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Review

Current Livestock Identification Systems

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ABSTRACT

Traditional livestock identification and tracking techniques have been used for a while, but their performance is constrained by their susceptibility to theft, fraud, and security issues**.** This review discusses bioactive identifiers, biometric identifiers, barcodes, radio frequency identification and others as current means of identifying livestock and the potential benefits of using biometric identification systems such as improved accuracy and efficiency, as well as their ability to provide more reliable data than traditional identification methods. We also discussed the challenges and concerns associated with the use of biometric identification systems. Selecting the best method from the classical approaches involves various considerations, such as the size of the farm, the cost, and the required functions of the identification process. The article concludes by discussing the future of biometric identification systems in the livestock industry. We recommend that farmers should consider these factors in choosing the best animal identification system for their farms.

Keywords: Barcodes, bioactive identifier, biometric, livestock, radio frequency identification

INTRODUCTION

Historically, animal identification has been developed to indicate ownership and prevent theft (Schnepf, 2009; Gambo and Gwaza, 2018). Today, animal identification has been expanded to include information on the animal's origins (for example, birthplace, parentage, sex, breed, and genetics) as well as traceability—the ability to trace an animal product back through the marketing chain to its source, while identifying those other animals or animal products with which it has come into contact (Schnepf, 2009). In addition, animal identification plays a crucial role in understanding disease epidemiology, vaccination, and production management (Awad, 2016). Also, the identification of individual animal is of utmost importance in keeping its breeding record appropriately and adequately.

Traditional cattle identification and tracking techniques, such as ear tags, branding, tattooing, and electrical methods, have been in practice for a while, but their performance is constrained by their susceptibility to theft, fraud, and security issues. Owing to their uniqueness, immutability, and low costs, biometric traits mapped into animal identification systems have emerged as a promising trend (Awad, 2016). Currently, animal tracking and product traceability require, at least, the use of a unique and individual identity code for each animal, and a transparent, credible and verifiable system to guarantee animal identity (McKean, 2001; Bowling *et al.*, 2008).

Varieties of animal identification systems currently exist in several countries, with differences based primarily on the amount and type of information collected and the extensiveness of the traceability system (Schnepf, 2009). These systems are typically temporary. Permanent cattle identification methods are not perfect in terms of reliability and accuracy, and problems arise concerning the cattle, the markers, and the system's operability. Electronic-based identification methods constitute the next generation of approaches. For instance, radio frequency identification (RFID) solves several problems present among the classical methods, but it raises many security, privacy, and operational challenges (Fallon *et al.*, 2002). Selecting the best method from the classical approaches involves various considerations, such as the size of the farm, the cost, and the required functions of the identification process (Awad, 2016).

BIOMETRIC IDENTIFIERS

Biometric identification systems are increasingly being used in livestock management to improve the accuracy and efficiency of animal identification. These systems use physical characteristics such as facial features, ear tags, and hoof prints to identify individual animals (Evans & Eenennaam, 2005). The use of biometric identification systems has been shown to reduce the time and cost associated with traditional identification methods, such as visual inspection and manual data entry (Kumar *et al*., 2019). Additionally, biometric identification systems can provide more accurate and reliable data than traditional methods, as they are less prone to human error. Furthermore, biometric identification systems can be used to track animal health and performance, as well as to monitor animal movement and location. This is beneficial for farmers, as it can help in better management of herds and ensure the health and safety of their animals (Kaur *et al*., 2019**).**

Various biometric identifiers have been suggested including retinal scans, muzzle patterns in cattle, facial recognition, immunological labeling, and DNA analysis (Small, 2019). They are considered more reliable than electronic identification because they cannot be falsified –in theory, the transponder of an RFID could be removed and inserted into the tag of another animal (Gonzales-Barron & Ward, 2005) in a process that is cumbersome and requires certain level of technical expertise which are real constraints in tampering with them.

Biometric identifiers for beef animals include muzzle print images, iris patterns, and retinal vascular patterns. Although using biometric identifiers has replaced human experts with computerized systems, it raises additional challenges in terms of identifier capturing, identification accuracy, processing time, and overall system operability (Bugge *et al*., 2007; Awad, 2016; Kumar *et al*., 2017). Sophisticated, mature biometric methods of face, fingerprint, or iris identification for humans cannot easily be applied to animal identification under experimental conditions on a livestock farm (Gonzales-Barron *et al*., 2008).

Currently, the state of the art in animal identification is the use of RFID tags. However, attaching or implanting chips can cause technical and health problems. Camera-based optical solutions are non-invasive and not stressful but very challenging to implement (Fallon *et al.,* 2002). Human faces, for instance, can mostly be detected and identified from a 2D view, whereas the detection of the pose and position of an animal's head under difficult lighting conditions and in front of a complex background can be nearly impossible using usual 2D cameras. Therefore, the goal of the current project in animal identification was to develop a device that uses multiple sensors for capturing 2D and 3D data. The information provided by the different cameras is fused to locate, measure, and identify the animal's head (Stahl *et al*., 2012). This technique is highly useful as it provides end-device that collects 2D and 3D data such as the image of the animals involved and this can be routed to one or more processing centres through the internet (Dieng *et al*., 2017). This process can be achieved in conjunction with Internet of Things (IoTs) technique in order to curb the menace of cattle rustling.

RADIO FREQUENCY IDENTIFICATION

Radio frequency identification (RFID) is an electronic animal identification method, especially for ungulate animals like cattle. RFID is made up of a microchip with a small transmitter radio and antenna for communicating with a reader. Different methods of application exist for RFID technology with microchip implants, ear tags, ruminal boluses, and neck collars being the most common ones (Bello *et al*., 2020). RFID ear tags have the technology embedded in the cattle's ear like a number ear tag. A Balling gun is used to administer ruminal boluses on cattle by retaining the ruminal boluses in the cattle fore-stomach. Neck collars, a resemblance of neck chains use the electronic tagging method instead of a number tag (Bello & Abubakar, 2019; Bello and Moradeyo, 2019; Bello *et al*., 2020). Irrespective of any RFID technologies used, a scanner must read the microchip, get the radio signal interpreted as a numerical code, and generate the cattle's recorded information from the software meant for herd management (Blancou, 2001). RFID technology provides individual unique identification codes, it requires no line-of-sight visual readings, and its signal can penetrate various walls and get read by the scanner, however, it is expensive to set up and tends to get the transponders lost (Bello & Abubakar, 2019). Due to the ability of RFID technique in recognition of all kinds of objects from a distance without necessarily having contact, it becomes irreplaceable for identification and tracking systems. Because of these characteristics, RFID finds its usefulness in product and inventory tracking as well as monitoring and identification of animals (Gwaza and Gambo, 2017). Thus, RFID becomes a viable tool to curb cattle rustling rampant in Nigeria. This is achieved through Livestock Identification and Traceability System (LITS), whereby rumen boluses are embedded with RFID microchips with which animals are traced throughout the production chain (Bowling *et al*., 2008). This chip is coded with virtually all information about the animal, such as, its origin, personal identification number, owner’s name, location of the animal, sex, and coat colour which will be uploaded on the extension officer’s computer and central database. Having done this, traceability and tracking system becomes easy with Global Positioning System (GPS) and RFID technology combined. As proposed by Karnjanatwe, (2005), cattle movement tracing and location of individual cow is possible when GPS technology is contained in RRFID tags. Despite usefulness of RFID technology, its implementation in country like Nigeria has suffered some setback. Among the challenges faced in its implementation include lack of political will from the side of the government. Furthermore, inadequate to poor network coverage is another problem confronting the implementation of this priceless technology as many rural areas where actual animal husbandry practice takes place are devoid of electricity as well as powerful network series such as 3G, 4G and 5G, thus, making the implementation of RFID a nightmare. Also, strong adherence to nomadic system of animal husbandry which involves movement of human and their herd without permanently settling in a place is also a stopping block for the actualization of this recently commercialized biometric identifier. Similarly, the cost involved might cheaper relative to other techniques but, it appears to be more expensive for inhabitants of a country where the majority live below poverty line. This will definitely translate to low patronage even if, this technology comes to stay. Although, these are some of the challenges facing the successful implementation of RFID in Nigeria, however, high success rate can be recorded if, the solutions suggested below are considered:

Provision of good communication network services is a prerequisite for the successful use of RFID. Settling of pastoralists through ranching programme will also make implementation of RFID usage easier and cheaper. Government can create an enabling environment by making a policy favourable for the adoption of this type of technology that safe guard the wealth of citizens as seen in Botswana, Canada, Australia, America and other parts of the world.

NOSE PRINTING

Nose prints are unique, unalterable, and permanent methods of identification commonly used for livestock identification. Nose prints are similar to human fingerprints in that no two nose prints of different livestock are the same when compared as there must be six identifiable matching lines or dots that differentiate them as found in human fingerprints (Bello & Abubakar, 2019). Headlock is mostly used to restrain the cattle whose nose is to be printed by having its nose dried and a small amount of ink placed on it, and then get the nose pressed onto an index card firmly held to copy the ink print onto the card (Neary & Yager, 2002). This method of identification is painless and unique to individual cattle; however, it requires a great effort to restrain individual cattle to get their nose prints, moreover, the prints cannot be stored nor read swiftly making it inefficient (Marchant, 2002).

Muzzle patterns were originally recorded as ink prints on white cards and were widely used in Japan for pedigree cattle identification (Gonzales-Barron & Ward, 2005). More recently, digital imaging of muzzle patterns, which maps the 'beads' and 'ridges' on the muzzle, has been developed (Gonzales-Barron *et al*., 2009). Barry *et al*. (2007) demonstrated that digital imaging of cattle muzzle patterns could achieve a recognition rate of almost 99%, but concluded that further work would be needed to automate the systems used. Corkery *et al*. (2007) demonstrated that an algorithm used for human facial recognition systems could identify sheep faces with 96% accuracy.

BARCODES

A barcode could be printed on the tag. This would be read using similar technology to that at supermarket checkouts. Barcodes for sheep tags have been ruled out because they may become obscured by muck and can only be read after cleaning. They are used on ear tags in the Republic of Ireland, but Shanahan *et al*. (2009) list several advantages over barcodes that would accrue from the implementation of RFID in the supply chain, including a reduction in labour costs; more efficient control of the supply chain due to increased information accuracy; better tracking and tracing of products; and enhanced profit margins (Small, 2019).

RETINAL RECOGNITION TECHNOLOGY

The retinal vascular pattern is a highly unique and distinct trait in livestock (Loftus & Meghen, 2011; Marchant, 2002). In Whittier *et al*. (2003), retinal images of four cloned sheep from the same parent line were evaluated to confirm the uniqueness of the retinal vessel patterns in genetically identical animals. According to Masters (2004), the uniqueness of each individual's retinal vascular pattern by the theory that retinal angiogenesis obeys a Laplacian process that provides the randomness needed for fractal behaviour—the same branching patterns observed in rivers, trees, roots or erosion channels. With this theory, the probability of two retinal patterns being identical is virtually zero.

Moreover, Shadduck & Golden (2002) indicated that the retinal vessels remain unchanged in the normally developing eye from birth to maturity. Although, there is strong evidence in favour of the suitability of retinal vascular pattern as a stable marker for livestock, very little work has been performed on assessing the recognition performance of this system. Rusk *et al*. (2006) evaluated the performance of the retinal imaging technology by verifying the identity of 317 4-H beef cattle and 220 sheep previously enrolled using this biometric system. Through a visual verification exercise (matching a pair of retinal images only visually), these researchers found a lower rate of false match (0.5%) and false non-match (1.6%) for beef cattle retinal images than for sheep retinal images (27.6% and 2.7%, respectively).

The Optireader device (Optibrand®, Colorado, USA) is the only near-infrared ocular fundus digital video camera designed expressly for capturing retinal vascular patterns of livestock. Data Management software not only allows data storage and data organisation but also has the capability of comparing the branching patterns of two retinal images using a built-in pattern-matching algorithm that produces a matching score value (Loftus & Meghen, 2011; Small, 2019).

Allen *et al*. (2008) evaluated the potential of retinal scans to identify cattle in Northern Ireland. They showed that the 1738 retinal scans (two from each of 869 animals) could be reliably differentiated, both visually and by computer. Images taken at later dates from the same animals showed that 98.3% could be matched by computer and the remaining 1.7% visually. A simulated ear tag switch for 115 animals indicated that all could be detected by subsequent imaging and computational analysis. Crucially, operators could be trained to use the image capture technology in one day, and each image could be acquired in two minutes, although the animal had to be restrained in a crush. The authors concluded that the system could be deployed as a stand-alone technology for animal identity verification and had the potential to improve the performance of ear-tag-based identification systems for cattle (Small, 2019).

DEEP LEARNING

The implementation of deep learning and machine learning models for animal identification, productivity, milk quality trait assessment, and welfare is an exciting development in the field of livestock management. This technology can be used to monitor the health and welfare of animals, as well as to track their productivity. The time, effort as well as the cost of production required to manually assess the animals can be greatly reduced (Fuentes *et al*., 2021).

Dac *et al*. (2022) developed a face recognition system for dairy farm cows using advanced deep-learning models and computer vision techniques. They proposed an easy to upgrade system as its fundamental steps are segmented into smaller modules. The steps to add or remove an identity to/from the database would not need to retrain other models. The accuracy across videos from 89 different dairy cows achieved an overall accuracy of 84%. The authors recommended that the computer program developed may be deployed on edge devices, and it could be integrated into welfare assessment for dairy cows.

BIOACTIVE IMMUNOLOGICAL LABELING SYSTEM

A bioactive immunological labelling system ('ImmunoTrack') was developed in Germany by Responsif GmbH (Gonzales-Barron & Ward, 2005). This uses highly antigenic peptide sequences with appropriate adjuvants to induce strong peptide-specific antibody responses in cattle or pigs. These anti-peptide antibodies can be detected, using standard techniques, in the live animal's blood serum or the meat 'juice' after slaughter. By varying the combinations of peptides the origin (e.g. country, region, farm) and other characteristics (e.g. breed, organic farming) can be encoded (Gonzales-Barron & Ward, 2005). However, this may not be feasible for use in field situations in Nigeria due to cost and logistic reasons.

LIMITATIONS OF CONVENTIONAL ANIMAL IDENTIFICATION SYSTEMS

Many studies have shown that ear tags are very likely to cause both short- and long-term complications to the integrity of the ears, especially in livestock. Aslani *et al*. (1998) described an outbreak of tetanus in lambs instigated by plastic ear tags inserted too close to the base of the ears. After examination of the ears of over 700 sheep, Edwards & Johnston (1999) found that approximately 28% of the animals suffered slight to moderate ear damage associated with plastic ear tags, including local inflammation, pronounced thickening, haemorrhages and mild sepsis. Edwards *et al*. (2001) compared the damage caused by inserting commonly used metal and polyurethane tags into the ears of ewes and lambs. They observed some incidence of tag loss due to the tag tearing through the ear and most significantly, they showed that the insertion of ear tags eventually resulted in an inflammatory response—and some discomfort and pain especially if the ear is handled when reading the tag.

For complete food chain integrity, an animal marker should be able to identify the animal from birth until its death. According to Fosgate *et al*. (2006), the results of a survival analysis modelling the rate of ear tags loss in buffalo – median ear tag retention of 272 days and an estimated ear tag loss rate of 0.0024 ear tags per day – has questioned the sufficiency of ear tags alone for long-term identification. On the other hand, electronic animal identification has certain limitations regarding injection sites in connection with migration problems and recovery in slaughterhouses (Fallon *et al.,* 2002).

While an animal can be allocated an identification number and the system of identification is made tamper-proof as far as possible, it may be necessary to verify an animal's identity against an invariant parameter in situations where the identity of the animal is in doubt (Dziuk, 2003). However, barcodes can be substituted from one animal to another, thus, affecting the traceability of such animals.

CONCLUSION

In conclusion, biometric identification systems offer a number of advantages over traditional methods, and their use is likely to continue to increase in the future. The implementation of artificial intelligence models for animal identification, productivity, milk quality trait assessment, and welfare is an exciting development in the field of livestock production and management. Selecting the best method from the classical approaches involves various considerations, such as the size of the farm, the cost, and the required functions of the identification process. We recommend that farmers should consider these factors in choosing the best animal identification system suitable for their farm.

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