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Abstract

Purpose – The aim of this empirical paper is to study information sharing in fresh food supply chains, with a specific goal of reducing waste and facilitating sustainable performance. The study focuses on material and information flow issues, specifically on sharing demand and shelf-life data.

Design/methodology/approach – This work has been designed as an exploratory case study in three fresh food supply chains, milk, fresh fish, and fresh poultry, in the Nordic countries. The cases are based on interviews and data from the databases of the companies involved. Each case focuses on analyzing information flow, particularly the current order patterns and forecasting and planning process, and material flow, focusing on the supply chain structure. In two cases significant changes have been made to forecasting processes and material flow, while the third case intends to identify the most beneficial uses of shared information to create a sustainable fresh food supply chain.

Findings –The performance of the perishable food chain can be improved by more efficient information sharing. The key to improved operations is *how* and for which purposes the shared data should be used. In addition, changes in the supply chain structure were needed to speed up the deliveries and ensure shelf availability. The cross-case analysis revealed that improved performance was obtained with parallel changes in information sharing and usage and in material flow.

Originality/value – Few studies approach the problem of waste and sustainability from an integrated supply chain perspective. This paper links data sharing with the sustainability performance of the supply chain as a whole.

Keywords: Fresh food, Supply chain, Sustainability, Waste reduction, Information sharing, Case study.

1 Introduction

Sustainability concerns are becoming an essential part of perishable food supply chain management. The average loss of food products over the whole chain from production to the retail shelf and the consumer's fridge is estimated to be 35% (Parfitt *et al.,* 2010); in other words, one-third of the food produced for humans is wasted (Gustavsson *et al.*, 2011). The food waste in different supply chain phases has been estimated in many studies, providing somewhat different results, depending on the measures and methods used, but the studies seem to agree that product groups such as fresh bakery products and fresh fruits and vegetables contribute most to the avoidable food waste, and are most significant in affecting the total turnover in all parts of the distribution chain (Hanssen and Schakenda, 2011; Kantor *et al.*, 2007; Griffin *et al.*, 2008; Mena *et al.*, 2011). The most common reason for waste at the retail store is that products' expiry dates have passed (Hanssen and Schakenda, 2011). The causes for this include ordering more than real demand or products reaching the store shelf too late and with a short remaining shelf life (Mena *et al.*, 2011). The origins of these effects have been identified as a lack of information sharing, forecasting difficulties and poor ordering, the performance measurement focus on cost, efficiency and availability, and problems in promotions management (Taylor and Fearne, 2009; WRAP, 2011a; WRAP, 2011b). Therefore it becomes evident that ensuring that the product reaches the end consumer in full quantity and in perfect condition is of crucial importance for increasing sustainability (Nereng *et al.*, 2009).

This paper takes a supply chain view in order to study the wasting of fresh food. The main environmental effect is not caused solely in the phase where the product is wasted; food products that end up not being consumed have an environmental impact without adding value. A further rationale is that poor planning practices and delays in previous supply chain phases can harm the operations in later phases (Parfitt *et al.,* 2010). Thus, producing volumes according to real demand and improving the efficiency and performance of the whole supply chain are expected to significantly reduce the perishable food waste. Past research and company practices have mainly focused on separate segments of the supply chain, for example farmers and growers, retailers, transport and distribution, or processing and manufacturing (Mena *et al.,* 2011). The purpose of this paper is to demonstrate how to benefit from sharing demand data and shelf-life data to achieve improved fresh food supply chain performance. The research question is: How can improved visibility be utilized to create a sustainable fresh food supply chain?

2   Literature review

2.1   *Fresh food supply chain characteristics*

Management and performance of supply chains for perishable food products are significantly affected by the specific features of fresh food, as well as current trends in the industry. Kittipanya-ngam *et al.,* (2010) identify three key characteristics of the food product market that affect the food supply chain: *demand uncertainty, customer order lead time (COLT),* and *supply chain lead time allowance (SCLT).*

Because of their limited lifetime, SCLT for perishable products is short. In addition, the retail customers in this market require short COLT (Kittipanya-ngam *et al.,* 2010). These two characteristics thus require *high responsiveness* by the supply chain management. The third characteristic, demand uncertainty, incorporates degree of product variety, new product development frequency and degree, and the stage of the product life cycle. Consumers' wishes are changing at an ever-growing rate, causing an increase in packaging sizes, the number of products, and the number of new products introduced (van Donk, 2001). In addition, Taylor and Fearne (2009) found that variability in consumer demand (creating uncertainty) does not only depend on natural causes such as seasonality and weather, but is also induced by promotional activities. The perishability of fresh food products limits the opportunities to use inventories as a buffer against variability in demand and transportation (Ahumada and Villalobos, 2009). Thus, increased demand uncertainty requires greater supply chain flexibility, rather than economies of scale. These speed and flexibility requirements actually support the same goals as the objective of waste reduction in perishable food supply chains.

In order to manage these requirements for speed and flexibility, different supply chain parties need to have collaboration at an operational level and at least partly integrated support systems (Kittipanya-ngam *et al.,* 2010). This is a challenge for the companies along the supply chain. Depending on the food product, there are different and numerous actors included in the food supply chain (Trienekens and Zuurbier, 2008). The facts that organizations do not share data openly or have not adopted advanced forecasting techniques have been identified as causes of food waste between suppliers and retailers (Mena *et al.,* 2011; Taylor and Fearne, 2009). In addition, used performance indicators are another cause of waste since they focus on cost, efficiency, and availability. A particular finding is that availability is attributed higher importance than waste in the current measurements.

2.2   *Benefits of information sharing in supply chains*

Advanced organizations take advantage of information sharing technology in managing their logistical processes, as was stated in a seminal paper on supply chain information sharing (Bowersox and Daugherty, 1987), and base decisions on accurate and timely information (Ellram et al. 1999). Since the 1980s the large body of supply chain literature has offered several solutions to the question of how to benefit from shared information (Cachon and Fisher, 2000; Gavirneni *et al.*, 1999; Kaipia and Hartiala, Lee *et al.,* 2000; Li *et al.,* 2006; Zhao *et al.,* 2002; Zhoua and Benton, 2007). Many of these studies focus on retail demand information sharing and have found that shared information can improve decisions with regard to quantity in a supplier's orders and the allocation of the supplier's inventory across retailers (e.g. Lee and Whang, 2000; Lee *et al.,* 2000).

Model-based studies have presented benefits of information sharing, for example cost savings between 1 and 35% (Chen, 1998; Lee *et al.,* 2000; Cachon and Fisher, 2000; Zhao *et al.,* 2002; Yu *et al.,* 2001; Gavirneni, 2006). It has

been stated that demand information sharing becomes more beneficial when variation in demand is high (Gavirneni *et al.,* 1999), and manufacturers obtain a greater reduction in inventory levels and reduce costs more when demand variability is high and correlated over time (Lee *et al.,* 2000). In the context of perishable foods, a limited number of researchers deal with the topic, even though information sharing has been suggested to be one of the most important means to reduce waste (Mena *et al.*, 2011, WRAP, 2011a, Thron *et al.*, 2007). An example is the model-based paper by Ferguson and Ketzenberg (2006), who study the value of information in retail replenishments for one product. They found out that information sharing is most beneficial when demand is variable, and product is perishable and expensive. Taylor and Fearne (2009) offer empirical insights into the topic by using case studies as the basis of a framework on demand management in fresh food value chains. Systematically identifying, quantifying, and eliminating the causes could lead to waste reductions and process efficiency improvements. Thron *et al.* (2007) discovered that the supply chain of perishable goods benefits most from information sharing or centralised control. They observed that even a partial collaborative inventory replenishment can lead to an improvement in overall supply chain performance.

In a large study focusing on manufacturing, distribution, and retail stages within the UK food and drink supply chain (WRAP, 2010) several significant opportunities for waste prevention were found. The later reports by the same organization (WRAP, 2011a, 2011b, 2011c, and 2011d) conclude that improving communication and forecasting and working in partnership with suppliers could reduce costs and waste in the whole supply chain. Good communication helps plan the crop and makes demand forecasting easier, thus obviating one of the most common reasons for waste. The reports identified four recommendations for waste reduction, of which three handled information sharing and collaboration. These studies serve as a valuable background for our study. However, there is scarce academic literature providing empirical evidence on how companies should actually share and utilize information for food waste reduction in supply chains. This paper is an effort towards filling that gap.

3   Research design

3.1   *Research method*

The purpose of this paper is to give empirical evidence on how shared information can be utilized to create a more sustainable fresh food supply chain. Since empirical research showing the dynamics between information sharing and the sustainable supply chain performance is rare, an exploratory case study method has been chosen. Case studies are able to explain and explore new phenomena (Eisenhardt, 1989) and offer a means for studying complex real-life events (Yin, 2009). In case studies, the variables can be identified, and patterns between variables observed (Eisenhardt, 1989).

The research involves three case studies of fresh food supply chains in the Nordic countries. The unit of analysis is a supply chain with three phases: producer, wholesaler/logistics provider, and retailer. The cases were selected to deal with products with a short shelf life. The chosen product groups are fresh milk in Case 1, fresh fish in Case 2, and fresh poultry in Case 3. Most studied products are packed goods with expiry dates on them, which made possible to observe remaining product shelf life. Furthermore, in all cases the supply chains suffered from various problems connected to shelf life management, demand responsiveness, and out-of-stocks at the retailer, and therefore a need for improvement had been identified (Table 1).

For Cases 1 and 2, the research method includes features from innovation action research (Kaplan, 1998) because the authors were actively taking part in the process and had the opportunity to affect the process. The authors had access to company databases where order data, point-of-sale (PoS) data, and delivery data were gathered. In addition, the processes and management practices were thoroughly studied. The third case is based on interviews and data from three supply chain phases. The authors conducted one semi-structured, in-person interview with the processor, one with the wholesaler, and two with the retailer. The main focus was to understand the flow of the product through the supply chain, times spent at different points, the information flow across different actors, and information usage. Besides that, forecasting and planning data and order data were obtained from the processor. Furthermore, data on the expiry dates of the products and delivery times of products were collected.

Table 1. Case features.

Case	Case 1 – Milk	Case 2 - Fish	Case 3 - Poultry
No. of products studied	10	Over 10	1
Product shelf life	7 days	5-30 days	11 days
Time period studied	10 weeks	10 weeks	1 month
Structure of supply chain	Milk supplier, logistics service provider, wholesaler, 26 retail stores	Fish grower and processor, logistics service provider, wholesaler, 671 retail stores.	Processor, logistics service provider, wholesaler, a retailer (1 retail store).
Main problems	Inadequate response to demand changes, high inventory levels in stores to ensure availability, inaccurate ordering.	Lots of wasted products or out-of-stocks at the retailer. Slow reactions to changes. Expensive structure with lots of handling.	No use of shelf life data, products reach the store with a short remaining shelf life.

3.2 Analyses

To analyse the cases we selected several parallel performance indicators (Table 2). Food products that end up not being consumed have a negative cost and environmental impact through the whole supply chain without adding value. The first indicator is therefore *the quantity of wasted products* at the retailer, which was considered in Cases 1 and 2. Waste in retail stores is measured as a percentage of total product sales,[1] and it includes, in addition to wasted products, price reductions (for example sales to staff), as well as broken items. In Case 3, the products that were close to being wasted were either frozen or processed by the processor or at the retailer, and data on waste were not available. Therefore, in Case 3, *the remaining shelf life at the retailer* is the main indicator of sustainability. Another observed performance indicator is *shelf availability*,[2] which is an important measure from the retailer's viewpoint, but which may exhibit a trade-off with respect to waste at the retailer if not carefully managed (Ettouzani *et al.*, 2012). Cases 1 and 2 considered this variable. The last indicator was *the share of value-adding and non-value-adding times (VA and NVA) in the total throughput time*, which was used in Case 3.

Table 2. Data, analyses, and measures used in the cases.

	Case 1 - Milk	Case 2 – Fish	Case 3 - Poultry
Data gathered	Order data and order practices and timetables PoS data Product age at the retailer, (gathered manually) Delivery data Lost profit Process and management practices	Order data PoS data Delivery data Process and management practices Lost profit	Order data Shelf life at the logistics provider Forecasting and planning data Durations of different activities Information-sharing practices
Analyses	Current material flow Ordering/sales patterns Current information flow Information-sharing practices related to forecasting,	Current material flow Ordering/sales patterns Current information flow Information-sharing practices related to forecasting,	Value stream analysis Information flow analysis Order pattern analysis Remaining shelf life distribution analysis

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[1] Measured as Lost Profit

Daily Lost Profit per product (%) = ((∑value of products wasted + ∑price reductions) / total product sales)*100

[2] Daily Shelf Availability per product = 1- (∑out-of-stocks / nr of retail stores)

Out-of-stocks are available in the PoS data.

	production planning, and shelf life	production planning, and shelf life	
Used measure	Remaining shelf life at the retailer Shelf availability Quantity of wasted products	Shelf availability Quantity of wasted products Remaining shelf life at the retailer Retailer margin	Remaining shelf life at the retailer Value-adding and non-value-adding times.

The use of parallel and different measures in the cases follows from the heterogeneous nature of food products, as well as differing practices in current operations in the companies. First, parallel measures are needed to mirror the balance between conflicting targets, for example between shelf availability (which favors large order quantities) and waste (favors small order quantities). Second, separate measures have varying significance for different products. A high level of wastage is more typical for products with high variations in demand, for example fresh fish, but not poultry, where processing and freezing serve as solutions to avoid waste. Third, the target values of each measure vary, depending on the nature of the product and its role in the product group in the whole store offering. For example, for fresh milk the shelf availability requirement is close to 100% throughout the week, but for fresh fish it is lower.

All the cases were first analysed separately (Table 2). The aim of these analyses was to identify problems related to information sharing in the supply chains reflected in product waste, remaining shelf life at the retailer, and product availability. In Cases 1 and 2, the changes were implemented, and the results are based on real-life changes. At the end, a cross-case analysis was carried out, with the purpose of identifying which changes improved the performance.

4 Case studies

In this chapter, the cases are treated separately to describe the actions taken.

Case 1: Forecast-based daily operations for fresh milk products

The first case represents a supply chain of fresh milk products with a shelf life of 7 days from packing. The companies involved had agreed on a pilot project to be carried out in a retail chain with relatively small stores in one town in 2010. The duration of the pilot project was 10 weeks and it involved ten milk and cream products. The requirement for delivery reliability for these products is high.

Before the pilot project, the operations were based on orders: the retailer placed an order with the wholesaler, who placed a summary order to the producer (Figure 1). The producer used a make-to-stock (MTS) order fulfillment strategy and the products were transported via the wholesaler to the retailer. Several changes were made. The wholesaler adopted a statistical order forecasting method based on advanced software. Furthermore, the order-picking was moved to the wholesaler instead of the producer, which meant that the wholesaler keeps a small buffer stock. Ordering schedule was delayed to enable the retailer to observe the actual sales during the daily peak hours, and more importantly, weekly peak hours, before placing the order. In the whole arrangement the wholesaler takes a remarkably bigger role in managing the supply chain: it is responsible for the forecasting process, as well as customer order-picking.

Before pilot project   **Pilot project**

| Milk supplier | | 3. Order-picking |

4. Delivery ↓   2. Summary order

| Logistics service provider |

5. Delivery ↓

| Wholesaler |

6. Delivery ↓   1. Order

| Retailer |

| Milk supplier |

2. Bulk delivery   1. Forecast-based order

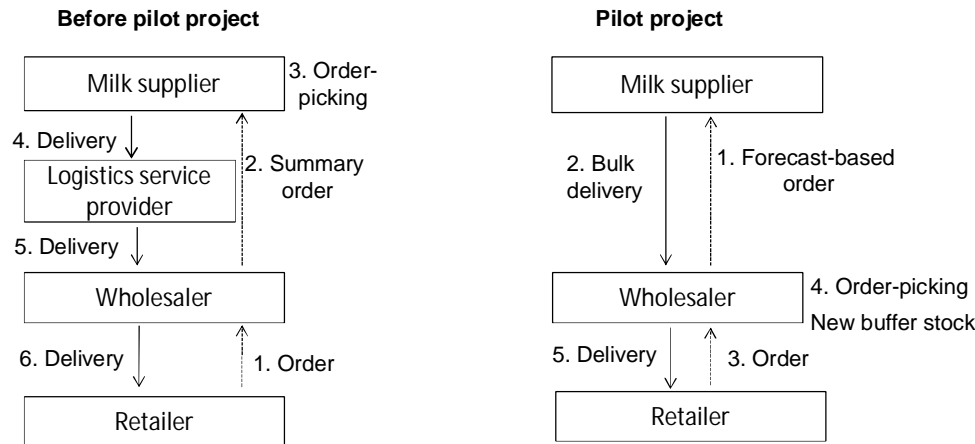| Wholesaler | 4. Order-picking New buffer stock |

5. Delivery   3. Order

| Retailer |

Figure 1 . Change from order-based to forecast-based daily operating model in Case 1. The numbers reflect the order of the activities.

The model brought savings and more efficiency into the process (Table 3). From the first day on, shelf availability improved compared to the pilot group result of the previous year. Each day during the pilot, the remaining shelf life of each product item was manually checked at the retail stores, to find out the impact of the new buffer stock on product freshness. Compared to the earlier situation, there were 7 stock-keeping units (SKUs) that were as fresh as before at the store or even fresher. For 3 SKUs the remaining shelf life decreased by more than 1 day. The result includes variations, and during the time period the remaining shelf life approached zero several times for various products, indicating a high risk of the products becoming waste. Therefore there is still room for improvement in balancing availability and lost profit. For all products waste was reduced: for one cream product over 20%-points. The change resulted in a more stable flow of goods, which was observed as more stable orders and workloads in the upper parts of the supply chain.

Table 3. Results in Case 1.

	Example products	Before pilot project	In pilot project
Shelf availability, %	Average of 10 SKUs	95.8-98.7	99.4-99.9
Lost profit, %	Average of 7 SKUs	4.5-9.2	1.8 -5.7
Remaining shelf life at the retailer, days	Coffee cream, 0,2 litres	2.8	2.7
	Milk, 1,5 litres	2	3.4
	Milk, 1 litre	4.5	3.2

After this pilot project the practice was widened to cover a larger geographical area with more stores. Still, the parties feel that only the mid-point of the potential benefits has been reached with the model, and the project will be further extended and deepened.

Case 2: Reducing waste and improving availability for fish products

The second case represents a supply chain of packed fish products with a shelf life varying from 5 to 30 days. The fish producer is rather small and is located in the neighboring country to the retailers. The current order-based replenishment system has caused high levels of product waste at the retailer, who, when placing orders, has to find a balance between having empty shelves (too low an order quantity) or causing high levels of waste (too high an order quantity). The producer used a MTS order fulfillment strategy based on its own forecast. Products were transported from the producer's stock to the logistics operator and from there to the wholesaler, who combined the products with other products and distributed those to the retailer.

A new forecasting method was applied in a similar manner as in Case 1. The pilot project included one retail chain with over 600 retail stores. The wholesaler places a forecast order with the producer, who delivers products straight from production to the wholesaler. This leads to the benefit that the retailer is able to place an order significantly

later. As a result of this arrangement products reach shops earlier and fresher, with a longer remaining shelf life. In numerical values, product availability at the store improved, and product waste fell by 57%. The retailer profit margin rose by 30%, while average shelf life rose (see Table 4).

Table 4. Results in Case 2.

	Before implementation	After implementation
Lost profit, %	10.9	4.7
Remaining shelf life at the retailer, days	11.1	14.7
Retailer margin, %	17.3	22.5

Here as well, the three-step cooperation worked well, and all parties were actively involved in the change process. Still, as the products being studied are different in nature, the best forecast model and parameters must be defined individually for each product in order to reach the optimal situation.

Case 3: Improving shelf life management for fresh poultry

The assumption for this case was that increasing the shelf life at the retailer will reduce the risk of wasting the product. The products observed in this case have 11 days of shelf life from slaughtering. The parties involved in the supply chain are the poultry processor, the wholesaler (dealing only with the information flow between the retailer and the processor), the logistics company (dealing with the material flow between the processor and the retailer), and the retailer.

In case of short remaining shelf life, the processor has the opportunity to repack or freeze products. This processing is a way to increase the shelf life, but adds cost and reduces the profit margin. At the retailer, in addition to selling the products at a discount, there is the possibility of cooking the products that have less than one day of their shelf life left.

The current state analysis revealed that chain-wide understanding on products' shelf life is lacking. It became evident that about 50% of the products have a shorter remaining shelf life than expected (at least 9 days) at the logistics company. The company records the products' date of expiry. The wholesaler has access to this data, but does not use it for planning or scheduling. The only use for this data is identifying if the remaining shelf life is 5 days or less, while in this case the retailer gets a certain price discount.

Next, looking at the time parameters influencing the product's shelf life, the value-adding (VA) and non-value-adding (NVA) time in the chain were identified (Table 5). It can be concluded that the greatest variability and the longest NVA time of the shelf life are caused at the poultry processor, where the stocking time can vary between a few hours and four days before shipping. Transport time is included in VA time, because transportation is necessary to reach the customer. The display time at the retailer varies, and could even be 10 days (out of 11) if the chain operated efficiently.

Table 5. VA and NVA times in Case 3.

	Processor	Transport	Logistics company	Total
Value-adding time	3.5 hours	4-7 hours	-	7.5-10.5 hours
Non-value -adding time	Approx. 5 hours - 4 days	-	10-13 hours	15-109 hours
Remaining shelf life at the retailer	-	-	-	145-242 hours (6-10 days)

The analysis reveals that special attention needs to be paid to the production planning and scheduling at the processor. The weekly demand pattern, combined with the fact that the processor does not produce during the weekend, forced the processor to mostly obey MTS strategy. The current information-sharing practice includes three

sets of demand data. First, a rolling 10-week forecast is used to plan chicken orders from the breeders. Second, a rolling 14-day forecast is needed in the production planning of the processor. This plan is later used for performing the MTS production and for placing orders with the breeders. Finally, aggregated shop orders are sent from the wholesaler to the processor about 2 hours before the slaughtering process begins. This information is the basis for the make-to-order (MTO) production/packaging. Individual shops send order information to the wholesaler earlier, about 5 hours before slaughtering begins.

Several suggestions for improvement were made. First, the shelf life data need to be included in the planning and control systems, as well as being considered as a performance indicator for different parties in the supply chain. Second, sending demand data from each shop directly to the processor could provide better knowledge of the demand and allow a larger MTO production. In this way stocking at the processor could be minimized, and a longer product shelf life at the retailer achieved. This suggestion needs to be coupled with change in the production strategy by adapting a chase strategy at the beginning of the week. Third, the intermediate storage and re-packaging by the logistics company could be left out if orders for individual retailers were packed at the processor and sent directly to retailers. In this way a gain of about 24 hours of shelf life could be achieved.

The results of each case are summarized in Table 6, and an estimation of the significance of the changes is provided.

Table 6. Summary of results.

Measure used	Case 1 – Milk		Case 2 - Fish		Case 3 - Poultry	
Remaining shelf life at the retailer	For 7 SKUs at the same level as before, for 3 SKUs shorter	+/-	Average improvement 3.6 days (32.4%).	++	Remaining shelf life at the retailer can be increased for 1-3 days	+
Shelf availability	Improved compared to the previous year and the entire chain level.	++	Was not directly measured. The 30% rise in retailer profit margin indicates excellent shelf availability.	++	Not measured.	
Waste	Reduced by 2.7-4.5 percentage points of sales	++	Quantity of wasted products was reduced by 57%.	++	Not measured. Freezing and processing are used as tactics to prevent waste.	
VA/NVA times	Not measured		Not measured		NVA decrease 1-3 days	+

Symbols: performance improved (+); improved remarkably (++); no or minor changes in performance (+/-).

5   Cross-case analysis

The implemented or planned changes in information flow and material flow and their impact in supply chain performance are studied. The most important changes were made in retail order patterns, in the planning and forecasting process, and in material flow, which aimed at streamlining and speeding up the flow (Table 7). These changes are discussed in the light of three key characteristics of the food product market: demand uncertainty, COLT, and SCLT (Kittipanya-ngam *et al.,* 2010).

Table 7. Summary of changes in Cases.

	Case 1 – Milk	Case 2 - Fish	Case 3 - Poultry
Changes in order patterns	New timing of order placing from retailers. The wholesaler gives a forecast-based summary order to the producer.	Retail orders to the wholesaler daily, forecast-based summary order to the fish producer.	Getting orders/PoS data from retailers to the processor 5 hours earlier.
Changes in forecasting	Improved forecasting process. Weekly demand pattern is well	A more accurate weekly forecasting process was	Early orders facilitate more accurate production planning

and planning process	predictable. Further requirements are set by the high delivery accuracy requirement. A larger part of the supply chain operates on the basis of forecasts.	put in place. Product obeys a weekly demand pattern and allows a weekly planning process to be followed.	and poultry processing because MTO is possible.
Changes in material flow	Change from cross-docking to order-picking at the wholesaler. New fast-cycling buffer stock at the wholesaler. The logistics service provider was left out.	Order-picking at the wholesaler; the logistics service provider was left out.	Logistics company left out of the process. Current delivery strategies to retailer shops (a few times per week) should be replaced by daily deliveries to increase product freshness.
Achieved improvements	Daily retailer orders postponed and can be based on peak hour sales and weekend sales – improves demand responsiveness. Improved shelf availability at the retailer without risking product freshness. The COLT was shortened by shifting OPP closer to the customer. This was possible because the improved forecasting process provides reliable forecasts for the upstream operations.	Weekly forecasts make the producer's operations more responsive. Combined with faster transportation, the product reaches the wholesaler on average 3.6 days fresher than earlier. Order-picking at the wholesaler ensures short COLT. Lost sales decreased by 57%.	Estimated benefits: Better follow-up of products and faster material flow, products 1 to 3 days fresher at the retailer. Moving to MTO production removes stocking delays at the processor. To reduce the high NVA in various phases in the chain, several improvements were suggested.

In the cases accurate and thorough use of shared data dampened the effect of demand uncertainty. A particular finding was the impact of store order-placing schedule on shelf availability and waste in the stores. To be able to respond to demand, the store order-placing time needs to be delayed as long as possible. This resulted in more accurate daily ordering and improved management of weekend sales and Monday orders in Cases 1 and 2. In Case 2, this was a remarkable improvement because fish sales grow towards the weekend. In addition, fresh food ordering is still in many cases a manual practice: members of store staff are needed to check dates on products on the shelf, as well as the remaining quantities. Therefore, the working hours of the store staff, which typically start early in the morning, need to be taken into account: the new structure allows orders in the morning for delivery the same day.

In previous studies, it was found that information sharing becomes more beneficial when variation in demand is high (Ferguson and Ketzenberg, 2006). This is supported by the case findings. In the context of fresh foods, the very accurate – daily, weekly, even hourly – demand follow-up needs to be emphasized.

The benefits in actual production can be seen in two ways. First, more accurate forecasts result in more responsive production planning. Second, the fine tuning of production, or replacing MTS production at least partially with MTO production, can be realized on the basis of the demand data. The benefits were achieved by more efficient store replenishment, more accurate follow-up of demand data in production planning, and improvements in the structure of the distribution channel. However, the benefits for the manufacturer from shared real-time information remain low.

In all cases the shelf life of the products is short, only a few days. One observation was that the SCLT in the supply chain needs to be shared efficiently between the actors. In Case 3 the non-value-adding time varied between 6 and 44% of total shelf life. Several tactics were suggested to improve the situation. First, the store ordering should be delayed as long as possible to base the order on the actual sales or current stock on the retail shelf. This is especially important during weekends, campaigns, or other periods that cause seasonal variation in demand. Second, the time from ordering to store delivery should be minimized, and for this reason logistics service providers were not favored. Third, to organize the time needed for the producer's production planning and balancing the incoming material quantities, upstream operations need to be based on forecasts.

It became evident that the location of the order penetration point, OPP, needs to be moved closer to the customer to achieve a shorter COLT. In Cases 1 and 2, the OPP was shifted from the producer to the wholesaler (Figure 2).

Now, the producer operates successfully on the basis of forecasts as the forecast accuracy has improved. The customer order-picking was shifted from the producer to the wholesaler. This change allows delayed ordering from the retailers and therefore more accurate demand responsiveness. In the future, the model could be further improved by shifting the OPP to the retail stores. Then the wholesaler will define replenishments to the retail store and operate a vendor-managed inventory (VMI).
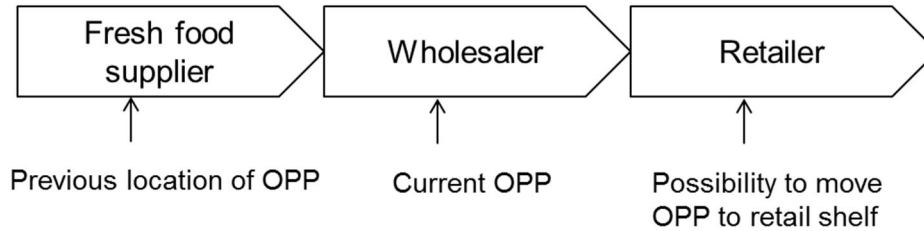

Figure 2. The location of OPP in Cases 1 and 2.

In Cases 1 and 2, a good forecasting process with the best available data was essential. This finding is in line with the literature, where poor forecasting was identified as one of the causes of inefficient supply chain management (Mena *et al.,* 2011; Taylor and Fearne, 2009). Implementing this required investments in software, as well as in staff and their capabilities. In Case 3, on the other hand, the key proposal is that the order should be placed early in order to avoid hectic situations in production. This is in line with the statement that it is not only the availability of demand data but the *timing* of sending the demand data that is important (Taylor and Fearne, 2009). There seem to be two ways to proceed: to develop forecasting based on accurate data to improve the upstream operations or to utilize actual demand data in order to improve production responsiveness and shelf life along the whole chain. The two ways are not contradictory. The objective should be to find the optimal trade-off for a particular scenario between, on one hand, the pattern of gathering data and, on the other hand, the forecasting precision.

6 Conclusions

This paper contributes to current knowledge on sustainable supply chain performance by operationalizing the information usage for waste reduction and improved shelf availability. In the context of fresh food with a short shelf life, waste can be reduced by ensuring that the product reaches the consumer in perfect order and with maximum remaining shelf life. On the other hand, waste reduction is the key factor in increasing the sustainability of the supply chain. Due to the short overall lifetime of the fresh food products, the time management becomes essential. The limited available time needs to be carefully shared between supply chain activities. The findings indicate that improving the performance in the supply chains requires focusing on multiple parallel issues in physical goods flow and in information flow. First, supply chain structure should be streamlined to avoid additional handling and delays. Second, the OPP location needs to support the specific features of fresh food supply chains: initial findings indicate that the OPP should be moved as close to the retail customer as possible. Third, the role of an efficient forecasting process becomes more important, because a larger share of the chain operates on the basis of forecasts, which also supports earlier research findings. Fourth, demand data should be utilized to balance operations between MTO and MTS production. Demand data forms a good basis for forecasting, and, on the other hand, can trigger larger MTO production instead of producing to stock. The way to utilize demand data needs to be selected in a way to support optimally the specific product characteristics and demand patterns.

In the cases treated in the paper, the main benefits from the improvements can be seen at the retail store level, while the development actions mainly concerned the upper parts of the chain. Therefore, improving the sustainable performance requires changes in the whole supply chain, not only in the phase where the problems occur or benefits are realized. From a manufacturer's point of view, the key question is how to improve the operations for its own products with strong retail chains and a centralized trade structure. In our case studies, the benefits in actual production remain low since producers have only limited opportunities to utilize shared demand data.

We conclude that the design of a supply chain needs to serve specific features of perishable products to achieve a more sustainable performance. It was found out that synchronizing information and material flow is essential when improving the sustainable performance of the supply chain. Fine-tuning the daily and weekly order schedule

according to the demand pattern, in combination with the capacity at the processor, has a remarkable effect on the responsiveness of the supply chain. The research presented gives a new perspective on how companies can deal with sustainability at an operational level by looking at the information and material flow management.

The findings are based on three Nordic supply chains, and not all the findings can be generalized. There is a need for more empirical studies on sustainable supply chain performance. One question not covered in this research is how measurement can cover contradictory goals and reflect the heterogeneous features of fresh food product groups with different performance targets. Another topic for future research is the suitability of product-centric supply chain management techniques in the context of fresh food. Furthermore, this paper has added a larger perspective on waste reduction, being not only a matter at the retailer but an issue that has to be dealt within the whole supply chain. This raises the question for future research of how the benefits and costs of sustainable performance are to be shared between supply chain parties.

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