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Review Article

Centralized need for smartphones in utilizing technologies developed for improving performances of dairy cattle: A review

A. K. Singh[1*], P. Singh[2], C. E. Girish[3], U. Kisku[3], B. Singh[1] and S. Ahmad Sheikh[1]

[1]Livestock Production Management Section, ICAR- National Dairy Research Institute, Eastern Regional Station, Kalyani-741 235, West Bengal, India; [2]Department of Animal Husbandry & Dairying, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj-211 007, Uttar Pradesh, India; [3]Dairy Extension Section, ICAR- National Dairy Research Institute, Eastern Regional Station, Kalyani-741 235, West Bengal, India

Abstract

Growing demand for higher quantity and quality milk is the prime concern of any dairy farm manager. Consumers have become more conscious about milk quality rather than only the quantity. However, milk productivity of cattle has risen with improved management practices, for producing good quality milk is still a great challenge due to several factors, such as deficit in quality feed and fodders, mastitis, reproductive problems, and other ailments, costly treatments, high labour cost, etc. Nonetheless, economically available technologies have helped a lot in achieving the target of quality milk production. These technologies help in quantifying the activities in the form of reliable data. Following this, with the help of an expert and statistician, meaningful results may be interpreted to optimize the production and health of dairy cattle. Remarkably, one cannot handle all facilities at every place; however, smartphones have solved this issue to a great extent. Smartphones are connected to animal activity data devices and may help in operating those technologically generated data to know the current situation about cattle. This management helps in controlling dairy operations to a great extent. The smartphone may be carried to faraway places and is much easier to operate. Handling dairy farm technologies may not require highly skilled professionals; short term training may be sufficient to operate smartphones. This review paper has been framed to provide a cohesive and informative discussion regarding the centralized need for smartphones to utilize the available technologies for dairy farms for optimizing animal performances.

Keywords: Dairy cattle, Dairy farm, Health, Performance, Production, Smartphone, Technologies

Highlights

- We studied some technologies for improving the performance of dairy cattle.
- We summarized the importance of smartphones in handling these devices.
- Smartphones connected with devices require proper setup and skills to be used.
- Smartphones may improve the efficiency of monitoring these devices.
- Management decisions based on such devices may be assisted by smartphones.

Introduction

Tremendous growth in the world's milk production has been achieved in the previous 5 decades. The productivity of cow has steadily reached about 2400 kg/year/cow (FAOstat, 2016). In addition to this, the milk producing cattle population also has increased considerably. Better genetic selection, nutritional practices, routine management and health care management facilities may be considered as the main driver of improved milk quantity and quality (Capper *et al.*, 2009; Singh, 2018; Singh *et al.*, 2021a; Singh *et al.*, 2021b). Consumer preference has been shifting from quantity basis towards more on quality aspects of food products (Kumari *et al.*, 2019; Kansal *et al.*, 2020). This is also applied towards milk

*Corresponding Author, E Mail: amitkumarsingh5496@gmail.com

and milk products. However, milk quantity is also important to meet the demand of the ever rapidly increasing human population. Major focus of dairy herdsman is the production of more milk of good quality to make more profit without considerably compromising its quality (Singh, 2019; Kumari *et al.*, 2020; Singh *et al.*, 2020a; Singh *et al.*, 2020b; Singh, 2021; Sriranga *et al.*,2021).

Earlier farmers used to own dairy animals, especially cattle, in fewer numbers as they produced for their own family and little for selling. However, these days the scenario is speedily getting changed. More and more industrial level commercial dairy farms are being established in India and other developing countries (Singh *et al.*, 2021a; Patil *et al.*, 2021). Developed countries have obtained this farming practices earlier itself. These advanced commercial dairy farms use advanced technologies (Rutter, 2017; Stampe and Muller, 2018; Caria *et al.*, 2020; Muñiz *et al.*, 2020) in order to obtain high production from high yielding animals (Akbar *et al.*, 2020; Singh *et al.*, 2021a). Small scale dairy farms are also coming up with these advanced devices (Beyene *et al.*, 2018; Dipu *et al.*, 2019; De Dios García-Villegas *et al.*, 2020; Singh *et al.*, 2020c; Visser *et al.*, 2020; Evangelista *et al.*, 2021). These technologically advanced devices are connected through the internet for connectivity. Some factors including high cost of nutrition, working labours, treatment of animals for common diseases such as lameness mastitis, etc. have sharply raised the cost of per kg milk production at dairy farms (Deming *et al.*, 2017; Deming *et al.*, 2018; Sadiq *et al.*, 2019; Singh *et al.*, 2020d; Singh *et al.*, 2020e; Singh *et al.*, 2021; Yadav *et al.*, 2021). However, the availability of economically affordable technologically invented devices has reduced these extra costs to a much considerable level (Caja *et al.*, 2016; Jelinski *et al.*, 2020; Smith *et al.*, 2020). The recent era has witnessed the growing use of the internet in every field of life. Be it agriculture, food industry, chemical, mining or livestock industry. The internet has improved the working module of such activities (Möcklinghoff-Wicke, 2018; Mandi and Patnaik, 2019; Beaver *et al.*, 2020; Neethirajan, 2020). Artificial intelligence and the internet of things have opened a new and smooth way for dairying (Bogue, 2013; Joubert, 2013; Chen and Lin, 2015; Hogeveen *et al.*, 2017; Ji *et al.*, 2017; Rateni *et al.*, 2017; Rudowicz-Nawrocka *et al.*, 2018; Drewry *et al.*, 2019; Saengwong *et al.*, 2021; Neethirajan and Kemp, 2021). These technologies may easily be accessed through smartphones. Smartphones can be easily operated from far located places with ease. However, with little training and experience, a person can easily operate these technologically connected advanced devices for dairying operations (Debnath *et al.*, 2017; Ducrocq *et al.*, 2018; Norton *et al.*, 2019; Cabrera *et al.*, 2020; Singh *et al.*, 2020f; Rukmana *et al.*, 2021).

There are several review papers related to mobile and mobile applications in agriculture and dairy farming. However, there are scanty literatures available highlighting the centralized need for smartphones in utilizing technologies implied at advanced dairy farms. Therefore this review was framed with an objective to discuss the centralized need for smartphones in utilizing technologies developed for improving the performances of dairy cattle.

Growing use of technologies in dairy animals

Mobile phones created a revolution in communication techniques of the whole world. It offers multi facilities apart from calling, such as SMS, weather forecasting, internet surfing, music and many others (Romani *et al.*, 2015; Andriamandroso *et al.*, 2017; Mandi and Patnaik, 2019; Jelinski *et al.*, 2020; Smith *et al.*, 2020). Mobile phones are a handy tool that offers a great scope to perform many tasks from even a distant place, such as controlling television channels or sending emails. It is available to most of people these days. India stands 2nd in terms of total smartphone users after China. As per estimation (https://en.wikipedia.org/wiki/List_of_countries_by_smartphone_penetration accessed on 4/1/2022), number of smartphones users increased in the year 2020 which was 439.2 million from 345.9 million. This shows a rapid increase in the number of users of smartphones. Smartphones greatly help to cater the need for continuous and updated knowledge regarding every field. The livestock sector is also becoming technologically improved for its various operations (Debauche *et al.*, 2017; Bodas *et al.*, 2018; Deming *et al.*, 2018; Wierig *et al.*, 2018; Bonelli *et al.*, 2019; Singh *et al.*, 2020g; Singh *et al.*, 2020h; Ahikiriza *et al.*, 2021; Medina-Rodriguez *et al.*, 2021). Diagnosis of animals may also be coordinated using smartphones (Ariff *et al.*, 2014; Ludwig *et al.*, 2015; Kumar *et al.*, 2016; Lewandowski *et al.*, 2016; Beyene *et al.*, 2017; Jang *et al.*, 2017; Mateen *et al.*, 2018; Groher *et al.*, 2020; Pereira *et al.*, 2020; Singh *et al.*, 2020i; Singh *et al.*, 2020j; Koszela *et al.*, 2021). Table 1 shows some technologically available devices for optimizing the performance of dairy cattle. Smartphones may help in assessing and monitoring different activities of animals and their interactions with their surrounding (Fig. 1).

Constraints and solutions for using smartphones in utilizing technologies

Smartphone usage, though it is quite easy to handle, has some limitations (Maina, 2015; Zhang *et al.*, 2017; de Oliveira Júnior *et al.*, 2018; Helfer *et al.*, 2018; Hogeveen *et al.*, 2021). For all the system setups, the animals have to be endowed with such technologies. The herd size must be large as the initial cost of such a technological network setup would be costly (Frandsen, 2015; Caja *et al.*, 2016; Singh *et al.*, 2021a; Broucek and Tongel, 2017). However, some researchers suggest that in the long run, these may become economically efficient (Caja *et al.*, 2016). Battery supply facilities may be a great constraint in handling these technologies (Knight *et al.*, 2018). A bypass data storage facility always has to be there, which may work even under electricity cut-off for a considerable time. Large farms are generally situated in remote areas where internet facilities round the clock may be a limitation. Abrupt weather conditions may also be a critical problem for transferring data signals to these technological setups. The working of these devices has to be in efficiently working conditions (Davis *et al.*, 2011; Beirne and Roessen, 2015; Klefot *et al.*, 2016; Fogarty *et al.*, 2018; Jadawala and Patel, 2018; Maroto-Molina *et al.*, 2019; Cairo *et al.*, 2020).

Technical know-how

First and foremost necessity of using smartphone in utilizing technologies related to dairy farm is thorough knowledge about applications that are used to monitor the activities of animals in addition to general usage of smartphones (Karetsos *et al.*, 2013; Mueller *et al.*, 2016; Rodriguez *et al.*, 2018; Mandi and Patnaik, 2019; Makau *et al.*, 2019; Fuentes *et al.*, 2020). Smartphones should be well equipped with good random access memory (RAM) and read only memory (ROM) for quick accessing and storage of data obtained from various activities of animals assisted devices. Furthermore, the smartphones may have a cloud storage facility wherein the herdsman may keep data for a considerable period (Gichamba and Lukandu, 2012; Edwards *et al.*, 2014; Rossi *et al.*, 2014; Vannieuwenborg *et al.*, 2017; Debauche *et al.*, 2019; Eastwood *et al.*, 2019; Sevastou *et al.*, 2020). Regular wiping up of unwanted data which may occupy the valuable storage of data generated should be done to assure proper memory space for newer valuable data accession and storage (Koo *et al.*, 2012; Patel and Patel, 2016; Dieng *et al.*, 2017; Neethirajan, 2017; Neubauer *et al.*, 2018; de Oliveira Júnior *et al.*, 2019).

Data protection

Any malware may steal valuable data of animals and herd. Any leakage of data may reveal all valuable information to third party which might increase unhealthy competition amongst different dairy farms. This may challenge the reputation of a particular farm from which the information gets leaked

Table 1. Some technologically available devices for optimizing performance of dairy cattle

Performances	Technologies used	Parameters studied	References
Estrus detection	Pedometer	Random forest classifier	hht://www.celotor.com/es/ celotor
	Afimilk pedometer	It stores no of steps in 2 hours	
Feeding activities	3D-accelerometer	Multiple linear regression analysis artificial neural network cluster analysis	Mattachini *et al.*, 2016
Mastitis detection	IOT sensors milking Robot	Measures the change in conductivity that arises from an increase in milk Na+ and Cl – concentration	https://www.afimilk.com/ parlor-automation;
	High-Quality Milk Sensors		Cabrera *et al.*, 2020
	DeLaval Online Cell Counts (SCC)	Somatic cell counts, Analysis of cell ADN by u.v. fluorescence	Dalen *et al.*, 2019
	AMS Sensor	MasPA (Machine learning application for mastitis detection)	Abdul Ghafoor *et al.*, 2021
Behaviours	Cow Manager SensOor	3-axial accelerometer	Cow Sensor - Monitor all cows on your farm 24/7 | Cow ManagerIceRobotics | Powering a Sustainable Dairy Industry
	Agis Automatisering (Harmelen, NL)		
	Cow Alert		
	IceRobotics		
BCS	Accelerometer	Random forest classifier	Bercovich *et al.*, 2013
	DeLaval BCS (Tumba, SW)	two-dimensional (2-D), three-dimensional (3-D), and thermal imaging	
	AlexNet	19 layer deep convolutional neural network (VGG19 model)	Çevik *et al.*, 2019
Lameness	Step Metrix	Time and force sensor	www.boumatic.com/eu--en/ products/view/stepmetrix
	BouMatic (Madison, WI, USA)		
	Gaitwise ILVO (Merelbeke, BE)		
	Vedio material, 3D vision cameras	deep learning algorithms	Wu *et al.*, 2020
Location position devices	WildCell	GPS	www.lotek.com/wildcell.hmt
	Lotek	RF	www.omnisense.co.uk
	Omnisense	temperature sensor	www.cattle-watch.com
	CattleWatch	2-axial accelerometer	
Rumen sensors	'eCow'	RF	www.ecow.co.uk
	'WellCow'	pH electrode	www.wellcow.co.uk
	'smaXtec pH' bolus	thermistor	www.smxtec.net
	Smartbow an eartag-based	SMS	
	Accelerometer	3-axial accelerometers	

Table 1., Cont. ...

Cont. Table 1.

Performances	Technologies used	Parameters studied	References
Calving and dystocia prediction	MOOCALL BIRTH SENSOR	Random forest & boosted tree	Zaborski *et al.*, 2019
	Vel'Phone, Medria (Châteaubourg, FR)	ThermistorSMS	www.medria.fr/en_GB/produits/vel.phone.html
Milking performance	Automatic milking robots and milking parlors	Dynamic linear modeling	Jensen *et al.*, 2018; Dallago *et al.*, 2019
		Artificial neural networks	
Physical parameters	Silent Herdsman Afimilk	3-axial accelerometer	https://www.afimilk.com/products/
	RumiWatch	RF	https://www.rumiwatch.com/
		RF and USB‡‡, 3-axial accelerometer, thermistor, pressure	

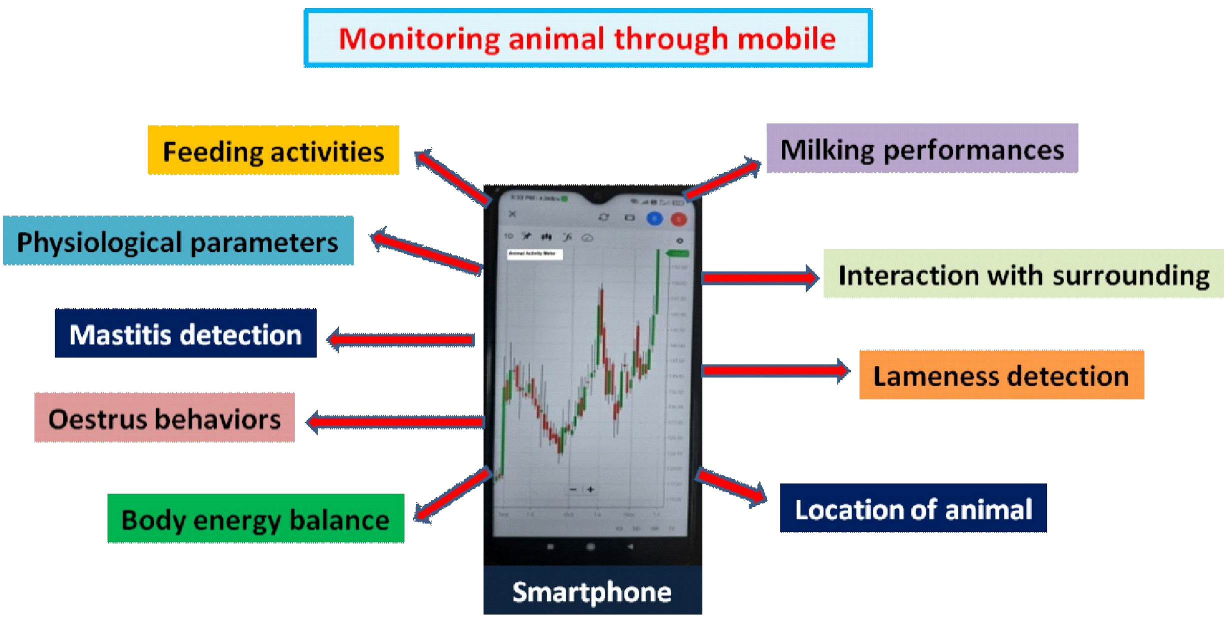

Fig. 1. Centralized use of smartphones in utilizing available technologies at dairy farm

regarding different standard management practices. Hence, it may be suggested that smartphones in which such technologies are managed may not be used for general purposes such as calling, internet surfing, etc. Any unwanted and extra application installation other than that is meant for dealing with such technologies, should be avoided. As this may become potential carrier for data hacking. Skillful usage of smart phone should be prioritized for enhanced data protection (So-In *et al.*, 2012; Anggraeni *et al.*, 2013; Sreeram and Gupta, 2017; Shalloo *et al.*, 2018; Mandi and Patnaik, 2019).

Battery of devices involved

Facility of battery should be always made available with devices which are involved in continuously gathering meaningful data from animal activities (Baumuller, 2012; Norton *et al*., 2019; Singh *et al*., 2021a). Though electricity facility may be always available, the facility of battery will additionally lessen the chances of losing data that may happen due to current failure (Knight *et al*., 2018; Fogarty *et al*., 2018; Maroto-Molina *et al*., 2019). It is a noticeable aspect that smartphone is directly and highly dependent upon the battery status. Low battery in smartphones may compromise data acquisition and hence, considerable battery status should always be available in smartphones. Easy availability of charging facility must be ensured for good battery status round the clock.

Internet and remote areas

Intranet facility may be made available for smaller area meant for data collection such as inside a dairy farm. Local area network may also be utilized for such purpose. However, internet facility may be considered superior for data accessing through long distances. Concerned person may monitor technologies from several thousand kilometers as and when needed with the help of internet connections and technology administrative applications (French *et al*., 2015; Andriamandroso *et al*., 2015; Allain *et al*., 2017; Connolly *et al*., 2018; Haladjian *et al*., 2018; Michels *et al*., 2019; Burda *et al*., 2021; Daum *et al*., 2022). Global positioning system may be considered as one of the best examples of utilizing internet facility for accessing data regarding gravitational coordinates of concerned human or animals or any object (Trotter *et al*., 2010; Soriani *et al*., 2012; Caja *et al*., 2016). However, there remains always some other side of the coin; proper availability of high-speed internet facilities in remote areas remains a challenge. Better speed offers quick data acquisition. Proper internet connections in remote areas would be beneficial for spreading the data accession as major larger dairy farms may be located in remote areas away from residential places of humans (Caja *et al*., 2016; Susan *et al*., 2019; Santos *et al*., 2020; Singh *et al*., 2021a).

Storage facility

Continuous availability of data storage facilities has to be present in this kind of animal activity data monitoring system. Good quality video recording may require huge data storage on hard discs. These may be of two types viz. self rewritable after a specific period of time, and other may be non-re writable kind of hard disc. These may be costly and cumbersome. Regular replacement requires careful observations of the threshold storage capacities of hard discs. Stored discs containing objectified data should be securely stored in a safe place without anyone's interference. Storage should be such that electronic and magnetic fields should not affect the stored data (Anderson *et al*., 2012; Spigarelli *et al*., 2020).

Electricity

Good units of electricity may be required all round the clock for the smooth working of such data collecting, storing, analyzing and interpreting systems. Extra electricity facilities such as generators and other devices may be installed so that current failure for a considerable period may not hinder the dairy operations and working of this system.

Complex applications

Applications may govern, monitor and operate the working of different technologies utilized at a dairy farm (McKean *et al*., 2012; Koo *et al*., 2013; Gargiulo *et al*., 2018; Reddy and Nandini, 2019; VanErp-van der Kooij and Rutter, 2020; Goller *et al*., 2021). Thorough knowledge of the working style of the installed application in smartphones is a must to operate the technologies present at dairy farms. A person who has no or incomplete knowledge regarding the working principles of these applications may create complex problems.

When these apps may control several operations, any unwanted happening may occur. However, training may help in eliminating this problem. Familiarity of concerned with such applications may assist in operating such applications efficiently (Hennessy *et al.*, 2016; Mandi and Patnaik, 2019; Owino *et al.*, 2020).

Abrupt weather conditions

Connectivity of certain devices through internet, intranet, local area network (LAN) or wide area network (WAN) may be directly and heavily dependent upon the weather climate of that region. Sudden change and abrupt weather conditions may lead to loss of connectivity, devices and well being of both humans and animals (Caja *et al.*, 2016; Norton *et al.*, 2019). Though much cannot be done against adverse weather conditions, but we may prepare well in advance for protective measures. The measures may include quick storage of devices in a safe place for a short period; animals and humans should be in sheltered and protected areas under harsh weather conditions.

Cost of devices

Costly devices may be considered as one of the major challenges in operating such technological devices (Mayo *et al.*, 2019; Singh *et al.*, 2021a). The smartphone itself may be quite costly and needs to match the specifications required by the technological system setup. The availability of economical devices would be suitable for cost minimization at dairy farm. However, the quality of devices must not be compromised with low cost devices. While purchasing the concerned the device including smartphones, a competitive price must be dealt with manufacturing firms for same piece of quality.

Information and working conditions of connected devices

Detailed and clear cut knowledge about the connected devices is a must need for operating such connected devices. Updates of new applications should be incorporated into knowledge data base of concerned person that are utilized to use such devices. In addition to that, all the devices must be proper working conditions. Regular maintenance and repair should be routinely followed to assure smooth working of all the devices. For instance, GPS devices may stop readily working due to some accident. Hence, all such technological devices should be routinely checked to avoid any loss of important data that might be collected during that period of time (Knight *et al.*, 2018; Singh *et al.*, 2021a).

Proposed working model for smartphone in augmenting performances

For collecting, processing and interpreting the data, there may be two pathways. One may be the storage of device data through a smartphone to computers and other processing and storing devices. The second one may be through by passing the smartphone usage. When by passing of activity data through smartphone is done, the direct connectivity of devices is made through processing and storage devices. In the coming days, most of the advanced high-tech dairy farms will use most of such technological innovated devices for collecting valuable data through animal activities in order to know their status, and these data may help in predicting the future performances so that management strategies may be planned in advance to optimize the performance of animals. Technologically innovated devices, their setups, the concerned animals, smartphones, various computers and other processing and storage devices become necessary for this working model. However, internet or other connecting media is always required in this kind of setup. The proposed working module is proposed in Fig. 2.

Conclusion

The availability of technologically innovated devices including smartphones at much affordable prices has opened the windows of quantifying the activities of animals which may

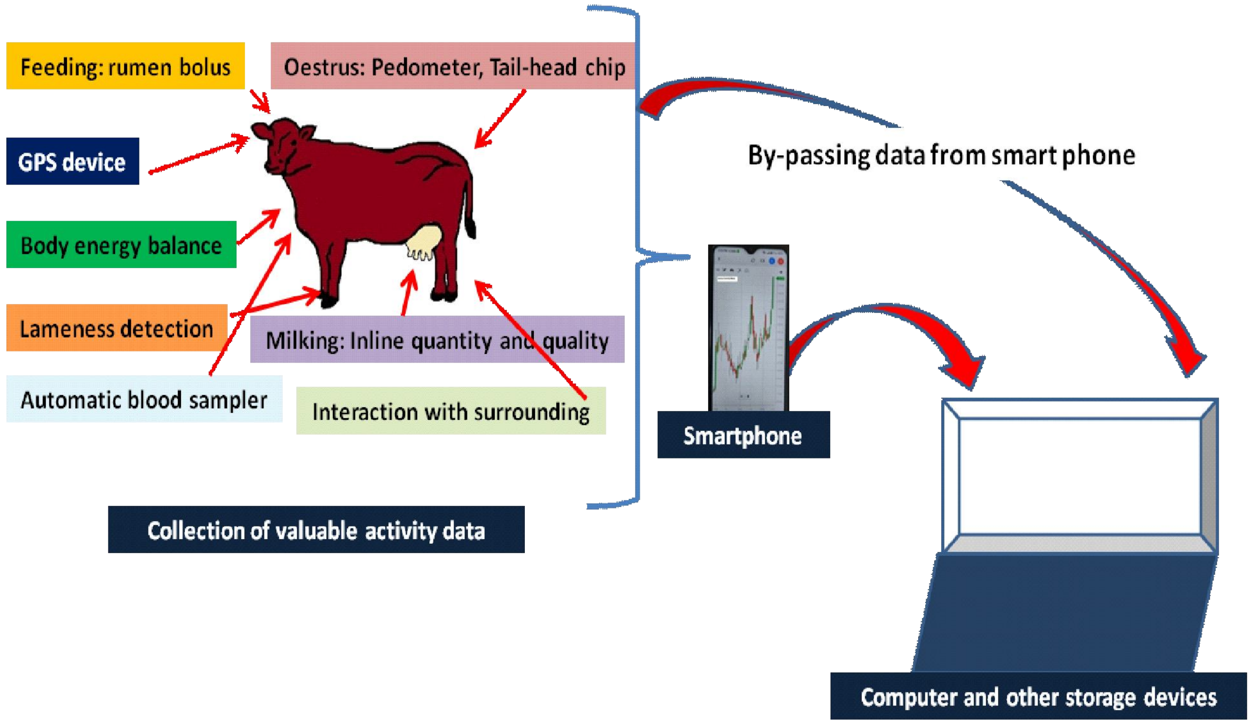

Fig. 2. Proposed working model for technological data collection from animal activity

hugely simplify the new era of dairy operations. These devices are generally present in large and advanced dairy farms. However, it must be understood that using such devices may not completely replace the need for experts in animal sciences and well verse statisticians to interpret such huge sets of data into valuable information. Nevertheless, smartphones may be highly useful in collecting, processing and interpreting these data through various connected devices' apps. These smartphones are portable and ready to be used by some skilled person who has considerable knowledge regarding working of apps. Some constraints including the technical know-how, updated knowledge base, proper working devices, high installation costs, large storage facilities, smooth internet connectivity, and abrupt weather conditions have to be kept into consideration for utilizing such innovative devices. Working on these constraints well before will certainly help in smooth working of our proposed working model. Conclusively we may remark that smartphones have centralized need to utilize these technologies for augmenting the production and health performance of dairy cattle.

Conflict of interest: Authors have no conflict of interest in this study.

Author's contribution: AKS: Conceptualized, designed, authored and edited this manuscript; PS: Wrote and assisted in graphical presentation of the article: GCE and UK: Edited and proof read the article for final version; BS and SAS: Assisted in writing, referencing, designing of the manuscript. All authors wrote and finalized this manuscript for publication.

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