Revista Científica, FCV-LUZ / Vol. XXXIII, Supl. Esp., 124 - 130, 2023, https://doi.org/10.52973/rcfcv-wbc019

PRECISION LIVESTOCK FARMING IN BUFFALO SPECIES: A SUSTAINABLE APPROACH FOR THE FUTURE

Ganadería de precisión en búfalos: un enfoque sostenible para el futuro

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ABSTRACT

The growth of the world population that will occur in the next 30 years will be responsible for an increase in animal-derived food and proteins of animal origin. The livestock sector will be obliged to face new challenges, such as the reduction of environmental impact, the improvement of animal-derived food quality and safety, the reduction of antibiotics, and the increase in efficiency. One of the strategies that could be adopted is Precision Livestock Farming (PLF), recognized as the most sustainable tool to improve farm sustainability. It can be defined as "*the continuous, automated, and real-time monitoring of production, reproduction, health, and welfare through the application of advanced information and communication technologies (ICT)*". In this new farm concept, animals, environment, machinery, and processes become "information objects" to enhance data; farm management and animals are defined as CITD systems: they are Complex, Individually different, Time-variant, and Dynamic. Several PLF technologies have been recently applied to buffalo species, improving some critical points of the farm, such as milking, nutrition, reproduction, and management. This short review reports some experiences carried out in buffalo species.

Keywords: Precision livestock farming, sustainability, buffaloes.

RESUMEN

El crecimiento de la población mundial que se producirá en los próximos 30 años será responsable de un aumento de los alimentos de origen animal y de las proteínas de origen animal. El sector ganadero se verá obligado a afrontar nuevos retos, como la reducción del impacto ambiental, la mejora de la calidad y seguridad de los alimentos de origen animal, la reducción de antibióticos y el aumento de la eficiencia. Una de las estrategias que podrían adoptarse es la Ganadería de Precisión (PLF), reconocida como la herramienta más sostenible para mejorar la sostenibilidad de las explotaciones agrícolas. Puede definirse como "el seguimiento continuo, automatizado y en tiempo real de la producción, la reproducción, la salud y el bienestar mediante la aplicación de tecnologías avanzadas de la información y la comunicación (TIC)". En este nuevo concepto de granja, los animales, el medio ambiente, la maquinaria y los procesos se convierten en "objetos de información" para mejorar los datos; La gestión agrícola y los animales se definen como sistemas CITD: son complejos, individualmente diferentes, variables en el tiempo y dinámicos. Recientemente se han aplicado varias tecnologías PLF a los búfalos, mejorando algunos puntos críticos de la granja, como el ordeño, la nutrición, la reproducción y el manejo. Esta breve reseña reporta algunas experiencias realizadas en búfalos.

Palabras clave: Ganadería de precisión, sostenibilidad, búfalos.

INTRODUCTION

It is known that the world's human population is actually about 8 billion, and it is estimated to reach 8.5 billion in 2030 and 9.7 billion in 2050. This sharp increase will occur mainly in developing countries, particularly Africa and Asia, where about 80% of the human population is distributed. This condition will cause an increase in the global demand for food, to 70% higher than in 2010 [1], for both plant and animal-derived food. One of this scenario's main limitations is the unavailability of further arable land. Simultaneously, the world is encountering a profound climate change [2] that is caused by the so-called "global warming," an increase of the global temperature that is expected to be about 3.5–5.5°C in 2080 [3]. Production, reproduction, and sensibility to pathogens or different environmental conditions are only some aspects that livestock will be (and are) obliged to face. The world's increasing demand for animal-derived food requires new strategies to increase farm efficiency and sustainability. The impact of livestock farming on natural resources is under further pressure [4] from consumers, who demand high-quality products, animal welfare, and traceability information.

On the other hand, it is known that livestock is one of the most demanding sectors in terms of resources for several reasons, such as land use (for both grazing and feed production) [5], water [6], and energy [7] consumption. Furthermore, it is often accused of being one of the main ones responsible for environmental impact, for both poor manure management, mainly for nitrogen and phosphorus pollution [8], and greenhouse (GHG) emissions: Livestock accounts for 30% of GHG emissions of the agriculture sector, which is responsible for 14.0% of world GHG [9]. This led to a new environmental awareness, and animals are assumed to be a source of impact on the environment and public health.

NEW CHALLENGES OF THE LIVESTOCK SECTOR

In this complex scenario, the livestock sector must face new challenges: the reduction of environmental impact, the improvement of animal-derived food quality and safety, the reduction of antibiotics, and the increase of efficiency in one health view are some of these. Several solutions have been proposed in this sense, such as cultured meat (for review, see [10]) and edible insects [11]. The former has several advantages: it does not require animals, is highly efficient (one billion burgers can be produced from one biopsy in 45 days [12]), meets the favor of vegetarians and vegans, and does not produce GHG. However, there are also some negative aspects: its production is expensive, and growth factors and antibiotics are used during production. Insects are considered one of the most sustainable sources of nutrients because of their high protein, vitamins, minerals, and unsaturated fatty acids content [13]. However, one of the main limitations of entomophagy is from a cultural point of view.

THE PRECISION LIVESTOCK FARMING (PLF)

Precision Livestock Farming (PLF) is recognized as the most sustainable tool to improve these aspects [14]. It can be defined as “the continuous, automated, and real-time monitoring of production, reproduction, health, and welfare through the application of advanced information and communication technologies (ICT)” [15]. The PLF approach includes many technologies that aim to utilize the vast amount of data that can be collected daily on the farm and transform them into useful information. Basically, Industry 4.0 is based on the utilization of the IIoT (Industrial Internet of Things) to develop a new and personalized production model: the IoHAT (Internet of Animal Health Things) [16]. In this new farm concept, animals, environment, machinery, and processes become “information objects” to enhance data farm management. One of the main differences between the traditional approach and that performed by PLF is the change in animal role. The latter has a central position in PLF systems since it is the main responsible for the information of the process. However, no animal is identical to another, and the same animal has different responses and behaviors according to its physiological or pathological condition.

Furthermore, it is more complicated than an electronic system, and its response can be different, variable, and dynamic based on different conditions. Indeed, in a PLF approach, the animals are defined as CITD systems, where they are defined as Complex, Individually different, Time-variant, and Dynamic [15; 17]. The great revolution that derives from this vision of the animal is that if, in the traditional vision, a group of animals is considered as a “unicum”, through the PLF approach, the same group is considered as a “set of individualities”, where each individual contributes with its variability and differences in response to the average.

Sensors utilized in PLF can monitor animals, the environment, and products. Several PLF technologies have been recently applied to buffalo species, improving some critical points of the farm, such as milking, nutrition, reproduction, and management.

BUFFALO SPECIES & PLF

The buffalo (*Bubalus bubalis*) species is widespread worldwide, particularly in developing countries. According to FAO statistics [18], more than 203 million heads are actually present, and about 98% of the total population is concentrated in Asia. Only 0.2% of the world population is bred in Europe. However, the majority of European buffaloes are concentrated in Italy, where buffalo milk is almost totally utilized for mozzarella cheese production. Throughout the last 40 years, buffalo husbandry in Italy underwent a profound transformation, modifying the farming conditions closer and closer to those of dairy cows.

Furthermore, the physiological characteristics of the species, such as seasonality, caused a completely different methodological approach [19]. A hard work of selection has been carried out: although the national average milk yield is 2,350 kg in 270 days [20], with fat and protein percentages of 7.72% and 4.65%, respectively, it is not rare to find farms with an average milk yield that exceeds 3,000 kg of milk/lactation. These productive levels were achieved through proper selective criteria, improvements in rationing schemes, environmental farming conditions, and management in general. Therefore, a growing interest is deserved in the application of several PLF technologies. Although their utilization is still limited, some interesting experiences have been reported in several fields.

- Identification and localization systems are nowadays considered indispensable for a correct management of the herd [21]. The most commonly technologies used in the buffalo are the radio frequency identification (RFID) technology [22]. RFID sensors are usually located in the rumen as boluses but can be also positioned as subcutaneous implants or ear tags and, as in cattle, sensors are developed using full duplex (FDX) and half duplex (HDX) technologies [23].

- Another field in which PLF has been applied in buffalo is the genomic prediction [24]. The technique consists in estimating the genetic value of thousands of markers (single nucleotide polymorphism - snps) distributed in the genetic heritage and associated with phenotypes of interest [25; 26; 27]. In 2013 the sequencing and assembly of the buffalo genome was completed (GCF_000471725.1; filed on NCBI in November 2013) and a new chip of a 90K SNP genotyping assay was designed and validated [28]. Quantitative Trait Loci (QTLs) associated with several features have been studied in buffalo, such as productive traits and lactation [29-34] reproduction [29; 35], welfare [36] and mastitis [37]. Through PLF technologies the collection of phenotypes can be performed with high precision and accuracy.
- Farm management can be improved in several ways. Milking has been improved through both the application of automated milking systems (AMS) and the adaptability to machine milking. The latest generation of milking robots is equipped with a digital camera and a laser triangulation sensor, utilizing a 3-D time-of-flight (Time-of-Flight-TOF) camera. Through AMS, animal welfare is increased, together with number of milkings/day, milk yield and milk quality [38-39]. The “milkability” has been study to recognize the capability of animals to release milk and identify those that can be adapted to machine milking by using lactocorder [40]. Another robotic technology is applied in calves: calf management can be improved through automatic milk feeder integrated with a robotic arm (Calf-rail®, Germany) for the administration of milk replacer.
- Animal welfare can also be monitored through machine vision and 3D vision for the simultaneous control of one or more variables (body condition, dimensions, weight, etc.). Through this approach it is possible to indirectly and non-invasively evaluate the biometry of Mediterranean buffalo calves, to estimate their growth, using depth cameras, as stereocamera or LIDAR [41-42] and to measure volume and weight of feed [43].
- Several Automated Estrus Detection (AED) technologies have been developed to monitor reproduction. A common problem of these tools is that behavioral and physiological changes are not typical of estrus: therefore, the warnings supplied by the AED technologies needs to be verified and confirmed through a gold standard (i.e. progesterone or a clinic exam by vets). For reproduction monitoring pedometers were used at the beginning of the 21st century [44] and sensitive telemetry devices (Heat Watch®, DDX Inc, Colorado, USA) were tested in Brazil [45]. Recently, also the infrared thermography (IRT) has been applied to the reproductive management of buffalo, in both female [46] and male [47].
- The monitoring of health is probably one of the most important advantages of PLF. Some physiological behaviors (feeding, rumination, lying, and standing) have been recently validated in buffaloes through NEDAP monitoring technology [48] and this can be used also for calving management [49]. Similarly, an algorithm for locomotion behavior by using 3-dimensional accelerometers (RumiWatch®) with high level of accuracy [50]. The health of the mammary gland has been largely studied, because of the high incidence of subclinical intramammary infections [51, 52]. For this reason, the SCC (Somatic Cell Count) or SCS (Somatic Cell Score) that represents its log-transformed value [53] is largely used to identify infections in buffaloes [52]. Furthermore, in the last couple of years, also other techniques have been studied in buffalo, such as Differential Somatic Cell Count (DSCC) [54, 55] together with the electric conductivity (EC) of milk [56] and IRT [46].
- The environmental influences were studied evaluating the effects of the bioclimatic index THI (Temperature Humidity index) on milk yield and characteristics. Several studies suggested that buffaloes are sensitive to heat [57, 58] and cold [59]. stress, suggesting the importance of this monitoring. Further environmental monitoring were carried out regarding methane emissions through Laser Methane Detector or LMD [60, 61] and pasture management [62].
- Product quality is studied through Infrared Spectroscopy (IRS), that allows the construction of prediction models and the detection of phenotypic traits that are not easily detectable, such as freezing point, pH, antioxidant power of milk, mineral composition, as well as coagulation characteristics, acidity and GHG emissions. Furthermore, the presence of buffalo milk in mixture with other milks can also be performed [63].

CONCLUSIONS

The increase in sustainability is one of the main aims requested by the livestock sector, including buffalo. To this aim, buffalo species will be obliged to face new challenges in the next few years, and this could occur only through the application of new technologies in order to enhance the grade of innovation. The PLF is probably the most applicable solution to reach these aims, allowing real-time, continuous, and automated monitoring of the main processes of the farm (such as welfare, health, production, and reproduction), the environment, and the quality of the productions. Although few studies have been carried out in buffalo in this field, an increased interest has been recently developed. One of the main problems that must be faced is the need for more specific algorithms and prediction models for this species; therefore, all these techniques must be validated in buffalo to obtain reliable results. For this reason, further studies should be carried out in the future to increase the knowledge in this field.

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