Design and Development of IoT-Based Intelligent Solutions with Blockchain for Indian Farmers on Livestock Management

Sanjay Mate[1][0000-0002-3960-259X],VikasSomani [2], Prashant Dahiwale[3]
[1]Research Scholar,
Sangam University Bhilwara and Dept. of Information Technology,
Government Polytechnic Daman, India.
matesanju@gmail.com
[2]Computer Science Engineering Department,
Sangam University,
Bhilwara, India.
vikas.somani@sangamunivesity.ac.in
[3] Computer Engineering Department,
Government Polytechnic Daman, India.
prashant.dahiwale@gmail.com

Abstract: As the world population is at the edge of passing 8 billion, more dependency on food, water, agriculture, and allied sector products. While providing good livestock products, animal welfare, sustainable environment, public health, and many other issues must be closely monitored. The purpose of this paper is IoT based solution for Indian farmers with some uplifting in existing infrastructure and the use of technology like Blockchain. Biosensors help farmers to receive real-time data from animal health, behavior, food intake, cattle shed or grass yard atmospheric values, etc. Bio-sensor will give a set of values, which is processed and integrated using a big data analytics system. It helps to sort extensive, complex data and generate patterns that ease farmers' decision-making. The sensor-enabled system using Blockchain technology helps to monitor livestock health, track the distribution of agriculture and allied products from farmer to end consumer, monitor and control the supply chain of milk, fruits, vegetables, meat, etc., and prevents economic losses. Using precise livestock farming technologies and management will improve the various sectors in Indian farming like workforce, the production cost of agriculture and livestock products, the welfare of animals, and a sustainable environment. Data security, privacy, and integration were considered before implementing multiple farm-based precise livestock management for Indian farmers.

Keywords: Livestock Farming, Animal welfare, Livestock products, Mastitis, Cow to Cloud.

1. Introduction

As per the World Food and Agriculture Statistical Yearbook 2021: Food and Agriculture Organization of the United Nations, Rome, 2021, the share of global agriculture GDP was 4% from 2000 to 2019. It has been stable in the last few years. Agriculture employed 874 million people in 2020, or 27% of the global workforce, compared with about 1 050 million (or 40%) in 2000. Three hundred thirty-seven million tons of meat were produced in 2019, 44% more than in 2000, with chicken meat representing more than half the increase. World milk production rose by 52 percent to 883 million tons in 2019, an increase of 304 million tons compared with 2000[1]. As shown in figure 1 and 2, World milk production and producer countries performance varies in last twenty years.

ITSPWC 2022, May 14-15, Karur, India

DOI 10.4108/eai.14-5-2022.2320163

Table 1 shows the major growth of Asia in milk production, while African milk production remains constant. In contrast, over the past twenty years, another part of the world has reduced milk. Calculating milk production includes milking animals like buffalos, camels, cows, goats, and sheep. Livestock production in developing countries like India provides more job opportunities in agriculture and allied sector product processing, packaging, and shipping, giving more jobs with sustainable growth. In India, agriculture has a major role in the National GDP, approximately 19% of the overall GDP. On the other hand, with a huge population for milk and other livestock products, consumers are more concerned about animal welfare, farming impacts on the environment like emission of greenhouse and farm gate gasses, and public health [2]. In the journey of reaching consumers' needs, water and land will be valuable resources to maximize production [3]. Research scholars, investors, and farmers depend on precise livestock management to meet the rising demand for livestock products and concerns about environmental sustainability, public health, and animal welfare.

Table 1: Percentage of World Milk Population on Regional Basis

The region	Year: 2000	Year: 2019
Asia	29%	42%
Europe	37%	26%
Americas	25%	23%
Africa	5%	5%
Oceania	4%	3%

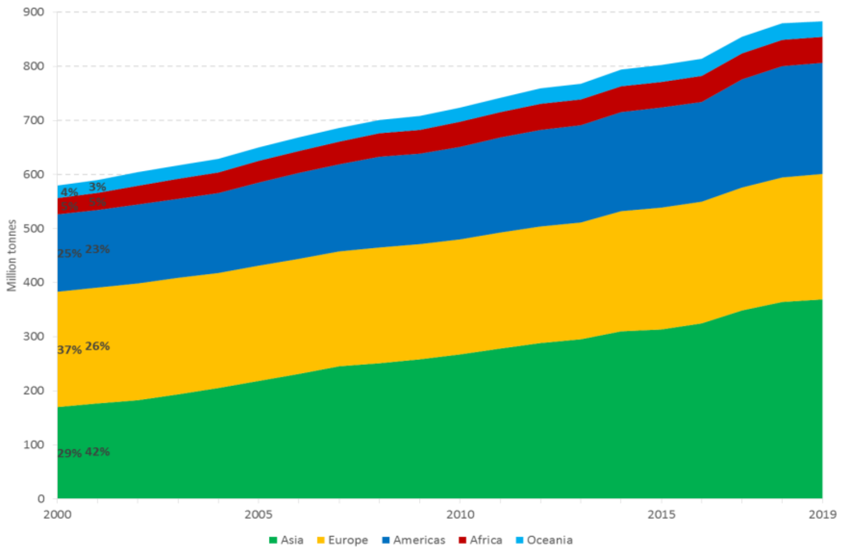


Figure 1: World Production of Milk [1]

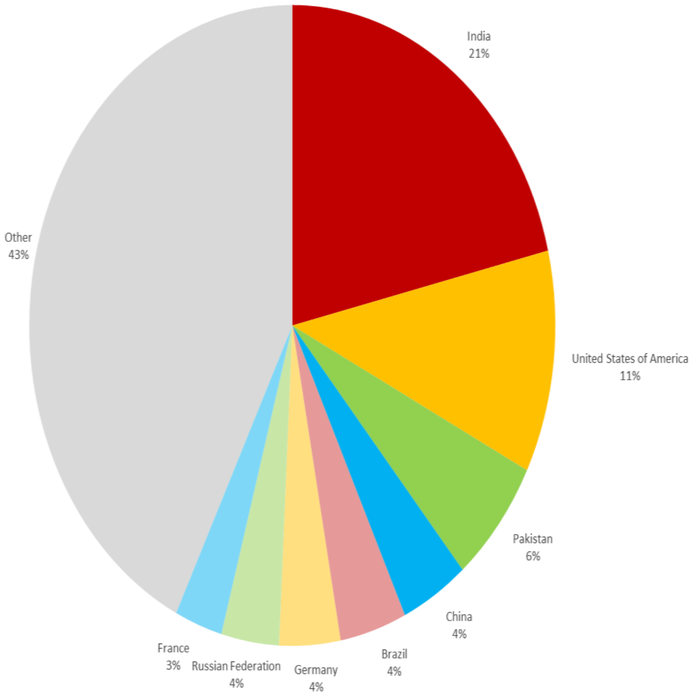


Figure 2: Milk Producer Countries in 2019[1]

1.1 Current State of Livestock Farming:

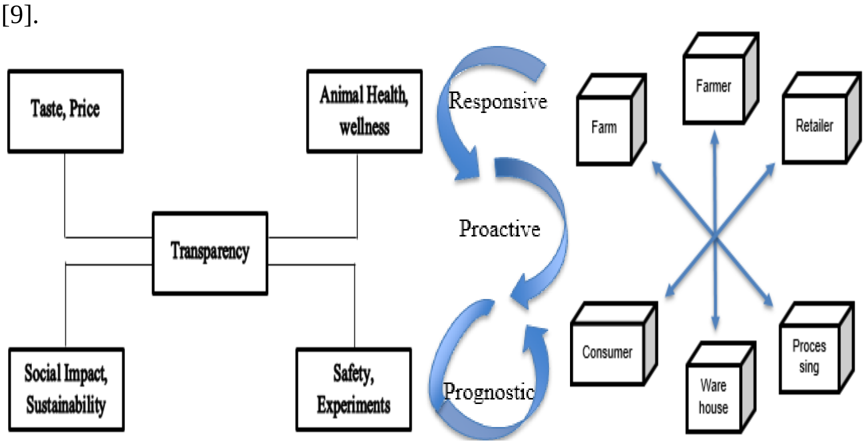
In the last few years, robotic usage is helping farmers in feeding livestock, biosensors help to detect diseases in their early stages, monitor feed intake, reproduction cycles, and milking cows, camels, buffalos, etc. Even though such successive jumps have been made over the traditional approach of milking animals, monitoring health symptoms, etc., there are many areas where farmers face issues in managing livestock in India. It is difficult for farmers with livestock to closely monitor animal health and welfare [4].The climate of India is not uniform for North, East, South, West, and seasonal climate change makes more atmospheric changes in all four areas due to seasonal activities like snow, rainwater, thunderstorms, humid, and sometimes more dry due to drought, etc. Climate change invites diseases in livestock, and issues like heat stress seem large in animals [5].

Further, farmers must stay alert, prevent a major outbreak and disease spread in livestock, and make preventive majors avoid economic losses [6, 7].IoT and other recent technology to improve overall farming infrastructure into digitized livestock agriculture technologies like big data analytics will be helpful, leading to precise livestock farming [8].Precise livestock farming technologies use principles that automate the livestock agriculture sector; it helps to monitor large populations of animals' health and welfare and detects health issues on time using previous data using symptom records even before disease occurs [9].Using precise livestock farming technology, animal health welfare, and a sustainable environment can be achieved by reducing food safety issues and utilizing resources utmost [10].

1.2. Challenges to Traditional Business Model:

A major reason for challenges to cost, validity, and timing of insights, as traditional methods require more human resources and time taking processes, which leads to more economic losses [11]. The traditional approach cannot closely monitor livestock nutritional feed intake and health symptoms of individual animals. If livestock is in large numbers, then more intensive labor is required for milking and cleaning cattle, buffalo, camels, sheep, etc. Running vaccination drives for livestock as per age to each individual at a certain interval is essential. As per the traditional approach in India, it is difficult to maintain a log of vaccination in the case of large animals on the farm. Milking animals such as buffalo, camels, cattle, and sheep need more attention during milking time. Reproduction rate and milking phase vary as per overall physical health, heat stress factors, etc.

Using bio-sensors helps monitor various parameters regarding animal health, feed intake, shed atmosphere, reproduction rate, etc. In India, livestock product end users or customers have become more concerned about the sustainability and welfare of animal products, expecting transparency from livestock farmers (Figure 3). Blockchain technology will assure end users about livestock products traveling without taking farmers'
Time. So, time for animal monitoring, health, environment friendly, and sustainable activity [9].



(a) (b) (c)

Figure 3:(a) Intelligent solution for Indian farmers for livestock management covers all domains with transparency using recent technologies (b)reducing risk factors and improving animal welfare and looking out for a predictive or prognostic approach to better function of infrastructure (c) bridging solutions with maintaining logs of activity for different activities using Blockchain technologies.

2. Biometric Sensing:

The livestock farmers use sensors for monitoring animals which is helpful to reduce time in physical visits or contact hours. It helps in cost cutting in the financial budget as it reduces human resources in monitoring. Sensing animals using devices like a camera, pedometer, microphone, and GPS, a single employee can precisely monitor a large group of animals. It is a reliable method and maintains animals' welfare [4, 7]. Sensors can check the animal's behavior and, if found abnormal, inform farmers, allowing them to examine and make decisions appropriately, which improves animal welfare [7]. Using biometric tools and some technologies like artificial intelligence, big data analytics, and providing such details for genomics helps to identify animals' welfare qualities and choose them for the breeding program [12]. Thermal sensors help measure body temperature remotely, and a sensor is not in direct physical contact. A skin temperature and TIR (i.e. Total Internal Reflection of optics) of the eye helps to detect animal illness or disease 5-6 days earlier than traditional methods [13]. It further helps to keep the condition in control and stop it from spreading to other animals [14]. Face detection methodology using machine learning algorithms is an exciting field for many researchers; it detects the face features of animals and computes them with patterns to recognize issues related with animal welfare [15]. Grimace scale is also a domain of interest for livestock and farmer welfare communities as it helps to identify animal affective state or pain [16]. Castration, dehorning, and tail docking are standard painful procedures through which animal livestock frequently passes [17].

2.1 Sensors for Animal Farm and Milking Animals:

In this, we will consider milking animals like buffalo, camels, cattle, sheep, etc. Various sensors are available from invasive and non-invasive categories for buffalo, camels, cattle, sheep, etc. Body temperature can be measured with the help of an invasive sensor or non-invasive Thermal Sensor. Animal stress is usually measured by body temperature; in the case of cattle, the temperature can be measured at different body parts like the vagina, udder, ear, reticulum rectum, etc. normal range of body temperature is 37.8oC-40oC [18]. The pathogen in the soil leads to Footrot in animals from muddy and wet soil [19]. Soil moisture sensor helps to maintain soil's dryness to prevent footrot infection. Johne's disease which includes signs of diarrhea, weight loss and disease like tuberculosis happens due to bacteria of the same species [20]. It affects the lungs. It’s curable and preventable. Need to monitor animals' health closely, especially feed intake, weight, waste droppings, etc. There are many diseases like mastitis, lameness, milk fever, diarrhea, pneumonia, etc., that can be monitored and prevented by close look up on symptoms shown by animals in regards to the above diseases. Dairy cattle can be continuously monitored with sensors, ZigBee, Arduino, microcontroller devices, etc., for heart rate, temperature, breath ketones, grazing rumination, mooing cough, respiratory rate, mastitis, milk quality, motion activities like standing, lying, etc. can be monitored with the help sensors [21,22]. A study by Williams et al. (2020), technology using RFID tags and accelerometer 95% accuracy is measured for correct classification of behaviors of animals [23].

3. Big Data Analytics and IoT role in Indian Livestock Farming:

In India, two organizations have noticeable work in livestock farming using Big Data and Machine learning, IoT, and recent technologies. Table 2 shows the details of companies using Big Data technology for livestock farming in India. The welfare of livestock is the main priority for all livestock consumers. Chitale dairy launched a program called ‘cows to the cloud’ where they started RFID tags on cows' collars and collected vital data about 50,000 cows that more than 10,000 dairy farmers owned. By monitoring the cows’ health and participating in genetic profiling, farmers can optimize nutrition, prevent diseases, and select the best cows for breeding. The farmers can also save time, which they use to invest their earnings into growing cash crops to supplement their dairy income [24]. VMware supports all digital transactions related to the ‘cows to cloud’ program of Chitale dairy.

PoultryMon is a hatchery/Farm, cold room, layer/brooder or broiler, flock management, feed plant, precise livestock farming, breeder farm, processing unit, etc. Smart poultry farm monitoring system created to deliver real-time poultry monitoring and consistent process monitoring through every level of operations. Smart poultry using IoT approach to deliver detailed hatchery monitoring, management, analysis & reporting on mobile.

PoultryMon provides continuously monitored incubators and hatchery automation, and climate control systems. It has features like real-time temperature, humidity, fan on/off operation, door and rack condition monitoring, etc., with remote monitoring. Data is recorded at some intervals automatically notifications were given to concerned stakeholders on certain values threshold level breaches. Real-time and historical data reports are available.

Table 2: Companies using Big Data technology for Livestock Farming in India

Company Name	Big Data Technology	Website	Location
Chitale Dairy	RFID tags on cows collar and IoT sensors to collect data on cattle diet and health	https://chitalegroup.ruha.co.in/	Palus, Maharashtra, India.
Poultry-Mon	Big data from sensors for poultry hatchery operations in a remote way	http://www.poultrymon.com/	Gachibowli, Hyderabad, India

Based on sensors' data and big data analytics, a prediction model can design a precise livestock farming system to enhance animal product capacity, productivity, overall welfare, etc.MooCare's predictive model helps dairy farming predict milk production [25].

4. Blockchain

Blockchain is the solution in distributed storage for various security and performance issues [26]. In a case study proposed by Daniel Soesanto et al. [27] in Indonesia, Livestock-related issues with data integrity, cost, type, size, and trust for consumer ingredients values and detection of food fraud can be achieved using Blockchain. Blockchain technology could provide a platform for detecting harmful packets back to sources; it improves traceability and accountability for wrong practices [28]. Figure 4 shows a major advantage of Blockchain is information shared across a peer nodes of network than under influence of any single entity or person or stakeholder.

5. Future Trends and Gap to be Filled Out:

A livestock agriculture is one of the less digitalized domain in 21st century and it has large potential to grow with digitalization [30]. Precise livestock farming using recent technologies like big data analytics, machine learning, Internet of Things (IoT), sensors, etc. can lead sustainable development in livestock farming while improving animal welfare. It is need of an hour to train new workforce with better operability for precise livestock farming, hand on techniques like quality control mechanism, database system, data models, etc [31].

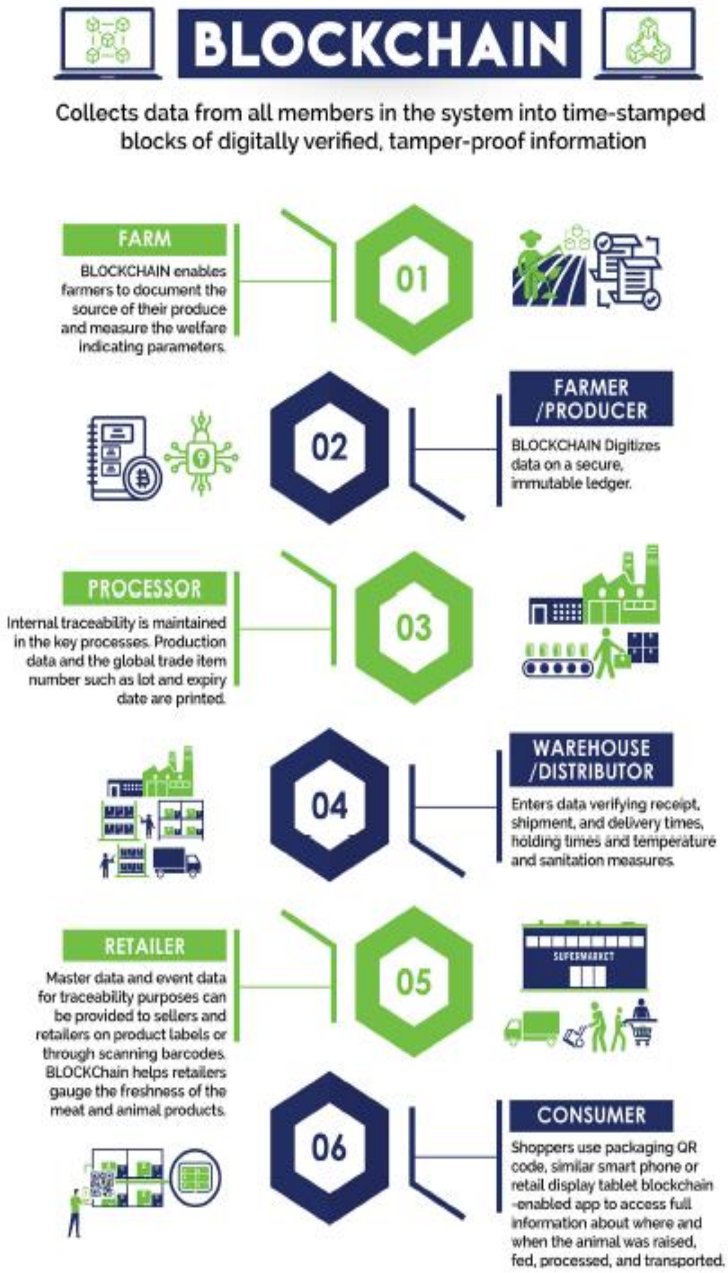


Figure 4: A Blockchain technology sharing information across all network nodes [29]

The main disturbance of digitalization of livestock in the India is lack of infrastructure, remote areas of North-East region and islands like Lakshadweep, Andaman and Nicobar are facing issues of digital communication and infrastructure for digitalization for example a sensor needs a wireless sensor network to establish communication between animal and server. In real life farm, while using sensor various issues may arise which weren't in testing lab. Adverse climate changes like heavy rainfall, humidity, sharp rise or drop in temperature, etc. may not be observed for sensor while testing at lab. Farmers in rural area may have disadvantage of insufficient broadband access [31].

Information, Communication and Telecommunication (ICT) infrastructure should be wide spread. Technologies like 4G, 5G should be reached to all. Hands-on skill improvement for digitalized livestock farming management. Farmers should have accessibility to software tools along with cloud based applications, awareness about technologies like Big Data, IoT, Blockchain, data models etc. Such factors needed to lighten up to reduce the gap between traditional livestock farmers to digitalized and precise livestock farmers.

As Asian countries are far ahead than others in milk production since 2000 [1], India will be leading country to provide livestock products to the world's rising population demands in near future. Many companies in different countries AgriDigital (Australia), AgriLedge (Australia), Agrichain (United Kingdom), Batch block (United Kingdom), Origin Trail (Hong Kong), Hunimal Blockchain Limited (Hong Kong) working for livestock products, food traceability, digital record keeping, animal welfare etc. Such companies uses Blockchain technologies like distributed ledger system, cloud based management platform, Ethereum Mainnet, etc.

6. Conclusion:

This paper focused on precise livestock farming using Sensors, IoT, Blockchain technology which discussed livestock products like milking, animal welfare. Use of invasive and non-invasive, biometric and biological sensor for dairy animals like buffalo, camels, cattle, sheep, etc. has a major role in providing real time data to livestock farming system. IoT is useful for communication between animals and livestock farming system to make decision on various scenarios of temperature, humidity, moisture, gasses etc. Blockchain assure about traceability of product and maintaining ledger helps to track back if in case any food is not acceptable at consumer due to any reason.

These technologies are under development stage in India except 'cow to cloud' program of Chitale Dairy in support of Vmware another organization is PolutryMon which uses sensors, IoT, Blockchain, cloud based applications, very few dairies in India are fully digitalized in livestock products. This paper will guide for new age farmers in India and investor looking for agriculture and allied sector specially livestock management along with digitalization with sustainable animal welfare.

7. Reference:

1. 1 FAO. 2021. World Food and Agriculture – Statistical Yearbook 2021. Rome. https://doi.org/10.4060/cb4477en
2. D.S. Ochs, C.A. Wolf, N.J. Widmar, C. Bir, Consumer perceptions of egg-laying hen housing systems, Poult. Sci. 97 (10) (2018) 3390–3396, https://doi.org/10.3382/ps/pey205

3. A. Baldi, D. Gottardo, Livestock Production to Feed the Planet: Animal Protein: A Forecast of Global Demand over the Next Years, Rel.: Beyond Anthropocentrism 5 (2017) 65, https://doi.org/10.7358/rela-2017-001-bald
4. A. Helwatkar, D. Riordan, J. Walsh, September. Sensor technology for animal health monitoring, in 8th international conference on sensing technology, Liverpool, 2014, pp. 266–271.
5. U. Bernabucci, Climate change: impact on livestock and how can we adapt, Animal Frontiers: the Review Magazine of Anim. Agri. 9(1) (2019) 3.
6. P.K. Thornton, Livestock production: recent trends, prospects, Philos. Trans. R. Soc. B. 365 (1554) (2010) 2853–2867, https://doi.org/10.1098/rstb.2010.0134
7. S. Neethirajan, Recent advances in wearable sensors for animal health management, SensBiosensing Res. 12 (2017) 15–29, https://doi.org/10.1016/j.sbsr.2016.11.004.
8. L. Klerkx, E. Jakku, P. Labarthe, A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda, Njas-Wagen. J. Life Sc. 90 (2019) 100315, http://doi:10.1016/j.njas.2019.100315
9. M. Benjamin, S. Yik, Precision livestock farming in swine welfare: a review for swine practitioners, Animals 9 (4) (2019) 133, https://doi.org/10.3390/ani9040133
10. T. Norton, C. Chen, M.L.V. Larsen, D. Berckmans, Precision livestock farming: building ‘digital representations’ to bring the animals closer to the farmer, Animal 13 (12) (2019) 3009–3017, https://doi.org/10.1017/S175173111900199X
11. M. Jorquera-Chavez, S. Fuentes, F.R. Dunshea, E.C. Jongman, R.D. Warner, Computer vision and remote sensing to assess physiological responses of cattle to pre-slaughter stress, and its impact on beef quality: A review, Meat. Sci. 156 (2019) 11–22, https://doi.org/10.1016/j.meatsci.2019.05.007
12. E.D. Ellen, M. Van Der Sluis, J. Siegford, O. Guzhva, M.J. Toscano, J. Bennewitz, L. E. Van Der Zande, J.A. Van Der Eijk, E.N. de Haas, T. Norton, D. Piette, Review of sensor technologies in animal breeding: Phenotyping behaviors of laying hens to select against feather pecking, Animals 9 (3) (2019) 108, https://doi.org/10.3390/ani9030108.
13. J.E. Koltes, D.A. Koltes, B.E. Mote, J. Tucker, D.S. Hubbell III, Automated collection of heat stress data in livestock: new technologies and opportunities, Transl. Anim. Sci. 2 (3) (2018) 319–323, https://doi.org/10.1093/tas/txy061
14. B. Martinez, J.K. Reaser, A. Dehgan, B. Zamft, D. Baisch, C. McCormick, A.J. Giordano, R. Aicher, S. Selbe, Technology innovation: advancing capacities for the early detection of and rapid response to invasive species, Biol. Invasions 22 (1) (2020) 75–100, https://doi.org/10.1007/s10530-019-02146-y
15. M. Marsot, J. Mei, X. Shan, L. Ye, P. Feng, X. Yan, C. Li, Y. Zhao, An adaptive pig face recognition approach using Convolutional Neural Networks, Comput.Electron. Agric. 173 (2020) 105386, https://doi.org/10.1016/j.compag.2020.105386
16. A.V. Viscardi, M. Hunniford, P. Lawlis, M. Leach, P.V. Turner, Development of a piglet grimace scale to evaluate piglet pain using facial expressions following castration and tail docking: a pilot study, front. Vet. Sci. 4 (2017) 51, https://doi.org/10.3389/fvets.2017.00051
17. B.R. Müller, V.S. Soriano, J.C.B. Bellio, C.F.M. Molento, Facial expression of pain in

Nellore and crossbred beef cattle, J. Vet. Behav. 34 (2019) 60–65, https://doi.org/10.1016/j.jveb.2019.07.007

18. Lukonge, A.B., Kaijage, D.S., Sinde, R.S.: ‘Review of cattle monitoring system using a wireless network,’ International Journal of Engineering and Computer Science, 2014, 3, (5), pp. 5819–5822.
19. Roginski, H., Fuquay, J.W., Fox, P.F.: ‘Encyclopedia of dairy sciences,’ vol. 1–4 (Academic Press, Amsterdam, 2003)
20. Joshi, S., Gokhale, S.: ‘Status of mastitis as an emerging disease in improved and periurban dairy farms in India,’ Ann. New York Acad. Sci., 2006, 1081, (1), pp. 74–83.
21. Keertana, P., Vanathi, B.: ‘IoT based animal health monitoring and tracking system using Zigbee’, Int. J. Res. Trends Innov. , 2017,2, (4), pp. 234–238
22. Patil, A., Pawar, C., Patil, N., et al.: ‘Smart health monitoring system for animals.’ 2015 Int. Conf. Green Computing and Internet of Things (ICGCIoT), Noida, India, 8 October 2015, pp. 1560–1564
23. L.R. Williams, S.T. Moore, G.J. Bishop-Hurley, D.L. Swain, A sensor-based solution to monitor grazing cattle drinking behavior and water intake, Comput. Electron. Agric. 168 (2020) 105141, https://doi.org/10.1016/j.compag.2019.105141
24. https://www.vmware.com/content/dam/digitalmarketing/vmware/en/pdf/customers/vmware-chitale-dairy-case-study.pdf
25. R. da Rosa Righi, G. Goldschmidt, R. Kunst, C. Deon, C.A. da Costa, Towards combining data prediction and internet of things to manage milk production on dairy cows, Comput. Electron. Agric. 169 (2020) 105156, https://doi.org/10.1016/j.compag.2019.105156
26. Wang, J., Chenchen, H., Xiaofeng, Y., Yongjun, R. and Sherratt, S. ORCID: https://orcid.org/0000-0001-7899-4445 (2022) Distributed secure storage scheme based on shardingblockchain. Computers, Materials & Continua, 70 (3). pp. 4485-4502. ISSN 1546-2226 DOI: https://doi.org/10.32604/cmc.2022.020648
27. Soesanto, D., L, L., &BambangPrijambodo. (2022). Food Fraud Prevention using a Block-chain-Based System: Case Study Slaughterhouse in Sidoarjo. *Jurnal RESTI (RekayasaSistem Dan TeknologiInformasi)*, *6*(2), 295 - 304. https://doi.org/10.29207/resti.v6i2.3937
28. J. Lin, Z. Shen, A. Zhang, Y. Chai, Blockchain and IoT based food traceability for smart agriculture, in Proceedings of the 3rd Int. Con. on Crowd Sci. and Eng, 2018, pp. 1–6.
29. Suresh Neethirajan, Bas Kemp, Digital Livestock Farming, Sensing and Bio-Sensing Research, Volume 32, 2021,100408, ISSN 2214-1804, https://doi.org/10.1016/j.sbsr.2021.100408
30. G.A. Motta, B. Tekinerdogan, I.N. Athanasiadis, Blockchain Applications in the Agri-Food Domain: The First Wave, Front. Blockchain. 3 (2020) 6, https://doi.org/10.3389/fbloc.2020.00006
31. J.E. Koltes, J.B. Cole, R. Clemmens, R.N. Dilger, L.M. Kramer, J.K. Lunney, M.E. McCue, S.D. McKay, R.G. Mateescu, B.M. Murdoch, R. Reuter, A vision for development and utilization of high-throughput phenotyping and big data analytics in livestock, Front. Genet. 10 (2019) 1197, https://doi.org/10.3389/fgene.2019.01197