A decision support model simulating quality data in fresh food supply chains

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Introduction

- Demand for and supply of organic fresh food rises
- Supply chain management in food logistics is challenged by
  - rising world population
  - ongoing urbanization
  - a shift to more fresh diets (Lundqvist et al., 2008)

Background

The logistics of perishables differs significantly from non-perishable items

- Limited shelf life
- Various sources of uncertainties
  - Biological variance
  - Unpredictable weather conditions
  - Seasonable fluctuating supply and demand
- Quality decrease over time, mostly depending on temperature and environmental conditions.

Background

Operational research methods present powerful tools to handle the complexity of food logistics

- Linear programming is the predominant modelling technique (Soto-Silva et al., 2016)
- Various works use simulation methods (Borodin et al., 2016)
  - Incorporate uncertainties
  - Integration of food quality models
  - Supply and market uncertainties taken into account
- Lacking consideration of changes in product quality and interdependencies between quality and chain design (van der Vorst et al., 2008)

Problem Description

- Dynamic problem with uncertain supply and demand
- Uncertain product quality
- Different requirements on food quality
- Product qualities subject to storage & transport conditions
- Objective
  - maximize total revenue
  - minimize food losses
  - maximize fill rate
- Decisions
  - Which product should leave the distibution center first?
  - To which quality threshold the products can be shipped from the cold store to the distribution center and from the distribution center to the retail stores?

Decision Support

Decision Support System (DSS)
Development of a DSS to maximize profit of the whole supply chain by reducing food waste along regional fresh fruit supply chains

- Combining geographic network data with simulation methods
- Modelling food decay based on quality functions, storage and transport temperatures
- Integration of stock rotation schemes and customer requirements

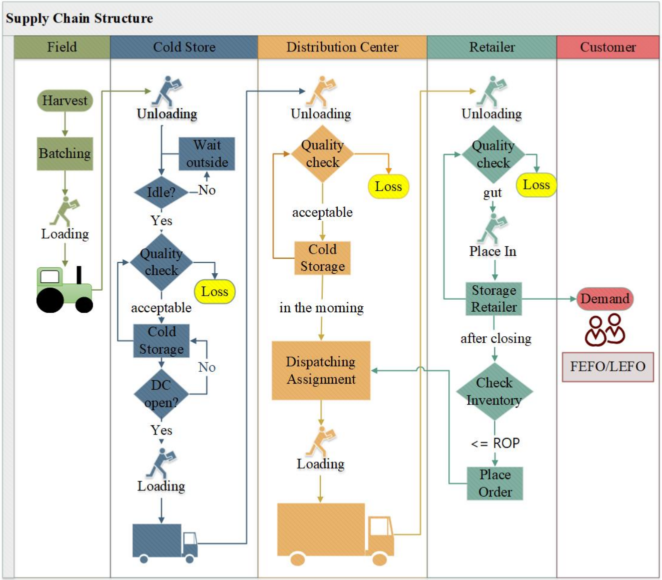
Decision Support

Discrete Event Simulation

- Regional fresh fruit supply chain
- Various temperatures along supply chain
- Quality updated continuously
- Retailers
  - Gourmet: high quality, low demand
  - Regular: mean quality, mean demand
  - Discounter: low quality (still acceptable), high demand

Components	Representation
Perishable Item	perishable product with implemented specific quality attribute
Producer	produces perishable product with biological variations in quality
Cold Store	reefer, stores perishable items until transport to distribution center
Distribution Center	cooled distrbiution center
Truck	climate controlled truck
Retailer	end destination of perishable items where consumers meet their demand

Decision Support - image from paper!



Decision Support

Modelling the quality of fresh fruits and vegetables

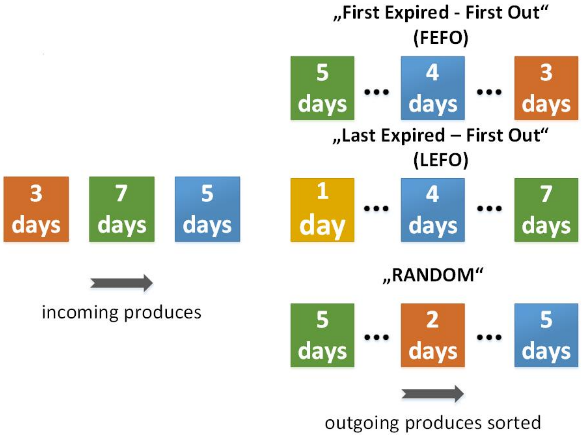
Generic Keeping Quality Model implemented (Tijskens and Polderdijk, 1996)

- Calculates keeping quality as a function of time, temperature, reaction rate and initial quality.
- ‘Keeping Quality’ is the time until a commodity becomes unacceptable.
- Limit of acceptance depends on
  - initial quality
  - intrinsic characteristics
  - consumer’s perceptions
- At constant environmental conditions, known initial quality and a defined quality limit, always the same quality attribute hits the acceptance limit first.

Decision Support

Stock Rotation Schemes (SRS)

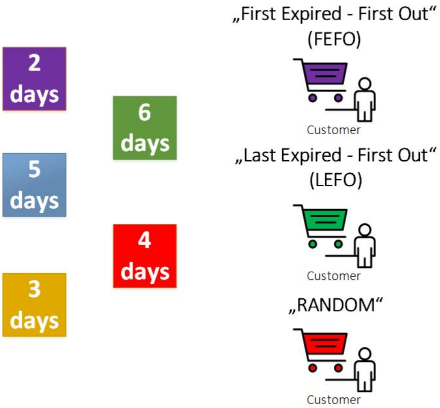
- Need to be adapted to product characteristics and requirements
- Implemented schemes



Decision Support

Demand Priority (SRS)

- consumers demand foods of different quality
- FEFO: they take the lowest quality
- LEFO: they take the highest quality
- RANDOM: they do not consider quality



Computational Experiments

Test Settings

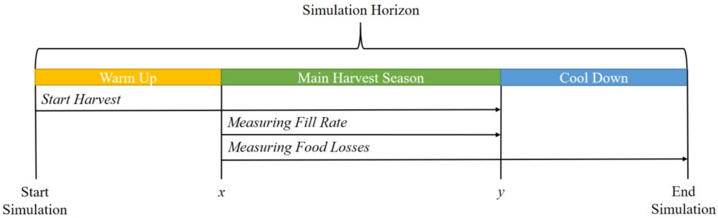
- Investigation of the impact of (i) stock rotation schemes, (ii) demand priority and (iii) quality thresholds on
  - Food losses (items)
  - Food quality
  - Fill Rate (%)
  - Total Revenue
- 25 replications per setting and averages are reported
- Developed with AnyLogic 8.2.3 facilitating GraphHopper and OpenStreetMap for real-world routing network

Computational Experiments

Study Area

A regional strawberry supply chain in Lower Austria and Vienna is modelled.

- 59 strawberry farmers in Lower Austria
- 1 distribution center westwards in Lower Austria
- 359 retail stores



Computational Experiments

Quality Losses of Strawberries

- Short shelf life (5-7 days)
- Generic Keeping Quality Model of Tijskens and Polderdijk (1996)
  - Keeping Quality limited by spoilage rate (Schouten et al., 2002)
  - Batch Keeping Quality

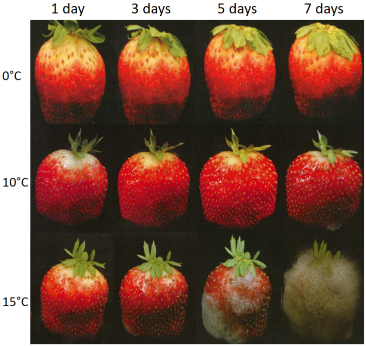


Figure based on Nunes, M.C. do N., 2008. Color atlas of postharvest quality of fruits and vegetables, 1.edn. Blackwell Publ, Ames, Iowa.

Handling temperatures along Strawberry Supply Chain

	Temperature (°C)			
Location	Hertog et al., 1999 (strawberries)	Nunes et al., 2014 (blackberries)	Nunes et al., 2003 (strawberries)	in this work
Field	—	23.9	—	23.9
ColdStore	12	—	3	3
Warehouse	4	1.1	3	3
Transport	10	0.6-0.7	3	3
Loading/Unloading	-	-	-	10
Retailer	16	6.7	20	20

Experiment: Stock Rotation Schemes

Impact of stock rotation schemes on food losses.

	Food Losses [items]			
Strategy	DC Unloading	DC Storage	Ret Unloading	Ret Storage
FEFO				
LEFO				
Random				

- Four warehouse trucks substantially reduce food losses under LSFO and FIFO whereas higher amounts of food losses occur under LIFO.
- If less trucks are available, the LSFO approach produces less food losses than the FIFO approach.

Conclusion

Conclusion

- Integration of food quality with delivery strategies in food supply chain simulations are of importance
- Applying the LSFO substantially reduces food losses
- Regional deliveries reduce travel distances, food losses and improve product availability

Future Work

- Expending the product range to consider interactions among various FFVs

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