such as buttermilk solids, whey protein hydrolysates, casein hydrolysates, plant sterols & stanols, dietary fibres, cereals, fruits, vitamins, bioactive peptides & natural antioxidants, prebiotics and probiotics could be incorporated into product formulation to enhance value and offer consumers a wider range of choice. Basic studies on TIDPs as a function of new processing treatments and interaction of milk constituents with added ingredients, which are likely to impact quality and safety of the developed products, need to be carried out. Innovations in process mechanization for the manufacture of Indian dairy product will be one of the major areas of research.

Milk is known to contain 500 bioactive components including bioactive peptides, growth factors, phospholipids, therapeutic proteins etc. There is increasing interests among the stakeholders for isolation, characterization, purification, development of scaled up production processes and utilization of these components in novel food formulations. Adoption of isolation processes such as membrane separation, super critical fluid extraction (SCFE) etc. in a cost effective manner remains a challenging task.

Innovations in process mechanization for the manufacture of Indian dairy product will be one of the major areas of research. The Indian dairy industry requires cost effective, energy conserving eco-friendly equipment for handling and processing huge quantities of milk. Hence, there is the need for innovative equipment design, testing, optimization, performance improvement and engineering interventions by application of science and engineering.

Dairy Economics and Extension

The Institute would endeavour to harness the emerging tools, techniques and research methods in econometrics and statistics, to provide direction for designing policies & programs, developing institutional mechanisms and facilitating decision-making process of the stake holders at micro, meso and macro level. The global economic and business environment is undergoing rapid changes that will have far reaching impact and implications for the dairy sector in India. Understanding the market and preparing itself to respond to emerging market trends would be the prime instrument for enhancing the domestic livelihood opportunities in the dairy sector and gearing up the sector to carve out a niche in the world dairy markets. This requires strategic planning for dairy development of the country, which will depend upon basic and precise availability of data, giving complete spatial and temporal view of dairying and dairy related linkages either vertical or horizontal.

The potential of science and dairy research will also be harnessed by validating and transferring the technologies related to increasing the animal productivity, value addition of dairy products and reducing cost of production. In this direction, it would be the endeavour of the Institute to establish Information Banks at the village level. These banks will act as the repository of dairy information and will provide necessary information not only on dairying but also on agriculture as a whole. All efforts will be made to integrate various private agents to the dairy extension mechanism to cover large number of rural masses, which will help in the nutritional security of the nation. Technological regime of village dairy innovation system will be strengthened by penetrating every segment of farming community for enhancing knowledge sharing by the actors of social and technical system. Effective intervention point will be identified in the value chain of dairy products to increase producers' share in consumer rupees. Strategic planning for animal health management to cushion the ill effects of changing climatic condition and strengthening Technological Administrative Task Environment (TATE) by incorporating farmers experience to overcome the challenges of dairy farming in

the backdrop of changing global scenario will be carried out. Effective Information and Communication Technology based quick extension delivery mechanism and grievance handling will be developed. For optimum communication with stakeholders ‘Training on Air’ will be organized to reach a large number of beneficiaries in the shortest possible time. Teaching – learning situation will be improved by incorporating advanced electronic gadgets and involving foreign collaboration.

Education & HRD

Increasing competition, demands for accountability, and higher volumes of available information are changing the methods of operation of the institutions of higher education in this globalized world. For higher education to enact substantial and sustainable changes in efficiency and productivity, a new way of thinking or paradigm that builds efficiency and a desire for continual learning must be integrated into institutional structures. The National Dairy Research Institute, therefore, would strive to harness the power of Education Technology to enhance quality of human resource in dairy-supply chain. The field of educational technology is exploding in terms of innovations being developed daily. The institute would attempt to meaningfully employ these innovations in educational technologies to produce quality human resource that have problem solving skills, critical thinking skills, leadership qualities, written and oral communication skills, societal literacy, ethics and moral character, international awareness and appreciation for lifelong learning. The policy framework for developing quality human resource would be brought about by a) adopting the improvement strategies and techniques such as Total Quality Management (TQM), Continuous Quality Improvement (CQI), and benchmarking which have emerged as a useful, easily understood, and effective tool for staying competitive, b) allocating a high priority, organizational commitment and leadership from faculty/staff to student learning mediated through educational technology c) providing support for the required techno-literacy within a pedagogical framework and continually increasing the capabilities of teaching support staff.

Strategy and Framework

The following strategy would be adopted to accomplish the vision and the goals of National Dairy Research Institute, and to enhance efficiency and effectiveness of Human Resource Development in Dairying (*see annexure 1*).

A. Research

A.1 Dairy Production

- Strengthening breed improvement programme of cattle (Sahiwal, Tharparkar and Karan Fries) and Murrah buffaloes by increasing the size of the nucleus herd by ONBS and establishment of several Network or Associated herd progeny testing schemes in cattle and buffaloes.
- Continuation of breed improvement programmes under field conditions using elite germplasm.
- Molecular genetic evaluation of indigenous cattle and buffaloes for traits like thermo tolerance, disease resistance and genetic disorders for improving the overall adaptability in view of the impending climatic change.
- Molecular cytogenetic profiling of different breeds of cattle and buffaloes will be established.
- Selection of cattle and buffaloes for thermo tolerance, disease resistance and genetic disorders will be carried out.
- Identification and dissemination of superior germplasm under farm and field conditions will be intensified in cooperation with various Animal Husbandry Departments under State Governments.
- Guidelines for the establishment of state-of-the-art laboratory for certifying disease-free semen and cytogenetic screening of the bulls will be developed.
- Identification of the phenotypic and environmentally regulated parameters of metabolic pathways in efficient lactating dairy animals.

- Identification of critical regulatory mechanisms-biochemical, neural, and endocrine- that can augment lactation in indigenous and crossbred cows and buffaloes.
- The nutritional management and requirement are highly variable in different agro climatic regions of the country. Therefore, modeling approach will be adopted for optimizing nutrient utilization and animal productivity.
- The mechanism of nutrient utilization under changing climatic conditions to enhance animal productivity will be elucidated using biotechnological approaches.
- Functional characterization of fertility genes and identification of fertility markers under different patho-physiological conditions will be carried out.
- Plant based extenders for semen will be developed.
- Basic research in the area of genomic regulation of gamete competence and embryonic development will be undertaken.
- Basic as well as applied research in the areas of assisted reproductive technologies and regenerative biotechnologies will be conducted.
- Understanding the production and reproduction potential of farm animals by discovery of biomarkers related to them through proteomics and genomic approaches will be investigated.
- Deep high throughput peptide based approach through proteogenomics for annotating the genes at the protein level for true validation of the gene expression will be conducted.
- Structure of proteins by X-ray crystallography and related techniques to generate a structural genomics database of farm animals for establishing structure and function relationship will be established.
- Aptamer linked nanoparticles for quality assessment will be developed.
- Development of modernized sensor based dairy animal production system for better animal comfort, early detection of abnormal conditions and for sound productive and reproductive management.
- Recognition of health status and comfort of animals from the behavior and voice modulations.

- Development of state of the art animal housing system for alleviation of heat stress and optimum comfort.
- Direct linkage with the stakeholders to test and refine the technologies developed so as to fulfill the requirements at field conditions.
- The biotechnique of oestrus synchronization for efficient endocrine treatment of infertile cows and buffaloes will be developed for obtaining 75% success in conception rates following fixed time AI.
- Efficient methods – either using molecular markers or endocrine techniques – will be established for early identification of breeding crossbred bulls at an early age.
- Efforts will be made to use medicinal herbs native to our country and possess valuable therapeutic properties for the betterment of livestock population through improved immunity and hence fertility and make them popular in the mainstream of veterinary science.

A.2. Dairy Processing

- Characterization and metagenomic analysis of new strains of dairy starters, probiotics and rumen microbes for studying their diversity will be carried out.
- Value enhancement of dairy products/ feed supplements for functional and nutraceutical attributes followed by validation using appropriate microbiological tools will be implemented.
- Validation of health benefits of probiotics/prebiotics/synbiotic dairy foods using animal models and human clinical trials.
- Safety evaluation of milk proteins/peptides/nutraceuticals using immunological and nutrigenomics approach.
- Biochemical and biotechnological tools will be utilized for developing bacteriocins for biopreservation of dairy foods.
- Micro- and nano-technological approaches in developing novel tools for effective and safe delivery of concentrated starters, probiotics, bacteriocins, bioactive peptides and other metabolites will be developed.
- New microbiological tools and techniques for monitoring quality and safety of dairy foods will be developed.

- Dairy foods will be imparted with functional attributes by various approaches such as use of artificial sweeteners, dietary fibres, incorporation of bioactive compounds, protein hydrolysates, micronutrients, synbiotics, reducing cholesterol, etc.
- Application of nanotechnology, biosensors, lateral flow assays, will be standardized.
- Nano - encapsulation as a novel delivery system for bioactive ingredients in functional foods will be developed.
- Rapid methods of testing for adulterants and contaminants using nanotechnology and other sensitive procedures.
- Functional dairy foods enriched in bioactive peptides and antioxidants will be developed.
- Milk and milk products rich in omega-3 fatty acids will be developed.
- Design and scale up equipments for mechanized production of indigenous milk products will be developed.
- The Institute will also design and develop equipments to meet the requirement of dairy processing industries.
- Efforts will be made to commercialize developed equipment for production of milk products.
- Develop processing and preservation technologies for mass production of quality dairy products with focus on traditional Indian dairy products for improving profitability of the organized dairy industry.
- Integrate new age processing know-how with the existing product lines to deliver enhanced processing efficiency and value to the consumers.
- Establish state of the art R&D facilities at the institute to understand the basic aspects of changes brought about in the processed product quality and interactions of new ingredients with milk molecules.
- Scaling up of laboratory scale R&D breakthroughs and rapid and efficient transfer of IPR enabled technologies through public private partnership.
- Development of intellectual property database to enable patent or IP search and management.

A3. Dairy Economics and Extension

- Data gaps will be filled covering vital aspects of dairying in India viz, milk production, marketed surplus, procurement, processing and distribution across different agro-climatic regions.
- Information technology will be used for developing databases on a uniform platform, which can be shared by the potential users including planners, administrators, policy makers, economists and the scientific community at large.
- Institutional mechanisms will be studied for enhancing the competitiveness of the dairy farmers and dairy sector through vertical integration in production, processing, value addition, and marketing of dairy products in domestic as well as global markets.
- Studies will be undertaken to understand the shifts in consumer behaviour and product profile for dairy products' demand and supply projections.
- Impact and responsiveness of dairy sector to multiple stressors such as the influence of industrialization of dairy sector on the structure of production and processing sector, household nutrition, human health and environment will be examined.
- Effect of climate change on vulnerability and adaptive capacity of dairy farmers will be investigated.
- Economic implications of decreasing natural resource base for dairy development would be adjudged.
- Research support will be provided for policy analysis
- Soft computing techniques will be applied in dairy production and processing.
- Database of all the available practices followed by the farmers with respect to dairy farming will be prepared.
- Information System (IS) and Expert System (ES) on dairying would be developed so that limited number of extension agents can address problems of large number of farmers within shortest possible time.
- Collaborations with other divisions, departments, National and International organizations would be increased which will ensure

effective field trails and assessing the feasibility of the dairy farming and processing technologies in the field settings.

- ICT based extension approaches to reach a large number of farmers would be given proper importance. M-extension and e-extension can help not only to transfer improved dairy farming technologies but also to solve the field problems without immediate field visit.
- State-of-the-art laboratories with improved teaching-learning situations can help the new generation students to compete with the global competitive job markets. Inculcating managerial skills, soft skills and problem solving by the help of decision support system would be required to meet the global challenges.
- Capacity building of farmer by providing suitable training and inculcating entrepreneurial characters will help in livelihood security and in turn, it will pave the road of holistic economic prosperity.
- Priorities and impact assessment of technologies and research investment in dairy sector.

B. HRD

- Demonstration of leadership in the integration of educational technologies in learning and teaching.
- Adoption of diverse and innovative research supported pedagogical approaches.
- Facilitation of learning through technologies such as blended online, paper based and face to face learning and interactive video teaching.
- A seamless integration of technology into the student learning experience will be developed.
- There will be a commitment to integrate design standards and models of practice, principles with educational technology in the University curriculum.
- Provision will be made for shared learning spaces and teaching experiences through development and enhancement of the necessary physical infrastructure and the Online Learning Environment (OLE).
- Academic and student networking and collaboration across courses will be facilitated.

- Sustenance of quality teaching in a continuing, effective and explicit way.
- Enhancement of quality of higher education, exposing students to work in R&D environment and prepare them to take up new and complex challenges of dairy industry.
- Objective trainings for students, faculty and industry personnel will be implemented.

Epilogue

NDRI is committed to meet the challenges of market driven growth momentum in the dairy sector through technology support for enhancing the livelihood security of the millions of dairy farmers and ensuring sustainable development of dairy sector in the country. NDRI envisions that innovations in dairy production, processing, policy and technology delivery mechanisms would lead to faster growth of the sector than has been achieved so far and make India a leading dairy nation in the world. The R&D activities at the Institute would augment farmers' income, generate employment opportunities, create trade surplus, and besides being economically sustainable, will also be catalyst in social and environmental sustainability of dairy production system in the country. There would be a two pronged strategy to harness the untapped potential of Indian dairy sector; the short/medium term approach for realizing the gains would emphasize more on nutrition, health and value addition aspects; while the longer term approach would be breed improvement and application of biotechnology for enhancing milk production. To sustain the benefits of research and development, the Institute would create an enabling policy environment, favorable work culture and infrastructural support at different administrative levels. The close interface with the various stakeholders, farmers, processors, policy makers, extension agencies, etc., both at national and international levels have been a strength of NDRI that would be further intensified for holistic development of dairy sector.

Concerted efforts would be made to transform the National Dairy Research Institute to the level of world class R&D and HRD institution that is especially sensitive to the techno-economic needs of the smallholder dairy producers. It would develop mechanisms to regularly monitor the economic environment at the global level, and will develop strategies to respond to the changes for the benefit of all the stakeholders in the dairy value chain.

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Annexure 1. Strategy and Framework

Goal	Approach	Performance measure
<p>To improve fertility and milk production in cattle and buffaloes</p>	<p>Strengthening breed improvement programme of cattle and Murrah buffaloes in cooperation with various Animal husbandry Departments under State Governments for enhanced productivity.</p> <p>Molecular genetic evaluation, genomic regulation, identification and characterization of fertility related genes and biomarkers and cytogenetic profiling of indigenous cattle and buffaloes for improving the overall adaptability in view of the impending climatic change.</p> <p>Application of modern endocrinological and biotechnological tools including gene regulation, gene manipulation and proteomics for elucidating the functional cellular processes, gamete competence, and embryonic development, for fertility enhancement of livestock.</p> <p>Harnessing the therapeutic and immunostimulatory properties of indigenous herbs and application of modelling approach for optimizing nutrient utilization, methane mitigation and animal productivity under different agroclimatic conditions.</p> <p>Identification and modulation of phenotypic and environmentally regulated neural, endocrine and metabolic parameters for enhancing milk production.</p>	<p>Sustainable and profitable livestock farming.</p>

Goal	Approach	Performance measure
Ensuring quality control through application of newer chemical and biotechnological concepts.	Rapid methods of testing for adulterants and contaminants using nanotechnology and other sensitive procedures. Establishment of National Referral Laboratory.	Development of new generation tools of testing for presence of adulterants and contaminants in milk. Accreditation of National referral Lab for milk quality control.
Value additions in the dairy foods supply chain for addressing the complete safety and improved public health.	Characterization and metagenomic analysis of new strains of dairy starters, probiotics and rumen microbes for studying their diversity. Value enhancement of dairy products/feed supplements for functional and nutraceutical attributes followed by validation using appropriate tools.	Establishment of a national depository of dairy microorganisms of public health significance and development of an interactive data base. Availability of functional fermented dairy foods with desired health claims.
Availability of healthy and novel products in the market.	Isolation of bioactive molecules from milk through novel techniques. Value additions through micro- and nano-technological approaches for delivery of bioactives in functional foods. Utilization of Probiotics / Prebiotics / new strains of starter culture / symbiotic dairy foods for health maintenance and disease prevention. Process mechanisation for manufacture of traditional dairy foods. Adoption of newer technologies for improved process efficiency. Enhancement of shelf life and marketability through technological interventions. Promotion of public-private partnership, management of intellectual property and effective transfer of technology.	Greater competitiveness and sustainability to the Indian dairy industry.

Goal	Approach	Performance measure
<p>Validation and transfer of the technologies related to increasing animal productivity, value addition of dairy products and reducing cost of production.</p>	<p>Development of Information System (IS) and Expert System (ES) on dairying and documentation of database of all the available practices followed by the farmers.</p> <p>Strengthening of ICT mediated extension approaches such as M-extension and e-extension to reach large number of farmers within shortest possible time not only to assist in transfer of technologies but also to address dairy farmers' problems.</p> <p>Development of State-of-the-art laboratories with improved teaching-learning situations to help the new generation students to inculcate managerial skills, soft skills and problem solving qualities to cope up with the challenges of global scenario.</p> <p>Databases on all economic aspects of milk production in the country including different agro-climatic regions, and application of ICT for sharing this information among various stakeholders and scientists.</p> <p>Study of Institutional mechanisms for enhancing the competitiveness of the dairy farmers and dairy sector through vertical integration in production, processing, value addition, and marketing of dairy products in domestic as well as global markets.</p>	<p>Enhancement of productivity and remunerative marketing for bringing about economic well being and livelihood security of farming families.</p>

Goal	Approach	Performance measure
<p>Latest education technology to enhance quality of human resource in dairy-supply chain.</p>	<p>Demonstration of leadership in the integration of educational technologies and adoption of diverse and innovative research supported pedagogical approaches.</p> <p>Facilitate learning through technologies such as blended online, paper-based and face-to-face learning and interactive video teaching and their seamless integration into the student learning experience.</p> <p>Development and enhancement of the necessary physical infrastructure and the Online Learning Environment (OLE) and sustenance of quality teaching in a continuing, effective and explicit way.</p>	<p>Meaningful application of these innovations in educational technologies to produce society ready human resource will lead to scholars with problem solving skills, critical thinking skills, leadership qualities, written and oral skills, societal literacy, ethics and moral character, international awareness and appreciation for lifelong learning.</p>