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Review on the Potentials of Cow (*Bos indicus*) Based Bioenhancers in Increasing Crop Yield and Farmers Income as well as the Soil Health and Environmental Sustainability

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Authors' contributions

This work was carried out in collaboration between all authors. Author Ashwani Kumar designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SB and Akansha Kushwaha managed the analyses of the study. Authors AP and NP managed the literature searches. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

The haphazard use of the chemical fertilizers and pesticides has detrimental effects on soil health, human health, groundwater quality and environment. This will cause more dangerous consequences for future productivity. Present status of all food grain production is in enough quantity for the population of our country but there is need to enhance the quality of food production, quality of soil, quality of ground water and quality of a healthy environment for better livelihood. These qualities can be obtained by replacing toxic chemicals through natural and organic input which is more vital for present prospect and future outlook. The "Cow" occupies the highest place of honour in Indian civilization. She is supposed to fulfil all desires of human beings,

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hence known as “Kamdhenu”. Owing to ignorance, after stopping of milk production, they are left uncared for forced to live extensively and eat polythene and other wastes in towns and cities. It is interesting that in Indian agricultural systems “Cow” particularly those with a hump (indigenous breed) is one of the key components, hence provision of at least one cow per hectare need to be promoted for Jaivik Krishi activities in organic farming. This review paper attempts to bring together the different use of cow based organic formulations in crop production and protection. It has been reported that organic formulation in crop production is productive and sustainable, but there is a need for strong support to it in the form of manifestation of subsidies, agricultural extension services and intensive research with solid proofs. With these efforts we can fulfil the dream of our present government; to double the income of Indian farmers.

Keywords: Bos indicus; cow-dung; cow-urine; bioenhancers; sustainable agriculture; organic farming.

1. INTRODUCTION

The exploitative agriculture for a long time in India has brought down the fertility status of the soil to a level that even provision of the high rate of fertilizers is unable to sustain the productivity of the soil. So as to sustain the productivity of soil and promote the health of the soil, combine use of organic and chemical fertilizers is imperative. The utilization of organic manure not only best serves with manage crop yields but also play a key role towards exhibiting both direct as well as indirect influence on the nutrient accessibility in soil by improving the physical, chemical and biological properties of soil and likewise enhances the utilization effectiveness of applied fertilizers. The escalating price of fertilizers in recent years, limit their use in crop production. Gupta and Yadav conducted a field trial in kharif season for evaluating cow urine efficacy against stem borers and cost-benefit in soybean production. Highest cost benefit ratio (1:18.9) was obtained from 75% cow urine [1,2]. Khanal carried out a field experiment in Nepal on farmer’s field during 2009-2010, to test the efficacy of cattle urine alone and in combination with urea as a potential supplement to nitrogenous fertilizers in improving yield and quality of cauliflower cv. Kathmandu Local. The highest curd yield and the highest benefit-cost ratio (5.84) were observed by application of 100 kg N ha-1 through urine [3]. The foliar spray of cow urine and water was studied on green gram. The use of foliar spray of cow urine results the higher gross (Rs. 22504) and net returns (Rs. 12558) with B: C ratio (2.32) per hectare due to foliar application of cow urine [4].

About 99.7% of human food comes from cropland, which is shrinking by more than 10 million hectares (almost 37,000 square miles) a year due to soil erosion. Arable land per person has already shrunk from 0.24 ha in 1950 to 0.12 ha today (Grain area of 732 million hectares (mha) in 1981 shrunk to 690 mha in 1999 as it was converted to non-farm uses like urban and industrial developments and abandoned due to soil erosion (Report of United Nation Environment Programme,1999). In the next 20 years, the world needs to produce enough food to feed an additional 70 million people per year [5,6].The Indian epic *Ramayana* described the importance of organic matter in soil management as “all dead things – rotting corpse or stinking garbage – returned to earth are transformed into wholesome things that nourish life. Such is the alchemy of motherearth.” In Vedas, soil was considered as ‘Mother’ and the human beings were treated as her ‘Sons’: “*Mata bhumi putro aham prthvya*” (Atharva Veda12.1.12) [7]. In the modern context, in similar vein, described soil as the mother of any agricultural activity [8]. It is now well established that every animate and inanimate objects emit energy of light which can be measured through Kirlian photography. In fact, the Vedic people knew it since 3500 BC. It is found that every plant has some energy level. In fact cow products are potent source for enhancing the aura energy of plants and thus helping in boosting the plant vigour and managing pest problems as enumerated below.

1.1 Cow and Aura Energy

Light emittion from animate and inanimate objects is known as Aura energy. An electronic gadget named as Universal Thermo Scanner which instantly measures the bio energy field of animate and inanimate objects. This instrument works on the principle of Aura energy and wave length. Such plants show negative energy which can be quantified by using Universal Scanner. Dr Murthy has measured energies of cow products known as Panchagavya. He has got amazing results to modern scientific world e.g. humans have positive energy of 2.5 to 2.8 m (m ‘Aura

energy measured in meters). While the cow has Aura energy of 4.5 to 6.0 m' and her products known as Panchagavya have Aura energy between 6-14 m'. Since cow products are the major ingredients in preparation of bio enhancers, hence salient features of these cow products are enumerated as follows:

1.2 Cow Dung

The use of cow dung has been indicated since the time of Kautilya (C.300 BC) and it was used for dressing seeds, plastering cut ends of vegetative propagated sugar cane, dressing of wounds, sprinkling of diluted solution on crop since ancient times. There are more than 60 species of bacteria and over 100 species of protozoa encountered in the rumen of cow. Bile salts confer hydrophilic coat to otherwise hydrophobic droplets, thus acting as emulsifying agents and have antiseptic properties. They have also identified Actinomycetes as *Streptosporangium pseudovulgare* which has shown anti-pathogenic potential against *Colletotrichum gloeosporioides* (anthracnose pathogen) and *L. theobromae* (gummosis, stem end rot and die back pathogens.

1.3 Cow Urine

The use of cow urine is known for a long time in India. *Gaw-mutra* (cow's urine) has been described as a liquid with innumerable therapeutic values, capable of curing several incurable diseases in human beings and plants. Cow urine is rich source of macro, micronutrients and has disinfectant and prophylactic properties. It purifies the atmosphere and improves the soil fertility. Cow urine has amazing germicidal power to kill wide varieties of germs. It helps in the proper functioning of the liver which ensures supply of healthy and pure blood. It gives disease resistance power to the body.

1.4 Cow's Milk

Cow's milk is called "*Gorasa*" or the juice excreted from the body of the cow. Indigenous cow *(Bos indicus)* milk possesses less cholesterol and high protein having high biological and nutritional value. Milk from an indigenous breed of cow is known to have better therapeutic values. Microbes like *Lacto bacillus* present in it, produce organic acids that promote crop growth and resists pathogens. Its regular consumption enhances physical and mental strength, keeps the body healthy and increases the potency. Cow curd and buttermilk are good appetizers and keep the digestive system normal through sustainable maintenance of pro-biotic bacteria.

1.5 Buttermilk

Buttermilk is by-product obtained during process of preparation of butter/ghee. It has lot of therapeutic values for human health and agriculture. Two to three weeks fermented butter milk had been used for the management of pests and diseases since ancient times. In a study, 35 bacterial and 21 yeast isolates have been isolated at HPKVV, Palampur and Himachal Pradesh. In *vitro* tests, 11 bacterial and 8 yeast isolates exhibited pro biotic activities. Four sp. Bacterial pro biotic were effective against selected plant pathogens with or without combination of cow urine.

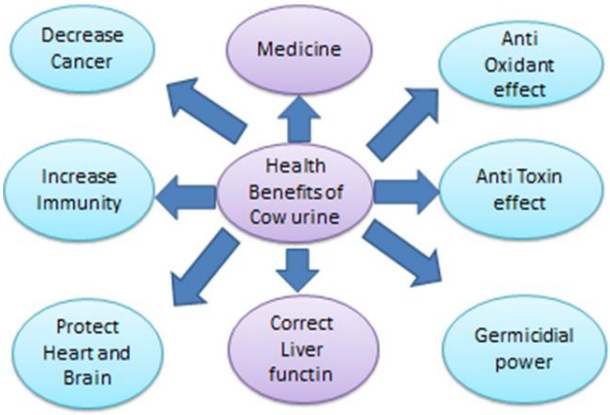

Fig. 1. Benificial effects of cow urine

1.6 Cow Ghee

Cow ghee is a very special medicinal substance and used in preparations of some bio-enhancers viz; amritpani and panchagavya and when used in agnihotra fire, acts as a carrier agent for subtle energies. Ghee is also rich source of energy among all the organic compounds, it comprises of glycerol, saturated and unsaturated fatty acids. Energies of Sun are captured through ghee and their impacts is spread over vast area which nourishes and strengthen every living being, where resonance point has been established [9].

2. STRATEGIES

- Rearing of indigenous cow *(Bos indicus)* need to be promoted in villages and cities to promote Jaivik Krishi.
- Indian breed of cows, which have hump is supposed to capture more cosmic energies, hence these need to be protected and promoted in every region of the country.
- Besides milk, (a health tonic) role of other bi-products i.e. dung, urine etc. also need to be documented and promoted.
- Intensive training programme need to be organized on various aspects to use cow bi-products in production system.
- Various organic production systems need to be evaluated to assess their efficacy.
- There is need to assess the possibility of integrating different organic production systems in order to obtain full potentialities.
- There is need to prepare package of practice for different crops being grown in different agro-climatic conditions.
- Mass awareness campaign is required to convey the message for the consumption of Jaivik produced commodities.
- There is need to help growers for certification, post harvest handling, value addition and domestic and overseas marketing.

2.1 Cow Urine in Organic and Natural Farming

Cadmium (Cd) losses in subsurface flow from stony soils that have received cow urine are potentially important, but poorly understood. This study investigated Cd loss from a soil under a winter dairy-grazed forage crop that was grazed either conventionally (24 h) or with restricted grazing (6 h). However, Cl concentrations in drainage were significantly higher ($P < 0.001$) from the 24-h than the 6-h grazed treatment plots, and positively correlated with Cd concentrations, and therefore, a possible mechanism increasing Cd mobility in soil. Further

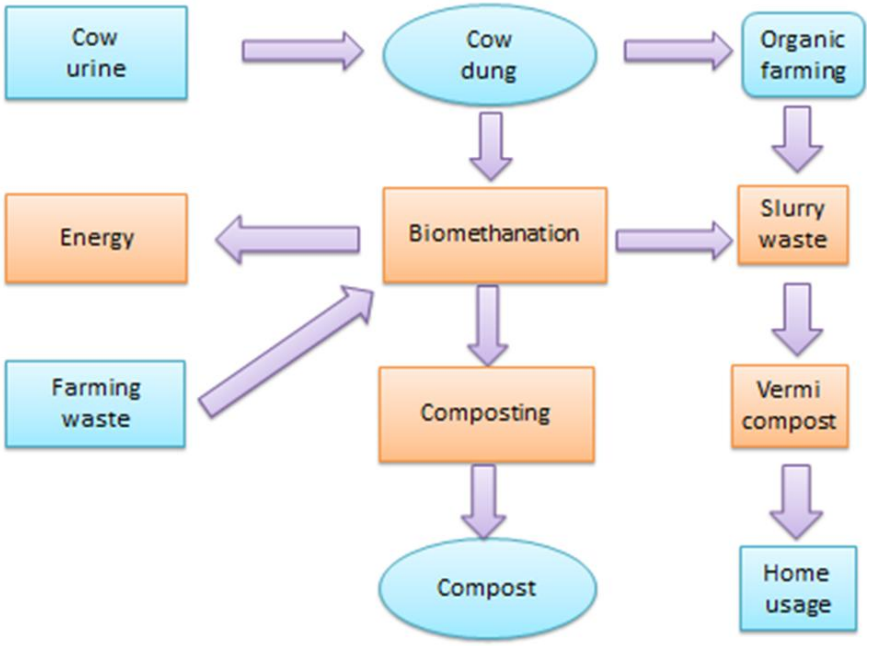

Fig. 2. Flow chart of use of cow dung and farming waste

study is warranted to confirm the mechanisms involved and quantities of Cd lost from other systems [10]. Patches of excreta voided by grazing animals are nitrogen (N) transformation hotspots in grassland ecosystems and an important source of N trace gas emissions and leaching. Only 0.01-0.12% of excreta N was lost via NO, whereas 1.69-12.7%, 0-4.58%, 16.4-24.6%, and 1.43-5.91% were lost by NH_3 and NH_4^+, NO_3^-, and leaching, respectively. The combined N_2O emission factors for dung and urine from cattle and sheep were 0.59% and 0.26%, respectively. More field studies are needed in the future with longer measurement periods from a wide range of climate zones to refine these N loss factors [11]. Fertilization with Se improves forage organic Se concentration, but comparisons with other forms of Se supplementation in feeding lactating dairy cows are scarce. Treatments consisted of 4 diets: control with low Se silages, without Se supplement (0.12±0.04 mg of Se/kg of DM); ISe with low Se silages and inorganic Se (0.80±0.14 mg of Se/kg of DM); YSe with low Se silages and organic Se from yeast (0.70±0.11 mg of Se/kg of DM); and FSe with high Se silages, without Se supplement (0.79±0.14 mg of Se/kg of DM). Results from the current study showed that the production of Se-enriched forages is an effective method to supplement dairy cows in Se as it was more available than YSe, and did not alter antioxidant status and performances of lactating dairy cows [12].

2.2 Cow *(Bos indicus)* Based Organic Farming

The present study investigated the use of fatty acid (FA) profiling in combination with chemometric modelling to verify claims for cow milk in terms of fresh grass feeding, pasture grazing and organic/biodynamic farming. The FA profile was determined for 113 tank milk samples collected in the Netherlands from 30 farms over four different months, and used to develop classification models based on the algorithm. Milk from cows at pasture could easily be distinguished from milk from stabled cows without fresh grass in the diet, but the correct prediction of milk from stabled cows fed fresh grass indoors proved difficult. The FA profile of organic/biodynamic milk was different compared to conventional milk but an unequivocal discrimination was not possible either in summer or in winter [13]. Conjugated Linoleic Acid (CLA) levels and fatty acid composition were measured to compare the fat composition in organic bulk milk, destined to the production of Grana Padano cheese, with those produced by the conventional system. The curds and Grana Padano cheeses were also analysed to evaluate the effects of the production technology on the CLA content. The animal diet appears to be the factor which has the highest effect on the CLA concentration in milk and milk products and an organic diet based on fresh or dried forage, that is rich in CLA precursory fatty acids, may improve the yield of fatty acids with beneficial effects on health [14]. The use of anthelmintics is strongly limited in organic farming. This may induce a change in the intensity (no. of worms) and diversity (proportions of species) of helminth infection. Helminths remain a major preoccupation in organic sheep farming: high levels of infection have been recorded on several farms and helminth diversity is always higher. Additionally, alternative treatments are used. The alternative therapies based on phytotherapy or homoeopathy is largely recommended in organic farming but do not have any demonstrated efficacy. More research is needed to evaluate such therapies [15]. Medication is an important focus area in organic animal husbandry. The combination of goals relating to improved animal welfare and reduced use of chemicals in general creates a common wish to reduce medication. In a study of development of health advisory service in organic herds, the dialogue between farmer, veterinarian and agricultural cattle advisor changed the treatment pattern markedly during a period of 6 months. Among important future challenges for veterinarians in organic farming is pointed at the constructive, open, and critical interaction with the single organic farmer as well as the organic animal husbandry system in general [16].

2.3 Characterization of Cow Dung for Farming System

Molecular characterizations of *Cryptosporidium* spp. in ruminants reared under traditional animal management systems are scarce and studies conducted thus far have revealed largely an absence of the pathogenic and zoonotic species. Cryptosporidium parvum in pre-weaned animals *Cryptosporidium*-positive specimens from pre-weaned calves on 10 farms and goat kids on 4 farms in Ankara, Balikesir, Corum, Kirikkale, and Kirsehir Provinces, [17] Turkey were genotyped by PCR-restriction length polymorphism analysis of the small subunit rRNA gene, which identified C. parvum in 27 calves and 9 goat kids and *Cryptosporidium ryanae* in 1 calf. Among the *C.*

parvum isolates successfully subtyped by DNA sequence analysis of the 60 kDa glycoprotein gene, three subtypes were detected in calves, including IIaA13G2R1 (20/23), IIdA18G1 (2/23), and IIdA20G1b (1/23), and four subtypes were detected in goat kids, including IIaA13G2R1 (3/8), IIaA15G1R1 (2/8), IIdA22G1 (2/8), and IIdA18G1 (1/8). [18]. Agriculture is one of the largest anthropogenic sources of greenhouse gases (GHGs) with dairy and beef production accounting for nearly two-thirds of emissions. Several recent papers suggest that dung beetles may affect fluxes of GHGs from cattle farming. Here, we put these previous findings into context. This mismatch derives from the fact that in intensive production systems, only a limited fraction of all cow pats end up on pastures, offering limited scope for dung beetle mitigation of GHG fluxes. These considerations give a new perspective on previous results, [corrected] and suggest that studies of biotic effects on GHG emissions from dung pats on a global scale are a priority for current research [19]. The weight gain performance and oocysts reduction, as response to the metaphylactic treatment with Diclazuril 0.25% at the start of a coccidiosis outbreak, was studied by a cases-controls transverse study [20]. The total contributions of steroids to the environment in China are estimated to be 139, 65.8 and 60.7 t/year from dairy cattle and human sources respectively [21]. The aim of this study was to establish if food production animals (cow cattle) and the wider farm environment were playing a role in the transmission of Cronobacter spp. was not carried by food production animals but was present in a range of diverse sample types and environs with particular association with dry environments [22]. Giardiasis is a notifiable disease of high prevalence in New Zealand, but there is limited knowledge about the sources of *Giardia duodenalis* genotypes. Significantly, no assemblage E (the genotype commonly found in cattle elsewhere in the world) has been detected in New Zealand livestock to date [23]. To estimate the prevalence of *E. coli* O157:H7 in milk and cattle faecal samples dairy and non dairy neighbouring households and to relate this prevalence to the risk to human health [24]. After prophylactic treatment of 50 calves with 62 mgkg (-1) day (-1) of sulfadimethoxine (SDM) for five days, the levels of the drug over time were followed in feces, bedding and stable manure, and then in the soil of a manured field and surrounding drainage courses. Analysis was done by HPLC after applying to the different matrices a quick and simple extraction procedure. The test gave negative results both after 24 and 48 h, confirming that microcrustaceans are less sensitive than other models to the toxicity of antibacterials. However, based on data from other authors, concerning algal toxicity and microbial inhibition, and on the analytical results from the current field study, the calculated worst-case EC50/PEC ratio for SDM both in freshwater and in soil was still >1000 [25]. Domestic environmental pollution resulting from urban livestock farming was investigated in Makurdi using parasitological techniques [26]. The high rate of parasitic infections in these areas might be related to the poor management by the farmers such as sharing the same grazing pasture [27].

Incompletely sealed rubber liners fitted to a milking machine shortly before the outbreak started was the probable reason, allowing faecal material to contaminate the milk over the period concerned [28]. The objectives of this study were to investigate the relationship between the concentrations of progesterone (P4) in the peripheral circulation and progestins in the faeces of cows in a smallholder farming area and to monitor the ovarian activity of such cows. During the dry season, most cows (58%) became acyclic as forage became scarce and of poor quality. Thirty-two calves were born during the study period, mostly during the first or last two months of the year, when there was enough forage. By the end of the dry season, the cows had lost, on average, 15% of their peak weight [29]. The reproductive performance of 46 cows in a semi-arid, smallholder farming area of Zimbabwe was monitored for a year. Half the cows were used throughout the monitoring period for various draught purposes, including ploughing and procurement of farm produce for marketing using carts. Body weights were significantly higher ($p < 0.05$) in non-working than in working cows in January and February. Ovarian activity was higher ($p < 0.001$) in non-working compared to working cows, particularly between November and February, while calving rates were also higher ($p < 0.05$) in non-working cows. It is concluded that using cows for draught purposes caused loss of body weight and reduced ovarian activity and conception rates [30].

During a microhistological study of faeces from domestic ruminants (cattle, sheep, goats), centrifugation was used to increase from 11 (classic method) to 93% the rate of dicotyledon epidermis in the total particles of the suspension. Regardless of the conservation method used

(drying or addition of salt, formol or ethanol), a better analysis of the dicotyledon part of the diet was obtained [31]. The chemical composition of grazing cattle, sheep and goat feces is described according to animal species, type of range (natural pasture or fields after crops) and season in a sub-Sahelian environment. Nutritive value (organic matter digestibility and digestible crude protein) of forages can be estimated from some chemical fecal criteria [32]. The prevalence of antibodies to *Brucella spp*, *Mycobacterium paratuberculosis* and the *Mycoplasma spp*. causing contagious bovine pleuropneumonia and contagious caprine pleuropneumonia was determined in various species of ruminants on a ranch in the semi-arid zone of southeastern Kenya. The possible occurrence of tuberculosis in camels is discussed. Under the conditions at the ranch, contagious bacterial diseases appear to be of minor importance in the domesticated wild herbivores. The introduced camels, however, might be a source of various infections such as brucellosis, mycoplasmosis and possibly tuberculosis for the other susceptible species [33]. Hoof health in clean cattle farming [34]. [Chemical and physical properties of semi-liquid manure in industralized livestock farming with reference to aspects of process technology and hygiene] [35].

2.4 Cow Dung Analysis for Organic and Untainted Production

Methane (CH_4) production and quality were enhanced by the co-digestion of cow dung and food waste (FW) mixed with organic fraction of municipal solid waste (OFMSW) under optimized conditions in bench and semi continuous-scale mode for a period of 30 days. Gas chromatography was used to analyze the chemical compositions of the generated biogas. CH_4 yields were significantly higher during co-digestion of Run II (7.59 L) than Run I (3.7 L). Therefore, the co-digestion of FW with OFMSW and Run II was observed to be a competent method for biogas conversion from organic waste resources [36]. The interaction of monensin and 2 supplemental Mg sources (MgO and $MgSO_4$) on total-tract digestion of minerals and organic nutrients and milk production was evaluated in lactating dairy cattle. Eighteen multiparous Holstein cows (139 ± 35 DIM) were used in a split-plot experiment with 0 or 14 mg/kg diet DM of monensin as the whole-plot treatments and Mg source as split-plot treatments. A diet with $MgSO_4$ without monensin increased the concentration of long-chain fatty acids in milk, suggesting increased mobilization of body fat or decreased de novo fatty acid synthesis in the mammary gland. Overall, when dietary Mg was similar, MgO was the superior Mg source for lactating dairy cattle, but inclusion of monensin in diets should be considered when evaluating Mg sources [37].The effect of copper (added as $CuCl_2$) on the anaerobic co-digestion of Phragmites straw and cow dung was studied in pilot experiments by investigating the biogas properties, process stability, substrate degradation and enzyme activities at different stages of mesophilic fermentation. Taking the whole fermentation process into account, the promoting effect of Cu^{2+} addition on biogas yields was mainly attributable to better process stability, the enhanced degradation of lignin and hemicellulose, the transformation of intermediates into VFA, and the generation of CH_4 from VFA [38]. Control of parasitic gastroenteritis in cattle is typically based on group treatments with anthelmintics, complemented by grazing management, where feasible. However, the almost inevitable evolution of resistance in parasitic nematodes to anthelmintics over time necessitates a reappraisal of their use in order to reduce selection pressure. This study has shown that acceptable growth rates can be achieved in FGS cattle with modest levels of treatment and correspondingly less exposure of their nematode populations to anthelmintics, which should mitigate selection pressure for resistance by increasing the size of the refugia in both hosts and pasture [39].The aim of this study was to assess the prevalence of the major helminth infections affecting organic dairy cattle in northern Spain. Milk and faecal samples were obtained from 443 milking cows. Treatment of cows with fasciolicides decreased the risk of F. hepatica infection in multiparous cows, whereas treatment with oxiclozanide or albendazol did not decrease the risk of C. daubneyi infection or O. Special attention should be paid to the impact of these infections on milk production [40].Biogas production from cow dung with co-substrate agricultural waste is one of the most demanding technologies for generating energy in a sustainable approach considering eco-friendly. The chemical composition of the substrates before digestion and after fermentation (biogas spent sludge) were measured in terms of fiber content and the values were noted as, total solids (0.53%), ash content (9.2%), volatile fatty acid (100 mg/L), organic carbon (46%) and a total carbohydrate (179 mg/g). The outcome of the study has supported the fact of conventional

combustion technology that has to be upgraded to prevent these hazardous emissions into the atmosphere [41].

The reduction of the gastrointestinal nematode (GIN) larvae population in faeces of cattle treated with Duddingtonia flagrans chlamydospores on a farm under an organic production system in Chiapas, Mexico, was assessed.flagrans diminished at 25.1% with respect to the control group ($p > 0.05$). A mixture of GIN genera including *Strongyloides sp., Haemonchus sp., Cooperia sp., Trichostrongylus sp., Oesophagostomum sp. and Mecistocirrus sp.*, were identified from coprocultures. It was concluded that treatment with *D. flagrans* chlamydospores reduces the GIN larvae population in grass and in faeces of calves maintained under an organic milk production system [42].The importance of nickel (added as $NiCl_2$) on mesophilic anaerobic fermentation of Phragmites australis straw and cow dung was demonstrated by investigating the biogas properties, pH values, organic matter degradation [chemical oxygen demand (COD)] and enzyme activities (cellulase, protease and dehydrogenase) during the fermentation process. After the start-up stage, the impact of Ni^{2+} addition on biogas production was mainly dependent on its effect on cellulase activities, rather than protease or dehydrogenase activities [43]. Appropriate trace mineral supplementation can improve immune response and hoof health in cattle and at much higher rates of supplementation to swine and poultry can alter microbial colonization of the gut, resulting in improved gut health.To our knowledge this is the first report of a dietary treatment decreasing the relative abundance of Treponema OTU in cattle feces; however, the potential benefits of this response on overall animal health and the mechanism for the observed responses are unknown and warrant further investigation [44]. A two-phase digestion system for treating agricultural waste is beneficial for methane production. This study explored the effect of solid content, temperature, and mixing mode on the process of hydrolysis and acidification using rice straw and cow dung launched in non-airtight acidogenic system. In addition, the study comprehensively analyzed a series of corresponding relationships among each operating parameter during the whole treatment process using canonical correspondence analysis [45]. The majority of foodborne outbreaks in the United States associated with the consumption of leafy greens contaminated with *Escherichia coli* O157:H7 have been reported during the period of July to November. For the second crop, the probabilities of having at least one plant with at least 1 CFU of *E. coli* O157:H7 in a crop were predicted as 15/228 (6.6%), 5/333 (1.5%), 14/324 (4.3%), and 6/115 (5.2%) in August, September, October, and November respectively. For organic fields, the probabilities of having at least one plant with ≥1 CFU of *E. coli* O157:H7 in a crop (3.45%) were predicted to be higher than those for the conventional fields (2.15%) [46].

Bioaugmentation using microbial consortia is helpful in some anaerobic digestion (AD) systems, but accelerated acidification to produce methane has not been performed effectively with corn stalks and cow dung. Similar trends were also observed in the unsterilized system, where the hemicellulose degradation rate and organic acid concentrations increased significantly by two-fold and 20.1% ($P<0.05$), respectively, and clearly reduced the loss of product. Finally, the acidogenic fluid improved methane yield significantly ($P<0.05$) via bioaugmentation [47]. Vermicomposting is a low-cost, eco-efficient process to deal with organic wastes. Moreover, the conversion of solids; the modified pH value; the reduction in total organic carbon (TOC); total Kjeldahl nitrogen (TKN), NH4-N, NO3-N, and C:N ratio; and the rich in total available phosphorus (TAP) and total potassium (TK) content by young and adult *E. fetida* were related to the growth of worms. Such work would benefit understanding and to increase the efficiency of vermicompost processing of different wastes [48]. India has a giant jute-producing basket which produces considerable quantity of toxic jute mill waste (JMW). Conversely, report on usability potential of JMW is rather scanty. The present study illustrates the efficiency of vermicomposting in bioconversion of JMW for agricultural use. A significant decline in heavy metal concentration (Cr, Pb, Fe, and Zn) in the vermicomposted JMW further establishes the potential of vermicomposting with *M. posthuma* in successful conversion of the toxic JMW into valuable product [49]. Nitrate may lower methane production in ruminants by competing with methanogenesis for available hydrogen in the rumen. In conclusion, nitrate lowered methane production linearly with minor effects on rumen fermentation and no effects on nutrient digestibility [50]. Fertilization with Se improves forage organic Se concentration, but comparisons with other forms of Se supplementation in feeding lactating dairy cows

are scarce. Dry matter intake, yield of actual, energy-corrected, and fat-corrected milk, as well as milk fat and lactose concentrations, were not affected by the dietary treatments. Cows fed ISe had lower milk protein concentration (3.44%) than cows fed YSe (3.58%) or FSe (3.51%). Results from the current study showed that the production of Se-enriched forages is an effective method to supplement dairy cows in Se as it was more available than YSe, and did not alter antioxidant status and performances of lactating dairy cows [51].

The effect of ferrous (added as $FeCl_2$) on the anaerobic co-digestion of Phragmites straw and cow dung was studied by investigating the biogas properties, pH values, organic matter degradation (COD) and enzyme activities (cellulase, protease and dehydrogenase) at different stages of mesophilic fermentation. At the end of fermentation (26th day), Fe(2+) addition decreased the cellulase activities led to lower COD contents and finally resulted the lower biogas yields than the control group. Taking the whole fermentation process into account, the promoting effect of Fe(2+) addition on biogas yields was mainly attributed to the extension of the gas production peak stage and the improvement of cellulase activities [52]. The application of cow dung ash was assessed for the removal of organic contamination from the wastewater using landfill leachate of known Chemical Oxygen Demand (COD) concentration in batch mode. The effect of various parameters like adsorbents dose, time, pH and temperature was investigated. Scanning electron microscope (SEM) images shows that after the activation, carbon particles disintegrate and surface of particles become more rough and porous, indicating the reason for high adsorption efficiency of ACA. Hence, ACA offers a cost-effective solution for the removal of organic contaminants from the wastewater and for the direct treatment of landfill leachate [53]. Milk production strategies focusing on longevity and limited use of concentrate are receiving increasing attention. To evaluate such strategies, knowledge of the development with age of animal characteristics, particularly digestion, is indispensable. Heifers spent more time eating and ruminating per unit of feed than cows, which resulted in a high fiber digestibility. Irrespective of the feeding regimen tested, older cows maintained intake and digestion efficiency with longer retention times and chewing rumination boluses more intensively. The results support efforts to extend the length of productive life in dairy cows [54]. Vermicomposting of animal wastewater treatment plant sludge (S) mixed with cow dung (CD) or swine manure (SM) employing *Eisenia fetida* was tested. The numbers, weights, clitellum development, and cocoon production were monitored for 60 days at a detecting interval of 15 days. The results provided the theory basic both for management of animal wastes and the production of earthworm proteins using *E. fetida* [55].

The objective of this study was to evaluate the effect of different forms of trace minerals (TM) and the use of different starch levels in dairy heifer diets on rumen fermentation and digestibility. Eight rumen cannulated dairy heifers (15.4 ± 0.8 mo of age and 438.31 ± 18.08 kg of body weight) were subjected to a split-plot, 4 × 4 Latin square design with 19-d periods: 15d of adaptation and 4d of sampling. Also, TM form affected fecal moisture and urine excretion, suggesting that ITM may stimulate water intake [56]. The aim of this study was to investigate the biochemical disintegration effect of hydrolytic enzymes in lab scale experiments. Influences of enzyme addition on the biogas yield as well as effects on the process stability were examined. The addition of proteases occurred with low and high dosages in batch and semi-continuous biogas tests. The feed mixture consisted of maize silage, chicken dung and cow manure. Phenylacetate and -propionate increased (up to 372 mgl (-1)) before the other volatile fatty acids did. Volatile organic acids rose up to 6.8 gl (-1). The anaerobic digestion process was inhibited [57]. In this study modeled full scale application of thermobarical hydrolysis of less degradable feedstock for biomethanation was assessed in terms of energy balance, greenhouse gas emissions, and economy. The integration of thermobarical pretreatment is beneficial for raw material with high contents of organic dry matter and ligno-cellulose: Solid cattle waste revealed very short payback times, e.g. 9 months for energy, 3 months for greenhouse gases, and 3 years 3 months for economic amortization, whereas, in contrast, liquid cattle waste did not perform positive replacement effects in this analysis [58]. Zero liquid discharge is currently an objective in livestock manure management to minimize water pollution. The specific methane (CH4) yield ranged from 165.4 ± 9.8 to 213.9 ± 13.6 NL CH4 kg(-1) volatile solids (VS) with an overall average of 188 ± 17 NL CH4 kg(-1) VS during 11 successive start-up cycles (231 days) and a maximum CH4 production rate of 10.2 ± 0.6 NL CH4 kg(-1) VS day(-1). The

inoculum-to-substrate (VS-based) ratio ranged from 4.06 to 4.47. It is possible start up psychrophilic dry anaerobic digestion of cow feces and wheat straw at feed TS of 35% within 7-10 successive cycles (147-210 days) [59].

Aim of this study was to find out suitable mixing ratio of food waste and rice husk for their co-digestion in order to overcome VFA accumulation in digestion of food waste alone. Four mixing ratios of food waste and rice husk with C/N ratios of 20, 25, 30 and 35 were subjected to a lab scale anaerobic batch experiment under mesophilic conditions. Biogas yield decreased with decrease in food waste proportion. In experiment 2, feedstock with C/N ratio 20 was subjected to anaerobic digestion at five S/I ratios of 0.25, 0.5, 1.0, 1.5 and 2.0. Specific biogas yield of 557L/kgVS was obtained at S/I ratio of 0.25. However, VFA accumulation occurred at higher S /me ratios due to higher organic loadings [60]. This paper reports experimental results which demonstrate psychrophilic dry anaerobic digestion of cow feces during long-term operation in sequence batch reactor. An average specific methane yield (SMY) of 184.9 ± 24.0, 189.9 ± 27.3, and 222 ± 27.7 (N)L CH4 kg(-1) of VS fed has been achieved at an organic loading rate of 3.0, 4.0, and 5.0 g TCOD kg(-1) inoculum d(-1) and TCL of 21 days, respectively. Average methane production rate of 10 ± 1.4(N) L CH4 kg(-1) VS fed d(-1) has been obtained. The low concentration of volatile fatty acids indicated that hydrolysis was the reaction limiting step [61]. In the present work bagasse (B) i.e waste of the sugar industry, was fed to *Eisenia fetida* with cattle dung (CD) support as feed material at various ratios (waste: CD) of 0:100 (B0), 25:75 (B25), 50:50 (B50), 75:25 (B75) and 100:0 (B100) on dry weight basis. Heavy metals decreased significantly from initial except zinc, iron and manganese which increased significantly. The post-vermicomposted ratios in the presence of earthworms validate more surface changes that prove to be good manure. The results observed from the present study indicated that the earthworm *E. fetida* was able to change bagasse waste into nutrient-rich manure and thus play a major role in industrial waste management [62]. The recently developed concept of high rate vermicomposting was successfully used to enable direct vermicomoposting of neem leaves-without any pre-composting or cow dung supplementation as previously reported processes had necessitated. In this period, all reactors were pulse-fed at the solid retention time of 20 days and were operated in the pseudo discretized continuous operation protocol developed earlier by the authors. The findings, thus, conclusively prove that, all-through, the brisk vermicomposting was caused almost entirely by the action of the 'parent' earthworms on fresh feed [63].

The aim of the present experiment was to compare silage prepared from maize having a brown midrib (BMR) mutation with control (CTR) maize to identify their effects on enteric methane emission, digesta mean retention time (MRT), ruminal fermentation and digestibility. Neither faecal archaeol content [µg/g] nor daily amount excreted [mg/d] is suitable to predict methane production in absolute terms [l per day]. However, faecal archaeol content has a certain potential for predicting the methane yield [l per kg DM intake] of individual animals [64]. The objective of this study was to investigate the effects of starch varying in rate of fermentation and level of inclusion in the diet in exchange for fiber on methane (CH4) production of dairy cows. Forty Holstein-Friesian lactating dairy cows of which 16 were rumen cannulated were grouped in 10 blocks of 4 cows each. Cows received diets consisting of 60% grass silage and 40% concentrate (dry matter basis). In conclusion, an increased rate of starch fermentation and increased level of starch in the diet of dairy cattle reduced CH4 produced per unit of eRFOM but did not affect CH4 production per unit of feed dry matter intake or per unit of milk produced [65]. Dietary phytoestrogens are metabolized or converted in the gastrointestinal tract of ruminants, only limited knowledge exists on the extent and location of this conversion in vivo. The objective of this study was to quantify the gastro-intestinal metabolism of phytoestrogens in lactating dairy cows fed silages with different botanical composition. The main metabolism of phytoestrogens occurred in the rumen and the main route of excretion was through feces and urine, with only a small part being excreted in milk. The concentration of phytoestrogens in milk can be manipulated through intake but the intermediate transfer capacity to milk appears to be limited by saturation [66].

The timing of feed intake entrains circadian rhythms regulated by internal clocks in many mammals. The objective of this study was to determine if the timing of feeding entrains daily rhythms in dairy cows. Specifically, insulin increased and glucose decreased more after evening feeding than after morning feeding. In conclusion, feeding time can reset the daily

rhythms of feeding and lying behavior, core body temperature, fecal NDF and iNDF concentration, and plasma blood urea nitrogen, glucose, and insulin concentration of dairy cows, but has no effect on daily DMI and milk production [67]. The present study investigated the optimum blending condition of protected fat, choline and yeast culture for lowering of rumen temperature. The additive however, significantly increased ($p<0.01$) propionate and subsequently had lower acetate: propionate (A/P) ratios than non-additive supplementation. High concentrate diets had significantly lower pH. Interactions between energy and additive were observed ($p<0.01$) in ammonia nitrogen production. Supplementation of diets with the additive resulted in lower rumen and rectal temperatures, hence the additive showed promise in alleviating undesirable effects of heat stress in cattle [68]. The aim of the present study was bioremediation of distillery sludge into a soil-enriching material. It was mixed with a complementary waste, cattle dung, and subjected to vermicomposting with (V) and without (T, control) *Eisenia fetida* in the ratio of 0:100% (V1, T1), 10:90 (V2, T2), 25:75 (V3, T3), 50:50 (V4, T4), 75:25 (V5, T5) and 100:0% (V6, T6), respectively. Survival rate, growth rate, onset of maturity, cocoon production and population build-up increased with increasing ratio of cattle dung. However, organic carbon, electrical conductivity and potassium showed an opposite trend [69].

The objective was to evaluate the emission of enteric methane by Nellore cattle subjected to different nutritional plans, as well as the intake and digestibility of nutrients from the diets supplied. Forty-seven animals in a confinement system (feedlot) were fed a corn silage-based diet for 35 days. In this treatment, the animals showed greater dry matter digestibility, whereas the organic matter digestibility was lower ($P < 0.05$). The digestibility of the dry matter was higher in confinement, whereas the digestibility of the organic matter was lower in this treatment ($P < 0.05$). The better quality of the diet in the feedlot promoted lower energy losses as methane [70]. The distinctive membrane lipids of the archaea can contain a wide range of chemical structures. The membrane lipid composition of ruminal methanogenic archaea has not yet been characterized. The greater proportion of fecal ether lipids as GDGT may reflect adaptation of membrane lipids within the same species, a shift toward methanogens that have a greater proportion of GDGT (e.g., Thermoplasmata), or both. The effect of ruminal environment on membrane composition means that it will be important to consider the production of both DGDG and GDGT lipids when developing a proxy for methanogenesis [71]. Earthworms can accumulate heavy metals in their intestines to a great extent. Impact of feed materials and duration of metal exposure on natural activity of earthworms are rather unclear; this investigation therefore addresses the impact of metal rich Tea Factory Coal Ash (TFCA) on reproduction, composting and metal accumulation ability of *Eisenia fetida* and Lampito mauritii. Moreover, gradual increase in the metal-inducible metallothionein concentration indicated the causal mechanism of metal accumulation in these species. TFCA+cow dung (CD) (1:1) were most favorable feed mixture for *E. fetida* and TFCA+CD (1:2) were good for L. mauritii in regard to metal accumulation and compost quality [72].

The performance of dry anaerobic digestions of cow dung, pig manure, and their mixtures into different ratios were evaluated at $35 \pm 1°C$ in single-stage batch reactors for 63 days. The experimental results demonstrated that the co-digestion resulted in 5.10-18.01% higher methane yields, 2.03-12.95% greater VS removals, 2.98-12.52% greater COD degradation and so had positive synergism. The dry co-digestion of 60% cow dung and 40% pig manure achieved the highest methane yield and the greatest organic materials removal efficiency than other mixtures and controls [73]. These data can add novel information to the scientific literature and can be used to improve national inventories of manure N output and greenhouse gas emissions and to develop appropriate mitigation strategies for young Holstein cattle [74]. Sixteen multiparous lactating Holstein cows were used in 2 experiments to evaluate the effects of reduced-fat dried distiller's grains with solubles (RFDG) on milk production, results from these experiments indicate that dairy rations can be formulated to include up to 30% RFDG while maintaining lactation performance, volatile fatty acids concentration, and intestinal supply of microbial N [75]. Various parameters were measured during a 90-day composting process of coffee husk with cow dung (Pile 1), with fruit/vegetable wastes (Pile 2) and coffee husk alone (Pile 3). Samples were collected on days 0, 32 and 90 for chemical and microbiological analyses. C/N ratios of Piles 1 and 2 decreased significantly over the 90 days. Denaturing gradient gel electrophoresis of rDNA and COMPOCHIP microarray analysis indicated

distinctive community shifts during the composting process, with day 0 samples clustering separately from the 32 and 90-day samples. This study, using a multi-parameter approach, has revealed differences in quality and species diversity of the three composts [76]. In this study, a herbal preparation containing *Dalbergia sissoo* and *Datura stramoium* with cow urine (DSDS) was evaluated. The results of the present study shows that the cow urine extracts of DSDS may be used as a potent antiseptic preparation for prevention and treatment of chronic bacterial infections [77].

3. CONCLUSION

After working on natural and Organic Farming, "Mother Cow" *Bos indicus*-Cow milk, curd, ghee for human health, manure as fertilizer for soil health, cow urine and buttermilk for pest and diseases management used to be well-established practice in each farming family. This is a revolutionary century for world agriculture and 'Sustainable Agriculture' is the keyword. It has to be 'economically sustainable' (at low-cost with high productivity); environmentally sustainable (without any adverse effects on soil, air, water and biodiversity and with potential to mitigate global warming); and 'socially sustainable (nutritive and protective foods for the society to promote human health and without any adverse effects). Diverse 'Organic Fertilizers' e.g. Farm Yard Manure, Cattle Dung Compost, Poultry Droppings, MSW Compost, Sewage Sludge, Microbial Inoculants and Plants Bio-fertilizers and *Earthworm Vermi* castings are being produced and used for farming all over the world some due to economic reasons where farmers cannot afford for the costly chemical fertilizers and others due to social and environmental reasons in developed nations who are getting aware of the potential impending dangers of use of agrochemicals in food production. To achieve sustainable crop and livestock production, the primary requirement is the maintenance of soil fertility and soil health. Organic farming systems being highly complex but indigenous cow based *(Bos indicus)* natural farming systems will be the next generation green technology option to maintain pure soil as well as human being health standards.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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