IDENTIFICATION OF REQUIREMENTS FOR IMPLEMENTING IOT ON THE SMART BEEF VALUE CHAIN

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ABSTRACT

Smart services for livestock value chains can improve both productivity and sustainability by providing valuable information for the decision-making and management systems. By blending Internet of Things (IoT) technologies with Big Data analytics, it is possible to increase information and data exchange among supply chain agents, gain predictive insights in farming and marketing operations, drive real-time operational decisions and increase the efficiency of processes. This work provides an overview of the beef cattle VC comprising its stages, stakeholders, processes, and the informational flow. It also identifies the main requirements for implementing IoT on the beef cattle value chain, which are organized in 9 main services and 31 sub-services or activities. It sets the ground requirements for the future development of a framework for Smart Beef Cattle Services. These can also be used for developing a more general Smart Livestock Farming framework. Farm management research may benefit from the resulting requirements, using it to build services and architectures for a panorama of further automation and autonomous operations of the farms and agricultural supply chains.

Keywords*:* IoT, farm management systems, Smart Livestock Farming, agribusiness, value chain.

1. INTRODUCTION

Value chains (VCs) can be defined as a series of interconnected processes or services, going through production, storage, processing, transportation and marketing of a specific product or commodity, adding value as it moves through the VC (Wolfert et al., 2017). Those commodities can be marketed for domestic or international markets and involve a complex series of stakeholders and products.

Smart services for the Beef Cattle farming refers to modern Information and Communication Technologies (ICT) applied to this livestock VC. They have the potential to deliver a more productive and sustainable production by integrating processes of the Precision Livestock Farming (PLF), Management Information Systems (MIS) and agricultural automation in order to provide better decision-making and more effective exploitation of operations (Banhazi et al., 2012). Additionally, it is possible to better comply with food-quality standards and sustainability labels to achieve higher value markets, increasing the value of their products.

The use of Internet of Things (IoT) technologies (ITU-T, 2012) aims at providing full coverage of the processes related to this livestock's VC. This can be done by collecting, transmitting, analyzing, and storing data from the entire agroecosystem. One example in the beef cattle VC is a system that registers and controls inputs purchase and consumption throughout the production processes, encompassing breeding, growing, finishing, slaughtering, meat processing, transportation and logistics, until its products reach the retailers and wholesalers, and finally the consumers' table.

Aspects of the IoT paradigm are vital to the Smart Beef Cattle VC concept. By using IoT, one is able to run the workflow among farmer, service provider, logistics provider, market and consumer synchronously all together. That means to establish contact with each participant of the VC, bringing data and collecting information about their processes, increasing the possibilities for controlling and improving the efficiency of their tasks (ITU-T, 2012). On the other hand, without applying IoT concepts, beef cattle farming may continue to work but will not be able to achieve higher performance levels and mitigate quality and environmental problems timely. Therefore, this work aims at setting the ground requirements for the beef cattle VC to operate under the IoT percepts.

2. METHODOLOGY

The methodology used in this paper can be divided into 2 steps:

1. **VC description:** this step aimed at describing the main stages, stakeholders, processes, and the informational flow of the beef cattle VC, based on a thorough literature review;
2. **Requirements and services identification**: we identified the main requirements and services needed to manage the information flow in the beef cattle VC, considering the use of IoT technologies and based on both periodic meetings with experts from International Telecommunication Union - Standardization Sector (ITU-T) and an in-depth literature review.

3. RESULTS

This section contains the main results of our research. It is divided into two parts: 3.1, providing an overview of the beef cattle VC; and 3.2, containing the requirements and services identified.

3.1. Overview of the beef cattle value chain

Different stages and perspectives are present in the beef VC, such as quality control, efficiency control, certification, sustainability, logistics, business economics, marketing channels, and informational flows (CEMA, 2017). The commodities inside such chains can be marketed for domestic (national, intra or inter-state), or international markets, involving a complex series of stakeholders and products. They can respond to ICT changes at the same time that are subjected to local, national and international laws and requirements. One main concern with the present work is to address the domestic facet of those VCs, leaving the international issues for future research.

The main stakeholders involved in the beef cattle VC are: Inputs and Services Suppliers; Farmers; Processing and logistics agents (transport, slaughterhouses, industries); Market agents (warehouses, distributors, traders and retailers); and Consumers. Figure 1 shows an overview of a generic beef cattle VC. It represents the main stages and steps during planning, production, processing, transportation and sale of animal products.

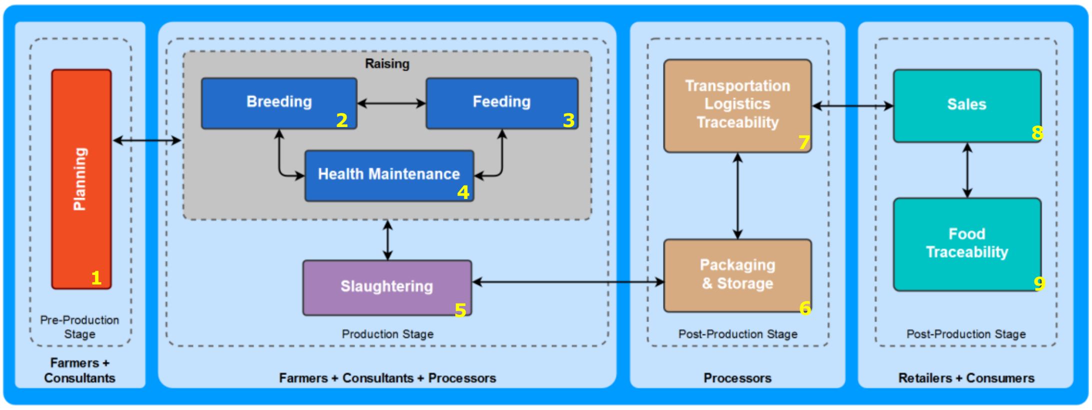

Figure 1. Overview of the beef cattle value chain

The **Planning** phase (number 1 in Figure 1) is the main component of the Pre-Production Stage. At this phase, the resources and raw materials are allocated according to the activities, workforce and production capacity. It includes such things as land, buildings, equipment, supplies and processes, as well as laws and regulations (environmental and product quality) that affect the business. In this step, the IoT requirements are brought up and the system capabilities are applied to meet them.

Breeding or Reproduction (number 2 in Figure 1) is the first step inside the Production Stage. It refers to herd increase through animal reproduction inside the farm or by artificial insemination or embryo transfer techniques. In this step, the main IoT requirement is the animal identification and breeding record, which is a demand for consumers of higher quality products.

Feeding (number 3 in Figure 1) comprises one of the most resource consuming activities in the Production Stage. It considers mainly animal feeding and water consumption and affects directly on the final product results and resource use efficiency. For ruminants, quality grass consumption is a major concern, but in many climates or rearing methods, hay, silage, as well as energy and protein-rich foods can be added to the diet (Coleman, Moore, 2003). In this step, it is important to record details about food components, the quality and quantity of ingested food by the animals and their weight gain. The most common IoT requirements for this step are Animal identification, Productivity monitoring, Health management, and Animal welfare.

Health maintenance (number 4 in Figure 1) is directly connected to the raising activities. Together with animal welfare, implies great concerns among consumers, due to their impact on product quality and safety. These not only represent a possible threat to human health but can also lead to direct production losses and resource use inefficiency. These concerns can commonly include how animals are kept and treated inside the farm, how they are transported and how they are slaughtered (HFAC, 2018; WSPA, 2011).

Slaughtering (number 5 in Figure 1) considers the reception of the living animals at the slaughterhouse and encompasses the activities related to killing them and processing the carcasses, resulting in the final products that are sold to the market. Due to sanitary concerns, animal slaughtering is only allowed in specific and quality controlled facilities. Some countries may require that these establishments ensure that the animals are handled and slaughtered humanely (Grandin, Nami, 2017). In this step, the most important IoT requirements are Animal identification, Climate control, and Animal welfare.

Logistics (throughout the whole VC) is present in great part of the beef cattle VC. It is important to provide the necessary amount of raw materials and inputs at the correct time during production, as well as it is responsible for providing a constant flow of animals for the slaughterhouse, to maintain its optimal working flow. Incorrect animal transportation and handling can result in product quality reduction, and in severe cases can lead to death (Sheridan et al., 1991). The most important logistics requirements are Animal identification, Climate control, Health management, and Animal welfare.

Traceability or product tracking and tracing (throughout the whole VC) is the capability to follow the path of a specified production batch throughout the VC, as it moves from one organization to the next, allowing the identification of critical quality control points. In the case of food contamination, it helps identifying the product batches that may have been contaminated (Dabbene et al., 2014). In general, food businesses engaged in the wholesale supply, production or food import must have a well-defined system, including production records covering, clearly described in a written document, to ensure that a fast and efficient recall is possible and timely (so called internal traceability). This information should be readily accessible for both Governmental agencies, and the end consumer, to identify what batches/product units must be recalled and their location in the VC (Verdouw et al., 2018). It should also be accessible for other companies in the chain, so they can maintain a description of the whole path of the product in the chain (so called external traceability). Recording can be done through means of barcodes, QR codes, RFID tags, and other tracking media.

3.2. Requirements and services identification

The identified requirements for the smart beef cattle VC services are presented in Table 1.

Table 1. Smart Beef Cattle VC main services and sub-services or activities

Services	Sub-Services or Activities	Steps related
Animal monitoring	Animal identification	ALL
	Animal tracking	2, 3, 4
Animal health maintenance	Prevention and control of diseases	4
	Increasing productive lifetime	2, 3, 4
	Increasing disease resistance	2, 4
	Animal welfare	2, 3, 4, 5
Nutrition and Productivity control	Forage quality improvement	3, 4
	Dietary improvements and substitutes	3, 4
	Feed supplements	3, 4
	Digestibility control (rumen microbiome)	3, 4
	Precision feeding	3, 4
Breeding and Genetic Improvement	Animal selection	2, 3, 4
	Genomic selection	2, 3, 4, 5
	Increasing performance on low-quality feed	3
	Low-methane production	2, 3, 4
Pasture Management	Pasture quality and quantity management*	3
	Carbon sequestration increase*	1, 3
	Integrated and Mixed systems*	1, 3
Waste Handling and Treatment	Manure collection*	4
	Biogas digesters efficiency management	1
	Gas emission control*	1
	Fertilizer production	1, 3
Climate control	Climate sensing and control for living animals	4, 5
	Final product temperature monitoring	6, 7, 8, 9
Logistics Management	Distribution recording	7, 8, 9
	Transport environment control	7
	Market analysis alerts	1, 8
Traceability Management	Production recording	1, 2, 3, 4
	Processing control	5, 6
	Product tracing	ALL
	Recall management	ALL

*Possible sustainability and environmental impacts

Animal identification is one of the key information along the beef cattle VC, since this register accompanies the animal throughout its life inside the farm and should remain attached to all products derived from it. Becomes essential to allow product traceability. The requirement is to use any kind of electronic identification (internal, external or subcutaneous) allowing easy and instantaneous identification of the animal, using a proper device or antenna. For example, RFID tags can be used on the skin and/or earrings.

Productivity monitoring is mainly applied to the Raising set of tasks on the Production Stage, which demands the management of feeding and the main processes inside the farm, so that the animals may experience optimal weight gain (based on feed conversion ratio and energy expenditure). The requirements in this category are related to the correct association of important production parameters with each animals' ID, such as weight and food consumption over time (in order to obtain feed conversion ratio), and movement (to estimate energy expenditure).

Health management is very important to guarantee product quality and safety. As indicated before, this category can be responsible for productivity losses or even possible threats to human health. Animal health monitoring can be improved with the use of internal and external sensors, capable of sensing and communicating important parameters to the server or the cloud, at a time interval that is appropriated for decision-making. Vital information such as the control of vaccinations, exams, pests, diseases, bruises, and other health-related records should be registered on the management system and at the animal's electronic identification device.

Climate control such as the ambient temperature and relative humidity can affect considerably the metabolism of farm animals, leading to thermal stress. This results in efficiency loss, increasing the animals' energy use. Other environmental factors may also influence the animals' thermal sensation and heat dissipation, such as air velocity and radiation (Babinszky et al., 2011). These factors can also hasten the final products quality reduction during transport, at processing units or at distributors and retailers. Regarding this issue, climate control can be improved with the help of environment sensors, capable of sensing and communicating important parameters at an appropriated time interval, and actuators capable of changing important factors in a timely manner.

Animal welfare is related to the reduction of animal suffering. When the animal is considered to suffer for any reason its efficiency in converting feed into muscle decreases, leading to direct losses for the farmer. This issue is interrelated to the climate control and health monitoring categories. At this point, systems capable of detecting abnormal behavior should be adopted, through GPS monitoring (for extensive farming) or image recognition (for confinements or intensive animal farming), in order to mitigate the issues related to this category.

Information and Communication Security regards the proposal of IoT devices integration on this VC, which is to seamlessly connect all stakeholders, providing the flow of important, strategical and sometimes crucial information. For this to happen, it is crucial to guarantee the continuity, integrity and security of communications between the stakeholders and the services here identified. Some principles that should be met are confidentiality, integrity, availability, authentication, lightweight solutions, heterogeneity, policies and key management systems (Mahmoud et al., 2015). Confidentiality and integrity are mandatory when dealing with livestock tracking, due to the sensitive nature of location data, especially in real-time solutions. It is important to mention that all the communication between users and the devices on animals, machines or places should be supported in real-time by the IoT infrastructure.

4. Discussions

On the beef cattle VC, multiple technologies will coexist for the different stages of data collection, processing and storage. This is especially evident in the Farm stage, due to its heterogeneous nature in comparison to the other VC links.

Since our main focus is to promote an overview and identify the main requirements and services of the beef cattle VC, the proposal of a framework considering those aspects, as well as the implementation aspects, must be further researched and discussed with both Farm administrators and stakeholders from other stages of the VC. In this sense, we believe that our work is an initial step towards this discussion, as it provides a subsidy for the development of a framework for Smart Beef Cattle Services based on IoT, as well as sets the ground rules for the development of similar research for other species or rearing methods. Therefore, it can be expected that farm management and operations research will greatly benefit from the resulting panorama and requirements.

Future work is related to the validation with different VC agents, the development of a framework for the beef cattle VC to operate under the IoT paradigm, as well as the extension to other livestock VCs, creating a Smart Livestock Farming infrastructure, and then, perhaps, expand to other agro-industrial VCs.

5. Conclusions

This work provides an initial step towards the creation of a Smart Beef Cattle value chain. It provides an overview of a typical beef production chain, specifies the stakeholders involved, its processes and the informational flow. It also identifies the main requirements for implementing IoT on the beef cattle value chain, which are organized in 9 main services and 31 sub-services or activities, allowing the value chain to function optimally using IoT technologies.

This work is an initial step towards a broader discussion, as it provides a subsidy for the development of a framework for Smart Beef Cattle Services based on IoT, as well as sets the ground rules for the development of similar research for other species or rearing methods, possibly scaling it up to a Smart Livestock Farming system.

In this sense, farm management research may benefit from the resulting requirements, using it to build services and architectures for a panorama of further automation and autonomous operations of the farms and supply chains.

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