Review Article

NANOTECHNOLOGYAND AYURVEDA:EMERGING OPPORTUNITY FOR PROFITABLE DAIRY HUSBANDRY

Abstract

Livestock development, dairy husbandry in particular, is an important source of food security and income generationfor marginal and poor farmers in India and other developing countries. However,productivity of the livestock owned by small farmers isvery low, because of inferior genetic base, nutritional deficiency and poor health care. While genetic improvement is being carried out by providing breeding services at the door steps of small farmers, balanced feeding and effective health care need greater attention. This paper identifies the problems faced by small livestock holders and identifies appropriate technologies which can benefit them.Application of nanotechnology and Ayurveda have good potential to provide effective treatment against major health problems such as infertility, metritis, mastitis, ecto and endo-parasites, while ensuring the supplementation of essential mineral nutrients. Nanotechnology for developing Ayurvedic medicines can be more effective than traditional herbal medicines and can significantly reduce the cost of treatment. Promising new generation products developed with this concept,such as 'Roofert' and 'Rookare' have been proving effective in controlling infertility, metritis and mastitis. There is a need for policy support and investment on research and development to tap the potential of these technologies for the benefit of dairy farmers.

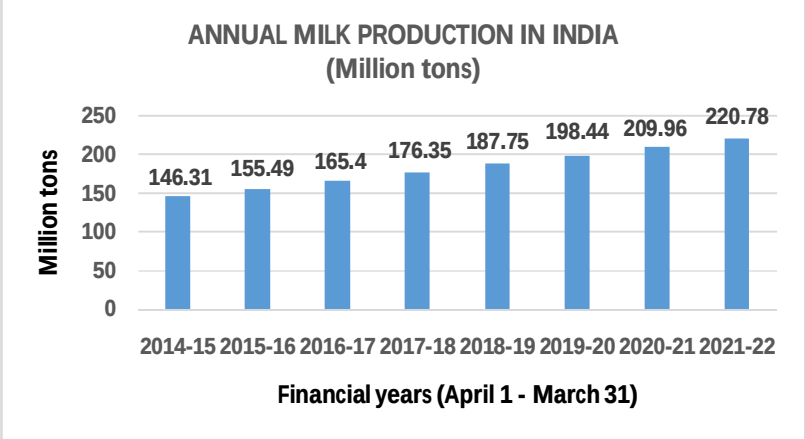
Keywords: Nanotechnology, nano–nutrients, Infertility control, mastitis control, Roofert, Rookare

Introduction

Livestock is an important source of food security and sustainable livelihood for most of the small farmers and landless families living in villages, in most of the countries in Asia and Africa. In India, where over 87 percent farmers are marginal and small land holders, apart from 10 percentlandless rural families, livestock is an important source of income and social security and forms an important component of agriculture in the national economy. Livestock sector hasmaintaineda steady compound annual growth rate (CAGR) of 7.93 percent during 2014-15 to 2020-21, as compared to CAGR of agriculture (crops) sector at 2.05 percent, manufacturing sector at 4.93 percent and services sector at 4.82 percent [1]. During the year 2020-21, agriculture (crops) has contributed 8.96 percent of the total Gross Value Addition (GVA) to the national economy, while the livestock sector has contributed 4.90 percent of the total GVA. The most significant fact is that the livestock sector has significantly benefitted the weaker sections of the society by improving the per capita availability of milk, eggs and meat [2]. Milk is the single largest agricultural commodity contributing 5 percentto the national economy and employing more than 80 million farmers directly and dairy husbandry has turned out to be a primary source of income for most of these rural families. India has ranked the top among the milk producing countries in the world, by contributing 23 percent of the global milk production. Milk production in India has grown at a compound annual growth rate of about 6.2 percentto reach the production from 146.31 million tonnes in 2014-15 to 220.78 million

tonnes in 2021-21, as presented in Figure 1 [1]. Dairyhusbandry is considered as a reliable and sustainable tool for food security and rural prosperity in India. Livestock is also a source of meat, skin, fibre, organic manure and draft power for farmers in the developing countries. Livestock dung is the primary source of organic manure, required to reduce the use of chemical fertilizers and to produce healthy and residue-free food commodities. Livestock is an ideal source of year round employment for women and elderly families, which can be managed without disturbing their domestic routines, free from any risk and investment. Thus, livestock development, particularly dairy husbandry can be a reliable programme for food security and poverty mitigation in most of the countries in Asia and Africa. For resource-poor families, who cannot afford to maintain cows or buffaloes, because of limited space and feed resources, sheep or goat husbandry can be the next option, because these species are tolerant to harsh weather conditions and require less resources. These small ruminants are generally reared for meat purposes, which also have ready market for meeting emergency cash needs [3].The objective of this paper is to review the present challenges faced by the livestock sector in India and identify the opportunities to address some of the problems related to nutrition and animal health by using nanotechnology and Ayurveda.

Figure 1: Trend of Milk Production in India (2014 to 2022)



Challenges of Livestock Sector Development

Large Population with Poor Yield: The livestock sector has made signification progress by contributing 25.6percentto the Agricultural GDP of India, while providing year round employment to about 9percent of the population in the country. Animal husbandry is contributing to about 15percent of the average farm income, but the performance of livestockin India has been far below the world average, because of various challenges. With a population of193.46 million cattle, 109.85 million buffaloes, 148.88 million goats and 74.26 million sheep, India owns the largest livestock population in the world [4]. However their productivity has been far below the world average, with respect to milk and meat production. The national average milk yield of cows in India in 2019-20 was1463 kg/lactation, as compared to the world average of 2200 kg/lactation. The average carcass yield of goats in India has been 11.0 kg as compared to the world average of 12.5 kg/goat[5]. Lower yield reflects higher cost of production and lower income to farmers.

Genetic Erosion: Milk production of Indian cows and buffaloes was affected due to several reasons such as poor genetic composition, scarcity of fodder and feed resourcesleading to underfeeding and nutritional deficiency, poor health status due to inadequate treatment facilities and irregular vaccination and general neglect on good management practices. Lower milk yield of Indian cows and buffaloes is primarily because of a larger population of nondescript animals, as compared to crossbred and indigenous breeds as presented in Table 1 [1]. It mayalso be observed that the nondescript indigenous cows and buffaloes, with an average daily milk production of 2.71 kg and 4.13 kg respectively, represent56percent of the adult female bovine population. These nondescript animals,generally in neglected conditions,are suffering from nutritional deficiency and various ailments. Traditionally, these animals were fed with locally available crop residues and home-made concentrates, which did not provide all the required nutrients. Such feeding practices affected the growth, production and reproduction, resulting in poor conception, infertility, longer calving intervals, low milk yield and susceptibility to diseases, resulting inlower income.

Table 1. Average yield of milk of Indian cows and buffaloes

Species/Breed	No. of Adult females (Million)	Milk yield (2020 -21) (Kg/Day)
Exotic Cows	2.50	9.15
Crossbred Cows	23.58	7.22
Indigenous Cows	12.13	3.34
Non-descript Cows	36.38	2.71
Indigenous Buffaloes	18.90	6.41
Non-descript Buffaloes	35.09	4.13
Goats	60.65	0.47

Source: Government of India, 2022 [1]

Poor Health Status: The other important factor which has been affecting the productivity of livestock is poor animal health, caused by various diseases, ecto-parasites, endo-parasites and eco-pathological disorders. Among these, most significant health problems faced by the dairy farmers in India are mastitis, metritis and infertility, milk fever, Foot Rot, and diseases such as Foot and Mouth Disease (FMD), Brucellosis, Anthrax, Lumpy skin disease, Infectious Bovine Rhinotracheitis (IBR), etc. In India, effective vaccines have been developed and made available at the door steps of dairy farmers, for effective prevention of most of these diseases [6]. Lumpy skin disease is a viral disease, transmitted by blood-sucking insects such as ticks, mosquitoes or certain species of flies, which causes fever, nodules on the skin of affected cattle and can also lead to death. The disease was prevalent in Africa, but moved to Europe in the mid-2010s and entered India recently, during the last two years [7]. Fortunately, vaccine is now available to prevent the infection in the near future.

Mastitis is inflammation of mammary glands of dairy animals, caused by infection of the udder by fungi, yeast, algae or virus, resulting in heavy economic losses. Subclinical mastitis

was found to be more rampant in India (varying from 10-50percent in cows and 5-20percent in buffaloes) than clinical mastitis (1-10percent). The incidences were highest in purebred Holsteins and Jerseys cows and lowest in local cattle and buffaloes. Occurrence of mastitis was mostly due to several species of bacteria and also due to fungal, yeast or viral infection. There are two types of mastitis, categorised on the basis of their symptoms. First type is the Clinical Mastitis, where visible changes in milk, udder or teats can be observed. Clinical mastitis is further classified into 4 categories, namely Per-acute mastitis (painful swelling of udder, fever, cessation of milk secretion and blood stained exudates from teat canal), Acute mastitis (similar to per-acute mastitis, with swollen udder and milk secretion changed to curdy yellow material), Sub-acute mastitis (change in milk composition but no changes seen in udder), and Chronic mastitis (persistent infection and udder turns hard due to fibrosis). The other type of mastitis is Sub-clinical mastitis, where there is only a change in milk composition with high somatic cell countand reduction in milk production,without any visible change in the udder or milk. More often, late diagnosis is the real problem, as the effective medicines can be used on the basis of the sensitivity test for control of the disease, if the problem is detected [8].

Metritis is another disease, where the cows and buffaloes suffer from enlarged uterus, followed by uterine discharge, due to bacterial infection after parturition. Good management practices and sanitation can prevent the incidences and infected animals can be cured with proper treatmentand suitable antibiotics.Infertility is one of the most important problems causing huge economic losses, particularly in high-producing dairy herds, caused by retained placenta, metritis, anoestrus, silent oestrus, cystic follicles, repeat breeding and abortions. Poor nutrition is also a major cause of infertility. Deficiency of vitamin A and beta-carotene in the feed can cause reproductive disorders, including placental retention. Deficiency of selenium, copper and zinc can induceproblems linked with infertility. Suitable treatment, based on the causes as determined by hormonal assays and feed supplementation with micronutrients can help the animals to conceive in most cases [9].

Milk fever is another important metabolic disorder, caused by decrease in the levels of ionized calcium in tissue fluids of heavy milking cows. Such insufficient calcium commonly occurs around calving period and milk fevergenerally occurs within the first 24 hours after calving, or during the next two to three days. It can be either clinical or subclinical. Clinical milk fever includes both “downer” and “non-downer” cows with less than 7 mg/dl of blood calcium. Sub-clinical milk fever includes cows with less than 8.4 mg/dl but more than 7 mg/dl of blood calcium.Typical symptoms of this illness are loss of appetite, constipation and restlessness, without any rise in the body temperature. The most common treatment for milk fever is intravenous infusion of calcium boro-gluconate. Instant normalization of blood Calcium levels is important to reduce the chances of death.Supplementation with magnesium for two to three weeks before calving will reduce the risk of milk fever, as it helps in better absorption of calcium [10].

Animal health is also affected by infestation of different ecto-parasites and endo-parasites. The main ecto-parasites affecting cattle are flies, lice, ticks and mites, which cause scabies.

Major internal parasites are gastrointestinal strongyles, which cause significant growth loss or stunting in cattle, respiratory strongyles such as *Dictyocaulusviviparus* which lives primarily in the airways of cattle and liver fluke (*Fasciola hepatica*), which enters the liver to cause metabolic disturbances. Based on the laboratory diagnosis, these parasites can be effectively controlled by allopathic or herbal medicines effectively. Good management practices are helpful to control the infestation to a significant extent [11].

Strategy for Improving Livestock Productivity

The major focus on improving the productivity of dairy animals like cattle and buffaloes, and small ruminant like sheep and goat should aim at the following aspects [12]:

1. Genetic improvement and improving breeding efficiency;
2. Regular health care through good husbandry practices, preventive vaccinations and timely treatment of sick animals;
3. Efficient nutritional management;
4. Development of an efficient value chain for backward and forward linkages.

Genetic Improvement and Breeding Efficiency: With the advancement of genomic science, selection of superior bulls and their progeny testing is now possible at a very young age and it is feasible to use only proven sires for breeding in the field. Use of sex sorted semen helps farmers to get over 90percent female calves to accelerate the expansion of their dairy herds. Early pregnancy detection tests which are now available in the field can save the delay in conception [13].

Good Health Care Practices: Good management practices such as ventilated housing, dry floor, proper drainage and sanitary practices, preventive vaccinations against prevalent diseases, periodic control of parasites and balanced feeding can minimise the health problems of dairy animals. Regular screening against diseases such as TB, JD, IBR, Brucellosis, and segregation of sick animalscan further ensure their safety. Timely diagnosis of the ailments and effective treatment can reduce economic losses,thereby preventing the sufferings by the animals. While chemical drugs and antibiotics are easily available for treating most of the animal diseases by the veterinarians, Ayurveda, an ancient herbal therapy developed in India and many other countries for more than 1-2 thousand years has effective solutions to cure many of the livestock diseases. Low cost, absence of side effects, ability to build immunity and overcome stress are other advantages of Ayurveda therapy [14]. Many Ayurvedic medicines are already available in the market and effectively used to control various ailments of livestock in India.

Efficient Nutritional Management: Balanced feeding with required macro and micro nutrients will continue to be a major challenge for the Animal Husbandry sector to harness its full potential in the future. This is because of scarcity of feed resources, traditional practice of

feeding of crop residues and locally available concentrates, absence of feeding supplementary minerals with the feed, inability of the animals to absorb certain nutrients, etc. [15]. In many cases, the dairy animals are underfed, and thus show the symptoms of nutritional deficiency. Imbalanced nutritioncan cause weight loss, poor body condition, delayed puberty, ovarian dysfunction, hormonal imbalances, leading to infertility. The balancing of nutritional requirements of farm animals for energy and different nutrients such as protein, fat, vitamins, and micro and macro-minerals is required to achieve optimal reproductive performance [16]. In many cases, the nutritional deficiency may not be due to lack of offered feed, but due to factors, such as digestion and absorption efficiency and physiological and metabolic status of animals. Hence, it is necessary to ensure that all the nutrients, both macro and micro-nutrients and vitamins are easily available to the tissues for easy absorption. Nanotechnology provides an excellent solution to improve nutritional supplementation, while keeping the cost of feeding under control [17]. Use of nano-materials for nutritional management will be the game changer the near future.

Utilisation of Nanotechnology for Livestock Development

The main benefit of nanotechnology is its ability to modulate the drug behaviour and consequently the biological effects. Nanotechnology is useful for feeding farm animals, because of their particle size varying from 1 to 1000 nm, stability at high temperature and pressure. It has the potential to improve animal fertility and reproduction, enhance sperm production, improve animal health and production, treat diseases, develop efficacious vaccinesand improve drug delivery systems [18]. This technology is also useful to improve the disease diagnosis and treatment, apart from improving the quality of milk and meat.

Nano-particles also have bactericidal and fungicidal properties, which are also effective against yeast cells causing bovine mastitis [19]. Silver nanoparticles can serve as antimicrobials, while nano-selenium, nano-chromium, and nano-zinc can improve animal productivity, reproductive performance, healthiness and quality of the products[20].Nano-zinc oxide can also boost milk yield and lower the number of somatic cells in milk. It has been reported that positively charged silver nanoparticles could be used to prevent the growth of *E. coli*, which is responsible for causing *Haemorrhagic enteritis* [21]. Nanoparticles of gold can penetrate the small intestinal epithelium and further spread to the blood, brain, lungs, heart, kidneys, spleen, liver and stomach. Some surface-functionalized nano-components can bind and remove toxins and pathogens. Nano-products can replace inorganic salts of these elements and chelates in the feed industry [22].

For reproductive management of farm animals, nanotechnology offers unconventional and innovative solutions, because the efficiency of biological and hormonal-based reproductive treatments are dependent on several biological factors, physiological and nutritional status of animals and additional factorssuch as digestion and absorption, making it difficult to treat effectively. Moreover, the treatment of reproductive-related diseases is challenged by the concerns about the intensive use of antibiotics and the development of antimicrobial resistant strains. In contrast, nanotechnology applications can present innovative solutions for

overcoming reproductive management challenges. Many hormones, antibiotics, biological molecules and nutrients can acquire novel physicochemical properties by using nanotechnology to improve bioavailability, higher cellular uptake, sustained release and lower toxicity, compared with ordinary products [23].

In the treatment of mastitis, nanoparticles show greater effect on bacteria than other drugs. The antibiotics presently used for treating mastitis have some side effects and nano-materials can drastically bring down the volume of antibiotics required for the treatment. There are other nano-products which have the capacity to break down the nutrients and carry them safely to various organs. They further facilitate easy transfer through intestinal membranes to blood and release precisely [24]. Nanotechnology can be helpful to increase the strength of micronutrients in processing and supplying. Use of nano-zinc for feeding dairy cows canimprove the milk production, as compared to the cows fed with conventional sources of zinc. Feeding of nano-zinc material to cows, which were suffering from subclinical mastitis resulted in significant reduction in somatic cell count in the milk [25]. Milking cows supplemented with nano-zinc recorded significantly higher milk yield, with higher protein and albumin content and with significantly lower somatic cell count [26].

There are several types of nanoparticles which are useful for livestock and their details are presented in Table 2 [24].These are useful as biocides and veterinary medicines, apart from improving nutrient delivery, boosting reproductive system and facilitating easy transportation of other molecules of nutrients, resulting in a miraculous effect on disease cure, growth and production [27].

Table 2. Role of nanoparticles in different applications

Types of Nanoparticles	Nanoparticles	Application
Natural	Casein micelles	Nutrient delivery
	Bio-cellulose	Biocide, Veterinary medicine
Metal	Gold	Biocide
	Copper	Biocide
	Calcium carbonate, Calcium citrate	Nutrient delivery
	Silver	Biocide, Veterinary medicine
	Iron oxide	Veterinary medicine
	Zinc oxide	Reproduction
	Titanium oxide	Reproduction
	Lectin coated Fe_2O3	Reproduction
Nano-structured	Lipid nanoparticles	Nutrient delivery
	Cruciferin	Nutrient delivery
	Carbon (Glucose delivered)	Veterinary medicine
	Mesoporous silica	Veterinary medicine, Reproduction

Polymer	Polyacrylate	Biocide
	Chitosan	Biocide
	Triclosan	Biocide

Source: Hill, 2017[24]

Potentials of Medicinal Herbs and Ayurveda for Livestock Development

Ethno-veterinary practices have been prevalent ever since the domestication of various livestock species and over 80percent livestock owners all over the world have been using herbal medicine for treating their sick animals. The traditional medicines for animal healthcare are easily accessible even to illiterate and small farmers, and these can cut down the costs significantly. Ethno-veterinary practicesare gaining popularity during recent years, because many pathogenic microorganisms are developing resistance to common drugs, while herbal medicines have no side effects [28, 29]. Herbal medicines for human ailments and livestock diseases have beenin use since thousands of years in India. Even presently, there are thousands of herbal healers with their traditional knowledge transferred from their forefathers, who are practicing Ayurveda. Major herbs used are commonly available across the country, while many of the tribal healers use special herbs which are naturally grown in their region.Traditional herbal healers in Tamil Nadu have identified 38 medicinal plants for treatment of various livestock ailments such as viral diseases, digestive ailments, reproductive ailments, parasitic ailments, wounds and injuries. The list of these species with their uses is presented in Table 3 [30]. Among them,*Curcuma longa*, *Azadirachtaindica*, *Vitexnegundo*, *Bambusaarundinacea*, *Justiciaadhatoda* and *Zingiberofficinale* were widely used for treating the livestock. *Azadirachtaindica* (neem) leaves were used for treating abrasions, anorexia, diarrhoea, flu, FMD, horn avulsion, skin infection and tick bites.

Some other popular treatmentsfor dairy cattle, practiced since centuries are application of turmeric on udder for treating mastitis, allowing animals to walk on hot sand and applying sand or linseed oil and turmeric externally to wounds caused by Foot and Mouth Disease, drenching linseed oil along with a mixture of ginger, turmeric and asafoetida and keeping the animal's mouth open for treatment of tympany, feeding bamboo leaves or a mixture of oil bran and pearl millet grain for retention of placenta, drenching of beal (*Aeglemarmelos*) fruit pulp and mango seed kernel for 2-3 days for curing diarrhoea, etc., which have been very reliable and safe [31], although more than 10,000 herbs have been reported to be useful for treating various ailments of livestock.Medicinal plants used for treating various animal diseases in different parts of India were compiled in India Pharmacopoeia 2014, British Pharmacopoeia (BP) 2014 and the United States Pharmacopeia (USP) 36 and these are summarized in Table 4 [32]. The properties of these herbs and their benefits have been scientifically validated. Most of these herbs are used for preparing Ayurvedic medicines in

India. There are many other important herbs used in veterinary treatment, which are not covered in the above two lists presented in Tables 3 and 4.

Table 3. List of Medicinal plants used by the Tribal healers in Tamil Nadu and their uses

Name the Plant species and Family	Diseases Treated	Livestock Species	Plant Parts to be Used	Method of Application
Abrusprecatorius Fabaceae	Anorexia, Fever FMDV	Cow, Buffalo	Dried leaf paste Fresh leaf paste	Applied externally Applied on wounds
Acalyphafruticosa Euphorbiaceae	Cracks on teats	Cow, buffalo	Fresh leaf paste	Applied on teats
*Acalyphaindica*Euphorbiaceae	Skin infection	Cow, buffalo	Fresh leaf paste	Applied on skin
*Allium sativum*Amaryllidaceae	Anorexia	Cow, buffalo	Fresh bulb paste	Given orally
Justiciaadhatoda Acanthaceae	Flu FMDV Muscle contraction	Cow, Buffalo	Fresh leaf paste	Given orally Given orally Applied/Diluted sprayed externally
*Allium sativum*Amaryllidaceae	Anorexia	Cow, Buffalo	Fresh bulb paste	Given orally
Aloe vera Asphodelaceae	Delayed puberty	Cow, Buffalo	Fresh leaf paste	Given orally
Andrographispaniculata Acanthaceae	Snake bite	Cattle, Buffalo, Goat, Sheep	Fresh leaf paste	Applied on bitten portion
Aristolochiaindica Acanthaceae	FMDV, Delayed puberty Anorexia Diarrhoea Abrasions	Cow, buffalo	Fresh leaf paste	Given orally Applied as ointment
Azadirachtaindica Meliaceae	Flu Horn avulsion	Cow, Buffalo	Fresh leaf paste	Given orally Mixed with

	FMDV Skin Infection Tick bite Post calving pain		Fresh leaf paste Fresh leaf paste Fresh leaves	honey given orally Applied on skin Leaves fed
*Bambusaarundinacea*Poaceae	Retention of foetal membrane	Cow, Buffalo	Fresh leaves	Feed as fodder
*Calotropisgigantea*Apocynaceae	Dog bite Eye infection FMDV	Cow, buffalo, sheep, Goat	Leaf latex powder Fresh leaf paste	Mixed with water and applied Given orally
Carica papaya Caricaceae	FMDV Delayed puberty	Cow, Buffalo	Fresh leaf paste+ Honey Fresh leaf paste	Given orally
*Citrulluscolocynthis*Cucurbitaceae	Hematomas Skin infection	Cow, buffalo, sheep, Goat	Fresh leaf paste	Given orally Applied on skin
Citrus limon Rutaceae	Diarrhoea	Cow, buffalo, sheep, Goat	Fresh fruit juice	Given orally
*Clerodendrumphlomidis*Lamiaceae	Blisters on udder Abrasions FMDV	Cow, buffalo	Fresh leaf and Rhizome paste Dried rhizome paste	Applied on udder Apply externally Given orally
*Curcuma longa*Zingiberaceae	Delayed puberty Horn avulsion Muscle contraction Skin infection	Cow, buffalo Cow, goat Cow, buffalo All animas	Dried rhizome paste	Cooked with rice and fed Apply on horn Apply on affected part Apply on skin

Daturametel Solanaceae	Bloating, FMD	Cow, buffalo	Fresh leaf paste	Given orally
Delonixelata Fabaceae	FMDV	Cow, buffalo	Fresh leaf paste	Given orally
Erythrinavariegata Fabaceae	Dog bite	Cow, buffalo, Sheep, Goat	Fresh leaf paste	Applied on the bitten part
Ficusbenghalensis Moraceae	Horn avulsion	Cow, goat	Fresh leaf paste	Applied on the broken horn
Lawsoniainermis Lythraceae	FMD Delayed puberty	Cow, buffalo	Fresh leaf paste	Applied on wound Given orally
*Lanneacoromandelica*Anacardiaceae	FMD	Cow, buffalo	Fresh leaf paste	Given orally
Leucasaspera Lamiaceae	FMD, Delayed puberty	Cow, buffalo	Fresh leaf paste	Given orally
Morindacitrifolia Rubiaceae	FMD Anorexia	Cow, buffalo	Fresh leaf paste Fresh flowers	Given orally Chopped and fed
Musa paradisiaca Musaceae	FMD, Delayed puberty	Cow, buffalo	Fresh flower	Chopped and fed
Ocimum sanctum Lamiaceae	Flu FMD	Cow	Fresh leaves Fresh leaf paste	Feed as fodder Given orally
Oryzasativa Poaceae	Anorexia Post calving pain	Cow	Dried seeds	Boiled rice given orally
*Pedalium murex*Pedaliaceae	Delayed puberty	Cow, buffalo	Fresh leaf paste with honey	Given orally
*Phyllanthusamarus*Phyllanthaceae	FMDV Anorexia	Cow, Buffalo	Fresh leaf paste	Given orally Diluted, given orally
Piper betle Piperaceae	Diarrhoea	Cow, Buffalo	Fresh leaf paste	Diluted and given orally
Pongamiapinnata Fabaceae	FMDV	Cow, Buffalo	Fresh leaf paste	Given orally
*Psidiumguajava*Myrtaceae	FMDV	Cow,	Fresh leaf	Given orally

		Buffalo	paste	
Sesamumindicum Pedaliaceae	Retention of placenta	Cow, Buffalo	Fresh leaves	Fed as green fodder
Solanumtrilobatum Solanaceae	Flu	Cow, Buffalo	Fresh leaves	Fed as green fodder
Syzygiumcumini Myrtaceae	FMDV	Cow, Buffalo	Fresh leaf paste	Given orally
Tamarindusindica Fabaceae	FMD Diarrhoea Muscle contraction	Cow, buffalo,	Fresh leaf paste	Given orally Applied on affected muscle
*Vitexnegundo*Lamiaceae	Flu FMDV	Cow, buffalo,	Fresh leaf paste	Given orally
Zingiberofficinale Zingiberaceae	Bloating Diarrhoea Hematomas	Cow, buffalo	Fresh rhizome paste	Mixed with cooked rice and given orally

Source:Jayakumara et al, 2018 [30]

Table 4. Medicinal plants for various animal diseases used in different parts of India.

Name the Plant species And Family	Diseases Treated	Plant Parts to be Used
Acacia nilotica	Foot disease, Acidity	Seed, bark, leaf
Adhatodavasica	Tissue healing, Cough, cold	Leaf
Allium sativum	Cough, cold, fever, Swollen throat, Skin infection, Pruritis, Snake bite, FMD, HS	Leaf, Bulb
Andrographispaniculata	Dysentery, Fever Insect bite Babesiosis	Whole plant Root Leaf
Asparagusrecemosus	Milking disorder, Diarrhoea, Dysentery, Indigestion, Haematuria	Root
Azadirachtaindica	Inflammation, Constipation, Ulcer, Prolapsed uterus, Indigestion, Lever disorders, Tissue healing, Smallpox Parasitic skin diseases	Leaf Seed
Bacopamonnieri	Paralytic attack	Whole plant
Berberisaristata	Cataract, Wounds, Food poisoning	Root, Stem
Boerhaviadiffusa	Improve vitality Jaundice	Leaf Root
Carica papaya	Eczema	Latex
Cassia angustifolia	Acidity	Pod, Leaf
Cassia fistula	Tongue sore, Fever, Constipation, Dysentery,	Leaf

	Swelling due to cold emetic Emetic	 Seed
Centellaasiatica	Fever Dysentery	Leaf
Clavicepsperpuria	Urine stimulant, Oxytocic, Abortifacient	Sclerotium
Coleus forskohlii	Spasmolytic, Antithrombotic, Anti-inflammatory	Root, Leaf
Coriandrumsativum	Constipation, indigestion, Fever, Haematuria, Dehydration, Chicken pox	Seed oil
Curcuma domestica	Constipation, Skin disease, Neck sore, Yoke galls, Indigestion, Mastitis, Expectorant	Rhizome
Cyamopsistetragonoloba	Laxative	Endosperm/ Gum
Eclipta alba	Antiseptic, Wound, swelling	Leaf
Embeliaribes	Diuretic, Astringent, Antibacterial, Anti-inflammatory	Seed
Foeniculumvulgare	Diarrhoea	Seed
Gymnemasylestre	Eye discharge, Anti-diabetic	Leaf
Hemidesmusindicus	Convulsive seizure	Leaf
Mangiferaindica	Diarrhoea, Eye disease, Food poisoning	Bark
Menthaarvensis	Fever, Dysentery	Leaf
Macunapruriens	Diarrhoea Ouster induction, Wounds, Cholera	Leaf Pod
Ocimum sanctum	Cough and cold, Rhinitis, Body ache, Purulent disease	Leaf
Picrorhizakurroa	Digestive disorders, Alimentary disorders, Dysentery, Intestinal worm, Tonsil	Root
Phyllanthusamarus	Malaria	Whole plant
Phyllanthusemblica	Intestinal parasites, Dyspepsia, Diarrhoea, Eye disease, Chicken pox	Fruit
Piper nigrum	Mastitis, Cough, Cold, Fever, Throat swelling, Intestinal disorder, Blood in excreta, Food poisoning Diarrhoea	Seed Flower, Fruit
Psoraleacoryfolia	Leucoderma, Antibacterial, Anthelmintic	Seeds
Ricinuscommunis	Acidity, Throat problem, Constipation, Endoparasites	Seed oil
Rubiacordifolia	Astringent, Diuretic, Antiseptic, Anti-dysenteric	Stem
Sidaacuta	Shivering, Joint pain	Whole plant
Syzygiumaromaticum	Anti-inflammatory, Carminative, Antibacterial Dyspepsia, Gastric irritation	Flower bud
Terminaliaarjuna	Haemostatic, Tissue healing, Heart ailments	Bark
Terminaliabellirica	Diarrhoea, Dyspepsia	Fruit
Terminaliachebula	Diarrhoea, Dysentery, Ulcer, Stomach ache,	Fruit

	Anorexia, Anthrax	
Trachyspermumammi	Hypocalcemia dower cow syndrome, appetizer, Expectorant, Indigestion, Dysentery, Blot, Fever	seed
Tinosporacordifolia	Tonsillitis, FMD, Anthrax, Blood purification Skin diseases	Whole plant Stem
Tribulusterrestris	Dysentery Diuretic	Root Fruit
Trigonellafoenumgraecum	Urinary disorder, Appetizer, Diarrhoea, Galactagouge, Fertility regulation, Gastric trouble, Tetanus, Food poisoning, Pneumonia	Seed
Withaniasomnifera	Fever, Ulcer, Expulsion of placenta, Convulsive seizures, Tissue healing, Antibacterial, Sex vitality improvement	Root
Zingiberofficinale	Blood purifier, Expectorant, Fever, Indigestion, Constipation, Stomach-ache, Food poisoning, Tetanus, Anthrax	Rhizome

Source:Rastogi*et al*, 2015 [32]

Ayurvedic Products for Boosting Livestock Production

India has advanced in commercial production of Ayurvedic veterinary medicines since many decades. Some of the popular products are Veterinary Liver Tonic, Anti Mastitis Veterinary Medicine, Veterinary Herbal Wound Spray, Veterinary Herbal Antidiarrheal Powder, Veterinary Vitamins, Veterinary Calcium Gel, Veterinary Pest Repellent Spray, etc. [33]. Ayurvedic products can be more effective than administering only the medicinal herbs, because of several advantages. Generally, the Ayurveda specialists collect the herbal parts at a particular stage of growth, during particular seasons to ensure that the harvested produces contain the best quality ingredients. Further, these herbs are processed with certain other products like mineral ashes (*Bhasma*) or butter oil or alcohol produced during the process itself to make the final product more effective. Thus many commercial herbal products are very popular among the farmers in India.

Several new generation products, blending different medicinal herbs and micro-nutrients are proving to be more effective and popular in the field. One such product, named as 'Roofert' has been developed to address the problem of infertility and repeat breeding [34]. It contains herbal extracts of *Latakaranja* (*Caesalpinia crista*),*Shatavari* (*Asparagus racemosus*), *Garger*(*Daucuscarota*),*Kapikachhu* (*Mucunapruriens*- velvet bean powder),*Ashwagandha* (*Withaniasomnifera*),*Gokshur* (*Tribulusterrestris*) and*Kokilaksha* (*Asteracanthalongifolia*),along with *VangBhasma* (Tin oxide). *Latakaranja*seeds serve as an antioxidant and stimulant to the uterus [35].*Shatavari* is a health tonic and used in drugs to treat reproductive ailments, as it improves female reproductive health complications including hormonal imbalance, polycystic ovarian syndrome (PCOS), follicular growth and development of oocyte,while reducing oxidative stress and increasing antioxidant level in the body [36]. It also nourishes the ovum and enhances folliculogenesis and ovulation, while

maintaining oestrogen and progesterone levels.*Kokilaksha*improves sexual stamina, because of its aphrodisiac properties [37].Both, *Kokilaksha* and *Shatavari*help to maintain the reproductive tract in good condition and support the synthesis of uterine milk, which is required for nourishing the embryo and to prevent early embryonic death. *Kapikachhu* seed is also a strong aphrodisiac.*Gokshura*is known for its immunity-boosting and aphrodisiac properties.It helps the animals in muscle development, improving endurance against stress and increasing the hormone levels [38]. *Ashwagandha* is a stress reliever. *VangBhasma*is beneficial in diseases of reproductive systems [39]. It rejuvenates the reproductive tract and helps in formation of healthy ova. Rooferthelps to maintain pH of the reproductive system, which is required to prevent sperm mortality.In a treatment study, 12 cows suffering from metritis were treated with Roofert bolus (1-0-1) for five days after completion of oestrus cycle, which resulted in a significant reduction in uterine bacterial count in 50 percent cows. The remaining 50 percent cows were treated with a repeat course of Roofert bolus. After completion of the second treatment cycle 10 cows had conceived, while the remaining 2 cows conceived after third round of Roofert treatment. The study further recorded that Roofert treatment resulted in 100 percent correction of abnormal length of oestrus cycle, which was caused by hormonal imbalance. The treatment also controlled abnormal vaginal and uterine discharge and corrected the pH of the discharge[40].

'Rookare' is another product for treating mastitis, which is a blend of trace minerals, vitamins, herbs and potassium iodide [41]. It contains minerals such as Calcium, Phosphorous, Cobalt, Copper, Selenium and Zinc, and herbal ingredients such as *Awala*(Indian Gooseberry - *Emblicaofficinalis*), *Beheda*(*Terminaliabellirica*), *Hirda*(*Terminaliachebula*), *Guggul*(*Commiphorawightii*), *Turmeric*(*Curcuma longa*),*Ginger* (Zingiberofficinale),*Neem* (*Azadirachtaindica*), and vitamins such as A, D and E, along with potassium iodide. This product derives its antifibrotic qualities from *Amla*, *Baheda*, and *Neem*. Vitamin C present in *Amla* inhibits protein kinase C, which results in increasing of cell division and proliferation. Zinc controls excessive proliferation of fibrotic cells and helps in formation of new blood vessels, thereby increasing the blood flow to healthy udder cells. Zinc also helps in early removal of dead cells. Potassium iodide removes dead and abnormal tissues and boosts the healing effect. It also supports the thyroid functioning and improves metabolism, and serves as an antiseptic to reduce somatic cell count. Turmeric, neem, ginger, *Guggul* and *Hirda* are natural anti-inflammatory herbs. Vitamin A, E and C along with Zinc and Selenium neutralize free radicals and cure inflammation. This unique combination in 'Rookare' is very effective in controlling Mastitis and helps in cleaning of alveoli by strengthening alveoli muscles. Anti-inflammatory herbs in Rookarebolus reduce inflammation and the antioxidants help to neutralize free radicals leading to lower somatic cell count in the milk. In a field studyconducted in Selu block of Parbhanidistrict,buffaloes suffering from mastitis with hard and swollen udder, producing watery milk having bad odour were treated simultaneously with Rookare bolus for 5 days at 2 bolus per day,while treating with antibiotics for 3 days.On the third day after starting the treatment, the consistency ofmilk had changed to normal, and at the end of 5 days, the hardiness of the udder was completely cleared and the milk production reached the normal level. The veterinarians reported that Rookare enabled the mastitis infected cows and buffaloes to

recoverfaster and early milk restoration after mastitis (Personal communication with Dr. AshwinBharad, at Selu, in Parbhani, Maharashtra).

'Roocal Gel' is an effective nano-product to treat milk fever. In a trial conducted on 6 different groups of cattle and buffaloes, showing theserum calcium level below the normal level of 8.4 mg/dl of blood, oral administration of Roocal Gel increased the serum calcium level above 8.4 mg/dl in 60 minutes. The serum calcium level further increased gradually, without any side effects[42].

'Nesstmin' is a promising product comprising of all the essential elements such as Cu, Zn, Fe, Co, I, Mn, Cr and Se, made available easily in nano-forms, with an average particle size of 250-300 nm.These minerals are essential for growth and development of immunity in the animal body. Such products are effective in treating the animals efficiently and economically, because of their multi-dimensional approach to control the problem and use nano-materials, which are required in very small quantity, along withlocally available herbs.

Livestock also suffer from various ailments caused by various parasites.There are excellent herbal products, apart from well-established home remedies to treat ecto-parasites and endo-parasites. The leaves and fruits of neem and certain other species can be used as an alternative to chemicals to treat infestations of ecto-parasites and wounds [43]. Herbal formulations made up of parts of plants such as *Gulvel* (*Tinosporacordifolia*), *Chibad* (*Cucumissativus var. hardwickii*), Neem (*A. indica*), *Nirgudi* (*Vitexnegundo*), *Vekhanda* (*Acoruscalamus*) can effectively control ticks [44].Leaf extract of *Nirgundi* (*Vitexnegundo*), Aloe (*Aloe vera*), Neem seeds, *Kirayat*(*Andrographispaniculata*) and *Akamadar* (*Calotrophis*) can effectively control intestinal worms [45]. Treatment of livestock with medicinal plants, having antibacterial activity is beneficial because of several reasons. Medicinal plants such as garlic, turmeric, basil and neem can act as immune-stimulants, which trigger early activation of non-specific defence mechanism in animals and enhance specific immune responses. Several such herbal products are now produced and marketed in India.

Theother benefits of herbal medicines are absence of any side effects on the animals and confidence in usage by the farmers and para-vets, with the initial knowledge acquired from the veterinarians. These products are very economical, because of lower cost. Some of the products also help to boost immunity and keep the animals healthy.

Opportunities in the Future

Ethno-veterinary practices and Veterinary Ayurveda are very well established fields of science and accepted by the veterinary professionals and farmers in India and many other countries, all over the world. However this branch of science has not received due credit and support from the policy makers, scientific community, field professionals and livestock owners so far, because of several reasons. Major reasons for the neglect of this sector are lack of effort to document the knowledge from ancient scripts and traditional field practitioners, lack of encouragement and financial support for research, poor emphasis on traditional medicine in formal professional courses, lack of extension services to popularise the benefits of medicinal herbs and Ayurveda among the professionals and farmers.

Nanotechnology is another important cutting edge science, which can benefit the farmers to produce safer food at lower cost.Apart from serving as nutrients and biocides, nano-particles can also help to carry various medicinal molecules to different organs requiring treatment without any degeneration [46]. Therefore, future investment on research should focus on using nanotechnology in Ayurveda and development of new products combing these two components to address various challenges faced by livestock owners. It is necessary to address these issues on priority through policy support and financial commitment for research, development and education. Hopefully, large number of herbal based medicinal products will be developed and greater awareness is created among the students, field professional and farmers,about the advantages of nanotechnology based Ayurveda in the future.

Conclusions

Livestock sector is an important source of livelihood and food security in India and other developing countries in Asia and Africa, particularly because of its potential to empower the poor and marginal land holders. There is further scope to increase the productivity and income by addressing the critical challenges such as genetical upgradation, nutritional supplementation and effective health care. Ayurveda and nanotechnology are proving to be very effective in addressing the health and nutritional needs because of their efficiency, safety and economy, apart from convenience. New generation products blending medicinal herbs and nano-particles of nutrients, carriers and biocides to address the health and nutritional issues can prove to be the game-changers, particularly in the dairy husbandry sector in India. Greater awareness to reach the field professionals and farmers about the advantages of these products and further research to develop new products are needed to tap the benefits of dairy farming further, while boosting the national economy.

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