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Towards a Diagnostic Instrument to Identify Improvement Opportunities for Quality Controlled Logistics in Agrifood Supply Chain Networks

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ABSTRACT

Western-European consumers have become not only more demanding on product availability in retail outlets but also on other food attributes such as quality, integrity, and safety. When (re)designing food supply-chain networks, from a logistics point of view, one has to consider these demands next to traditional efficiency and responsiveness requirements. The concept 'quality controlled logistics' (QCL) hypothesizes that if product quality in each step of the supply chain can be predicted in advance, goods flows can be controlled in a pro-active manner and better chain designs can be established resulting in higher product availability, constant quality, and less product losses. The paper discusses opportunities of using real-time product quality information for improvement of the design and management of 'AgriFood Supply Chain Networks', and presents a preliminary diagnostic instrument for assessment of 'critical quality' and 'logistics control' points in the supply chain network. Results of a tomato-chain case illustrate the added value of the QCL concept for identifying improvement opportunities in the supply chain as to increase both product availability and quality. Future research aims for the further development of the diagnostic instrument and the quantification of costs and benefits of QCL scenarios.

Keywords: Food Logistics, Supply Chain Management, Product Quality, Information

1 Introduction

Consumers expect food in retail stores to be of good quality, to have a decent shelf life and to be fit for purpose (Smith and Sparks, 2004). Furthermore, consumers demand great product diversity, safety, convenience (e.g. ready to eat products), and (more and more) sustainability. More powerful well-informed customers are thus stimulating retailers and other actors in the food supply chain network to adapt new business concepts. They require year-round availability of high-quality fresh products (such as fruit and vegetables, meat products), which has stimulated partners in food supply chains to pursue a coordinated approach to establish more effective and efficient supply chains, i.e., supply chain management (SCM).

Supply chain design and management has received a lot of attention in the academic as well as business world (c.f. the books of Simchi-Levi et al, 2007, Chopra and Meindl, 2007, Christopher, 2011 as well as many academic articles (e.g. IJOPM, 2007)). SCM is about matching supply and demand; it is about the integrated planning, coordination, and control of all business processes and activities in the supply chain to deliver superior consumer value at less cost to the supply chain as a whole, while satisfying requirements of other stakeholders (e.g. the government or NGOs) in the supply chain network (Van der Vorst and Beulens, 2002). SCM should result in the choice of a supply chain scenario, i.e., an internally consistent view on what a supply chain should look like (within the total network) in terms of supply, production and distribution processes and their coordination. From a logistics point of view, it mainly deals with choices regarding the design of distribution networks, transport and production infrastructures, inventory management, and management of goods and information flows.

The design and management of AgriFood Supply Chain Networks (AFSCNs) is, however, complicated by an intrinsic focus on food quality. The way in which product quality is controlled and guaranteed in the supply chain, is of vital importance for the supply chain performance; product's appearance, safety, and shelf life can be adversely affected due to inadequate control of appropriate temperature conditions (Smith and Sparks, 2004). Therefore investments in chain design should not only be aimed at improving logistics performance (like cost and delivery service requirements) but also at the preservation of food quality so that the right products are delivered with the right quality at the right place and time.

Typically, food degradation is related to intrinsic properties (like initial microbial contamination, composition, respiration rate, and specific breed or cultivar characteristics), environmental conditions (like variable temperature and humidity conditions at different stages of the supply chain network), and the time the product is exposed to these conditions (Luning and Marcelis, 2009). For example, the type of packaging, the availability, and capability of temperature-conditioned warehouses can affect the environmental conditions. Food science literature pays much attention to quality decay modeling and the development of Time Temperature Indicators (TTI) to monitor individual temperature conditions and its impact on quality levels of food products throughout distribution (Sloof et al. 1996, Taoukis and Labuza 1999, Schouten et al. 2002, Bobelyn et al. 2006). When combining these quality change models with logistics decision-support models, new opportunities arise to improve the performance of AFSCNs.

This paper discusses opportunities to use real-time information on actual product quality in a pro-active way to improve the design and management of AFSCNs. If the real quality of products that arrive at a certain supply chain process is known in advance, one might be able to optimize that process (or the environmental conditions) and maybe goods flows could be steered in all phases of the AFSCN in a pro-active manner to those customers/markets where they are valued the most. The paper presents a preliminary diagnostic instrument, to assess 'critical quality' and 'logistics control' points that can use product quality information in the supply-chain network. Improvement opportunities in the supply chain have been identified as to increase product availability of the right quality at the right place and time. An exploratory case study illustrates the value of such a diagnostic instrument.

2 Temperature-Controlled Agrifood Supply Chain Networks

A temperature-controlled AFSCN requires products to be maintained in a temperature-controlled environment, rather than exposing them to variable ambient temperatures at the various stages of the supply chain (Smith and Sparks, 2004). In this paper, we focus on fresh foods (like, meat and dairy products) and flowers that need controlled temperatures to maintain or even improve product quality (due to ripening of fruits, think of "ripe-on-arrival"). Effective quality control and logistics control of these highly perishable products becomes increasingly important, considering the increasing consumer demand for ready-to-eat products (Brunner et al, 2010).

There are a number of difficulties in managing temperature-controlled AFSCNs, such as the short shelf life, which puts additional requirements on speed and reliability of logistics systems and require specialized transportation and storage equipment. Furthermore, modern chains distribute multiple types of products – often requiring different temperature regimes. This means that a 'best fits all' solution is taken, which means that the temperature is not optimal for most of the products. Moreover, one must be careful for product interactions, for example, bananas produce ethylene that accelerates the ripening process of other fruits. Finally, in these chains, temperature control and prevention of product interactions are very important from the perspective of food safety; typical safety problems concern *Listeria* in cheese products, *Salmonella* in chickens and eggs, *BSE* in cattle, *E-colli* in vegetables, etc. These typical food related issues should be considered when designing a FSCN, using risk assessment as an important tool (Luning and Marcelis, 2006).

It is clear that the design and management of temperature-controlled FSCNs is a complicated process. How, for example, can a retailer ensure that products are always under the appropriate temperature regime when they travel from a field in Australia to a store shelf somewhere in Europe? Although, fruit and vegetables might look fresh from the outside, the real intrinsic quality and remaining period of consumer acceptance might be poor. Retailers and chain partners realize that they can distinguish themselves in the market place by setting up a reliable temperature-controlled FSCN that guarantees product quality and reduces shrinkage (price cuts) in retail outlets

3 State fo the Art

In a recent special issue in *OR Spectrum* on agrifood supply-chain management, edited by Martin Grunow and Jack van der Vorst (2010), Akkerman et al. (2010) present an extensive literature review on design and management of agrifood distribution networks. They concluded that, in the operations management literature, limited shelf lives of food products, requirements on temperature and humidity, product-interaction effects, strict time windows for delivering, high customer expectations, variability in supply and demand, and low profit margins make distribution management of fresh products a challenging area that has only recently began to receive more attention in the operations management literature.

In the last few decades, a lot of work has been done to improve the quality and safety of food products at the market place. Advanced quality and safety management systems have been developed and implemented in food supply chains (Luning et al, 2009, 2010). Also breeding and cultivation practices have changed in order to upgrade the initial product quality at harvest and anticipate to climate changes (e.g., Ortiz, 2008).

From a logistics point of view, the main emphasis was on the development of new responsive distribution systems, using new management concepts that improve delivery reliability and lead times via increased information exchange and changes of roles in the chain. Much has been written on supply chain collaboration programs, with an emphasis on Quick Response (QR), Collaborative Planning, Forecasting and Replenishment (CPFR) and Vendor Managed Inventory (VMI) stimulated a.o. by the availability of RFID technologies. We refer to Cao et al. (2010), Chan and Chan (2010), Chen and Paulraj (2004) and Choi and Sethi (2010) for nice literature reviews on these topics. These developments are supported by innovations in logistic means, such as reefers (i.e. temperature-controlled containers used in intermodal freight transport). Although, technological developments (such as RFID) and quality assurance systems encourage logistics improvements, up to now, a complete integrated perspective has not yet been considered.

Temperature monitoring and recording is a prerequisite for chain control and any logistics management system that aims on product quality optimization at the consumer's end. New technological developments such as time-temperature integrators or indicators to individually monitor the temperature conditions of food products throughout distribution, offer possibilities to improve temperature monitoring throughout the distribution system if they are connected to the IT infrastructure (e.g. Giannakourou and Taoukis 2003). This allows for improved shelf life estimation from a chain perspective (using quality prediction models), as is for example shown by Tijskens (2004) for fruit and vegetable chains, Raab et al. (2008) for pork and poultry chains and Dalgaard et al. (2002) for fish chains. The additional information gained from these technologies would allow for more advanced logistics decision-making about, e.g., the inclusion of quality change models during the complete distribution process knowing the required product quality at its final destination, a concept called “Quality Controlled Logistics” by Van der Vorst et al. (2005, 2007, 2009).

4 Quality Controlled Logistics

Fresh SCNs are characterized by heterogeneous batches of products (i.e. product quality differs in the batch and between batches) delivered by a diversity of producers to multiple market outlets that have different demands. Long supply chains of perishable products suffer from high risk of quality degradation. Storage, handling, transport, and distribution conditions have a strong impact on freshness and shelf life of fresh products. The common strategy for dealing with the variability in quality is tailoring the supply chain towards ‘average’ quality. This might not be, however, the most effective approach, since variability can also be strategically exploited through the flexible management of quality differences for specific market outlets. Instead of homogenizing food product quality in the chain, we advocate differentiation of product flows based upon the absolute batch quality and quality variation at different stages in the AFSCN. This might improve chain revenues via improved product quality on retailer shelves and/or improved matching of supplied products at a certain price to specific market segments. Batches of high quality could be sent to different market segments with higher benefits.

Quality Controlled Logistics (QCL) makes use of variation in product quality, developments in technology, heterogeneous needs of customers, and the possibilities to manage product quality development in the distribution chain. Using the definition of logistics management of the Council of Supply Chain Management Professionals (CSCMP), we define QCL as *that part of supply chain management that dynamically plans, implements, and controls the efficient, effective flow and storage of food products, services and related information between point of origin and point of consumption in order to meet customers' requirements with specific attention to the availability of specific product qualities in time by using real-time product quality information in the logistics decision process* (van der Vorst et al., 2007).

Figure 1 shows the essence of the QCL concept. It aims for product differentiation and maximization of added value created in the AFSCN by the timely harvesting and batch separation (based on quality criteria) in all processing stages and pro-active control of goods flows. Appropriate strategies for logistics management can be developed based on scientific insights in the dynamic product quality behaviour profiles throughout the supply chain and understanding of the impact of technological and managerial conditions. More in detail, QCL starts with obtaining a detailed knowledge on customer requirements in the different market segments (Table 1). At the harvest (or breeding) stage products are collected and clustered based on variation in quality parameters. It is well known that for example one stable with pigs or one tree with apples deliver products with different quality levels. For example, due to sun light exposure apples or mangos on the outside of the tree have different quality then products inside the tree, or between the sun-side and the shade-side of the tree. QCL makes use of these quality distribution profiles by batching products of the same quality at the beginning of the supply chain. In the following supply chain stage comparable decisions have to be made, each time a match is made between customer demand for specific products and the price that is paid for the products with the available supply of products with a specific (variation in) quality prediction. Subsequently one has to determine what actions can be taken to either redirect the goods flows to other markets or try to influence the quality level of the products using technological equipment, e.g. changing storage time, temperature, and atmosphere or target another consumer group.

It is clear QCL refers to inter-disciplinary analysis of supply chains requiring collaboration between food technology and social scientists. In order to further develop the QCL concept we identified the following six specific elements based upon literature review and case studies (Figure 2):

a. Consumer preferences and acceptance period of product quality attributes

This element refers to (1) the quality attributes that consumers prefer as well as the target values of each attribute, and (2) the acceptance period (AP; Schouten et al., 2007b), i.e. the time period consumers find all attributes of a product acceptable and will buy the product. By consumer research, it becomes possible for a specific consumer group to determine the limits of acceptability for the specific quality attributes like color and firmness or taste. If this is known, it becomes possible to aim for these specific characteristics for the products in retail shelves.

b. Critical Quality Points

A critical quality point (CQP) refers to a point in the process where variation in product properties and or processes results in unacceptable and or irreversible deviations in required quality attributes of the final product (Luning and Marcelis, 2009). Relating insights in chain conditions to dynamic behavior profiles of quality attributes enable the determination of the effects of different chain configurations on the final quality of the products. This supports the determination of locations in the chain where certain measurements should be done and logistics and quality control actions should be taken. As a result, one can change conditions such as temperature, storage time, and order picking procedures as well as for example the moment of positioning the product in the shelves (Van der Vorst and Beulens, 2002).

c. Product quality measurement and prediction

At present there are several techniques in development that enable the measurement and prediction of the dynamics in quality development of fresh food products in the FSCN objectively. They enable the prediction of the ripening or quality decay under different environmental conditions, which provides the necessary information to supply chain actors to act pro-actively. It therefore allows for the positioning of food in retail shelves precisely at the optimum quality window of the product (Schepers and Van Kooten, 2006).

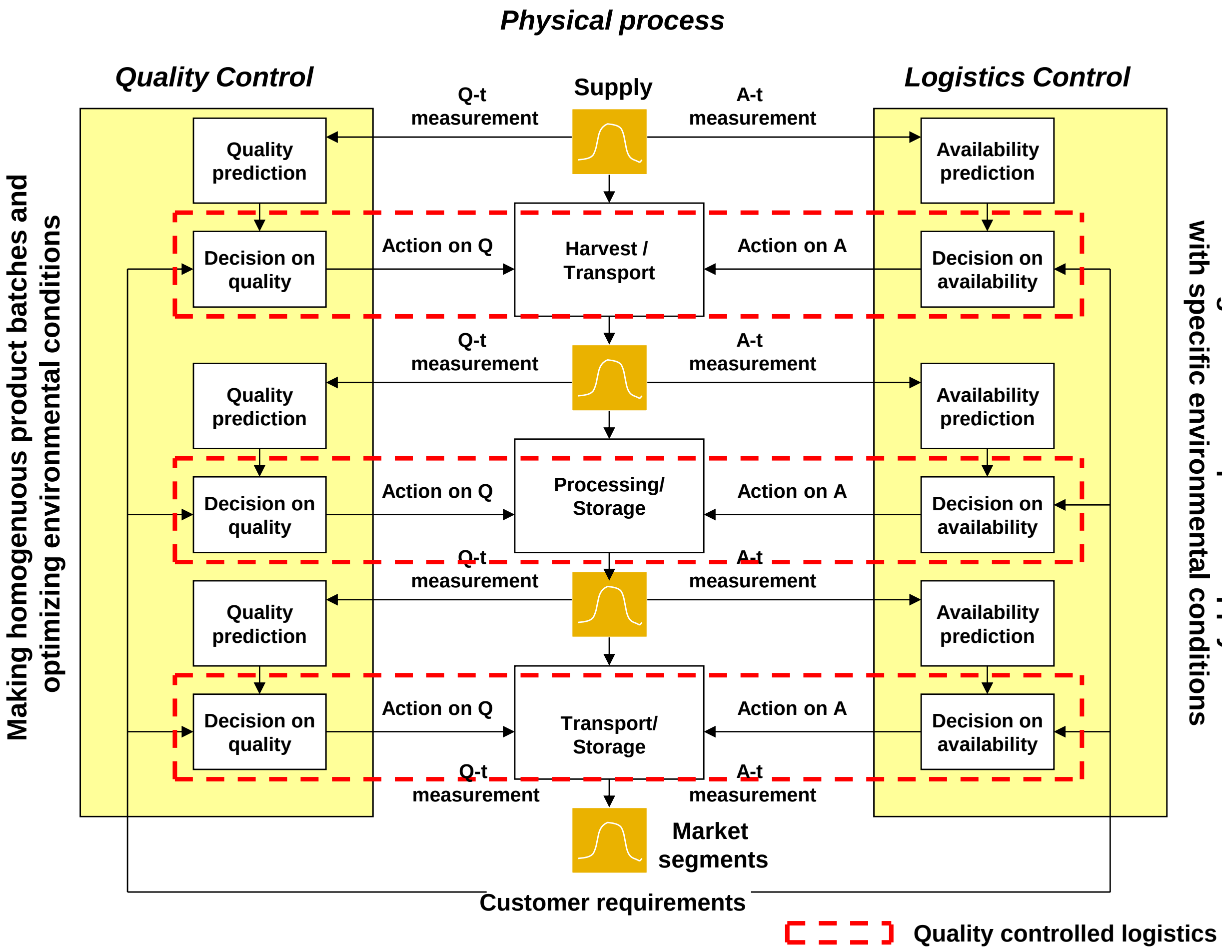

Figure 1. Overview of the Quality Controlled Logistics concept (Van der Vorst et al., 2007)

d. Logging and exchange of information

The fourth element relates to data logging and exchange of information with supply chain partners. The quality of fresh food products is strongly dependent on its temperature exposure history, from production through distribution and storage to consumption. Monitoring and exchanging critical parameters, such as temperature history throughout the product's entire life cycle, is of crucial importance. Moreover, monitoring temperature history allows accurate prediction of shelf-life if models are available and could replace the sometimes meaningless expiry dates on fresh produce (Bobelyn et al., 2006). New technologies like RFID and GPS provide innovative means to capture data. Next to quality and environmental data also demand, inventory and supply data could be exchanged in the supply chain

e. Local dynamic/adaptive logistics and quality control

In the end, QCL comes down to adaptive control based upon customer wishes and current product quality, i.e. to change the flow of products and environmental conditions to which these products are exposed to. Furthermore, new stock rotation and order picking systems can be implemented, which are not based on First-In-First-Out (FIFO) or Last-In-First-Out (LIFO), but on First-Expired-First-Out or Right-Quality-First-Out (RQFO). In the case of FEFO, the products with the closest expiration date are advanced first, and with RQFO exactly that batch is delivered, which has the right quality for that particular customer.

f. Supply chain management (SCM)

Finally all SCM practices as discussed earlier (like CPFR, VMI etc.) can be applied in the complete supply chain to match supply and demand using the advanced product information and logistics decision policies; production and distribution lead times can be shortened, full chain transparency created and waste and costs reduced.

Table 1.
Generic logistics decisions versus specific QCL decisions

Generic logistics decisions	**Specific QCL decisions**
Determine generic customer service standards • Customer needs (quantity, quality, etc.) • Customer service levels (lead time, reliability, etc.) • Determine requirements on supply of products in each stage of the chain.	Determine customer acceptance levels and periods for specific market segments using accepted and measurable quality standards. Translate this into specific product quality requirements for each stage in the supply chain (next to of course volume and timing requirements).
Determine facility network design • Number, location of stocking points • Equipment selection, capacity planning	Use customer requirements data, information on supply qualities and volumes and transport scenarios with quality predictions to determine the required network design and equipment.
Determine inventory management • Position Customer Order Decoupling Point (CODP); push-pull strategies • Warehousing policies	Use supply chain data to determine the optimal position of inventory points in the network taking predicted quality changes (and thus environmental conditions) into account.
Determine information flows and order processing • Ordering rules • Order inventory interface procedure • Order picking procedures	Determine Critical Quality Points (CQPs) to monitor quality changes. Use quality prediction models and product quality information to apply optimal picking policies (e.g. first-expired-first-out policy). Re-sort batches if needed. Aim for homogenous batches for specific market segments.
Plan order fulfilment • Allocate harvested produce to customer orders and deliver the products without dealing with quality changes and differences that occur in the supply process. A batch is not re-sorted or re-allocated unless serious issues arise. • Determine transport management (mode, scheduling)	Dynamic logistics planning in the complete chain based upon real time product-quality information (using critical quality points and predictive models). If needed, batches are re-sorted into homogeneous batches, re-allocated to different market segments, transported with different modes or environmental conditions are adapted to meet customer requirements. Technologies such as data loggers, RFID and GPS are used to capture all relevant information, translated into meaningful information through models.

These six elements are combined in a preliminary diagnostic instrument that indicates the operational requirements of each QCL element (see Figure 2). The next step is to develop different performance levels to assess specific supply chains and to analyse the relationship between the QCL elements and actual supply chain performance. To further build on the QCL concept and illustrate its applicability, some case studies in the fresh produce chain were conducted, of which the tomato chain is described below.

5 Illustrative Case Study in the Tomato Supply Chain

The supply chain for fresh tomato starts with the breeders. From the breeders, products (in the form of breeds) go to the growers, who again deliver (sometimes as part of a grower association), to a large number of wholesalers and sometimes direct to retailers. Harvesting of tomatoes occurs just after reaching the breaker stage of ripening (Schouten et al. 2007a). They are then stored and transported at the prescribed optimal temperature of 12 ˚C. The period of storage and transport is kept to a minimum given the constraints of the logistics of large quantities and the variable market demand. From wholesalers, products (fresh tomato) are delivered to retailer/supermarket. Supermarkets are the main distribution channels of vegetables, with an international market share of 65%. It is expected that their importance in the distribution of fresh vegetables will only increase. The period between moment of harvest and positioning in the retail shelf for sale generally varies between 4 and 10 days. Retail managers try to procure amounts that can be expected to be sold within a few days. The last (or actually first) chain actor is the consumer (ultimate user).

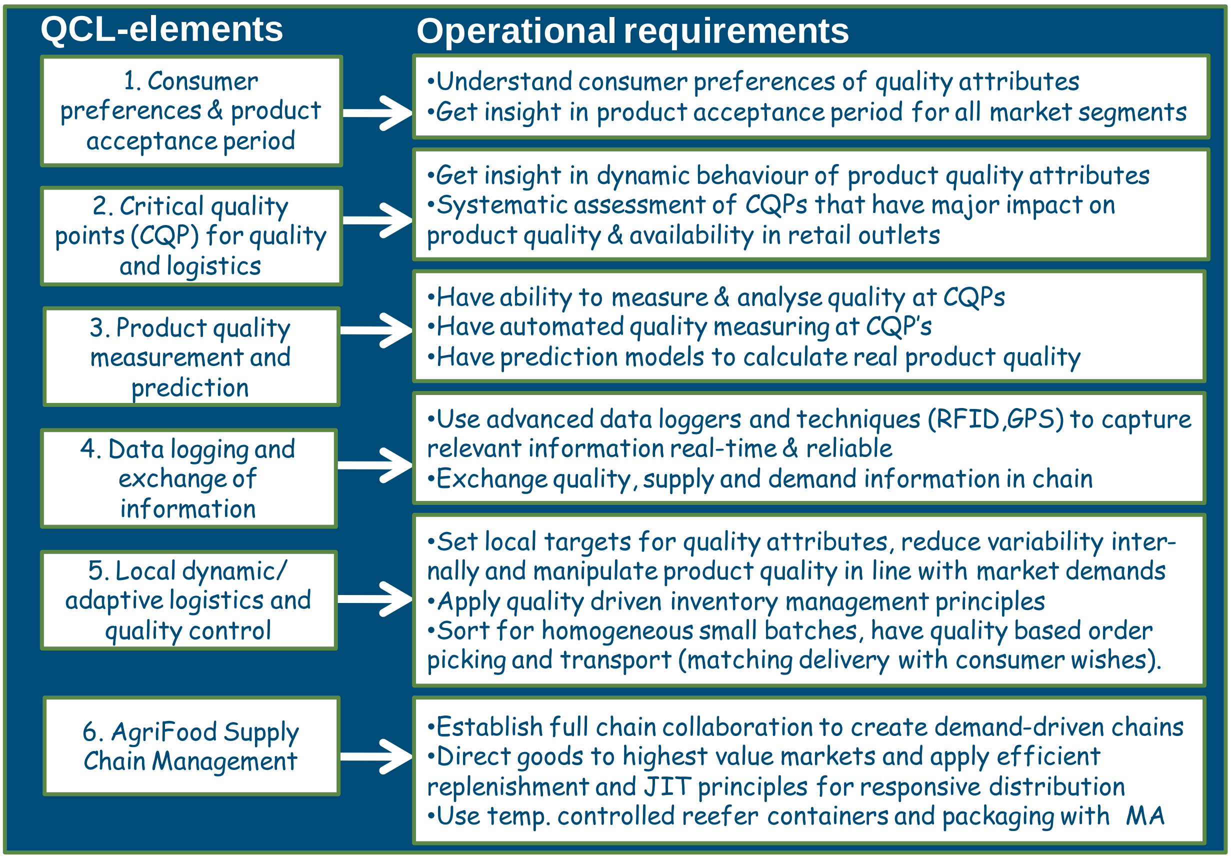

Figure 2. Operational requirements of QCL elements

5.1 Product quality

It can be seen that along the supply chain of tomato, different actors are involved. Each of these different actors has their own judgment about the quality of the product; as we say quality is in the "eye of the beholder". These judgments and decisions will influence the final quality of the product as perceived by consumers. The way food quality is defined, controlled and guaranteed in the network, is of crucial importance to chain performance. According to Zuniga-Aris et al. (2008), wholesalers and retailers emphasize visual attributes such as size, shape, colour and shelf life, taking into consideration consumer preferences. However, consumers are also interested in other aspects related to food quality such as taste, freshness, appearance, nutritional value, and safety. Producers and processors commonly prefer profit and attributes, like higher yields, suitability for mechanical harvesting and industrial preparation, and resistance to plagues and diseases. In practice, the color and the firmness of the tomatoes in the shelves varies considerably over time (e.g. Batu, 2004). Also the taste can vary from acceptable to far below acceptability (Bruhn et al., 1991) even within the same cultivar and origin of production. This leads to complaints from consumers and retail managers about insufficient quality (van Kooten, 2006).

Growers associations produce tomatoes with differences in quality due to differences between individual growers and between batches of one grower. This is troublesome since customers demand constant product qualities with a maximum consumer-acceptance period. Current practice in the horticultural chain is to harvest tomatoes just after they reach the breaker stage (when they are still green), and transport them at the lowest temperature that will not induce chilling injury. This may result in an insufficient color (pink color stage) and firmness development (too firm) at consumption. On the other hand, when tomatoes are harvested and transported over long distances or stored too long in retail shops, firmness can become a limiting quality attribute, now due to tomatoes being too soft. The quality levels of both color and firmness are of importance for consumers (Tijskens and Evelo, 1994) and thus determine price settings.

5.2 Acceptance Period

Schouten et al. (2010) researched the acceptance levels for both color and firmness of tomatoes when Dutch consumers want to buy them for direct consumption and also for consumption after several days. This determines an acceptance period in which the tomatoes are optimal from the consumer point of view. Based on a new quality development model using biological variation in batches of products it is possible to predict the development of both color and firmness through time at different temperatures. This can be done on batches of products and allows predicting the time it takes, depending on the temperature, before the batch becomes acceptable and until when the batch will stay acceptable.

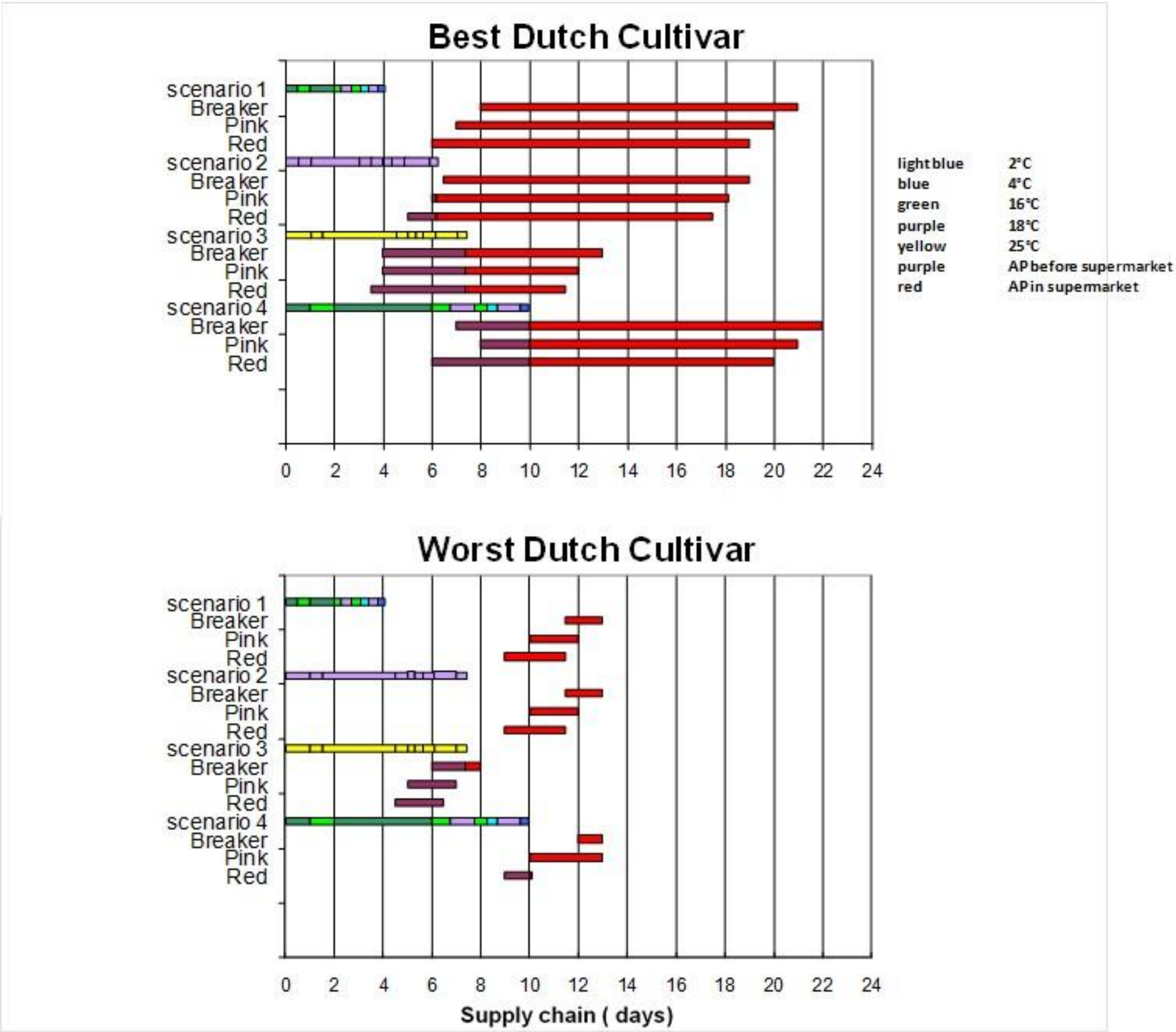

Figure 3. Scenario analysis showing the best and worst Dutch tomato cultivar considering the length of the AP for three different harvesting maturation levels (breaker, pink and red) (Schouten et al., 2010). Each scenario represents a different supply chain setting with different throughput times and temperatures.

The acceptance period model was determined for 10 different tomato cultivars from one Dutch seed company. Growing and harvesting at three different maturation levels (i.e., breaker, pink and red) occurred in the same greenhouse for all cultivars. A tomato supply chain from a well-known Dutch producer group was studied. From this study, twelve different supply chains were designed. The selected chains reflected different seasons, e.g. in the summer the supply is large and so the chain duration lengthens, while in winter the supply is small and the chain duration is short. Storage was at 12, 16, and 18˚C. Harvesting of the tomatoes on Friday created a weekend effect prolonging the chain duration. Major results are depicted in Figure 3.

Figure 3 shows that the best Dutch tomato cultivar has an acceptance period between 12 and 13 days long compared to the worst Dutch cultivar with an AP varying between 1 and 3 days. Figure 3 depicts the different scenarios as horizontal bars; the end of the bar shows the time the product arrives at the outlet shelf. The bar colors indicate the different chain temperatures the tomato batch experiences throughout the chain. It is clear that the short AP (shown in Figure 3 at the *worst Dutch cultivars*) causes a mismatch between acceptability and the moment the batch arrives at the shelf; in most cases, the tomatoes are far from optimal when displayed to the consumer. Except in Scenario 3 (whole chain at 25˚C), where the tomatoes are mainly overripe when the consumer can buy them. The only case that we have a good match is in scenario 4 when they harvest the tomatoes in the pink stage of maturity. It is clear that if tomatoes have a short AP, hence a short selling period, this demands high precision chain management, which is unpractical. Optimization of the situation is possible, but would require exact knowledge of all chain conditions ahead of time in order to decide on the precise chain temperature and harvest maturity per batch. These are rather impossible demands in fast flowing high-volume chains like tomato chains. On the other hand, we see the *best Dutch cultivar* has a long AP in all scenarios. Such a cultivar, allows for more freedom of decision making. On the other hand, Figure 3 shows that in scenario 1 the chain is too short to match directly with the AP. A proper logistic decision in this case would be to store the tomatoes or keep them at a higher temperature to make sure they reach the shelf in an optimal ripening state. Scenario 3 (at 25˚C), shows that part of the AP is lost due to early ripening within the chain. A proper logistic decision would be here to lower the chain temperature.

5.3 QCL Analysis in the Supply Chain

Based upon a literature review and real-life case analysis we identified a number of improvement opportunities when applying the QCL concept in the tomato supply chain (see table 2).

6 Conclusions

Operations management in FSCN usually takes quality as given. If one approaches product quality as a dynamic issue and uses time dependent quality information, then more degrees of freedom come to the forefront that will improve supply chain performance. We have introduced a new concept called Quality Controlled Logistics that provides a framework for concurrently optimizing product quality and availability in market outlets, which will minimize shrinkage and maximize revenues. Six basic QCL-elements are presented:

1. Define consumer preferences on product quality attributes and definition of the consumer product acceptance period
2. Define the critical quality points (CQP) in the supply chain that have major impact on the product quality attributes
3. Measure product quality attributes and use quality change models to predict product quality in all supply chain stages
4. Log data and exchange of (demand and supply) information with supply chain partners real-time
5. Use local dynamic/ adaptive logistics and quality control in each stage to optimize product quality
6. Use AgriFood Supply Chain Management practices to direct specific products batches – under specific environmental conditions – to specific market segments.

The tomato chain case illustrated that QCL offers new possibilities to improve supply chain performance for fresh products. Future research aims for the further development of the diagnostic instrument and the quantification of costs and performance improvements of QCL scenarios in multiple cases.

Table 2.
Overview of identified improvement opportunities in a real life tomato supply chain

QCL element	*Improvement opportunity in the tomato chain*
1. Consumer preferences & AP	• Different market segments and its customer requirements should be identified. Next, the APs for these specific markets should be determined.
2. Critical quality points (CQP)	• More insight should be gathered on the CQPs. • Transport conditions such as temperature need to be set. This setting depends again on the travel/ storage time and how far the tomatoes need to be developed at the retailer.
3. Product quality measurement and prediction	• Different quality classes are defined with help of procedures and standards, such as colour scale card for manual grading. Batches should get their own ID code showing quality score. • As the product arrives at wholesaler site, there should be advanced measurements of tomatoes quality. • Regular monitoring should take place to adjust product offerings related to APs. • Predictive models of tomato quality at the grower should be used to support the decision to harvest tomatoes at a certain stage and time.
4. Data logging and exchange of information	• Detailed information on quality status of cargo and environmental conditions should be registered and communicated to chain partners using information standards and data loggers. Then all chain partners know now the origin, quality level, the storage and travel conditions of that particular batch including the quality development. • Retailers should predict demand and pass this information to other chain actors enabling responsive demand driven logistics.
5. Local dynamic/ adaptive logistics and quality control	• Tomatoes should be harvested in uniform stage of maturity for specific market segments. If there is variation in the harvested fruits, sorting and grading on tomatoes should result in classified batches based on their quality level. • With the help of the different quality classes harvested, a planning/prediction can be made about how fast the product needs to go from the grower to wholesaler and also the conditions (such as temperature) needed to maintain or change the quality. • Inventories should be managed and allocated to customers based on quality category.
6. AgriFood Supply Chain Management	• With support of information about APs and real product quality (using predictive models), the environmental conditions needed should be adjusted in the chain according to wished final development/maturity stage of fruit at arrival. • Quality levels of tomato batches and their related AP should be considered when applying SCM practices in order to deliver the right amount of product at right place at right time with the right quality. The tomatoes must be in the right stage of development and maintained at appropriate temperature to be able to present within the acceptance period by the time they arrive at retailers.

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