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Effective use of product quality information in meat processing

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Abstract. This paper presents a case study on use of advanced product quality information in meat processing. To serve segmented customer demand meat processors consider use of innovative sensor technology to sort meat products to customer orders. To assess the use of this sensor technology a discrete-event simulation model is built. Various scenarios were defined for processing strategy (buffered or non-buffered), the number of end product groups to sort to and the availability of product quality information. The performance of these scenarios is measured w.r.t. order compliance, labor consumption and throughput-time.

Our results reveal that the current processing and product sorting strategy is ineffective for sorting to a large number of end product groups. Furthermore, the current availability of product quality information is insufficient to ensure high levels of order compliance for advanced product quality products.

Keywords: meat processing, quality information, decision making, simulation

1 Introduction

As witnessed in several recent studies [1, 2] there is a growing interest from retail and consumer organizations in high-quality, healthy and convenience food. As a result, demand for product quality features has become more segmented and product variety has increased significantly. By differentiating production strategies and processes to exploit this segmented demand, food processors may create extra value [1]. To realize this, demand preferences of customer segments must be translated into clear process and production specifications for different supply chain actors [3, 4]. Furthermore, flexible production systems must be designed that match product quality features of supplied livestock with variable market specific demand.

Recent developments in ICT and sensing technology have improved the

means to gather, communicate and process information [5]. This allows for more effective use of product quality information by food supply chain actors. Specific characteristics of food chains, such as temperature-dependent change of product quality, require an interdisciplinary focus in supply chain design with attention to both food engineering and operations management [2, 6]. This interdisciplinary focus incorporates acquiring product quality information, understanding food systems and consumer preferences, and use of quantitative models to improve food quality and product availability throughout the supply chain [7, 8].

An extended literature review by Akkerman et al. [2] on quantitative operations management approaches and challenges in food distribution concluded that use of product quality information in decision making was seen in some recent work, but that it remains a challenging research area. We contribute to this field of literature in the EU-funded Q-porkchains project (FOOD-CT-2007- 036245) by assessing use of advanced product quality information in meat chains in several case studies. In these case studies, use of different quality information sources in logistics decision making is assessed at different stages in the meat supply chain.

In this paper we present the case study of a European multi-billion euro pork processing company. This company faces variation in multiple quality features of animals delivered to them, resulting in variation in processing performance and final product quality. An innovative sensor technology has been developed in order to provide advanced product quality information in the form of estimates of a certain quality feature. This advanced product quality information offers opportunities for meat processing companies to satisfy demand for premium segments by identifying and selecting products with high product quality. Sorting for more product quality features will, however, result in higher complexity, which might affect processing efficiency. We hypothesize that use of advanced product quality information has the potential to improve quality of premium products, and that a higher sorting complexity make a flexible production setup more favorable. To test this hypothesis we present a simulation model in this paper.

2 Research methodology

To determine the effects of advanced product sorting on processing efficiency several methods were applied. A literature review was conducted to improve insight in topics relevant to this case study. This review included supply chain design, Key Performance Indicators (KPIs), supply chain flexibility, and modeling and simulation techniques. After the literature review a process analysis at our project partner was performed. Based on insight gained in the process analysis and gathered data a discrete-event simulation model is developed. This simulation model assesses the effects of different product sorting and processing strategies, accuracy of available product quality estimates, and changes in supplied and demanded product quality.

2.1 Review of literature

A supply chain network should be specifically designed to enhance the value creation of the companies involved, while keeping the characteristics of that specific chain in mind [9]. These specific characteristics include a combination of supply, demand and processing characteristics (e.g. variation in supplied quality, uncertainty in demand), and the availability of information. To create an effective match between a variety of quality features and a variable demand for end product quality features a flexible supply chain is needed. A flexible supply chain is defined in a review on supply chain flexibility by Stevenson [10] as '*a supply chain that is able to adapt effectively to disruptions in supply and changes in demand whilst maintaining customer service levels*'. An effective supply chain design is required for this, which includes use of suitable KPIs and control mechanisms.

A common approach to evaluate the performance of alternative supply chain designs on supply chain performance is the use of simulation models. Several simulation approaches exist, of which Discrete Event Simulation (DES) is an appropriate method for tactical and operational decision making [11], which is most widely used in business and manufacturing industries [12], and. In a review on simulation in supply chains, Terzi [13] indicates that discrete-event simulation is a suitable method to evaluate supply chain designs since: (i) companies can perform a what-if analysis prior to taking a decision; (ii) various supply chain designs can be compared without interrupting the real system; and (iii) it permits time compression so that timely policy decisions can be made.

2.2 Process analysis

After a literature review the processing chain of our project partner was analyzed, and a number of company experts were contacted. Setting of performance indicators, development of logistics scenarios, and simulation outcomes were discussed on a regular basis with company experts such as operations management staff, production planners, plant managers and quality managers to ensure validity of our findings. More information on the characteristics of the processing chain can be found in the following section.

3 Case description

We consider a processing chain in which carcasses of different quality classes are sorted and processed to end product groups (see **Fig. 1**). Initially, each carcass class is matched with a number of potential end product groups. This matching is based on the expected quality of parts that originate from a particular carcass class. The carcasses are then transferred to the cutting room, where they are cut into carcass parts. The carcass parts are individually allocated to an end product group depending on (i) the end product groups that are matched with that particular carcass class, (ii) the measured and estimated quality features of the carcass parts, and (iii) the quality specifications of the end product groups.

Each carcass part is processed according to the specifications of the end product group it is assigned to. These processing steps (e.g. debone, trim fat, remove tail) are performed manually at processing stations. Since these basic processing steps are highly standardized, people at the individual processing stations can be transferred from one process to another with limited transfer time (estimated at 2 minutes in our model). However, if several end products groups are processed simultaneously, all processing stations required for at least one of the end products groups need to be manned.

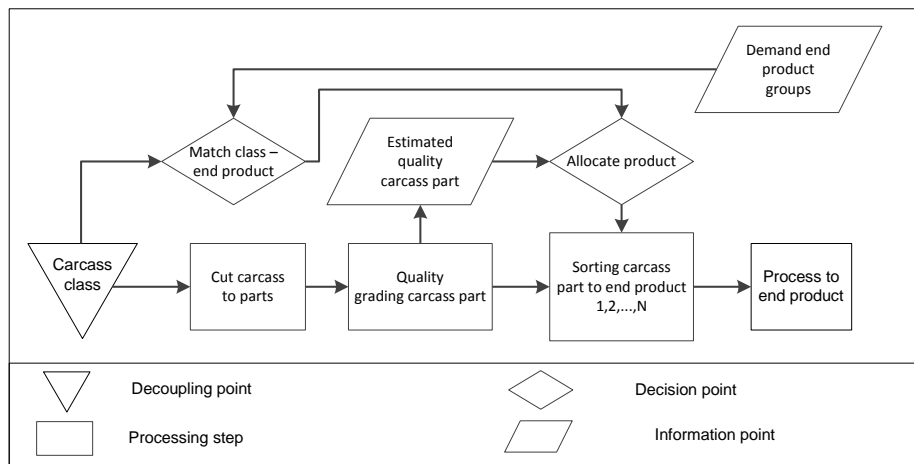


Fig. 1. Schematic overview of current processing chain

Based upon the literature review and in co-operation with our project partner the performance indicators in this simulation study are defined as (i.) compliance to customer specifications for advanced product quality features (% of products delivered within specifications), (ii.) labor requirement in the processing chain (hours / ton product), and (iii.) the time-period between carcass cutting and finalizing the end product (hours). Other common performance indicators in meat chains, such as raw material yield, are influenced mainly by at decision levels outside the scope of this research.

Logistics scenarios.

We limit our analysis to two processing strategies (1, 2), three product-sorting strategies (A, B, C), and their combinations (1A, 1B, 1C, 2A, 2B and 2C). The processing strategies are (1) direct processing of carcass parts after carcass cutting (corresponding to **Fig. 1**), and (2) sorting of carcass parts to end-product buffers and process them batch-wise (corresponding to **Fig. 2**). Product buffering requires an extra investment in labor, since carcass parts need to be loaded and unloaded to special buffer hooks.

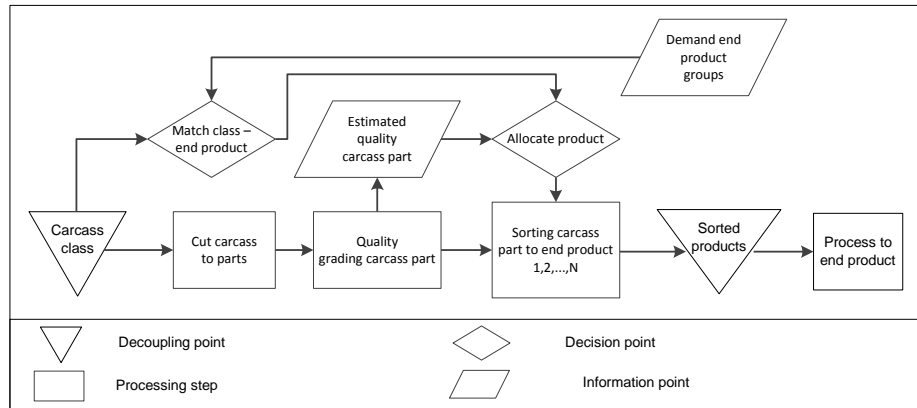


Fig. 2. Schematic overview of buffered processing chain

The three product-sorting strategies in this paper are: (A) carcass classes are matched with a limited number of end-product groups without specifications for advanced quality features. This sorting strategy is currently adopted by our partner firm. In strategy (B) carcass classes are sorted to a larger number of end-product groups, some of which include advanced quality feature specifications. No advanced quality information is available for sorting in this strategy. This strategy serves as a reference to assess use of innovative sensor technology for product sorting. In strategy (C) carcass classes are sorted to a large number of end product groups, some of which include advanced product quality feature specifications. Advanced product quality information, based on innovative sensor technology, is available. This last strategy represents a situation in which advanced product quality information is used to sort to premium products. A complete overview of the various sorting and processing strategies can be found in Table 1.

Table 1 Summarized description of sorting strategies

Scenario	Buffered	Sorting strategy	End product groups with advanced quality features	Advanced product quality information available	Total number of end-product groups
1A	no	A	no	no	limited
1B	no	B	yes	no	high
1C	no	C	yes	yes	high
2A	yes	A	no	no	limited
2B	yes	B	yes	no	high
2C	yes	C	yes	yes	high

4 Model design / simulation model

To assess the various logistics scenarios a discrete event simulation model using the 'Stochastic Simulation in Java' (SSJ) toolbox (<http://www.iro.umontreal.ca/~simardr/ssj/indexe.html>) was developed. Our industrial partner provided, together with data regarding the relation between carcass quality features and the quality features of carcass parts, a dataset with carcass quality data. The accuracy of advanced product quality feature estimates was determined based on experimental data gathered using the new sensor technology.

The output we present in this paper is based on a simulation including 70728 carcass parts, originating from 12 separate carcass quality classes slaughtered in 15 consecutive days. Demand for end product groups and the related processing steps is represented by 36 end product groups for scenario 1A and 2A, and 60 end product groups for scenarios 1B, 1C, 2B, and 2C. We consider a total of 9 possible processing steps. To make the labor requirement of the various end-products comparable we adjusted the various end product recipes by assigning each of the end products to the same number of processing steps, resulting in similar processing time for each end-product group.

In case of non-buffered production (scenario 1A, 1B, 1C) carcasses that are cut are directly processed at the processing line, resulting in a short throughput-time. Since in processing strategy 2 carcass parts are buffered by end-product group and processed serially, a time period between carcass cutting and processing is required. If the period between the start of both activities is too short some carcass parts are not sorted to their end product group in time to be processed on the same day, in which case they will be processed the following day. A large time period between the start of carcass cutting and processing, however, will result in a high average product throughput time. In our experiments we have chosen an offset of 1,5 hours between the start of carcass sorting and processing a time gap at which all products are processed at the same day, while minimizing overall throughput-time.

In our experiments we consider 15 processing days, directly related to the available slaughtered carcass data. Based on available carcass data, the relation and distribution between quality features of whole carcasses and carcass parts, and randomly generated numbers, the quality features of individual carcasses were simulated. Each of the experiments was replicated 4 times since model outputs showed only little variation.

5 Findings and results

The findings in Table 2 suggest that the labor efficiency of the current, non-buffered, processing strategy is reduced by sorting for advanced product quality features. Furthermore our results indicate that the product quality information that is currently available is insufficient to deliver products with advanced product quality features with high order compliance. This suggests that both the current processing strategy and the availability of product quality information are inefficient to deal with

increasing product variety and demand for premium quality products. The use of advanced product quality information allows meat processor to make a significant improvement in order compliance for products sorted to advanced quality specifications. With the current sensor accuracy a portion of products will still be delivered out of specifications.

Our results show that a redesigned processing setup (sorting meat products to order-buffers) improves efficiency in case of high end product group variety. An assessment of the innovative sensor technology showed that considerable improvements in order compliance can be achieved by using the advanced product quality information it provides.

In Table 2 we observe that the throughput time of 2A, 2B, and 2C is slightly smaller than 1,5 hour time period between the start of carcass sorting and processing of carcass parts. This is due to a small overcapacity of the processing lines if compared to the carcass cutting capacity.

Table 2 Scenario overview and results

Scenario	Products buffered	Number of end product groups	Advanced product quality information available	Out of advanced order quality specifications	Labor requirement (hour / ton)	Throughput -time (hours)
1A	no	low (36)	no	-	0.924	0.01
1B	no	high (60)	no	49 %	1.062	0.01
1C	no	high (60)	yes	18 %	1.062	0.01
2A	yes	low (36)	no	-	0.885	1.48
2B	yes	high (60)	no	49 %	0.980	1.48
2C	yes	high (60)	yes	18 %	0.974	1.48

Based upon our findings we conclude that more flexibility is required to deal customers with a more complex, order-driven demand. Furthermore we observe that producing more differentiated end products using more product quality information makes a supply chain redesign favourable.

By presenting this results we add to the field of literature that uses product quality information in decision making, which was one of the challenging research areas formulated by Akkerman et al. [2].

Research limitations / implications.

Both the review of literature on consumer trends and expert interviews with practitioners showed that consumer demand is becoming more differentiated and more critical with respect to product quality. This trend results in a more complex production structure, with production shifting from forecast driven (make to stock) to more demand-driven production strategies (make to order).

These trends lead to an increase of product variety at meat processing plants that, according to our findings, will reduce processing efficiency in the current processing setup. Meat processors must therefore take measures to increase processing flexibility, find means to gather and exploit advanced product quality information,

and adopt a more demand-driven production setup. Our simulation showed that use of order buffers improves processing flexibility. It would, however, be interesting as well to see how current market trends affects automation of processing steps at meat processors.

Another interesting direction for future research would be to assess whether the processing chain can be redesigned at other points in the processing chain as well to enable meat processors to exploit product quality information more effectively.

In the current simulation study the selection of products based on estimated product quality information was based on a basic categorization to “high” or “low” range. Use of more sorting groups might prevent low quality products ending up in the high quality range which could improve order compliance. It would be interesting to look into the sensitivity of the order compliance to these changes.

Practical implications.

Our findings can be used to support strategic decision-making w.r.t. infrastructure and processing setup of slaughterhouses and cutting rooms. Furthermore, this simulation model can be used as a basis for investment analysis in advanced sensor technology.

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