Challenges for Quality Control in Temperature-Controlled Import Supply Chains

van der Klein, Michel; Verduijn, Thierry; van Duin, Ron

Publication date
2023

Document Version
Final published version

Citation (APA)
van der Klein, M., Verduijn, T., & van Duin, R. (2023). *Challenges for Quality Control in Temperature-Controlled Import Supply Chains*. 51-67. Paper presented at Vervoerslogistieke Werkdagen 2023, Mechelen, Belgium.

CHALLENGES FOR QUALITY CONTROL IN TEMPERATURE-CONTROLLED IMPORT SUPPLY CHAINS

Michel van der Klein / Rotterdam University of Applied Sciences (CoE HRTech, Logistics Engineering)

Thierry Verduijn / Rotterdam University of Applied Sciences (CoE HRTech)

Ron van Duin / Rotterdam University of Applied Sciences (CoE HRTech), Delft University of Technology

Abstract

Technology provides offline and real-time visibility on the conditions of the cargo in the transport chain and creates opportunities to intervene in the supply chain execution to safeguard the quality of the products. However, end-to-end supply chain solutions to monitor and guarantee real-time product quality are lagging in implementation. The adoption of new end-to-end supply chain solutions and technologies requires a solid definition and understanding of quality and the impact of the supply chain on the loss of quality and its commercial consequences. In this paper, we present an explorative analysis of three cases in which the drivers for quality is linked to supply chain improvements and control and the selection of solutions and technologies.

1 Introduction

Both in the food and flower sector product safety and product loss are seen as societal challenges. The global percentage of food lost after harvesting at the farm, transport, storage, wholesale, and processing levels is estimated at 13 percent in 2016 and 13.3 percent in 2020. These percentages correspond to a food loss index of 98.7 in 2016 and 101.2 in 2020 (FAO, 2022). Identical numbers can be noticed in the flower industry. Doughty (2019) states that waste rate of flowers (which is the amount that die in transit or arrive too damaged to sell) averages about 15% from supermarkets and 20% from wholesalers.

With the Port of Rotterdam, the Netherlands has an important share in the global trade in food products. Recent data show that 19 million tonnes of goods are transported to the Netherlands via the port of Rotterdam every year. Of these, about half consists of fruit and vegetables. With a 5 percent growth forecast for reefer transport (transport of temperature-sensitive products), there is also a clear growth potential. This is also evident from Maersk's plans to realise a large cross-dock and cold store on Maasvlakte II in 2023. For Maersk, Rotterdam is the largest port for temperature-controlled cargo. For flowers Flower Auction Aalsmeer and airport Schiphol have been for many years world leading. From a supply chain perspective, flowers must also be temperature-controlled to keep up the freshness and lifetime of the flowers. Traditionally flowers are transported by airplanes. Over the last year one can observe also a strong growth towards containerised transport of flowers (by making use of Ethylene).

Maintaining product quality is a supply chain challenge: the main focus is on temperature control, although other aspects like humidity, and packaging may also be relevant. In business and academic papers advanced information technologies are generally presented as a solution to monitor and maintain product quality in transport chains. Technology provides offline and real-time visibility on the conditions of the cargo in the transport chain and creates opportunities to intervene in the supply chain execution to safeguard the quality of the products. Still, it can be observed that end-to-end supply chain solutions to monitor and guarantee real-time product quality are lagging in implementation as the adoption of new technologies requires a redesign of supply chain networks and supply chain collaboration.

An alternative approach is to start from the supply chain characteristics and the quality of products, and their need to ensure and improve quality in the supply chain. From these processes make the link to the need for data and supply chain quality control and then search over the possibilities to choose the adequate adjustments in supply chain execution. A framework that provides supply chain actors with an overview of which data and control mechanisms can contribute to the effectiveness, feasibility, and product loss/ value reduction improvement given the characteristics of the product and supply chain. To our knowledge, the setup of such a kind of framework from a supply chain's necessity has not been found. Therefore, the goal of this paper is to identify what factors have an impact on the adoption of advanced technological solutions that cover the entire transport chain in temperature-controlled supply chains.

To investigate this research goal an explorative analysis of three case studies in food and flowers supply chain is carried out. Based on a cross analysis some general findings are derived how the supply chain and product quality control are connected and how the supply chain partners can improve their performance on controlling their supply chain processes from door to door. The cases are selected for three different types of perishables, different types of modalities and loading units. After this introduction a short review on perishable food control is provided in Section 2. This is followed by three case descriptions in Section 3. Section 4 shows outcomes of the cross-case analysis. Section 5 comes up with the general findings and discussion.

2 Research on perishable food control

The literature on food quality control in supply chains is overwhelming and would lead to many pages of literature review. To avoid such an exercise in this paper the most important notions and shortcomings are brought forward in this paper. From an applied research perspective, the focus is more related to implementation in practice on cold supply chains. Therefore, we want to know the influence of the supply chain on the quality of the product and how the quality is defined. From a business perspective, it is important to identify which redesign of processes and control is needed to generate a better quality and/or a better value proposition. Especially the value proposition is often the missing link in most research papers as it is found a common sense that a supply chain strives for this. At the same, the most important question seems to be forgotten who should invest and who is willing to pay for the quality improvement? Related to the redesign of the supply chain which data and technologies should be applied to obtain a better level of performance and how they can be managed by the related stakeholders. Finally, the question should be answered how the implementation of a new advanced data/technology system can be translated to a proper business case. Although many studies and papers have been found on food quality control it can be stated that technically almost everything is possible, but due to all kinds of lock-in market conditions, competition, and governance structures, the perishable food market lags behind in implementations.

With respect to product quality (from the supplier side) the literature is nowadays booming with the application of AI. integrating AI into the food manufacturing process, companies can maximize efficiency in quality control (Koksal, 2021). According to Mordor Intelligence, artificial intelligence in the food and beverage market was valued at $3.07 billion in 2020 and is expected to reach $29.94 billion by 2026 at a CAGR of over 45.77% during the forecast period of 2021 - 2026. Most of these (IOT-based) initiatives are happening at the source and production side of the supply chain to be the representative quality state of the product at the final destination. The conditions under its voyage seem to be of less value. The argument for this can be found in one of the pillars of food quality: the safety of the food. Reducing the presence of pathogens and detecting toxins in food production is a key part of AI.

A bit controversial to the former development is the notion that there has been little attention in the food science literature to the statistical quality of parameters, and especially their uncertainty. Therefore, in addition to the well-known biological variability of foods, it is important to study the significance of the uncertainty of parameters in more detail, certainly if the scope is to make a real model prediction. Knowing the unknown and explaining the non-explainable is the research challenge in data research as most models remain at an uncertainty level of 30%.

Accordingly, in the literature, there is research related to the dynamic conditions occurring in the distribution chain of perishable foods. Application of an optimised quality and safety assurance system for the chilled and frozen distribution chain requires continuous monitoring and control of storage conditions, from production to consumption, using smart or intelligent packaging to monitor shelf life in the non-isothermal conditions of the food chain. Time Temperature Integrators (TTI) are smart labels that show an easily measurable, time-temperature-dependent change that cumulatively reflects the time-temperature history of the food product. Based on reliable models of shelf life and the kinetics of the product and the TTI response, the effect of temperature can be monitored and quantitatively translated into food quality, from production to the point of consumption (Taokls & Giannakourou, 2018).

The scientific literature on food quality control in perishable supply chains provides obviously a lot of directions for new ways of measuring. Still, one can observe that implementation in practice is lagging and mostly do not know what/how to implement. Lamberty and Kreyenschmidt (2022) explain very well what the main cause of this practical blockade could be. They state that managerial decision-making, the improved transparency about the quality status of products can be used for optimized logistic control. Decisions can be based on a solid data basis and instead of rejecting batches with suboptimal quality, alternative distribution strategies or channels can be considered. From a dietary perspective, a real-time monitoring system enables products with high nutritional value, because the ambient conditions during storage and transport are directly connected to the preservation of nutrients. Additionally, consistently high product qualities at the point of sale can benefit food marketing. Several studies show the promising potential of applications for optimized product qualities and reductions in products lost and wasted along the supply chain. However, there is still a lack of studies implementing a comprehensive monitoring system including device, network, and application layers in a real scenario.

The complexity and heterogeneity of fresh products and their supply chains as well as technical challenges hinder implementation. Until now, there is no "one-size-fits-all" solution. Therefore, this paper deals with case-based research (Yin, 2014) to come up with further knowledge on supply chain-specific and process-related factors, as well as knowledge on generic concepts for implementing (an IoT-enabled) monitoring system for fresh fruit and vegetables**.**

3 Description of temperature-controlled cases

In this section, three cases are described. Case 1 is related to flowers, case 2 is related to table grapes and case 3 is about bobby beans. The case research is conducted independently from each other. For all cases a similar methodology is applied which means an in-depth case study focussing on improvement of quality of products and supply chain optimisation. An overview of the supply chain characteristics of the cases is presented in Table 1.

Table 1: Supply chain characteristics of selected cases

	case 1: Flowers	**case 2: Table Grapes**	**case 3: Bobby beans**
Import chain	from Kenya to Amsterdam	from South Africa to Rotterdam	from Morocco to Rotterdam
Mode of transport	Air	Container	Truck
Transport unit	Boxes, air cargo pallet	Reefer container	Temperature controlled trailer
Temperature control	fragmented, temperature and non-temperature controlled transports or storage	temperature control in transport unit door-to-door	temperature control in transport unit door-to-door
Lead time	30 hours	30 days	96 hours
problem/issue	Quality of flowers of a specific shipment after arrival in Amsterdam cannot be measured and impact of the transport chain on the quality of flowers of a specific shipment is not known. Quality control in flowers shipped per maritime container is much more transparent and reliable. The air cargo transport chain needs to improve its supply chain quality performance.	A large proportion of grapes originating South Africa arrive in Europe in substandard condition. Quality inspectors advise, but producers decide what is shipped, based on own product quality perceptions. Potential factors affecting the arrival quality are known, but not how and to what extent and the interdependency of those factors	Increasing absolute and relative number of hot-arrivals (temperature too high). A few causes of the temperature increases are listed, but it is not clear what cause is most likely to be the main trigger.

3.1 Air cargo flower supply chain

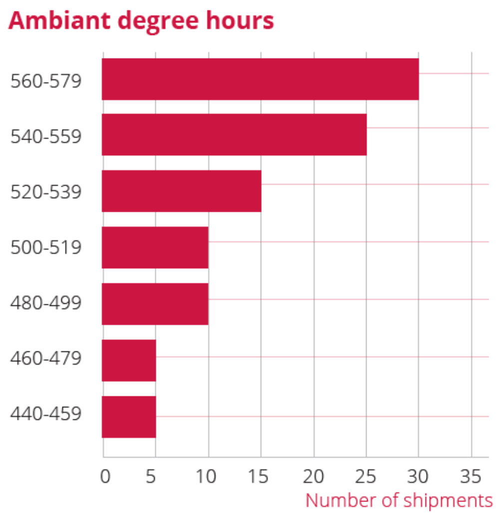
Flowers are transported from growers in Kenya to the flower auction and traders in the Netherlands (e.g. Aalsmeer, Naaldwijk) on daily basis. Flowers are transported in boxes and boxes are stored on top of each other on air cargo pallets. In the transport chain the shipment is handled by consecutively the grower, local transport operator, forwarder, cargo handler at export, airline, cargo handler at import, forwarder, local transport and Royal Flora Holland import services and trade facilitation. Leadtime is 20 to 30 hours. Flowers must be transported at 4 to 8 degrees Celsius to prevent loss of quality and ensure sufficient vase life for the consumer. Quality of the product diminishes with temperature exposure.

The objective of the Holland Flower Alliance (HFA) is to maintain the quality of the flowers during transport. HFA is a collaboration of KLM Cargo, Schiphol Airport and Royal FloraHolland. Together, they aim to strengthen the competitive position of Schiphol/Aalsmeer as flower hub. The hub faces increasing competition from Middle East airport and carriers, digitization of trade & increasing influence of digital trading platforms and scaling up in trade and retail organisation. Consequently, the importance of day trading shifts to purchasing contract and scheduled delivery of large, homogenous shipments of flowers. The need to send these shipments via the flower hub in the Netherlands is gradually diminishing. Also transport of flowers in maritime containers is growing steadily as quality of flowers can be controlled more effectively. Improving the performance of the air cargo supply chain of the HFA partners is one of the strategies to maintain the competitive position of the flower hub.

Use of temperature-controlled air cargo containers or packaging that can maintain temperatures is too expensive. An effective measure to maintain quality ensure that the boxed flowers are transported and stored in temperature- controlled areas and transport equipment. However, not all supply chain processes can be executed in temperature-controlled areas or with temperature-controlled equipment. Therefore, an end-to-end supply chain quality management system in which all operators collaborate needs to be developed to monitor temperature exposure and improve processes in case of excess temperature exposure. In scientific research the concept of degree hours has proven to be a reliable metric to indicate loss of quality. A degree hour indicates exposure to one degree Celsius for one hour. The loss of quality is the sum of the total temperature exposure.

A four-year explorative study was performed by HFA and students of master and bachelor education in industrial design, supply chain management, aviation operations management and logistics management (Verduijn et al., 2019; Verduijn et al., 2022). The objective of the study was to design a cold chain management concept that allows product quality management in the end-to-end supply chain and facilitates collaboration between all stakeholders. The degree hours concept was selected as the basis of the quality management system because it defines loss of product quality in terms of two parameters that can be controlled in the supply chain: lead time and temperature.

The cold chain concept expresses the reliability of the transport chain: to transport goods in specified conditions. The first decision taken was to exclude product quality and product quality temperature as the primary targets, but to focus on the ambient temperature. The ambient temperature can be controlled and monitored by the air cargo supply chain. This is an important starting point because flowers that are not well-ventilated during transport will automatically scald and become warmer. The next step explored was the allocation of 'allowed' degree hours to the various processes and actors in the supply chain and the design of performance indicators that would indicate to what extent each part of the transport chain had delivered their services as requested (see Figure 1). The problem to be solved was to design KPIs that reflect the performance of a specific process or actor only and exclude the impact of deviations realised in preceding steps. If flowers already have too high temperatures in the transfer, the degree hours of the next step will automatically be higher.



	Norm			Deviations		
	L	T	ADH	Av L dev	Av T dev	Av ADH dev
1 Grower	38	2,5	95	-8	0	-20
2 Local Transport	7	6	42	-2	20	88
3 Forwarder Nairobi	7	2,5	17,5	2	0	5
4 Ground handler Nairobi	4	4	16	0	11	44
5 Airline	9	9	81	0	0	0
6 Ground handler Schiphol	3	11	33	0	-3	-9
7 Forwarder	3	12	36	0	-4	-12
8 Dock services	2	12	24	0	-8	-16
9 Importer/Auction	12	13	156	0	0	0
	85		**500,5**	**-8**	**16**	**80**

Figure 1. Example of KPI dashboard for ambient degree hours (ADH) (Zidek, 2018)

Collecting and gathering the data to feed the degree hour model on supply chain level is a big challenge. The use of data loggers on each shipment or air cargo pallet was considered too complex and too costly to organize on a structural basis for each shipment. The aim was to collect the data on shipment movements and ambient temperature from the various stakeholders. Field research indicated what areas and processes are temperature controlled and what temperature data was registered. The missing link is the information of the movement in and out of the temperature -controlled areas. Existing status messages in air cargo reflect the handover of cargo between stakeholders, but do not provide sufficient detail about the conditions within a process or actor. Collecting and gathering all internal movement and temperature data from all stakeholders is likely to be costly and the willingness to share this data is probably limited. Therefore, a risk-based approach, collecting only the data in processes with a high risk of unwanted temperature exposures seems more realistic.

Finally, the value case of the cold chain concept was explored. The primary problem that has been established is that trading parties would like to have an improvement in quality or more information about the conditions in the logistics chain, but that they are unable to indicate what added value this will yield commercially and what the willingness is to pay more for a premium air cargo service or for temperature and lead time data of a shipment. And if an added value price is paid, it is unclear how the chain parties distribute this added value fairly across the chain so that all parties are prepared to invest. In order to be able to recoup the costs of the quality management system, all parties must look for a way to achieve cost savings at the same time. This means that the ambition to improve the competitive position through quality will once again become a traditional logistics project aimed at cost reduction.

3.2 Maritime transport chain of table grapes

In Case 2 table grape variables are investigated that affect quality along a supply chain from South-Africa to Europe during the 2019/2020 season (Rossouw, 2022). This supply chain takes up to 30 days and even more from the harvesting stage to the retailer in Europe. Although inspections take place by in-house quality controllers and on national level controllers of the perishable products export control board a lot of table grapes arrive in Europe in substandard conditions, highly influencing revenues and profits. To qualify quality the table grape industry uses the results of a total score on different features. An example of a quality score of an in-house quality survey in the export country can be found in Figure 2.

ID	Product		Detail		Lug Inspection		Brix	Carton Weight	External Quality		QC Score	General Comments	Tolerance Comments
Grading: GREEN													
1	**Farm Name** **Commodity** **Variety Name**	[redacted] FARMS GRAPES GRAPAES	**Size** **Mark** **Pack** **Target Market**	XL [redacted] 4.5 KG EUROPEAN	**Berry Temp** **Stem Condition**	20.20 FRESH	14.50	4.68	**Berry Size** **Browning** **Colour Uniform** **Decay per Carton** **Loose Berries** **Marks** **Split Berries**	18.00 N GOOD 0.00 6.00 6.00 0.00	GREEN	Good Quality. . Weights Are Too Light - But It Was Fixed Immediately. . Only One Pallet Was Packed With Underweight Boxes.. Berry Size Is Borderline. .	Optimal Temperature No Decay
Grading: RED													
2	**Farm Name** **Commodity** **Variety Name**	[redacted] FARMS GRAPES GRAPAES	**Size** **Mark** **Pack** **Target Market**	L [redacted] 10X500G EUROPEAN							RED	The Grapes Look Good.. The Individual Punnets Are Too Light.. The Weights Per Table Was Adjusted Immediately.. Two Pallets Is Packed Already..	Underweight punnet

Figure 2. Quality control report of expert warehouse (Rossouw, 2022)

The quality control score is on a 1-3 Likert scale, where 1 stands for green, 2 for amber and 3 for red. In the country of arrival, a similar classification system exists. Red and amber scored shipments will respectively definitely or probably lead to income-loss because of lower sales-prices, repacking costs, reduced shelf life or shipments thrown away. The figure reveals that not all known variables out of literature review are included in the qualifying system and that the features have a mix of nominal, ordinal, interval and ratio-values. End-scores are therefore bias-sensitive.

Based on 467 shipments relating to 135 containers an attempt has been made to predict the real outturn quality by constructing models using supervised machine learning. The idea is that a predictive and even a prescriptive model, using independent variables with the highest effect-cause-relationships with the dependent variable quality score upon arrival, will enable marketeers to make a more scientifically based allocation decision to grow which kind of table grapes and where and to whom to ship the different batches of them, all facing different values for the decisive variables. Out of literature review and calculated correlations the following 9 variables were selected to feed the models. 1) table grape variety; 2) external packaging (cartons holding internal packaging); 3) internal packaging (what has direct contact with the table grapes); 4) sugar content at harvest; 5) decayed berries found in warehouse; 6) the exporter's quality score and prior to harvest variables on 7) rainfall; 8) relative humidity and 9) average temperature. It is noteworthy that no relation could be observed between outturn quality and the number of temperature-breaks (temperature is for more than 90 minutes above + 2 degrees Celsius or below – 1.5 degrees Celsius), number of spikes (sudden increases in temperature) and fruit age at the time of arrival. This is the reason why these have been left out of the model.

The model that gave the best outcome on the unseen test data, with an accuracy rate of 0.63, was the Random-Forrest Classifier, however there is a distinction between the classes. Red class is predicted as best with an accuracy rate of 0.7 followed by green and amber scoring 0.64 and 0.57 respectively. From the 9 independent variables used in the model the following variables scored highest on having quality-impact in the modal itself: 1) climatic variables two weeks prior to harvest (42,5% of impact); 2) the specific variety (20,7); 3) °Brix (sugar-content) at harvest (18,3%) 4) the number of decayed berries found in the packhouse (5,3%); 5) the overall packhouse quality score in export country (2,9%) and 6) the type of packaging used (10,4%).

More research into more variables and into more cases stretching over more seasons and cold chains, with the help of automized data collection and trying other machine learning models is advised in order to increase reliability, internal and external validity of a to be constructed model. Because of lower performance in amber and green predictions of the used model in this case, future models can be converted using binary classification and using as dependent variable not arrival score but the likelihood of a financial claim. An extra reason for doing this is that not all amber will result in loss and losses because of amber and red classified shipments can sometimes be passed on to third parties. Complicating in the model-building process is that due to the market (over- or undersupply), sales prices will fluctuate and the classification process at the import country could be influenced by the market, i.e. in case of a saturated market with low profit margins importers could deliberately class table grapes as amber or red while these grapes would normally be classified as green or amber in a seller's market.

3.3 Bobby beans by road transport

Case 3 was researched for a company into the international truck-enabled 4-days lasting supply chain of bobby beans (Bani, 2021). The company involved was facing an absolute and relative increase in their Dutch based warehouse with pallets bobby beans arriving too hot (2 degrees above the setpoint temperature of 6 degrees Celsius) and consequently thereof an increase in products classified as waste (the products have to be thrown away) and as commission (lower sales-price). Two possible causes were formulated: 1) out of labour-costs aspects a growing percentage of the shipments had been prepackaged in the export country instead of in the import country. Packaging would probably have blocked the cooling airflow in the truck; 2) cooling infrastructure in the export country lacked capacity during harvesting peak periods. By hypothesis-testing based on the years 2018-2021 prepackaged bobby beans have significantly higher arrival temperatures than unpackaged bobby beans for both off-season and high-season and both prepackaged and non-packaged bobby beans have not significantly higher arrival temperatures when comparing off-season with high-season. The company could quantify the loss because of prepackaging by using a temperature-classification-scale. Although the company is aware that more variables than temperature alone affect quality it allocates arrival temperature and the corresponding kgs of prepackaged and non-packaged bobby beans to one of 3 temperature-intervals which are linked to 3 categories, and 3 different realized sales-prices, which is 0 in case of waste. The categories are good, commissioned and wasted products.

The following recommendations were drawn up: 1) implement a new standard operating procedure for reliable temperature assessment, where both export-side and import-side will have to adhere to. The present procedure was to measure the temperature on the side of the pallet, whereas the hottest spot was in the centre of the pallet. The new procedure will prevent false positives, read too hot shipments, from being shipped, or not getting the right treatment upon arrival. 2) set up a structured information (temperature) sharing tool on pallet-level between export and import warehouse to obtain deeper knowledge in the shelf life of bobby beans 3) Improve the master-data (completeness/ comprehensiveness) within the company enabling the development of tools for better cost-benefit analysis and trade-off-advice related to temperature-control and supply chain organization and design.

The following topics could be part of a next study: 1) check the total volume, including other products than bobby-beans throughout the year. Peaks and throughs in bobby beans volumes can be flattened on aggregated level due to other products having an anti-cyclical pattern to the bobby beans; 2) as the major part of pre-packaged products is transported by ship investigate shipments that were convoyed by sea and analyse if there is a difference between sea- and truck-transports.

4 Cross case study analysis: supply chain challenges in quality control

The supply chain challenges in quality control in the three cases were analysed and compared using the four research questions already introduced in the literature review:

1. How is quality defined and how is quality affected by the supply chain?

2. What supply chain redesign or control is desired to guarantee or to maintain quality and business value?
3. What kind of data and technology are conditional to realize supply chain redesign and control?
4. How is quality control and investment in advanced data-usage and technology translated into a business case for the participating stakeholders?

4.1 Definition of quality in a supply chain context

The cases show that a distinction must be made between intrinsic product quality, the condition of the product upon arrival in country of import and the circumstances in which goods are transported (see Table 2). In all three cases, the quality of the product is inspected by means of quality control, but the focus on the impact of the supply chain on quality is different. In the flower chain, the products are inspected for product characteristics, but it cannot be determined upon arrival what the loss of quality has been in the transport chain. An excessively high temperature on arrival does indicate that there is a loss of quality, but not how great that loss of quality is and what the main cause is (the intrinsic quality of the product or the impact of the transport chain). In the case of the table grapes, it appears that the intrinsic quality, i.e. the product, has a major influence on the loss of quality that occurs in the chain. In case 3, measuring the temperature of the product on arrival seems to be a reliable indicator of the loss of quality and the commercial consequences.

Table 2: Definition of quality and impact of the supply chain on quality in the three cases

	case 1: Flowers	**case 2: Table Grapes**	**case 3: Bobby beans**
Quality definition & impact of the supply chain	The product quality of the flowers can be assessed with the concept of degree hours: the accumulative exposure time of the shipment during transport	Temperature control in the cold chain. Temperature should stay within a predefined interval. Passive loggers were made use of during transport enabling feedback but not feedforward.	Temperature control. Temperature should stay within a predefined interval. During transport two loggers are real-time measuring truck temperature and allows company to directly contact truck-driver in case of breach of boundaries

As a consequence, the stakeholders in the cases have made different choices in terms of the scope of the chain for which they take responsibility and the way they take responsibility for the quality of the product. In case 1, the stakeholders in the air cargo transport chain clearly delineated their responsibility to the transport chain and therefore decided not to take the temperature of the product as the basis for quality control. The logistics chain parties only want to guarantee that the products have been transported under the agreed conditions and that the total temperature exposure in the chain is not exceeded. As a result, decisions about which products or batches are or are not suitable for export to Amsterdam have been placed outside the responsibility of the transport chain. That is the step that can still be taken in case 2. From the statistical analysis performed on the quality of the table grapes, pre-harvest and product characteristics have much more impact on the arrival quality than the impact of the transport chain itself. During the research done in case 2 no correlation could be found between the three investigated transport related variables and quality. In case 3, there is agreement on the use of temperature as control variable, but better understanding on the variables determining quality is still wanted.

4.2 Supply chain strategies for quality control

In the cases, the stakeholders focus on different strategies in supply chain design and control to exploit, guarantee or improve the quality of products. In all three cases (see Table 3), the stakeholders try to gain more insight into the quality of the product upon arrival in the Netherlands in order to improve commercial decisions: matching the quality of the product to the specifications of market channels or customers. The ambition in all three cases is to do this on the basis of product and supply chain data about a specific shipment or batch. In case 1 and 3, the objective is also to assess the supply chain conditions and performance to identify structural supply chain improvements in supply chain operations that limit the loss of quality of the products. It is striking that in case 2, it is concluded that the transport chain itself has little or at least limited impact on the quality of the product upon arrival and has therefore been excluded from the explanatory model. In case 1 and 3 the focus is especially on creating the right conditions for maintaining product quality along the transport chain.

Table 3: Supply chain strategies for quality improvement in the three cases

	case 1: Flowers	**case 2: Table Grapes**	**case 3: Bobby beans**
Supply Chain Redesign & Control	Quality control at chain and box level: (1) solve structural bottlenecks in operations based on degree hours performance of different processes in the transport chain; (2) commercial decisions by buyers to allocate shipments to market channels or customers based on the degree hours of a specific shipment or box of flowers; (3) operational interventions in air cargo operations for shipments exceeding degree hours criteria	Improved assessment of product quality at the time of export allows improved allocation of batches of product to various local and international markets. Ultimately, prediction of the arrival quality at importer's warehouse based on inherent quality at time of export will be used. The impact of transport chain on quality was not significant.	The aim is to improve the transport chain operations structurally based on correct temperature measurements and sharing this and other chain data, enabling better analysis and understanding of shelf life and offering a base for better allocation-decisions

Only in case 1, the ambition is to intervene in the operational process on the basis of up-to-date information about the quality of the flowers and to prevent the flowers from arriving with degree hours that are too high. However, it is unlikely that this will be realised in practice. The processes op Schiphol and Aalsmeer have already been optimized to maintain quality. There is little opportunity to reduce the degree hours. Intervening in the supply chain is already possible in case 3 because the temperature in the trucks is available in real time. However, experience shows that problems with the cooling installations of the trucks are rare and intervention is sporadically necessary.

4.3 Data collection and technology

Table 4: Overview of data collection and technologies in the three cases

	case 1: Flowers	**case 2: Table Grapes**	**case 3: Bobby beans**
Data requirements	To calculate degree hours performance on shipment level, actual data is needed on the temperature exposure and the residence time in each area in which shipments are located. Some of this data is registered, but not shared. The current status messages used in the air freight chain are insufficient to calculate the degree hours performance.	Pre-harvest, harvest, post-harvest data, transport data are used as input for the prediction model. Transport data were not selected in the final model. Its contribution to the reliability of quality at arrival was negligible. Need for crowd sourced data-collection and automized data collection from the field / vineyard and financial data to create a predictive model with high accuracy.	Improvement on master-data on supply chain costs, activities/ processes and machinery registered and linked to the right costs, enabling trade off decisions + temperatures throughout the chain on pallet level
Technologies	Flowers are not transported in a transport unit from door to door, adding sensors or devices to a transport unit is not possible. Structural use of data loggers in boxes of flowers is too complex to organize and too expensive. Collecting the existing temperature and movement data from the partners in the transport chain is an alternative approach, but a big collaboration and IT-integration challenge.	Technologies to measure and transmit real time information to databases, that are linked via EDI to learning models enabling a real-world table grape quality risk management tool	A new standard operating procedure, prescribing the use of an extended probe for temperature measurement inside the pallet + dynamic calculation tool using master-data for better allocation of resources (e.g. packaging in export country or at later stages) + communication tool to share temperatures throughout the chain preferably at pallet level (at short term excel...at longer term via a to-be-implemented ERP-system)

In all cases, availability and analysis of data is the core of quality improvement. The challenge is to collect data from different sources. It is striking that the data needed to properly measure or predict quality is often not registered in the logistics chain. Temperature data is often registered by chain parties because of internal quality systems, but not shared in the chain or stored in such a way that it can be shared with the chain. In case 1, logistics data that is shared in the chain is also not sufficient to achieve reliable monitoring of quality, because it does not indicate within each link in the chain when a shipment has been in a conditioned space. Even though devices that record the temperature or other conditions of the shipments in the chain would be the solution to arrive at reliable and complete data sets, the cases show that this solution is technically not possible or feasible (the economic feasibility is discussed in the next section). discussed).

4.4 Value case and governance

Table 5: Value cases and governance in the three cases

	case 1: Flowers	**case 2: Table Grapes**	**case 3: Bobby beans**
Value Case	Better control of quality should allow traders to direct flowers to the right markets based on improved product quality information.	Insight in the product quality of grapes allows traders to reduce financial losses due to allocating products to sales channels based on quality characteristics and reduce claims and product loss.	Insight into product temperature enables better temperature control of the supply chain and reduces the number of commissioned or wasted shipments and product loss and enables better allocation decisions.
Quantifying the value of product quality	The added value of reliable information about quality loss in the transport chain cannot be quantified because the buyers do not yet use the information and do not know how the information can be used to generate added value to customers or to reduce product loss.	Loss of value could be quantified when price- and market information could be added to the model and the model is better trained.	Loss of value because of product quality is quantified in a simplified manner. The focal company this way knows how to allocate product to various sales channels and has overview of product losses.

The business case for measures to monitor or improve product quality lies in all cases in achieving a higher commercial value and to a lesser extent reducing product loss. In all cases, a better allocation of shipments based on the quality of a specific shipment results in a higher margin. In case 2 and case 3, the stakeholders involved also seem to be able to quantify the added value in order to financially justify the investments in an end-to-end quality management system. This is possible because the quality management in case 2 and case 3 is initiated by the product owner who has direct contact with the customer. In case 1 it appears very difficult to translate the added value of the quality management system or the higher quality into a financial value. The growers who own the product have little or no idea of the benefits that buyers have from a higher or reliable product quality. But even if that financial value is known, the question is whether the available revenues are used to compensate for the extra costs of all parties in the chain. Willingness to pay more for information on the supply chain conditions or for guaranteed, and verifiable conditions is limited. Mainly because the business is driven by reputation of growers and airlines. If there is value generated at the end of the supply chain, it is unlikely that growers or forwarders will share this with the airlines and ground handlers. Basically, the transport chain is an accumulation of a dyadic buyer-supplier relationship in a competitive air cargo market. It is very hard for companies to differentiate and maintain a competitive advantage. So, focus is on price and not on quality, End to end supply chain improvements are only possible if all stakeholders can reach a cost reduction simultaneously.

5 Conclusions and recommendations

In this paper we have examined three cases to gain insight into why and how supply chain partners want to control and improve the quality of products in the supply chain. Insight into the determining factors is necessary to better understand how advanced data science techniques and information technologies can effectively contribute to quality control in practice and to gain insight into the issues that parties encounter in this respect.

Defining and making quality measurable is the first issue to be answered. It is essential to separate the intrinsic quality of the product and the performance of the supply chain to maintain the quality of the product. Although the integral quality of a product determines its commercial value, logistics parties can only take responsibility for the conditions in which the shipment has been transported and cannot be held accountable for the quality upon arrival. Defining and making product quality or loss of quality in the chain measurable is highly dependent on the product. The temperature on arrival is a commonly used indicator because it is easily measurable, but the cases show that it is not enough to make reliable statements about the product quality of a specific shipment or about the conditions of the transport chain.

It is not surprising that the most important driver for quality management in the chain is optimizing the commercial value of the products. What is surprising is that the stakeholders are not only looking for structural improvement and control of the quality of products in the chain, but also want to use data from the chain to determine for a specific shipment in which channel or to which customer a shipment can be sold. It is essential that the data of specific parties or shipments is available and shared in the chain. The cases also show that real-time visibility with modern technology is not necessary to improve quality in the chain. Real-time insight into the conditions of the shipment provides little or no reason to intervene in the supply chain. The case studies do show that statistical data is a powerful tool for improving the chain. The statistical analysis in case 2 and 3 show that (off-line) collected data can help to find the determining factors and causes for quality loss.

In this paper, we have reflected on various studies to gain insights into the trade-offs chain parties make in guaranteeing product quality in the supply chain. This was a first, small step to see from the rich context of a supply chain project why or not the step to advanced data science and information technology is taken. After this exploratory paper, the next step is the more systematic analysis of the literature and the development of a conceptual model that indicates how quality objectives, product and chain characteristics lead to the choice of a technology.

Acknowledgements

TKI Dinalog/NWO-funded project 'Smartest Connected Cargo Airport Schiphol'
Collaboration of Holland Flower Alliance & Amsterdam University of Applied Sciences.
Greening Corridors, SIA-SPRONG.

References

Bani, S. (2021). *Cooling down Moroccan Bobby Beans* [Bachelor thesis]. Rotterdam Mainport Institute of Applied Sciences.

Doughty, K. (2019). Roses Are Red, But They Might Not Be Green. Website Roses Are Red, But They Might Not Be Green | ACEEE visited at 27th January 2023.

FAO, (2022). Sustainable Development Goals. Website12.3.1 Global food losses | Sustainable Development Goals | Food and Agriculture Organization of the United Nations (fao.org) visited at 26th January 2023.

Koksal, I. (2021). Using AI to increase food quality. May 8 2021. *Forbes*/Innovation/Enterprise tech.

Lamberty, A. & Kreyenschmidt, J., (2022). Ambient Parameter Monitoring in Fresh Fruit and Vegetable Supply Chains Using Internet of Things-Enabled Sensor and Communication Technology. *Foods,11*, 1777. https://doi.org/10.3390/foods11121777

Rossouw, C. G. (2022). *An investigation into table grape risk factors that affect quality along the export supply chain* [Master thesis]. Faculty of Economics and Management Sciences at Stellenbosch University.

Taoukls, P.S.; Giannakourou, M.C. (2018). Modelling food quality. *Food Sci. Technol. (Lond.)*, *32*, 38–43.

Verduijn, T., Vunderink, S., Bombelli, A., Tavasszy, L., van Damme, D., Romero-Silva, R., & Mujica Mota, M. (2019). *Smartest Connected Cargo Airport Schiphol: Research on innovations strengthening the logistics performances of air cargo supply chain at Schiphol Airport.* (Publication series AUAS Faculty of Technology, Amsterdam University of Applied Sciences.

Verduijn, T., Berg. E. van den, R. Kooter (2022), T*emperature Control in Air Cargo Flower Supply Chains, Overview of the concept development and student research carried out on behalf of the Holland Flower Alliance 2016-2021*, Amsterdam University of Applied Sciences

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Sage.

Zidek, M. (2018). Defining a method to measure the performance of the flower cargo chain Nairobi-Aalsmeer [unpublished bachelor thesis]. Amsterdam University of Applied Sciences.