



Cow products: boon to human health and food security

Arti Prasad¹ · Naresh Kothari¹

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Abstract

The world population exceeded 7.8 billion people in 2020 and is predicted to reach 9.9 billion by 2050 as per the current increasing rate of 25%. In view of this, ensuring human health and food security has become an issue of key importance to countries with different degrees of economic development. At the same time, the livestock sector plays a strategic role in improving the economic, environmental, and sociocultural stewardship of any nation. The cow (*Bos indicus*) has held a distinctive role in human history ever since its domestication because of its valued harvests like dairy products (milk, clarified butter, yogurt, curd, and buttermilk) excreta like dung and urine. These products, except dung, provide all the necessary energy and nutrients to ensure the proper growth and development of the human. They are the source of many bioactive substances, which possess immense pharmacotherapeutic action against various physiological, metabolic and infectious disorders, including COVID-19. The use of urine and dung can be considered a low-cost agricultural practice for farmers and has been extensively used in modern agriculture practices to ensure food security via soil fertility, plant pathogens, and pests. Cow urine mediated synthesized nanomaterial also display distinctive characteristics and novel applications in various fields of science and technology. Thus, this paper aims to provide a comprehensive overview of cow products, describing their biochemical constituents, bioactivities, and their utilization in the area ranging from human welfare to agriculture sustainability. An attempt is also made to present possible applications in [bioenergy production](#) and pollution reduction.

Keywords Livestock · Cow · Nutrition · Human health · Food security · Bioenergy

Introduction

Health and food security are essential to all organisms, most pointedly to human beings. Primarily both are states of cognizance as well as physical conditions, and if they are inattentive, the human being can die eventually (Friel and Ford 2015). Food security is also a part of the panoply of conditions that signal directly compromised human beings' health status (Gregory and Coleman-Jensen 2017). It has worsened the effects of all types of diseases (i.e., infectious diseases, deficiency diseases, physiological diseases, etc.) and can accelerate negative perceptions of self-worth in children and elders (Siddique et al. 2017; Wells et al. 2020). In view of the current population growth, which is exceeded 7.8 billion in 2020 and is predicted to reach 9.9 billion by

2050, human health and food security are probably the major global issue (Pawlak and Kołodziejczak 2020). The United Nations (UN) has introduced health and food security as a prime concern among Sustainable Development Goals (SDG) and set different targets to resolve this issue with available resources (Pérez-Escamilla 2017; Gil et al. 2019). Cattle, including cows (female) and bulls (male), have held a very distinctive role in human history ever since their domestication. Earlier, they were raised for their products like milk, meat, and leather and are also used as draft animals in farming and transport practices (McInerney 2010). Nowadays, they are important contributors to any developing nation's economic, environmental, and sociocultural stewardship across Europe, Asia, and sub-Saharan Africa. In Asia and sub-Saharan Africa, 75% of the rural population and 25% of the urban population are directly benefited by the cattle in terms of food, income, employment, and social security (Enahoro et al. 2019; Varijakshapanicker et al. 2019). The cow (*Bos taurus* or *Bos indicus*) has been placed at a high pedestal for enormous usages of their valued harvests like the dairy products (colostrum, milk, clarified

✉ Naresh Kothari
nitukothari95@gmail.com

¹ Laboratory of Public Health Entomology, Department of Zoology, M. L. Sukhadia University, Udaipur, Rajasthan, India

butter, yogurt, etc.) and animal waste like dung and urine (Gupta et al. 2016; Mandavgane and Kulkarni 2020). Such products are the major ingredient in “Panchagavya” that has been widely used as a rejuvenating tonic, immune booster, and other therapeutic formulations in Ayurveda for millennia (Joshi et al. 2015). They are also huge sources of many bioactive substances, responsible for their diverse pharmacological actions (Joseph et al. 2020; Mandavgane and Kulkarni 2020). In the past few years, several investigations have been confirmed their effectiveness, individually or in combination with herbal formulation, for the treatment of many infectious, physiological, and metabolic disorders in humans, including cancer, diabetes, hypertension, and viral diseases (Randhawa and Sharma 2015; Suk et al. 2018). Recently, cow urine has been used for nanomaterial synthesis (copper, silver, and palladium nanoparticles) with numerous biomedical applications (Vinay et al. 2019; Prasad et al. 2020; Padvi et al. 2020). Recent studies also revealed their immune-modulating efficacy against SARS-CoV-2 (COVID-19) infection in humans (Jawhara 2020; Mann and Ndung’u 2020). In addition, pathogens and soil degradation worsen the current deficit of the global food supply in which about 7.8 billion people are inadequately fed. Agricultural losses can mean that people become dependent on imported or synthetic foods, often replacing a balanced diet with such foods create further health problems (Pawlak and Kołodziejczak 2020). The literature suggests that cow products seem to be beneficial against various phytopathogens (i.e., bacteria, fungi, nematodes, etc.) responsible for abridged agricultural production (Jandaik et al. 2015; Nega and Getu 2020). A number of studies have also revealed their ability to replenish nutritional deficiencies in soils and improve gross agricultural yield (Kaleri et al. 2020; Praburaman et al. 2020). Due to their large range of nutritional components and bioactivities, cow products have attracted increasing focus from a number of research fields. Therefore, the present paper aims to provide a comprehensive overview of different cow products, describing their biochemical constituents, bioactivities, and their utilization in the area ranging from human welfare to agriculture sustainability. This review also intends to highlight the possible application of cow products in **bioenergy production** and remediation of environmental pollutants.

Cow products for human health management

The secretion or products of animal origin, especially bovine animals, have been mentioned as healthcare remedies in most ancient medicine systems, including Traditional Chinese Medicine, Western Medicine, and Indian Medicine. Due to their broad spectrum of nutritional components and

bioactivities has also received attention from modern pharmacopeia and many other research fields. The following are only a few examples (discussed in sub-sections) to illustrate the utilization of cow products in the area ranging from human nutrition to pharmacotherapeutics.

Overview on nutritional aspects of cow products

Since ancient times, rural and urban households have used different cow products in their everyday lives without bothering much about their nutritional and other scientific context. Nutritional studies in the last few decades showed cow products, especially milk and milk-derived products, to be complete, versatile, and nutritious foods for humans (Watson et al. 2017). It seems that such products are nutrient-dense and provide high-quality dietary supplements (i.e., carbohydrates, protein, fat, micronutrients, etc.) in an easily absorbed form that can advantage both nutritionally vulnerable and healthy peoples (Buttar et al. 2017; Panahipour et al. 2018). Among cow products, colostrum (first mammary secretion during the first 0–120 h after delivery) and milk are the old trusted form of health drink, which roots back to ancient pharmacopeia and till today regarded as imperious stuff for the holistic growth and development of the body (Puppel et al. 2019; Sharma et al. 2019). Cows can provide readily available nutrient-rich colostrum and milk in large quantities. Nutritionally, they are a source of dietary supplements and the source of a wide variety of protective factors (Fig. 1). However, colostrum is considered the most

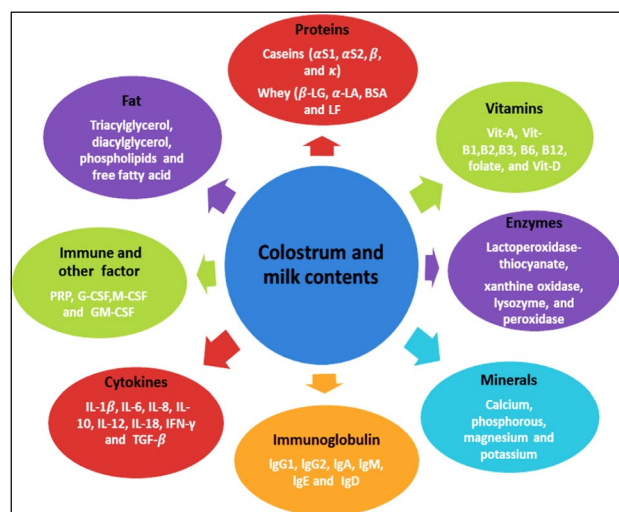


Fig. 1 Overview of different constituents present in cow colostrum and milk. β -LG = β -lactoglobulin, α -LA = α -lactalbumin, BSA = bovine serum albumin, LF = lactoferrin, IL = interleukins, IFN = interferon, TNF = tumor necrosis factor, TGF = transforming growth factor, PRP = proline-rich polypeptide, G-CSF = granulocyte colony-stimulating factor, M-CSF = macrophage colony-stimulating factor, GM-CSF = granulocyte–macrophage colony stimulating factor

nutritive form of cow milk, but its biological and nurturing value decreases over time (Table 1). Earlier, colostrum was usually consumed in its liquid form for the dietary purpose of both children and adults worldwide (Butter et al. 2017). Nowadays, the solid form is used to manufacture colostrum-based nutraceuticals that are dispensed and formulated into capsules, tablets, and powder using low-heat pasteurization and indirect steam drying (Dzik et al. 2017). Cow milk has the highest consumption among animal milk in India, Brazil, China, Sudan, Ethiopia, the USA, Argentina, and Paraguay. Antony et al. (2018) reported that it has a 90% share in world total milk production, followed by buffalo milk (5%), goat milk (3%), and sheep milk (2%). Cow milk appeared to occupy a unique position among many dietary foods as it contains a sufficient concentration of valued nutrients that ensure the necessary nutrient needs for humans' cognitive and physical development (Table 2). Proteins are the fundamental part of cow milk and mainly comprise a

soluble component (whey protein, 20% of milk protein fraction) and an insoluble component (caseins protein, 80% of milk protein fraction). Nutritionally, both components are good sources of amino acids, which are essential for the growth and health maintenance of human beings (El-Sayed and Awad 2019; Scholz-Ahrens et al. 2020). Cow milk is considered a high-quality protein source compared to goat milk, taking into account the essential amino acid, especially isoleucine, threonine, methionine, and tyrosine (Table 3). Clarified butter known as "ghee" prepared by heating milk, is also considered a good source of lipophilic composition such as conjugated linoleic acid and vitamins (A and E) that exhibited several nutraceutical actions, both in vitro and in vivo (Rani and Kansal 2012; Pena-Serna and Restrepo-Betancur 2020). Cow milk yogurt is also popular nutritious fermented food and is usually consumed for dietary purposes worldwide. Mainly, fat (total lipid) constitutes the main fraction of both clarified butter as well as yogurt and

Table 1 Changes in the nutritional composition of cow colostrum (%) over time (Horecka 2016)

Compositions	Immediately after calving (0.5–1 h)	After 12 h	After 24 h	After 48 h	After 6 days	After 25 days
Water	66.4	79.1	84.4	86.3	87.9	87.6
Casein	5.57	4.47	4.23	3.91	2.76	3.0
Albumin, globulin	16.92	8.98	2.63	1.23	0.75	0.5
Fat	6.5	2.5	3.6	3.7	3.7	3.8
Lactose	2.13	3.51	4.24	4.51	4.78	4.6

Table 2 Average nutritional composition of cow's milk compared with dietary reference intakes

Characteristics/composition	Amount (per 240 mL or 244 g) ^a	Recommended dietary allowance (adequate intake) ^b		
		Children (1–13 years)	Younger (13–30 years)	Older (above 30 years)
Energy (kcal)	145–150	1000–1800	1800–3200	1800–2200
Protein (g)	7.65–9.0	13–34	34–56	46–56
Fat (g)	7.98–8.20	25–35	20–35	20–35
Carbohydrates (g)	11.28–12.8	130	130	130
Vitamin A (µg)	55.5–118.5	55.5–118.5	300–600	700–900
Vitamin D (µg)	0.05–3.10	0.05–3.10	15	15
Vitamin B1 (mg)	0.090–0.11	0.090–0.11	0.5–0.9	1.0–1.2
Vitamin B2 (mg)	0.390–0.45	0.390–0.45	0.5–0.9	1.0–1.3
Vitamin B3 (mg)	0.200–0.23	0.200–0.23	6–12	14–16
Vitamin B6 (mg)	0.088–0.11	0.088–0.11	0.5–1.0	1.2–1.3
Folate (µg)	12.01–12.68	12.01–12.68	150–300	300–400
Vitamin B12 (mg)	0.87–1.22	0.87–1.22	0.9–1.8	2.4
Calcium (mg)	276–310	276–310	700–1300	1000–1300
Phosphorous (mg)	205–252.5	205–252.5	460–1250	700–1250
Magnesium (mg)	24–35.5	24–35.5	1.2–1.9	1.6–2.3
Sodium (mg)	105–130	105–130	1500–2200	2300
Potassium (mg)	377.5–415	377.5–415	3000–4500	4700

^aValued from Pereira (2014) and Singhal et al. (2017)

^bValued from Anonymous (2017) and Wang et al. (2016)

Table 3 Essential amino acids, their supply by cow milk, goat milk, and cow colostrum, and requirement of human

Name of amino acid	Concentration in cow milk (mg/100 g) ^a	Concentration in goat milk (mg/100 g) ^b	Concentration in cow colostrum (g/100 g) ^c	Requirement (mg/kg body weight/day) ^a
Histidine (His)	87	122.73	1.46	10
Isoleucine (Ileu)	170	160.54	1.51	20
Lysine (Lys)	327	342.86	4.09	30
Leucine (Leu)	380	341.01	4.73	39
Methionine (Met)	111	77.95	0.93	10
Cystine (Cys)	29	30.62	0.85	04
Phenylalanine (Phe)	173	175.45	2.52	25
Tyrosine (Tyr)	183	162.51	4.49	
Threonine (Thr)	167	138.67	3.32	15
Tryptophan (Trp)	42	-	-	04
Valine (Val)	225	210.23	2.83	26

- not determined

^aValues from Scholz-Ahrens et al. (2020)

^bValues from Ceballos et al. (2009)

^cPuppel et al. (2019)

is responsible for their highly energetic and nutritive value (Shori and Baba 2014; Antony et al. 2018). Among animal waste, cow urine has been extensively used for nutritional purposes for a long time, especially as a health drink. Recent studies have demonstrated the presence of many essential micronutrients (calcium, phosphorous), vitamins (B1, B2, and C), and enzymes (amylase, acid phosphatase, lactate, and lactate dehydrogenase, etc.) in cow urine (Mohanvel et al. 2017; Ketan et al. 2020). Studies also confirmed that cow dung harbors a rich microbial diversity and a good source of essential enzymes and metabolites of human interest (Gupta et al. 2016; Semwal et al. 2019). Joseph et al. (2020) revealed 20 bioactive compounds in *Bos indicus* and *Bos taurus* dung samples. However, cow breeds with differences in genetic makeup and several other aspects (i.e., age of animal, lactation and gestation stage of the animal, feed-related factors, and climatic influences) have a striking effect on chemical composition as well as the nutritional value of different cow products (Singhal et al. 2016; Puppel et al. 2019).

Cow products in the traditional pharmacopeia

Cow products are well known for their traditional practices of medicine since time immemorial. These products have received extensive importance in Ayurveda, while slighter attention has been given to Traditional Chinese Medicine and Western Medicine (Wang and Carey 2014; Rai 2019). Ayurvedic classics such as Charak Samhita, Sushruta Samhita, Bhasajya Ratnavali, and Arya-Bhishak described different properties of cow products

and therapeutic potentials. Cow milk has been mentioned for its ability to strengthen the seven Dhatus (tissues) such as Rasa (plasma), Rakta (blood), Mamsa (muscle), Meda (adipose tissue), Asthi (bone), Majja (bone marrow), and Shukra (reproductive tissue) in Charak Samhita. It has also been used to improve memory and boost immunity (Raut and Vaidya 2018). Cow ghee or Ghrita (clarified butter) has been mentioned to treat wounds, chronic fevers and nourish the body tissues and vital fluid. Fresh butter is considered for curing skin diseases and several other problems caused due to blood impurity (Shukla et al. 2012; Joshi 2014). In Ayurvedic therapeutics, cow urine (Gomutra) is frequently referred to for use because of its yearlong availability, cost-effectiveness, and special sanctity attached to the cow in India. In Charak Samhita, it is mentioned as a regulator governing several abdominal and dermatological disorders such as itching (Kandu), eczema (Vicharchika), and acne vulgaris (Yauvanpidika). Similarly, Sushruta Samhita described their properties as a cognition enhancer (Medhya) and reversal of certain cardiac (Hrid Roga), gastrointestinal (Udar Roga), and kidney-related problems (Randhawa and Sharma 2015; Steer 2019). The therapeutic potential of Panchgavya has been described in Apasmar-Chikitsa-Adhyaya of Charak Samhita with specific indications for cognitive and memory decline (Apasmar). It is also mentioned for the prevention of jaundice (Kamala), fever (Jwara), arthritis (Amavata), ulcer (Mukhapaka), asthma (Tamakaswasa), and brain disorder (Raut and Vaidya 2018). Similarly, cow bile has been described to treat a wide number of disorders in Traditional Chinese Medicine (Wang and Carey 2014).

Cow products in the modern pharmacopeia

In the prevailing trend toward natural bioactive products, there seems to be an increasing preference for different cow products associated with various perceived health benefits (Pereira et al. 2014; Mandavgane and Kulkarni 2020). The active constituents of the cow milk, especially proteins (i.e., caseins, lactoferrin, and albumins), immunoglobulin (IgG, IgM, IgE, and IgD), and cytokines (interleukins and interferon), have been widely used in the treatment of several physiological or metabolic disorders related to the brain, kidney, heart, and other organs (Watson et al. 2017). These active constituents have a significant protective influence on specific disease conditions of particular target organs by modulating signaling pathways and other elements (Mohanvel et al. 2017; Jawhara et al. 2020). Peptides derived from the digestion of cow proteins have demonstrated anticancer and antimutagenic properties, including mechanisms of DNA damage mitigation and apoptosis induction via both the extrinsic and intrinsic pathways (Pepe et al. 2013; El-Fakharany et al. 2018; Sharma et al. 2019). Milk-derived extracellular vesicles contained several immunomodulatory miRNAs and membrane protein CD63, characteristics of exosomes (Pieters et al., 2015; Benmoussa et al., 2016). Panahipour et al. (2018) reported that pasteurized cow milk and the aqueous fractions of yogurt and buttermilk enhanced the expression of TGF- β target genes (IL11, NOX4, and PRG4) in gingival fibroblasts. Lactoferrin is a major iron-binding glycoprotein from cow milk known to have an immunomodulatory role, and recently, their immunocompetence efficacy has been emphasized against SARS coronavirus 2 (SARS-CoV-2) or COVID-19 (Mann and Ndung 2020). The active constituents of cow urine prevent the free radical formation, act as bio-enhancer, reduce blood glucose, and efficiently repair the damaged DNA, thus showing anticancer and anti-diabetic efficacy (Dutta et al. 2006; Mohanvel et al. 2017). Recently, Padvi et al. (2020) suggested that cow urine mediated synthesized copper oxide nanoparticles (CuO NPs) can be used for antineoplastic therapy. The cow products also displayed inhibitory effects against various human pathogenic microorganisms (Randhawa and Sharma 2015; Hoh and Dhanashree 2017). Likewise, cow urine mediated synthesized CuO NPs, palladium nanoparticles (PdNPs), and silver oxide nanoparticles (Ag₂ONPs) exhibit excellent antimicrobial activity against various strains of bacteria and fungi (Vinay et al. 2019; Prasad et al. 2020; Padvi et al. 2020). Table 4 summarizes the evidenced-based pharmacotherapeutic potential of different cow products and their possible action mechanism.

Health risk assessment

Studies on cow milk and other dairy products consumption have shown a controversial and complex effect on human health. For instance, lactose is the main carbohydrate present in cow milk which is further hydrolyzed into two isomeric forms, alpha, and beta by a b-galactosidase known as lactase (Schaafsma et al. 2008). Lactose intolerance or b-galactosidase deficiency is an overlay term, and more than 50% of the world population has persistent lactose intolerance. Lactose intolerance or b-galactosidase deficiency causes several gastrointestinal distresses like abdominal cramps and bloating, flatulence, diarrhea, nausea, and vomiting (Matthews et al. 2005; Pereira 2014). Currently, there is also a growing concern about the consequences of cow milk β -caseins (A1 β -casein and A2 β -casein) on lactose intolerance (Brooke-Taylor et al. 2017; Daniloski et al. 2021). A1 β -casein generally contains a histidine amino residue at 67 positions, which is more likely to undergo enzymatic cleavage yielding in the product β -casomorphin-7 (BCM-7), a recognized μ -opioid receptor agonist. It has also been reported to exert various adverse effects on the gastrointestinal system (i.e., increased inflammation, worsening of post-dairy digestive discomfort symptoms, delayed transit, motility, etc.) in lactose tolerant and lactose intolerant subjects (Jianqin et al. 2015; Summer et al. 2020). While A2 β -casein contains a proline residue at this site and is unlikely to undergo enzymatic cleavage. It did not aggravate such gastrointestinal dysfunctions in subjects with lactose intolerance (He et al., 2017). Recent clinical studies have demonstrated that gastrointestinal symptoms of milk intolerance can be avoided by consuming milk containing only the A2 β -casein (Sheng et al. 2019; Ramakrishnan et al. 2020; Kay et al. 2021). Likewise, cow milk protein allergy can be associated with IgE reactions, and immediate reaction symptoms include anaphylaxis, edema, and much gastrointestinal distress such as vomiting, diarrhea, and bloody stools (Fiocchi et al. 2010). Some studies reinforce the role of cow milk and other milk-derived products as important nutrient sources, justifying their place in a healthy diet (Pereira 2014; Butter et al. 2017), whereas others suggest a possible association of milk consumption with increased risk for obesity, diabetes, osteoporosis, cancer, and cardiovascular disease (Holmberg et al. 2009; Tunick and Van Hekken 2015). Thorning et al. (2016) has performed a detailed meta-analysis study on milk, and dairy products suggested that intake of milk and dairy products contribute to meet nutrient recommendations and may protect against the most prevalent chronic diseases with the least adverse reports (Fig. 2). In addition, the presence of pesticide residues as well as heavy metals in milk and dairy products is well evidenced throughout the world, which can be responsible for many harmful effects on human health (Norouzrad et al. 2018; Jadhav et al. 2019).

Table 4 The reported pharmacotherapeutic potential of different cow products and their mode of action

Pharmacotherapeutic potential	Types of CPs	Used form	Possible action mechanism	References
Anticancer	Urine	Urine-derived copper oxide nanoparticles	Upsetting the levels of reactive oxygen species and apoptosis	Padvi et al. 2020
		Urine distillate	Promoting cell apoptosis and repairing mechanism of damaged DNA	Mohanvel et al. 2017
		Fresh urine	Reduction in tumor incidence, tumor yield, tumor burden, and cumulative number of papillomas	Raja and Agrawal 2010
	Milk and derived product	Redistilled urine distillate	Protecting DNA strand break, chromosomal aberration, and micronucleus formation	Dutta et al. 2006
		Milk lactoferrin	Induced cell cycle arrest at the G1 and G2 phases, activation of the intrinsic apoptotic pathway	Sharma et al. 2019
	Milk cheddar cheeses	Milk cheddar cheeses	Constrain nitric oxide production and augmented the cell population at G0/G1 phase	Rafiq et al. 2018
			Enhanced the expression of interleukin1 (IL1), proteoglycan4 (PRG4), and NADPH oxidase (NOX4)	Panahipour et al. 2018
	Clearfield butter oil	Clearfield butter oil	Altering membrane lipid composition and downregulates the enzyme activities responsible for carcinogen activation in the liver(cyclooxygenase-2, PPAR- γ) and upregulates carcinogen detoxification activities in the liver (uridinediphosphoglucuronosyl transferase and quinone reductase) and mammary tissues(γ -glutamyltranspeptidase)	Rani and Kansal 2011

Table 4 (continued)

Pharmacotherapeutic potential	Types of CPs	Used form	Possible action mechanism	References
Antidiabetic	Urine	Urine distillate	Reducing the level of elevated blood glucose and serum creatinine	Mahida et al. 2017
		Urine ark	Increased peripheral glucose utilization and sensitivity of insulin receptors, and decreased glucose absorption from the intestine	Sachdev et al. 2012
		Urine distillate	Reduction of the elevated blood glucose and serum cholesterol	Gururaja et al. 2011
	Urine	Fresh urine	Stimulate peripheral use of blood glucose	Jarald et al. 2008
	Milk and derived products	A1 and A2 casein hydrolysates	Increased fasting blood glucose levels, blood biochemical and decrease in levels of insulin and C-peptide	Thakur et al. 2020
Anti-diabetic		Fermented milk containing conjugated linoleic acid	Decreased levels of fasting blood glucose, serum insulin, and leptin and increased oral glucose tolerance and insulin tolerance	Song et al. 2016
	Milk derived products	Milk derived yogurt	Inhibition of α -amylase and α -glucosidase	Shori and Baba 2014
	Urine	Urine distillate	Reduction in dietary fat absorption by reducing the pancreatic lipase activity and enhancing their excretion in feces	Ketan et al. 2020
		Fresh and urine distillate	Reduced BMI, abdominal circumference, obesity index, atherogenic index, total cholesterol, triglycerides, LDL-C, and VLDL-C while increased HDL-C level	Sharma et al. 2017a, b
		Fresh urine	Decrease in body weight, BMI, abdominal circumference, serum triglyceride HDL-C, LDL-C, VLDL-C, and serum total cholesterol	Saini 2016
Anti-obesity and dyslipidemia		Urine ark	Reduction in the serum level of total cholesterol, triglycerides, and VLDL	Manubhai et al. 2014
		Fresh urine	Reduced the levels of the thiobarbituric acid reactive substance	Lavania et al. 2011
	Milk and derived products	Fermented milk containing conjugated linoleic acid	Decreased concentrations of serum total cholesterol, triglycerides, and LDL cholesterol	Song et al., 2016

Table 4 (continued)

Pharmacotherapeutic potential	Types of CPs	Used form	Possible action mechanism	References
Immunomodulatory	Urine	Urine distillate	Increased B and T cells proliferation	Ambwani et al. 2018
		Urine distillate	Marginally up-regulated the heterophil, basophil, and monocytes proliferation	Tadavi et al. 2017
	Milk and derived product	Urine distillate	Enhancing neutrophil activity	Durga et al. 2015
		Fresh and urine distillate	Improving B-cell blastogenesis, T-cell blastogenesis, serum IgG level, and serum IgM level	Ganguly and Prasad 2010
Wound healing and anti-ulcer activity	Urine	Powdered milk	Increasing immunoglobulin concentration (IgG and IgM), chitotriosidase activity, and complement system activity	Hernández-Castellano et al. 2015
		Urine ark	Increasing granulation tissue formation and collagen content	Hirapara et al. 2016
	Milk and derived product	Urine distillate	Intrusion of polymorphonuclear cells, neovascularization, and fibroblast proliferation	Mishra et al. 2009
		Clearfield butter	Increase formation of keratinization, angiogenesis, fibrous tissue proliferation, and collagen formation	Prasad and Dorte 2006
Neuro and brain-protective	Urine	Milk	Up and down-regulation of membrane receptors including prostaglandin E2 and histamine H2 receptor	Gespach et al. 1987
		Fresh urine	Improved levels of acetylcholinesterase (AChE)	Sharma and Chadha 2016
	Panchgavya	Panchgavya ghrita	Improved levels of GABA and reduced levels of dopamine and plasma corticosterone	Kumar et al. 2013
Nephro-protective	Urine	Panchgavya ghrita	Increased the spontaneous motor activity	Gosavi and Jhon 2012
		Urine ark	Lower levels of urine oxalate, serum creatinine, blood urea, and CaOx depositions restored kidney weight	Shukla et al. 2013

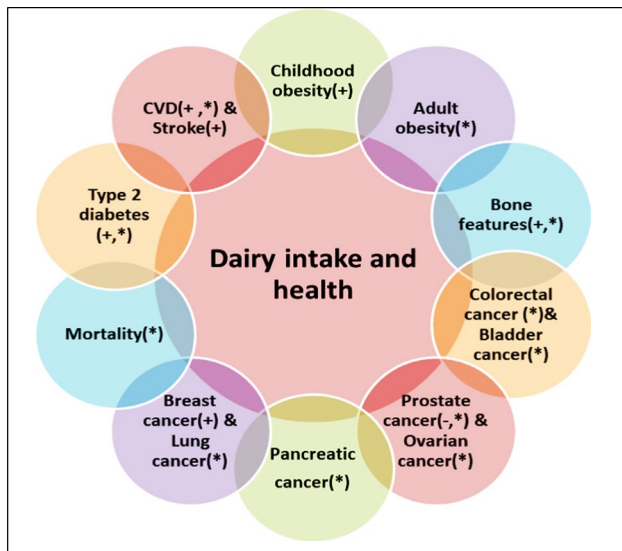


Fig. 2 Overview on effects or association between dairy product intake and health outcomes. + = favorable effect/association, * = no effect/association, — = adverse effect/association

Cow products in agriculture management

Since human civilization, agricultural practices have played a strategic role in improving the availability of food and achieving food security. In the current scenario, global agricultural production is mainly associated with two major problems: first, environmental measures as floods, droughts, and variability in temperature or rainfall, secondly plant disease because plant pathogens are difficult to control as their population shows variability with time, space and genotype. The indiscriminate use of agrochemicals adversely affected soil fertility, crop productivity, and, more specifically, the environmental system is also a major bottleneck. In order to combat the losses caused by such factors, it is necessary to define the problem and seek eco-friendly remedies. Cow products, especially urine and dung, can be considered a low-cost agricultural practice for farmers and has been extensively used in traditional and modern agriculture practices like organic farming and hydroponics. Therefore, in sub-sections, we summarized the utilization of different cow products in areas ranging from plant disease control to yield attributes and soil sustainably.

Cow products in plant disease management

The agricultural harvests of food interest, mainly crops, vegetables, and fruits, are often seen to be infected by one or the group of pathogens and pests, causing a loss in yield and sometimes even the quality (Savary et al. 2012). One reason is that pathogens and pests have co-evolved with

vegetation since the origin of the human-made agricultural system (Pathak et al. 2018). At a global scale, pathogens and pests are causing an average 30% yield losses in six most important food crop, including wheat (10–28%), rice (25–41%), maize (20–41%), potato (8–21%), and soybean (11–32%) losses (Savary et al. 2019). For millennia, cow urine and dung have been extensively used in traditional agriculture practices. There has been a spate of literature on these products, particularly concerning their use in the management of different diseases and harmful pests. It seems that the treatment combination of cow urine and cow dung shows marked effect on certain disease-causing phytopathogen through either a direct or indirect mechanism (Table 5). Apart from this, several green bio-formulations have been prepared by mixing ratio of either the dung or urine with distinct botanicals, which can be used as pest repellent in agricultural practices (Mandavgane et al. 2005; Kumawat et al. 2014). Agniastra is a natural bio-pesticide prepared by mixing up cow urine with neem leaf extract (*Azadirachta indica*) and ginger paste. Similarly, Neemastra is a broad spectrum bio-pesticide commonly prepared by mixing up cow dung and cow urine with neem leaf extract and water. Its uses on crops provide the resistance to several pests and increase the overall crop productivity due to the immunostimulant stirring of the active principles in both the cow urine and neem leaf extract (Chaudhary et al. 2017; Rawat et al. 2020). Brhmastra and Dashaparniarka have also been prepared by mixing cow waste with multiple botanicals (i.e., *Annona reticulata*, *Carica papaya*, *Punica granatum*, *Psidium guajava*, etc.), and water. Its foliar applications have been reported to exert protection and strong repellence against sucking pests, pod/fruit borers, and some mosquitos (Soni and Yadav 2019; Middy et al. 2020). The research focuses on cow urine and cow dung microbiota, which possesses antagonistic effects against disease-causing pathogens and pests. *Bacillus subtilis* strains are the most predominant isolates from cow dung that have displayed adverse effects against phytopathogenic fungi *Rhizoctonia bataticola*, *Fusarium solani*, and *Fusarium oxysporum* (Swain et al. 2012; Radha et al. 2014). Likewise, Lu et al. (2014) has investigated bacterial strains (belongs to genera *Bacillus*, *Proteus*, *Providencia*, *Pseudomonas*, *Staphylococcus*, and *Microbacterium*) from cow dung for nematicidal activity against two predominant nematode *Caenorhabditis elegans* and *Meloidogyne incognita*. The author revealed that most of the isolated strains displayed antagonistic activity against both the nematodes. Piasai and Sudsangan (2018) have investigated four species of *Gelasinospora* isolated from cow dung against plant pathogenic fungi. It has been observed that all isolates of *Gelasinospora* inhibited mycelial growth of *Phytophthora palmivora*, *Alternaria alternata*, *Colletotrichum capsici*, and *Curvularia lunata*.

Table 5 Applications of cow products in biological control of various pathogen and pests

Used cow products	Pathogens/pest and disease	Host plants	Demonstration of activity	References
Urine and Panchgavya (PG)	<i>Lipaphis erysimi</i> (Kalt.)	Mustard	5.0% of both urine and PG shows 80% and 96.67% mortality rate	Yadav and Tiwari 2020
Urine	<i>Meloidogyne incognita</i> (root-knot nematode)	Tomato and eggplants	10% concentration show 98.78% juvenile mortality and 75% egg hatching inhibition after 72 h of incubation	Gupta et al. 2020
Urine	<i>Phytophthora nicotianae</i> var. <i>parasitica</i> (buckeye rot)	Tomato	The highest mycelial growth inhibition (62.12%) was found at 15% concentration	Shridhar et al. 2019
Fresh, photo-activated, and sterile urine	<i>Aspergillus flavus</i> , <i>Aspergillus niger</i> , <i>Rhizopus</i> sp., <i>Alternaria</i> sp., <i>Mucor</i> sp., <i>Fusarium</i> sp., and <i>Penicillium</i> sp.	Wheat	100% concentration was most effective for inhibition of mycelia growth	Ghosh et al. 2018
Urine	<i>Sclerotium oryzae</i> (stem rot)	Rice	5, 7.5, and 10.0% concentration resulted 100% mycelia growth inhibition	Prakash and Sinha 2017
Urine and dung	<i>Colletotrichum falcatum</i> (red rot)	Sugarcane	The percentage mycelial growth inhibition found to be varied with time of incubation, and it was maximum after 5 days of incubation	Patel et al. 2016
Urine concentrate	<i>Fusarium oxysporum</i> , <i>Rhizoctonia solani</i> , and <i>Sclerotium rolfsii</i> (Damping-off and wilting)	Methi (<i>Trigonella foenumgraecum</i>) and Bhindi (<i>Abelmoschus esculentus</i>)	The growth retardation of <i>F. oxysporum</i> , <i>R. solani</i> , and <i>S. rolfsii</i> was 78.57%, 78.37%, and 73.84% at 15% urine concentration, respectively	Jandaik et al. 2015
Urine	<i>Alternaria alternata</i> , <i>Botrytis cinerea</i> , <i>Glomerella cingulata</i> , <i>Monilinia fructigena</i> , and <i>Penicillium expansum</i> (post-harvest rot)	Apples	Urine based bio formulations resulted in 84.7% reduction in the post-harvest rot after 75 days of storage at 4 °C	Tomar and Raj 2015
Urine	<i>Fusarium lateritium</i> (Fusarium bark)	<i>Coffea arabica</i>	Undiluted urine show marked inhibitory effect on conidial germination, germ tube length, mycelial growth rate, and sporulation	Gotora et al. 2014
Urine	<i>Xanthomonas oryzae</i> (bacterial leaf blight)	Paddy	Showed 10 to 13 mm zone of inhibition	Murugan et al. 2012
Urine and buttermilk	<i>Rhizoctonia bataticola</i> (charcoal rot), <i>Sclerotium rolfsii</i> (collar rot) and <i>Fusarium solani</i> (root rot)	Soybean	Reduced mycelial growth, number, and size of sclerotia with increasing urine concentration, while mycelial growth and number of sclerotia of <i>R. bataticola</i> were completely inhibited at 500 and 1000 ppm of buttermilk	Sapre and Verma 2006
Urine and dung	<i>Fusarium solani</i> (root rot)	Cucumber	Highest inhibition of conidial germination (%) was found after 2 h of incubation, while highest mycelial growth inhibition (%) was found after 7 days of incubation of both urine and dung	Basak et al. 2002

Streptomyces strains procured from cow dung have also displayed decent antagonistic activity against the strain of genera *Aspergillus*, *Fusarium*, *Macrophomina*, and *Rhizoctonia solani* (Semwal et al. 2018).

Cow products in plant growth, yield, and nutrient attributes

Toward a food security vision, crops need to be equipped with better growth, yield, and nutritional properties (Gimenez et al. 2018). To fulfill the above-desired crop characteristic, one possibility is to use products that themselves have to boost means and can strengthen plant health and yields (Raklami et al. 2019). Cow products are the rich source of various inorganic and organic substances, which can regulate plants' physiological and biochemical mechanisms (Mandavgane and Kulkarni 2020). Different cow products and their formulations, such as Panchgavya, Beejamrut, Amritpaani, etc., have been extensively evaluated to sustain agricultural production in terms of growth, yield, and nutritional qualities of the crop plants (Table 6). Panchgavya is well-recognized liquid manure for this purpose, while Beejamrut and Amritpaani are considered good sources for plant growth stimulation (Barar et al. 2019). Generally, these formulations have been prepared by thoroughly mixing cow dung, cow urine, and other ingredients. Its uses on crops increase crop plants' overall biological efficiency, quality, and yield (Aswani et al. 2020; Dodamani et al. 2020). The treatment combination of such liquid organic inputs with other bio-formulations has shown encouraging results in reducing the overall cost of crop cultivation practices (Tripura et al. 2018). In the recent past, the focus has also shifted towards cow waste as a potential source for plant growth-promoting bacteria (PGPBs) which have active compounds of multifarious importance for plant growth promotion (Girija et al. 2013; Bhatt and Maheshwari 2019). Several strains of PGPBs have been isolated from cow dung and explored to augment and boost plant biological, functional, and nutritional assets (Lin et al. 2018; Bhatt and Maheshwari 2020).

Cow products in the management of soil sustainability

Since the green revolution, indiscriminate and disproportionate uses of agrochemicals like chemical fertilizer and pesticide resulted severe threat to soil sustainability (Elbana et al. 2019). Both the cow urine and dung contain significant amounts of major nutrients like nitrogen (N), phosphorus (P), and potassium (K) required for soil mineral balance and fertility. Singh et al. (2014) has reported that high dose of cow urine application resulted in increased dissolved nutrients of amended soils. Significantly higher soil organic carbon and available N, P, and K were obtained with the applications of cow urine with other formulations

(Kgasudi et al. 2020). On the other hand, cow dung has been considered as low-cost natural fertilizer because it supplements good organic matter (Mukhuba et al. 2018). Jeevamrut is a natural liquid fertilizer prepared by mixing cow dung and cow urine with other ingredients (i.e. jaggery, legume flour, etc.). It contains the huge count of microbial load that enriches the biological and mineral balance of the soil (Pathak and Ram 2013; Boraiah et al. 2017; Jain et al. 2021). Similarly, cow dung and cow urine-based compost are one of the most significant and frequently used organic matter in integrated soil management practices. Research shows that compost applications improve the nutritional balance of the soil and the soil texture and structure (Iwuagwu et al. 2019; Nguyen et al. 2020; Shafique et al. 2021). Ghana Jeevamrutham is the solid or granular form of Jeevamrut and also acts as natural fertilizer. It is a low-cost improvised preparation that enriches the soil with beneficial microfunna. The treatment of Ghana Jeevamrutham in balanced forms has improved soil fertility and maintained various crops' nutritional quality (Sawant et al. 2019; Barar et al. 2019). Research interest is also given to the indigenous microbial diversity of cow dung as they can transform soil nutrient profiles via processes like solubilization, chelation, mineralization, and oxidation or reduction (Radha et al. 2014; Bhatt and Maheshwari 2019; Aiysha and Latif 2019). Recently, Adekiya et al. (2020) has reported that cow dung biochar application improves the nutritional profiles (soil pH, organic carbon, N, P, K, Ca, Mg, moisture contents) and the culturable microflora of the soils.

Cow products in other sustainable uses

Cow products displayed miscellaneous applications in some other valuable aspects like bioenergy production and pollution reduction, which are described below under subsections. To respect the length of the paper, the detailed outcomes of respected studies are avoided in this paper, while interested readers may refer to cited documents. In addition, summarized result of the case study report on cow product-based manufacturing unit (Mandavgane and Kulkarni 2020) is pictorially presented in Fig. 3.

Bioenergy production

Ever-increasing energy demands for day-to-day human activities such as transportation and industrial practices have depleted the non-renewal energy source and caused drastic environmental intrusions (Joshi et al. 2019; Halkos et al. 2020). Renewable energy in the form of biofuels and biogas offers the opportunity to improve access to modern energy services for the global community (Achinah et al. 2017;

Table 6 Applications of cow products on plant growth, yield, and nutrient attributes

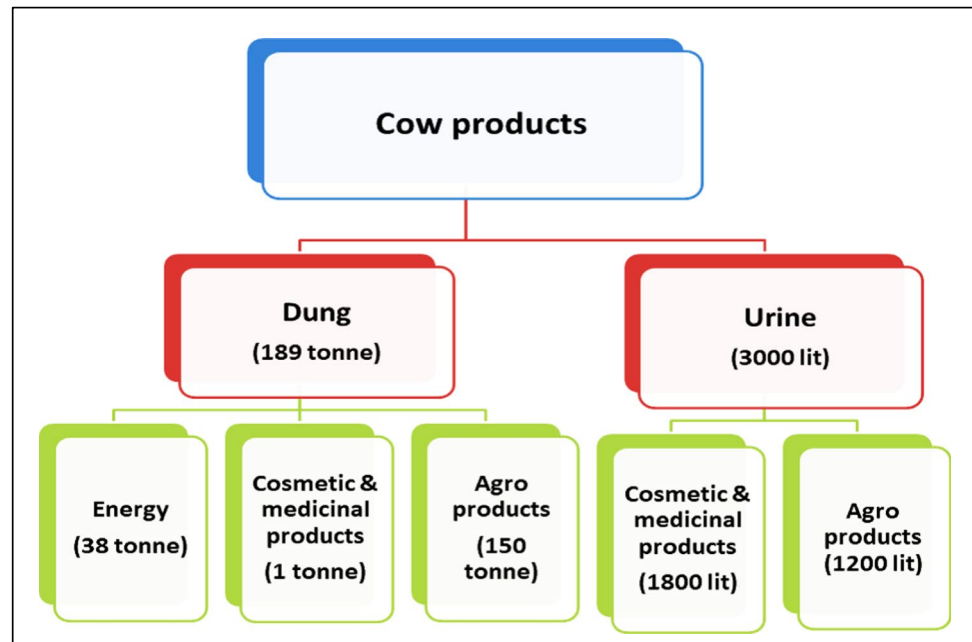
Name of plants/crops	Applied cow products	Mode of application and outcomes	Reference
Cowpea (<i>Vigna unguiculata</i>)	Panchagavya	Foliar application of 3% panchagavya significantly improved plant height and seed yield	Meyyappan and Sivakumar 2020
Chinese white cabbage (Bok choy)	Dung	Plants under cow dung amended soil significantly increased total leaf sugar, vitamin C, polyphenols, total protein, and amino acids content	Kaleri et al. 2020
Tiger nut (<i>Cyperus esculentus L.</i>)	Dung biochar	Applied via soil (10 t ha ⁻¹), improved growth and yield	Adekiya et al. 2020
Balsam (<i>Impatiens balsamina</i>)	Panchagavya	Pre-soaking application (24 h) of 2% panchagavya solution show improved germination, shoot, and root length	Kumar et al. 2020
Maize	Panchagavya	Applied via soil, increased physio-morphological (root and shoot length up to 10–21%) and biochemical properties (chlorophyll, total carotenoids, antioxidative enzymes, and total protein)	Praburaman et al. 2020
Rice	Urine	Foliar application (4 sprays) of 4.4% and 10% urine concentrate positively enhance various growth and yield attributes	Sadhukhan et al. 2019
<i>Rosmarinus officinalis</i> (Rosemary)	Urine, dung slurry, and buttermilk	Applied via pre-sowing seed treatments, urine (5–15% concentration) and dung slurry applications show increased seed germination (%), while buttermilk had an adverse effect	Sharma et al. 2019
Passion fruit (<i>Passiflora edulis</i>)	Urine	Applied via soil, increased the leaf area and quality indexes of seedlings	Freire and Nascimento 2018
Custard apple (<i>Annona squamosa</i>)	Urine	Soaking application of 20% urine concentration show improved survival percentage of seedlings and seedling vigor index	Yadav et al. 2018
Wheat	Urine	Foliar application of 75% and 100% urine solution show 18.01% and 27.21% higher grain yield, respectively, over control	Sadhukhan et al. 2018
Chickpea (<i>Cicer arietinum</i>)	Panchagavya	Foliar application of 4% panchagavya significantly enhance the number of nodules, the weight of nodules, seed and stover yield as well as economics	Panchal et al. 2017
Pigeonpea	Urine	Foliar application of 4% urine solution significantly increased plant height, number of branches, leaf area, dry weight, seed yield, and harvest index	Yogita et al. 2017
Bhindi	Panchagavya	Foliar application of 3% panchagavya solution enhanced physio-chemical (number of fruit, fresh weight, dry weight) and biochemical properties (chlorophyll and carotenoid content)	Rakesh et al. 2017

Table 6 (continued)

Name of plants/crops	Applied cow products	Mode of application and outcomes	Reference
Cucumber	Urine	Urine with bio-fertilizers show positive effect on yield, growth and quality parameter and reduced at least 50% of water requirement	Kumar et al. 2017
<i>Stevia rebaudiana</i>	Dung	Applied via soil (5–10 t ha ⁻¹), increased growth characteristic, and leaf biomass yield	Zaman et al. 2017
Mustard	Urine	Increasing levels of urine application (up to 900 l/ha) markedly improved growth parameters, yield attributes, and nutrient uptake	Pradhan et al. 2016
Rose (<i>Rosa hybrida</i>)	Urine	1–3% concentration positively enhance flowering, quality, and yield characteristics	Baghele et al. 2016
Radish (<i>Raphanus sativus</i> L.) and Chinese cabbage (<i>Brassica rapa</i> subsp. <i>pekinensis</i>)	Panchagavya	Pre-soaking and foliar applications of 33% and 100% panchagavya increased germination and growth	Anandham et al. 2015
Methi and Bhindi	Urine	5% concentration significantly improved morpho-physiological (leaf length, leaf area, root length, plant height), biochemical (protein, carbohydrates, and chlorophyll) parameters of both plants	Jandaik et al. 2015
Maize	Urine and Panchagavya	Higher grain and stover yield, plant height, and number of leaves with both panchagavya and cow urine, comparable to fertilizer treatments at the higher level (200% and 300%)	Devakumar et al. 2014
Zucchini (<i>Cucurbita pepo</i>)	Urine	Foliar application of 5% urine significantly improved fresh matter, and the number of total commercial fruit/plant	de Oliveira et al. 2013
Pigeon pea (<i>Cajanus cajan</i>)	Panchagavya	Soaking application (10 ml/kg), enhanced length of root and shoot, dry mass leaf area, chlorophyll content, and photosynthetic activity	Amalraj et al. 2013
Tomato	Urine	Improved plant height and dry matter accumulation at a concentration below 8.23%	Belan et al. 2013
Soybean	Urine	Foliar application of 6% urine solution significantly enhanced morpho-physiological (leaf area, dry matter, plant height), biochemical (chlorophyll, protein), and yield contributing parameters (number of pods, seed weight, seed yield)	Deotale et al. 2011
Lettuce	Urine	Improved vegetative characteristics (i.e. fresh and dry mass of leaf, stem, and root) and commercial yield when urine solution applied at 1.25% to leaves or 1.0% to soil	de Oliveira et al. 2009

Table 6 (continued)

Name of plants/crops	Applied cow products	Mode of application and outcomes	Reference
Groundnut	Urine	Foliar application of 4% urine solution significantly enhanced morpho-physiological parameters such as plant height, number of branches, leaf area, total dry matter production, and pod yield hectare	Deotale et al. 2008

Fig. 3 Valorization of cow urine and dung based manufacturing unit

Sharma et al. 2017b; Joshi et al. 2020). For long, caked or dried cow dung has traditionally been used by households as cooking fuels in many parts of the developing world. In the last two decades, there has been increasing research interest in **bioenergy production**, especially biogas using cow dung as substrate (Gupta et al. 2016; Mandavgane and Kulkarni 2020). On average, 1 kg of cow dung can produce 35–40 l of biogas (Kalia and Singh 2004), while dung generated from 3 to 5 cattle/day can run an 8–10 m³ biogas plant which can produce 1.5–2 m³ biogases per day. Research also continues to enhance biogas production via the use of additives, recycling of slurry and slurry filtrate, variation in operational parameters (i.e., temperature, hydraulic retention time, and particle size of the substrate), and use of fixed-film/biofilters (Li et al. 2014; Haryanto et al. 2018; Adekunle et al. 2019; Oibileke et al. 2020). Activated carbon has also been synthesized from cow dung by a modified chemical activation method. The synthesized activated carbon reflects excellent properties like a supercapacitor with a distinct electrochemical application (Li et al. 2018; Ramalingam et al. 2020). Some recent studies also suggest that cow dung can be converted into an electrode material

for energy conversion systems such as Li-ion batteries and fuel cells (Feng et al. 2018; Thiruselvi et al. 2020).

Bioremediation of pollutants

Bioremediation using microbes is a widely accepted method for the removal of hazardous environmental pollutants (Giovanella et al. 2020). Hydrocarbon and heavy metals are the major pollutants in water as well soil and pose a serious threat to living creatures and environments (Wang et al. 2020). Literature suggests that the cow dung contains a diverse group of microorganisms capable of biodegradation of hydrocarbons into environmentally friendly elements (Aghalibe et al. 2017; Varjani et al. 2017; Neethu et al. 2019). Another practical application of cow dung microorganisms is in the remediation of heavy metals like chromium, strontium, and arsenic (Wang et al., 2017). Many cow dung strains have been applied to biodegrade biomedical and pharmaceutical waste (Randhawa and Kullar 2011; Patil et al. 2019). Cow dung ash (CDA) has also been explored as a low-cost adsorbent to remove textile dyes and other organic contaminants (Ahmad et al. 2020).

Recently, cow urine mediated synthesized silver oxide (Ag₂O) nanoparticles show good photocatalytic degradation of methylene blue (Vinay et al. 2019).

Conclusion and future prospectus

The present review deals with the first comprehensive outlook on cow products to human health and food security, the prime most concern among United Nations Sustainable Development Goals. The nutritional richness of cow milk and other dairy products is unquestionable; they are a good source of high biological value substances with polyvalent roles in immune function, as well as pharmacological actions. Understanding the mechanisms enabling their biological process can promote novel applications in the nutraceutical and pharmaceutical sectors. Cow excreta like urine and dung contains distinct compounds for human interest and is an effective tool to sustain agriculture production via governing soil sustainability, plant health, and yield attributes. The application of cow urine and dung microflora potential can promote both human health and plant health; however, comprehensive screening of these microorganisms for the production of virtuous antimicrobials, enzymes, and metabolites needed to be investigated. It is undoubtedly evident that more detailed studies of cow products are required, as there is still tremendous scope for advancing research and development to novel applications in various fields of science and technology, including bioenergy and pollution abatement in a green and clean manner.

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