RFID Deployment and Use in the Dairy Value Chain: Applications, Current Issues and Future Research Directions

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Abstract

RFID technology is currently considered as a key enabler of supply chain transformation. However, very little has been written about the deployment and use of RFID in the dairy industry. Drawing on an extensive literature review and a case example, this exploratory study seeks to present current applications and issues related to RFID's adoption in the dairy industry and discuss future research directions.

1. Introduction

Radio Frequency Identification (RFID), a wireless automatic identification and data capture (AIDC) technology [1], is being acclaimed by academics and practitioners for its high operational and strategic value in improving the performance of the value chain [2] [3]. Any basic RFID system is a combination of three main components: a tag containing a microprocessor; a reader and its antennas; and a host computer equipped with a middleware program where business rules to support business processes execution are configured [4]. RFID technology offers greater capabilities compared to traditional AIDC (e.g., bar coding). The advantages of using RFID include: no need for line of sight; unique object level identification; multiple tags objects reading; more data storage capability; and data read/write capabilities [4]. In addition, RFID technology allows real-time data collection and sharing among multiple stakeholders [5], intra-and inter-organizational business processes renovation and end-to-end supply chain visibility [1].

However, despite the high potential of RFID technology, its widespread adoption and use is still very low, and estimated between 7% and 15% in the supply chain [6] even though some analysts predict that the RFID market will grow from $5.25 billion in 2008 to reach $5.56 billion by the end of 2009 [7]. In addition, the vast majority of peer-reviewed studies on the adoption and use of RFID technology is still confined to the retail industry [8]. Furthermore, very few papers have been written on the deployment and use of RFID technology in the dairy value chain. Therefore, this paper is an initial attempt at bridging the current knowledge gap in the literature. More particularly, the paper draws on prior research agendas on RFID technology [2] to examine the following two questions:
(1) What is the current level of RFID deployment and use in the dairy value chain?
(2) What are the potential research areas where the deployment of RFID is likely to improve the dairy value chain?

In order to address these questions, this paper draws on the value chain model and an extensive literature review of peer-reviewed papers dealing with RFID deployment and use in the dairy industry. Then, using the dairy value chain we perform an analysis of a case example and all peer-reviewed papers found to assess the level of the deployment and use of RFID technology in order to highlight future research opportunities.

The remainder of this paper is structured as follows: Section 2 presents the value chain model, the dairy value chain and discusses key issues within the dairy industry. Section 3 describes our research methodology. Section 4 presents the case example, our results and discussion. Section 5 is our conclusion and future research directions.

2. Context of the study

2.1. The value chain model

The value chain model was developed and proposed by Michael Porter as a tool to describe and analyze all activities that are performed by a business for value creation to support its competitive position within one industry [9]. The model identifies five primary activities which contribute directly to the creation or delivery of a product or service to the final customer and, therefore to business value creation, and encompasses inbound logistics, operations, outbound logistics, marketing and

sales, and service. The model also identifies four secondary or supporting activities or those used to support and enhance the effectiveness and the efficiency of primary activities. The secondary activities are related to corporate infrastructure, human resources management, technology development, and procurement. Each value chain is part of a broader industry value chain or value system which is a "collection of individual business unit value chains that together produce and deliver the goods and services to the final customer" [10] (p. 83). The industry value chain allows each firm to analyze its position relative to other firms in the overall activities required to provide a product or a service to the final customer [10].

The value chain model is acknowledged as a useful tool that allows firms to understand how Information Technology (IT) might influence their competitiveness [9]. As Michael Porter states, "technology is embodied in every value activity in a firm, and technological change can affect competition through its impact on virtually any activity" [9] (p. 166). Therefore, we propose in this paper to use the dairy value chain to analyze the current level of RFID deployment and use within the dairy industry. We discuss the current context of the dairy industry and present its value chain in the next section.

2.2. The dairy industry: current context and its value chain

The dairy industry is an important part of various economies. For example, the dairy industry is estimated to be worth nearly $35 billion [11] in the United States (US). In Australia, it is the largest value-added food industry with "ex-factory" production, estimated at $11.5 billion in 2007 & 2008 [12]. Currently, this industry is experiencing similar trends faced by other sectors, such the globalization of markets, intense competition and growing cost pressures. In addition, the dairy industry needs to deal with specific challenges such as low-margin, strict traceability requirements, deregulation by many governments, and requirements regarding the safety and freshness of dairy products. For example, the deregulation of the dairy industry in US has affected the price of many dairy products (e.g., milk) with the price plunging by almost 50% in March 2009 [13]. Also, the dairy industry had recently experienced two major cases of food contaminations in the dairy value chains in Canada and in China. These contaminations have lead to the recall of three brands of cheese in Canada, the death of six children and illness of about 300,000 others in China [14]. Therefore, tracking and tracing all activities within the dairy value chain have become vital to avoid such contaminations, increase the visibility and overall performance of the said value chain. RFID technology is recognized in the growing literature on the technology as a viable means of realizing these value chain objectives [15].

The dairy value chain encompasses six primary activities: feed inputs; production; collection; processing and manufacturing; marketing; transport and distribution, and consumption. This generic dairy value chain starts with the feed inputs and is followed by production. Currently, an increased number of dairy farms are looking for ways of enhancing their feed utilization in order to reduce their carbon footprint without affecting the milk production, but also to cope with rising prices of feed inputs due to the demand for bio-fuels [16, 17]. The production takes place on various farms and involves calving, cattle raising, milking and pasteurizing [11]. Milk is collected by specialized refrigerated trucks and taken to various plants for its processing or manufacturing. Dairy manufacturing includes all production processes used to produce fresh dairy products, and butter and milk powders (p. 10) [12]. Subsequently, all manufactured products are transported to distribution points (e.g., supermarkets, restaurants) where they are sold for consumption [12].

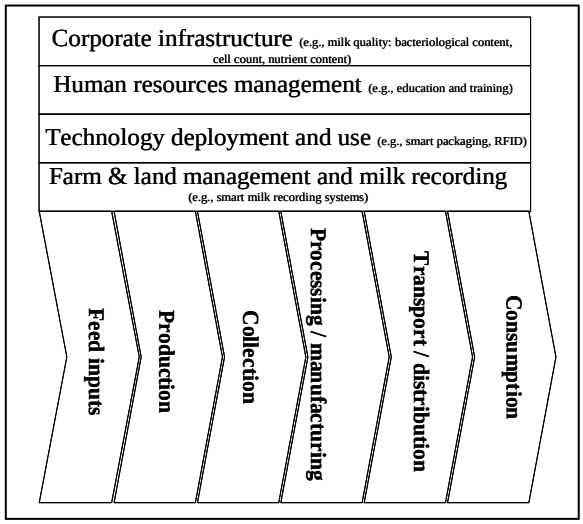

Figure 1. A generic dairy value chain adapted from [11, 18-20]

3. Methodology

Despite the growing use of RFID in various industries, its adoption in the dairy industry remains fairly low. For example, in a recent review by [6], the authors found only three articles on RFID applications for each of the following two applications: "animal detection" and "food" management [6] (p. 515).

However, the authors in their analysis recognize the importance of RFID as a key enabler of animal management and farming in the near future. Therefore, this paper is an initial attempt at bridging the current knowledge gap in the literature by conducting a review of existing studies on RFID within the dairy industry.

Because of the exploratory nature of our study, a qualitative research was conducted through the analysis of secondary data. More specifically, an extensive review of past peer-reviewed conference and journal papers dealing with RFID technology in the dairy industry was undertaken. An electronic search of relevant peer-reviewed full-text articles was done within the following major online databases: ABI/INFORM Global, IEEE Xplore, Wiley InterScience and Science Direct, using "RFID Technology" or "RFID" and "dairy industry" or "dairy" as keywords. In our preliminary search 52 papers were found. The analysis of the relevance of the content of each paper to our research objectives allows us to retain 22 papers. To further understanding of the implications of the introduction of RFID to the dairy industry, a dairy farm located at Numbaa, near Nowra, on the south coast of NSW was used as a case example.

4. Results and discussion

We now present and discuss the results of the review of past peer-reviewed conference and journal papers dealing with RFID technology in the dairy industry and the case example.

4.1. Current RFID deployment and use in the dairy value chain

Based on the review of past peer-reviewed conference and journal papers dealing with RFID technology in the dairy industry, a total of 22 papers were retained and analyzed using the dairy value chain. Table 1 presents the sources of papers and the number of articles per source.

From Table 1, we can notice that from the 22 articles found, 16 of them (73%) are journal articles while the remaining 6 articles (27%) are from the conference papers. In addition, each source of publications has one published article except the Computers and Electronics in Agriculture Journal, Meat Science Journal and the International Conference on the Management of Mobile Business which each has 2 articles.

Table 1. Sources of papers and the number of publications per source

Type	Source	Number of articles
Journal papers	Biosystems Engineering	1
	British Food Journal	1
	Computers & Security	1
	Computers and Electronics in Agriculture	2
	Environmental Impact Assessment Review	1
	Industrial Management & Data Systems	1
	International Journal of Physical Distribution & Logistics Management	1
	Journal of Food Engineering	1
	Journal of Theoretical and Applied Electronic Commerce Research	1
	Journal of Organizational and End User Computing	1
	Management Research News	1
	Meat Science	2
	Sensor Review	1
	Veterinary Microbiology	1
	Total	**16**
Conference papers	International Conference on Information and Computing Science	1
	International conference on Information processing in sensor networks	1
	International conference on Mobile multimedia communications	1
	International Conference on the Management of Mobile Business	2
	RFID Eurasia Conference	1
	Total	**6**
	Overall Total	**22**

Table 2 presents the distribution of past peer-reviewed articles in the dairy value chain. Regarding primary activities, the main observation is that six articles discussed RFID applications in the feed inputs activity, seven articles are related to RFID applications in the production, four articles discussed RFID applications in the collection activity and in processing and manufacturing activity, whereas twelve articles are concerned with RFID deployment and use in the transport and distribution activity. Finally, three articles presented RFID applications in the consumption activity.

It is relevant to note that the literature review identified no articles that discussed the sociological implications of the introduction of RFID to the dairy industry.

With regard to supporting activities, eight articles discussed RFID applications in the corporate infrastructure, three presented RFID applications in the human resource activity; two articles discussed RFID applications in the technology deployment and use, whereas six articles presented RFID applications in the farm & land management and milk recording activity.

Table 2. Positioning of past peer-reviewed articles in the dairy value chain

	Activity	RFID application domain & reference
Primary activities	Feed inputs	• [21-24], [25], [26] e.g., RFID can be utilized to control feeding [21-23].
	Production	• [21-23], [24], [25], [27], [28] e.g., RFID can be used during the milking and pasteurization, to obtain the information stored regarding each cow's last recorded volume of milk production [23].
	Collection	• [24], [27], [28], [29] e.g., RFID can be utilized to enable the track and trace of dairy products at different locations throughout the supply chain [27].
	Processing and manufacturing	• [26], [30], [31], [32] e.g., RFID can be used to pull data from dairy production-line control system and provide information about the specific location of a case or pallet of dairy products [30] or to improve the dairy (e.g., cheese) fabrication process and production control [31].
	Transport and distribution	• [29], [21-23], [24], [26, 33], [27], [34], [32], [35], [36] e.g., RFID can be utilized to enhance cattle movement [21], [35], [33], or dairy products movement [34].
	Consumption	• [27], [32], [37] e.g., RFID can be used for promotional information for dairy products in a retail store [37].
Supporting activities	Corporate infrastructure	• [21-23], [30], [33], [36], [38], [39] e.g., RFID can be utilized to maintain the link with the Australia n National Livestock Identification System (NLIS) database [21], [38] or to the American National Animal Identification System (NAIS) [36]. In addition, the technology can be used to comply with NLIS requirements [21] or Wal-Mart mandate [30].
	Human resources management	• [21-23] e.g., RFID can be utilized to reduce labor requirements [21-23].
	Technology deployment and use	• [40], [41] e.g., RFID can be utilized for smart packaging [40].
	Farm & land manageme nt and milk recording	• [21-23], [25], [36], [42] e.g., RFID can be utilized on dairy farms to enhance total farm management [21], monitor health problems in livestock [21], [36], track of medication, animal vaccination and animals' diet [36].

However, in this growing literature on RFID technology in the dairy value chain, very few articles focus on the impact of RFID technology as enabler of optimization and coordination of all interdependent activities in the value chain for competitive advantage. These articles tend to focus only on the impact of RFID technology on a limited number of primary activities or secondary activities, and therefore, they tend to ignore the RFID network externalities. As previously mentioned, no article discussed the sociological implications.

4.2. The Australian National Livestock Identification Scheme (NLIS) tag in action in a Numbaa dairy farm

The dairy farm for this case example is located at Numbaa, near Nowra, on the south coast of NSW. The farm, which began operations in June 2009, has four full time employees, two of which are family members, and one part time employee. Currently, 350 cows are being milked twice a day, at 0500 and 1500. An average of 9000 litres of milk is obtained daily. The milk is stored

in a 25,000 litre bulk vat on site and is collected every second day.

At present, the cows are managed by means of four different identification tags. One tag is the Farm Management tag which is specific to this farm and is used to monitor such things as feeding, milk quantity and health of the cow. Cows also have the National Livestock Identification Scheme (NLIS) tag. This regulatory tag enables cows to be traced. At this farm, the NLIS tag is linked to the Farm Management tag via the farm computer. In Australia, cattle producers are required to use either the NLIS tag or an RFID tag for the cows' identification and to report their cows' movements to the NLIS database [43]. Clearly, the farm under study has chosen the first option for cows' identification. The third tag used at this farm is a registration tag to identify cows registered as stud stock. A fourth tag is a national identification tag linked to the registration tag..

The Numbaa farm owner reports that their existing identification system enables automation of feeding, drafting and milk sampling and is useful for record keeping, especially in relation to medication use. Their system also enables them to be linked to the Hazard Analysis Critical Control Points (HACCP) Australia, a national food safety audit program. However, there are some reported challenges related to the existing system. For example, tags can get lost, deteriorate or get damaged, and at times, reader quality is poor. The farm owner reports states that a lifetime traceable tag would be preferred.

5. Conclusions and future research directions

In this paper, we presented the literature review of peer-reviewed papers dealing with RFID deployment and use in the dairy industry. In addition, we used the dairy value chain to perform an analysis of the 22 peer-reviewed papers found and the case example in order to assess the level of the deployment and use of RFID technology in the dairy industry. Our review showed that the vast majority of articles found tend to focus only on the impact of RFID technology on a limited number of primary activities or secondary activities, and therefore, they tend to ignore the RFID network externalities. Therefore, more research needs to be done to assess the impact of RFID technology on the interdependency of the dairy value chain activities and the key technical and business challenges of integrating RFID technology within the whole dairy value chain. Exploring key facilitating factors which will increase RFID adoption within the said value chain should also be included in future research.

Furthermore, most dairy products are commodities and differentiating or tracking them using RFID at various levels (item-box-pallet levels) could be challenging and not necessarily cost-effective. In addition, the milk from various farms can be co-mingled (e.g., during the collection and/or processing/manufacturing), therefore, it would be useful to investigate how RFID technology could be used to identify from which milk a given cheese is made. Other areas for future research into the use of RFID in the dairy industry include: assessing the impact of feed sources on other dairy activities; tracking culled dairy cattle into beef markets; determining the business value of RFID item tagging within the dairy value chain; and evaluating the impact of RFID item tagging in the tracking and tracing of dairy products for improved customer safety within country and between countries.

In addition to exploring the impact of RFID technology on commercial aspects of dairy farming, future research could also investigate its sociological implications by adopting, for example, an occupational perspective. An occupational perspective is derived from occupational science, a new member of the social sciences, which generates knowledge and understanding about occupation, the everyday things people do to occupy their time (including paid employment) and the socio-cultural, geo-physical and political influences that shape occupation. Applying an occupational perspective could facilitate an exploration of the impact of the introduction of RFID technology on the occupation of dairy farming, and highlight influences upon the habits, roles, rituals of dairy farm owners and their employees, on design and use of the work place, and on the whole raft of critical transactions and interactions that occur on a daily basis on the dairy farm. Given the RFID technology is yet to be used in Australian dairy farming on a large scale, and that no other studies on dairy farming have adopted an occupational perspective, it is from the introduction of RFID. However, other occupational science research would indicate that there would be value in evaluating the influence of RFID on worker satisfaction, health related work ability, and workplace design.

Reviewing the recent peer-reviewed literature on the use of RFID in the dairy industry has identified a range of commercial applications, some industry-specific issues as well as future areas of research. Also, by considering potential implications of the introduction of RFID technology for one particular dairy farm, the value of including the adoption of an occupational

perspective when evaluating emerging technologies has been highlighted.

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