CHALLENGES IN UTILISING RFID IN INTERNATIONAL FRESH FOOD SUPPLY CHAINS

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ABSTRACT

Purpose Tracking of items in food supply chains is a prerequisite to fulfilling traceability requirements on food safety and quality. This paper explores challenges to ensuring item readability in environmental contexts and the impact on customer service of RFID utilisation in tracking items in an international fresh food supply chain.

Design/methodology/approach A series of RFID readability tests were carried out to assess the technical challenges of RFID utilisation in an international fresh fish supply chain. A single multi-unit business case study based on interviews was conducted to explore the impact on customer service of sales that involve RFID utilisation.

Findings The results show that the presence of saltwater, water and low temperature has a negative impact on the readability of RFID tagged items. A potential adverse impact on customer service is the absence of visible product information in the utilisation of RFID in sales.

Research limitations/implications The findings increase the understanding of challenges in RFID-enabled tracking of items in food supply chains. The research is limited to an international fresh fish supply chain between two Nordic countries. Other food supply chains need to be investigated for further generalisation of the results.

Practical implications Many proposed RFID-enabled food tracking solutions have not been tested to see how they meet environmental contextual challenges. This paper presents valuable findings that will support practitioners in utilising RFID to track items in food supply chains.

Originality/value The paper is one of the first to address challenges in utilising RFID for tracking items in an international fresh food supply chain.

Keywords: tracking, international food supply chain, RFID technology, case study, customer service.

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1. INTRODUCTION

Tracking of items in international fresh food supply chains is a growing industrial requirement. In the last two decades, consumer demands on products that are safe and quickly traceable (Trienekens et al., 2012) and regulatory requirements on food traceability have increased as an effect of food safety incidents. Tracking of items in food supply chains (FSCs) is regulated in the European Union by the General Food Law, which entered into force on 1 January 2005 (Folinas et al., 2006). In the European fisheries sector, tracking of items to meet the preservation of living resource requirements stated in the European Common Fisheries Policy (CFP), come under Regulation 404/2011 (Regulation 404/2011, Article 67). Consumer demands on the availability of a wide assortment of products have increased global food trading because of the limitations in domestic production and local supplies (Whipple et al., 2009). This has increased the requirements on food tracking across international borders.

To comply with tracking requirements, operators in the food industry are searching for new identification technologies to automate existing processes to reduce errors, handling and delivery times, and manual intervention. Radio frequency identification (RFID) has been put forth as one such technology that offers logistics and business management benefits in the tracking of items in FSCs (Kelepouris et al., 2007; Regattieri et al., 2007; Jones et al., 2005; Abad et al., 2009; Martinéz-Sala et al., 2009; Senneset et al., 2010) and in customer service (Ngai et al., 2008). Moreover, Senneset et al. (2007) stress that awareness of ensuring readability of RFID-tagged items and the level of implementation should be regarded as a challenge in implementing food traceability systems. But RFID also has technical constraints, such as lack of readability of items near water and metal (Wu et al., 2006; Shanahan et al., 2009; Delen et al., 2007).

Introducing RFID in FSCs entails the integration of the technology into existing customer-facing sales and logistics processes, and existing environmental supply chain contexts. The research papers listed above present the benefits and challenges of adopting RFID to track items in FSCs. However, there is a gap in the literature about RFID-enabled tracking of items that presents business challenges regarding impact on the readability of RFID-tagged items and on customer service in international FSCs. This paper explores those technical and business challenges based on the environmental context and on customer service in an international fresh fish supply chain.

The paper is organised as follows. Section 2 describes the research methodology. Section 3 reviews the literature related to RFID-enabled item tracking in FSCs, and the customer service impact of RFID utilisation. Section 4 introduces the case under study. Section 5 presents the results and analysis. Section 6 presents conclusions, additional utilisation challenges and research suggestions.

2. METHODOLOGY

A combination of qualitative and quantitative methods was used within a single, multi-unit analysis case study (Yin, 2009) in a natural setting. Studies of emergent phenomena in natural settings generate relevant theory based on an understanding of practical observations (Voss et al., 2002) in a way that facilitates the development of new general theories, propositions and knowledge creation (Flyvbjerg, 2011; Eisenhardt, 1989). The use of case studies has also been emphasized as appropriate in logistics (Näslund, 2002) and especially for solving research problems in the food industry (Lyons, 2005). Several researchers have highlighted the advantage of using a mixed-methods approach in logistics research (Dunn et al., 1994; Mangan et al., 2004). According to Mangan et al. (2004) a methodological combination of quantitative and qualitative research approaches eases the creation of multiple insights into solving management research problems. In this paper, a quantitative approach (i.e., statistical method) was used to explore technical challenges in utilising RFID in the environmental supply chain context. Qualitative interviews were used to explore the business challenges related to the potential impact on customer service in the use of RFID in sales. To ensure overall validity, the results were triangulated with results from the analysis of direct observations of processes, orientation of RFID tags and readers, and the review of internal documents (e.g., delivery notes, labelling stickers and sales bills), according to Yin (2009).

An international fresh fish supply chain between Sweden and Denmark was selected as the research setting because it suited the research purpose. The supply chain includes (1) a returnable asset system of RFID-tagged fish boxes between the two Nordic countries; (2) environmental elements of water, saltwater, and low temperature, all of which can influence the readability of RFID-tagged items (i.e., fish boxes) and (3) paper-based labelling, manual sales operations, and international sales agreements between the two countries (i.e., a Dane is able to sell fish on the Swedish market, and vice versa). Furthermore, the FSC selected is governed by legal and consumer requirements on food traceability (i.e., preservation of food safety and environmental sustainability), contributing to industrial interest in utilisation of RFID.

A series of RFID readability tests were conducted over a four week period to explore the impact on RFID tagged items in the international fresh fish supply chain. The aim of the readability tests was to identify technical challenges in utilising RFID based on the environmental context and logistics management processes in the FSC described. Companies included were the major Swedish- and Danish fish box provider (fish box suppliers), a Swedish fish auction company (wholesaler), a 25 m Swedish trawl vessel (primary producer), and three consultancy firms (in charge for test setup).

To enable an objective evaluation of the readability of RFID-tagged items, research organisations and researchers involved acted as observers during the test period. The readability tests were conducted on RFID-tagged fish boxes in the presence of saltwater, water and low temperature in supplying and receiving flows of fish boxes between the fishing vessel and the fish auction. A total of 929 RFID-tagged fish boxes were automatically scanned on seven separate occasions at the fish auction: three each in receiving and shipment of fish boxes, and one when the fish boxes were exposed to saltwater. After completion of the tests, the researchers conducted a statistical analysis of the data.

To explore the potential impact on customer service of utilising RFID during sales, interviews were conducted with operating personnel, buyers, and managers at the fish auction and at the Swedish fish box provider. Three employees of the fish auction, two of the Swedish fish box provider, and six at different domestic food wholesaler and retail companies which were customers at the fish auction participated in the interviews. Potential effects on customer service when utilising RFID during sales were analysed from visibility of item level information (Zhou, 2009) and temporal (i.e. time for registration and sales) aspects. The interviews comprised two different scenarios: fully integrated (i.e., fully RFID-enabled sales) and partly integrated (i.e., RFID combined with existing manual sales methods and paper-based labelling techniques). To increase validity, results from the completed analysis of each interview were sent to the respondents and confirmed by them (Yin, 2009).

3. LITERATURE REVIEW

3.1. RFID-enabled item tracking in food supply chains

RFID-enabled item tracking in supply chains has been an op since the 1970s (Attaran, 2007). Consequently, many published studies presents logistics and business benefits from implementing RFID. For example, utilisation of RFID can improve effectiveness and efficiency in manufacturing (Zelbst et al., 2012), reduce labour costs for routine work and inventory control in global service supply chains (Véronneau and Roy, 2009), and monitor environmental contexts (Ruiz-Garcia et al., 2009). Identification systems based on RFID are designed to track physical items by using radio waves that enable the automatic tracking of items that are out of sight. In operation, an RFID-enabled tracking system must consist of (1) RFID tags (Attaran, 2007; Ferrer et al., 2010; Jedermann, 2009; Mehrjerdi, 2008; Tu and Piramuthu, 2008); (2) RFID readers that emit, receive and respond to radio frequency signals within different RFID frequency bands (Jedermann et al., 2009; Tajima, 2007; Mehrjerdi, 2008; Finkenzeller, 2008); (3) RFID tag data and interface protocol standards (Wu et al., 2006; Attaran, 2007; Jedermann et al., 2009); and (4) an information management system (Tu and Piramuthu, 2008; Zhu et al., 2012; Delen et al., 2007).

Several studies have examined the benefits of implementing RFID in the food industry. For example, implementing RFID in food retail improves monitoring and inventory management in relation to enhanced efficiency, safety, accuracy in transport, storage, and warehousing operations, and decreases costs of labour and inventory (Jones et al., 2005; Prater et al., 2005; Sahin et al., 2002). Regattieri et al. (2007), Jones et al. (2005), Zhu et al. (2012) and Sahin et al. (2002); all conclude that implementing RFID can reduce response time during product recalls. RFID can also be used to track and monitor customer behaviours (Jones et al., 2005; Sahin et al., 2002), physical product conditions (such as temperature and humidity) during distribution and storage to enhance food safety and quality (Jedermann et al., 2009; Abad et al., 2009; Martinéz-Sala et al., 2009), and in the tracking of live animals (Pettitt, 2001; Hsu, 2008) and of returnable transport items (RTI) (Senneset et al., 2010). This generates environmental as well as cost benefits because of the reduction of spoiled food (Martinéz-Sala et al., 2009; Sahin et al., 2002; Zhu et al., 2012), creates opportunities to comply with regulatory food safety and quality requirements (Pettitt, 2001; Hsu, 2008), and enhances traceability of RTIs (Senneset et al., 2010).

The implementation of RFID-enabled tracking systems in food supply chains has been shown to improve information visibility through real-time tracing of information throughout the entire FSC. Zhou (2009) shows improved item level information visibility of a RFID-enabled tracking system that is affected by the extent of the information system, number of distributed items, revenue and control incentives. Ngai et al. (2008) report service benefits from the real-time item level visibility information of implementing RFID in a sushi restaurant.

Although many benefits of implementing RFID in food supply chains have been reported, RFID-enabled item tracking in FSCs is limited by technical and business challenges;

Technical challenges: Ensuring the readability of RFID tagged items is identified a challenge in implementing RFID to enable traceability in FSCs (Senneset et al., 2007). This is affected by unique identification and tracking of RFID tagged items based on the choice of RFID tags used determined by costs and the environmental context, as well as by the configuration of RFID readers (Wu et al., 2006; Shanahan et al., 2009; Angeles, 2005; Delen et al., 2007). Table 1 summarizes studies of RFID-enabled item tracking, showing food product, environmental context and the type of RFID tags used.

Table 1. Summary of tracking items in different food supply chains

Source	Food product	Environment	RFID tags used
Petitt (2001), Shanahan et al. (2009)	Live animals	Humid, wet, cold	Passive LF, 134.2 kHz
Sugahara (2009)	Lettuce	Humid: 95% RH Chilled: 0-5ºC[1)]	Passive HF, 13.56 MHz
Regattieri et al. (2007)	Cheese	Chilled: 4-8ºC Humid [2)]	Passive HF, 13.56 MHz
Hsu et al. (2008)	Live fish	Wet	Passive HF, 13.56 MHz
Abad et al. (2009)	Caught and filleted fish	Wet, humid Chilled: < 5ºC	Passive HF, 13.56 MHz
Mai et al. (2010)	Caught and filleted fish	Wet, humid Chilled: < 5ºC	Active RFID tags

1) http://postharvest.ucdavis.edu/pfvegetable/LettuceCrisphead/ (accessed 10 Jan 2013)
2) http://www.parmigianoreggiano.com/taste/store/store_parmigiano_reggiano.aspx (accessed 10 Jan 2013)

Researchers cite other technical challenges in implementing RFID to enable tracking of items in FSCs: management of information volumes (Tu and Piramuthu, 2008; Angeles, 2005; Delen et al., 2007); lack of global RFID standards (Regattieri et al. 2007; Martinéz-Sala et al., 2009); and importance of standardized frameworks (Ringsberg and Mirzabeiki, 2013; Storöy et al., 2013; Thakur et al., 2011).

Business challenges: The implementation and on-going operational costs of RFID-enabled systems are recognised as business challenges for tracking items in FSCs (Jedermann et al., 2009; Regattieri et al., 2007; Jones et al., 2005; Ngai et al., 2008b; Mehrjerdi, 2008; Mai et al., 2010). Mehrjerdi (2008) identifies these as the costs of RFID readers, of RFID tags consisting of chip costs, of antenna inlay, assembling, and licensing. Mai et al. (2010) also include costs for hardware (i.e., computers), software and system development, internet service, labour, and training of personnel. The costs of RFID item tagging are dependent on the performance requirements in the supply chain (Kärkkainen, 2003). Further, the total cost of implementing RFID in supply chains is limited by the willingness among supply chain stakeholders to share implementation costs in relation to achieved business benefits (Jones et al., 2005; Angeles, 2005; Martinéz-Sala et al., 2009). It should be noted that the costs of using proprietary frameworks (such as EPCIS) and unique identification numbers (such as Global Returnable Asset Identification (GRAI) numbers provided by the GS1standardisation organisation (GS1, 2013) may be included in the total costs of an RFID-enabled item tracking system.

3.2. Impact on customer service of RFID-enabled item tracking

The impact of logistics operations on company revenues is affected by customer service (Jonsson and Mattsson, 2005). This includes all customer-facing contact operations and the delivery of services or products to customers. Customer service includes aspects of delivery service (e.g., stock availability, inventory service, delivery accuracy and flexibility), information service (e.g., optimising delivery times, minimising order quantities, stock and item tracking), and logistics service (e.g., quicker and reliable identification of goods in deliveries) (Mattsson, 2012).

RFID improves service flexibility and standardisation of service outputs in the delivery of customer service (Ferrer et al., 2010). Several research papers describe customer service benefits that a food company can achieve through the utilisation of RFID: it improves customisation of products (Prater et al., 2005; Sahin et al., 2002) and management of perishable items (Regattieri et al., 2007). Other customer service benefits are improved fulfilment of customer requirements for shelf availability (Jones et al., 2005) and staff availability (Tajima, 2007). However, Lee et al. (2008) emphasize that RFID utilisation to identify items mainly focuses on inbound logistics and operations (i.e., physical creation of the product/ service), and excludes outbound logistics, marketing and sales, and customer operations.

4. CASE DESCRIPTION

The international fresh fish supply chain studied to explore challenges in utilisation of RFID to track items, is illustrated in Fig. 1.

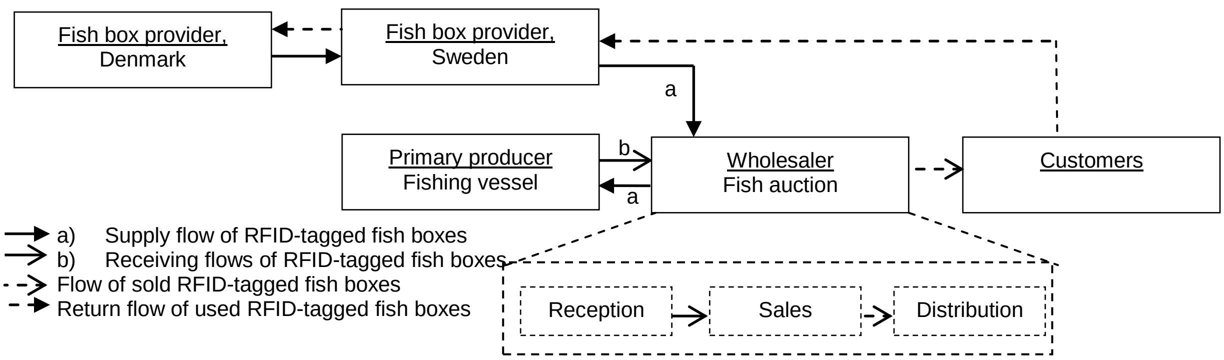

Fig. 1. The international fresh fish supply chain studied.

The supply chain starts at the Danish fish box provider when it distributes empty, dry and clean RFID-tagged fish boxes to the Swedish fish box provider. There, pallets of the fish boxes are first scanned, put into storage locations, and then leased out to producers (i.e., fishing vessels). Forklift (FLT) drivers pick up pallets of the RFID-tagged fish boxes and distribute them to the producers (i.e., supply flows of RFID-tagged fish boxes) (a) by passing the boxes through a RFID portal at the fish auction which registers the number of RFID-tagged boxes. The boxes are used in dedicated fishing activities in which they are filled with freshly caught fish embedded in ice to preserve quality. The dedicated fishing activities are followed by landing activities. In the landing activities, RFID-tagged fish boxes are labelled with stickers containing primary production information, reported to the fish auction and lifted onto pallets on the quay. The FLT drivers pick up the pallets of the boxes containing fresh fish and distribute them to a fish auction hall (i.e., receiving flows of boxes); (b) an installed RFID portal at the fish auction registers the number of RFID-tagged fish boxes in the receiving flows. The auction hall has a constant temperature of +4°C and a humid atmosphere.

Upon reception at the fish auction, delivery notes for each landed catch in received RFID-tagged fish boxes are manually registered in the auction business management system. Sales bills, including primary production data from reported fishing activities, i.e., fish species (in Swedish), net-weight, date of fishing activity, size-class, vessel external marketing denotation (e.g., GG13), and fishing zone are printed out and placed in each fish box to be used in later sales.

The fish auction sells the boxes of fresh fish to customers (e.g., retailers, wholesalers and restaurants) at daily auctions (Monday to Friday). Buyer data from each finalised sale are manually entered into the auction business management system by the auctioneer, and the fish boxes purchased are labelled with sold notes by the buyers. Lists of the purchased RFID tagged boxes of fresh fish are printed out from the auction business management system and placed into the fish boxes by buyers. Each sale is reported by the auctioneer to the Swedish fish box provider. The FLT drivers pick up pallets of the purchased fish boxes and distribute them from the auction hall into cooling lorries owned by the auction or by third-party logistics (3PL) companies. These 3PL companies also return used and dirty fish boxes from the auction customers to the Swedish fish box provider. Once returned, the RFID-tagged fish boxes are scanned and washed in a hot water washing facility at the Swedish fish box provider. Pallets of empty, dry and clean boxes are picked up by FLT drivers who deliver them to return lorries headed to Denmark, or to storage locations at the Swedish fish box provider.

Readability test set-up

To explore the readability of RFID-tagged fish boxes based on the environmental context, and consequently to identify technical challenges in utilising RFID in an international fresh food supply chain, a series of readability tests of the RFID-tagged fish boxes in (a) supply and (b) receiving flows at the fish auction were carried out (Fig. 1). In addition to these two types of tests, a separate, third test was conducted to explore the effect of the presence of saltwater on RFID readability. This test involved a batch of 100%-readable RFID-tagged fish boxes that was covered with a saturated salt solution. The setup of the tests considered three influencing factors: RFID-tagged items, RFID reader configuration and information management.

RFID tagged items: Original RFID-tagged PVC plastic fish boxes (space limit 30 kg) were used and equipped with two passive Alien Higgs-3 circuit tags (i.e., EPC Gen 2 passive UHF 64-bit, operating readability frequency of 840-960MHz) (Alien Technology Corporation, 2012). Each RFID tag was glued vertically under a protective plastic plate on one outside short end wall of the fish box. A unique GRAI number was applied in conjunction with each RFID tag to track through unique identification of each fish box. Thus, each RFID-tagged fish box had two unique identities to ensure identification.

RFID reader configuration: Two RFID portals were used in the readability tests – one installed indoors at the shipping gate and the other at the receiving gate of the fish auction.

Each portal consisted of two portal legs that included two readers and eight antennas oriented in line with the antenna on the RFID-tagged fish boxes. The configuration provided a readability radius of up to 10 meters in any direction from each portal leg at maximum effect (30 dB). To enable reliable communication between the two RFID portals and the RFID-tagged fish boxes, each portal was configured according to the ISO 18000-6C standard, used for air interface communications for EPC Gen 2 passive UHF RFID tags (860 MHz to 960 MHz frequency) (O'Connor, 2006).

Information management: Registered readings of RFID tagged fish boxes that passed through each portal were stored as EPCIS events in a database according to the EPCIS (Electronic Product Code Information Service) framework. EPCIS events capture properties of an RFID reading by answering the questions "what?", "where?", "when?" and "why?" and exchange them in XML (Extensible Markup Language) (EPCglobal, EPC Information Services [EPCIS] Version 1.0.1 Specification, 2007). Benefits of adopting the EPCIS framework to ensure traceability of food products have been presented by Thakur et al. (2011). An example of EPCIS event information from an RFID reading is presented in Table 2.

Table 2. EPCIS transaction event information from an RFID reading

EPCIS event question	Data set	Data example
WHAT?	Fish box identity	urn:epc:id:grai:5704589.00012.212432
WHERE?	Portal identity	gothenburg.portal2
WHEN?	Timestamp	2012-05-17T01:26:55.037+02:00
WHY?	Business process (Shipping/Receiving)	urn:epcglobal:cbv:bizstep:shipping

An XML and web-based interface was used to extract and sort EPCIS events stored in the database. The total number of RFID-tagged boxes in each batch was noted as a reference number of boxes used.

5. RESULTS AND ANALYSIS

The paper presents results regarding utilisation of RFID in an international fresh fish supply chain, based on the impact on the readability of RFID tagged items and customer service. Figure 2 presents a summary of the results from the three RFID readability tests.

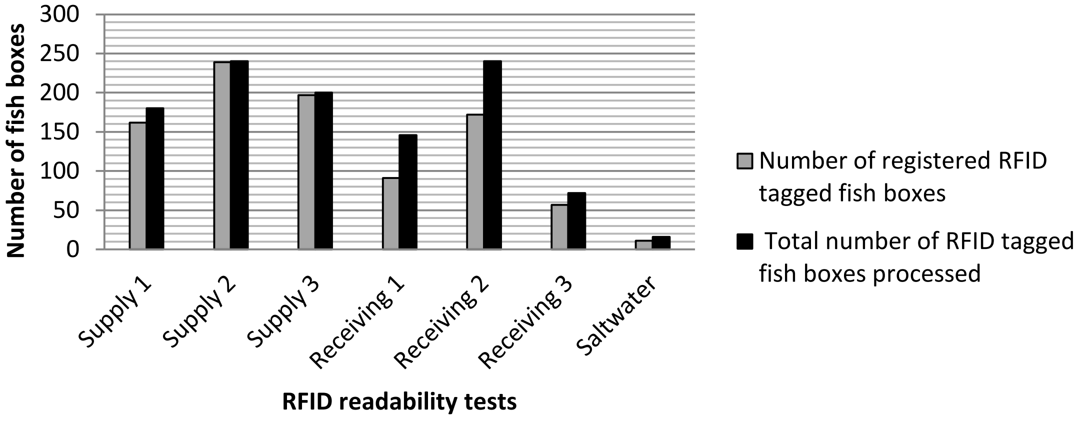

Fig. 2. RFID readability of empty, dry and clean (Supply 1-3), wet and cold (Receiving 1-3), and saltwater exposed RFID tagged fish boxes compared to the total number of boxes processed.

A comparison of RFID readability from the three tests is presented in Fig. 3. The figure shows an average readability of approximately 96% for empty, dry and clean RFID tagged fish boxes, and an average readability of 69% for wet and cold RFID tagged fish boxes. Similarly, the average readability for RFID-tagged fish boxes exposed to saltwater was approximately 69%.

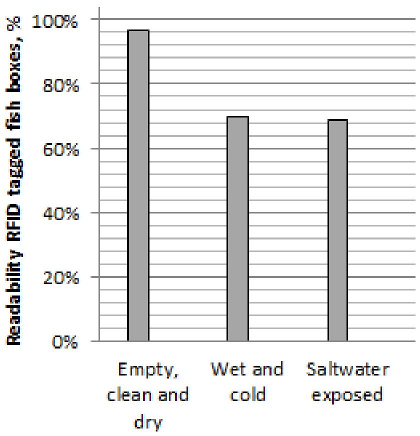

Fig. 3. Comparison of RFID readability between empty, dry and clean, wet and cold, and saltwater-exposed fish boxes.

The results presented in Fig. 3 show that the readability of RFID tagged fish boxes is adversely affected by the environmental context of the supply chain. Water affects readability of RFID tagged fish boxes in receiving flows adversely because it obstructs the electrical signal used for communication in a passive RFID tag-based tracking system. This signal is dependent on the electrical conductivity in the radio wave sent out from the RFID portal antenna to the RFID tag antenna. Electrical conductivity is adversely affected by water because of the water's reflection and absorption characteristics. Similarly, low temperatures adversely affect electrical conductivity, and thus readability of RFID tagged fish boxes in receiving flows. Low temperatures decrease the electron speed in electric signals used for communication in a tracking system based on passive RFID tags. Surprisingly, the readings from the RFID-tagged fish boxes exposed to saltwater also show an adverse impact on readability. According to physics theory, saltwater improves electrical conductivity, and hence should improve readability. The adverse results on RFID readability, though, may be explained by interference in the direct electric signal between the reader and the RFID tags on some of the fish boxes. Electric fields used for communication in an RFID based system using passive RFID tags, have different shapes, sizes and directions. A passive RFID tag passing through a field automatically tries to reply to the strongest electric signal. The conductivity improvement characteristics of saltwater create interference between electric signals in the electric field stemming from RFID-tagged fish boxes in the batch, resulting in adverse readability results.

The results from the three readability tests emphasize technical challenges related to RFID tagging of the fish boxes, by showing that this needs to be improved, particularly in isolating and protecting the RFID tags against water, saltwater and low temperatures. Direct observations of the RFID-tagged fish boxes revealed that each RFID tag was protected against water and saltwater by a plastic plate, directly glued on the outside of the fish box wall. Thus, the protection against water and saltwater is dependent on the tightness of the glued seal between the plastic plate and the fish box wall. Similarly, the protection against low temperatures from the fish box content depends on the 5 mm thickness in the fish box wall. Furthermore, the results from the readability tests present technical challenges in management of information according to unique identification of RFID-tagged items in the database. This is linked to the GRAI number used in conjunction with the two RFID tags, which implies that a double amount of identity numbers needs to be managed to ensure the tracking of each fish box. Other technical challenges addressed in the results from the readability tests are the configuration of RFID readers and use of international data communication standards to ensure tracking of RFID-tagged fish boxes across country borders.

The impact on customer service during sales was analysed by comparing the two scenarios titled “fully integrated” and “partly integrated”. The comparison comprised evaluation of visibility of item level information and time for registration and sales from utilisation of RFID during sales.

Fully integrated scenario: The two RFID tags on each fish box completely replace paper-based sales bills and labelling stickers that include primary production information printed in plain text. A sale is initiated by the auctioneer, who scans one of the RFID tags on a fish box with a handheld scanner receiving a list presented on the scanner screen of registered RFID tagged boxes offered for sale by a specific producer from the auction business management system. Then the boxes of fresh fish are sold to customers according to the daily auction process. In the end of the auction process purchased RFID tagged boxes are scanned by the auctioneer with a handheld scanner. This creates a link between the purchased RFID tagged fish box and a registered buyer in the auction business management system.

Partly integrated scenario: Paper-based delivery notes and sales bills printed in plain text are replaced by the two RFID tags on the fish box. The paper-based labelling stickers that present sales information as printed text are kept to supply customers with production information. After initiation of sales by the auctioneer, the process of utilising RFID is identical to the fully integrated scenario.

The results obtained from the analysed interviews allow for a comparison of potential impact on customer service of RFID utilisation during sales between the two scenarios. Table 3 presents a comparison of potential customer service impacts based on visibility of item level information, and time for sales and registration at the fish auction according to involved FSC actors. In the table, a positive customer service impact is indicated by “+” and an adverse impact by “–”.

Table 3. Summary comparison of potential impact on customer service between a fully integrated scenario and partly integrated scenario from utilisation of RFID in sales.

Supply chain actor	Position	Summary comparison		
		Item level visibility information	Time, registration	Time, sales
Fish auction	Manager	+	+	–
Fish auction	Operating personnel	+	+	–
Fish box provider, Sweden	Manager	–/+	+	–
Fish box provider, Sweden	Administrative personnel	–/+	+	+
Auction customer, retail	Personnel	–	+	–/+
Auction customer, wholesaler	Personnel	–	+	–/+

The comparison of customer service impact presented in Table 3 shows that utilisation of RFID in sales, such as in the ‘fully integrated scenario’, can have a potential negative impact on customer service. This is because a removal of labelling stickers presenting production information printed as plain text adversely affects the information service aspect of customer service. Customers at the fish auction must take part in and often make their purchase decisions based on clearly presented production information, such as the quality of products provided by a specific primary producer. To meet this requirement, utilisation of RFID during sales indicates that additional technology is needed to present information. Likewise, the results presented in Table 3 show that utilisation of RFID can have a potential negative impact on customer service related to time used during sales. This potential impact is linked to additional work that may be required from utilisation of RFID during sales. The results also emphasize a reduction in time for registration of RFID-tagged fish boxes during sales, having a potential positive impact on customer service.

6. CONCLUSIONS

This paper explored challenges in environmental contexts and the impact on customer service during sales in utilising RFID in an international fresh fish supply chain. The results from the

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three quantitative RFID readability tests of RFID-tagged fish boxes indicated an adverse impact on readability and hence on the ability to track items in an international fish supply chain between two Nordic countries. RFID tag readability is dependent on the environmental context of the supply chain and is adversely affected by water, saltwater and low temperature.

The results highlight *technical challenges* in RFID tagging of items to ensure readability for product tracking in the different environmental contexts of FSC. Improved RFID tagging of items such as fish boxes can be achieved by casting the RFID tags into the plastic, or by gluing them behind plastic plates that are placed underneath and inside the box handles. Readability of RFID tagged items is also affected by the choice of RFID tag, which is determined by utilisation requirements. Other technical challenges to ensure tracking in international fresh FSC are the configuration of RFID readers, use of different RFID interface protocol standards and RFID frequency bands, as well as information management of readings. The latter can be facilitated by using cloned identities (i.e., the two RFID tags have the same GRAI number), and by adopting standardized frameworks such as EPCIS (Thakur et al., 2011) or the TraceFood framework (Storöy et al., 2013).

The qualitative interviews indicated *business challenges* of the adverse impact of RFID utilisation on information service to customers during sales. Costumers require a high level of information visibility in order to make buying decisions. Utilisation of RFID can have adverse effects on the ability to present information, since a RFID-enabled tracking system has to take into account the need for additional technology to present information to meet customers' visibility information requirements. This is because the introduction of RFID increases the costs of presenting information, such as the cost of handheld RFID scanners and mobile phone apps. In addition, the results from the interviews indicated a potential negative impact on customer service linked to time and hence costs for additional work. It should be noted that the costs of utilising RFID in FSC is still an area for further development.

Utilisation of RFID in food supply chains is unlikely to disappear soon. Food company managers who are interested in RFID-enabled item tracking need to prioritize the technical challenges to ensure readability of RFID-tagged items. In light of the results on potential customer service impact, managers would be wise to focus on how to integrate RFID-enabled tracking into their existing business processes, being observant of customer requirements on information visibility, additional costs and time for additional work. Insufficient tracking of items in FSCs can have economic consequences for primary producers in terms of product losses and increased leasing costs of RFID-tagged items (such as fish boxes), as well as for the providing company in terms of replacement costs for lost RFID-tagged items. Food industry companies can also suffer economic losses from inadequate compliance with regulatory and consumer food traceability requirements, since this requires 100% unique identification and hence tracking of RFID-tagged items in FSC.

This paper contributes to the current body of knowledge in the logistics of utilising RFID to track items in food supply chains. Future research should investigate the impact on readability over a longer period that includes different types of weather and temperature variation. The readability study was conducted in a fresh fish supply chain, highlighting environmental contexts specific to that industry, and further research should investigate the readability of RFID-tagged items in food sectors that include other environmental contexts.

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