Dual Sourcing in Food Supply Chain Networks: the case of Egyptian strawberries

Dr. Roberto Rossi

veg-i-trade
safe food for a changing world
The Veg-i-Trade Project (2010-2014)

“Global trade with stakeholders in many different countries makes the management of food safety extremely difficult.” http://www.veg-i-trade.org/

Concerns have emerged regarding the safety of fresh produce in response to recent outbreaks and alerts linked to fresh produce and derived food products:

• Irish pork recall 2008
• Germany E. coli O104:H4 outbreak 2011
The Veg-i-Trade Project (2010-2014)

Objective: Veg-i-Trade will develop control measures of a managerial and technological nature in the supply chain of crop production, post-harvest processing and logistics to minimize food safety risks.

Numbers:
- 23 international partners (12 academic, 11 industrial)
- 10 countries involved
## Workpackages

<table>
<thead>
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<th>Workpackage</th>
<th>Description</th>
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</thead>
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<td>Mapping of the economical structure and organisation of the fresh produce supply chain at European and global levels and the identification of new trends in European consumption patterns</td>
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<td>WP2</td>
<td>Development and validation of diagnostic instruments as a tool for the systematic assessment of the performance of Horticulture Safety Management Systems in the fresh produce chain</td>
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<td>WP3</td>
<td>Formulation of adaptation scenarios of Horticulture Safety Management Systems to anticipate globalization and climate change, leading to the description of Quality Assurance (QA) recommendations on EU and global levels</td>
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<td>Study of the pre- and post-harvest conditions, including agronomical cultural practices and further processing techniques, packaging and storage conditions, on plant physiology and microbial ecology of fresh produce</td>
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WP6
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Risk communication in order to respect the principle of food sovereignty in the setting of risk management strategies

WP6 | WP7 | WP8

Strengthening international collaboration by scientific cooperation, exchange of information and capacity building between trade partners in fresh produce in a global food market

WP10 | WP11
The Team

J.G.A.J van der Vorst, Wageningen University, Professor of Logistics Management

R. Rossi, Wageningen University, Assistant Professor, University of Edinburgh, Lecturer in Management Science

F. Lopez-Galvez, Postdoctoral Researcher, University of Ghent, Belgium

W.A. Rijpkema, Wageningen University, PhD candidate (now supply chain manager at FrieslandCampina)

...and many others colleagues from Veg-i-Trade!

2/8/17
Publications (selection)

R. Rossi, J. Van der Vorst, L. Jacxsens and M. Uyttendaele, "The Impact of Advanced Inventory Control Policies on Quantitative Microbiological Risk Assessment in Food Supply Chains", working paper


Two Key Concerns

Veg-i-Trade focused on two key aspects:

Quality of products

Safety of products

traded in global food supply chain networks.
Global supply chain network
Decision support system

Strategic decisions:
- open/close a hub
- produce/not produce
- serve a given area
- ...

Flow of goods

Potential

Selected

Producer
DC
Retail store
Transportation
Demand centroid
Tactical decisions:
- how frequently to deliver
- production cycles
- target stock level at hub
- …
Decision support system

Operational decisions:
- production quantity on a given day
- order quantity at DC
- truck load from DC to Retail outlet
Quality/Safety change models
A global logistic chain
Impact of Dual Sourcing on Fruit Quality

• We investigated the impact of dual sourcing strategies on quality of fresh fruit traded in international food supply chains.

• Dual sourcing is an established practice in supply chain management – see (Veeraraghavan and Scheller-Wolf, 2008; Schimpel, 2010; Klosterhalfen et al., 2011).
Dual sourcing

• When a company adopts dual sourcing, it typically ships a large volume of products via a cheap, but usually slow shipping mode, which we will call “regular”.

• However, the company also has the flexibility to ship more products when needed via an expedited shipping mode, which is more expensive.

• Companies adopt dual sourcing to enhance flexibility of their sourcing strategy.
Dual sourcing

- An issue that, to the best of our knowledge, has not been investigated yet in the literature, is the impact of dual sourcing on fresh produce quality.

- Most of existing literature on dual sourcing focuses on products such as electronic components, spare parts management, car manufacturing, etc (Schimpel, 2010).

- Clearly, a longer transportation time does not affect the quality of these products.
**Dual sourcing**

- However, little research exists on dual sourcing applied to fresh food produce.

- For fresh produce, a **lean and fast chain** is key to product quality on retail shelves.

- An interesting issue then is to study if **dual sourcing**, which is a common strategy among firms to reduce costs, may jeopardize product quality in food supply chains.
Research questions

1. Does a dual sourcing inventory control policy, whilst reducing costs, guarantee a sufficient quality at consumption and reasonable waste?

2. How sensitive is a dual sourcing policy to variations of initial quality and temperatures along the chain?

3. What is the impact of fuel cost variation on final product quality and on waste?
Methodology: hybrid simulation/optimization approach
Case: fresh strawberries

• Industrial partner
  – Special Fruit, Meer, Belgium
  – Magrabi Agriculture, El Cairo, Egypt

• Import areas
  – Egypt
  – Spain
  – Netherlands

• Quality
  – growth of Botrytis cinerea

• Safety
  – no safety threats
Strawberry supply chain sourcing areas and distribution center
Strawberry supply chain
sourcing areas and distribution center

Table 1: Import regions of strawberries for different seasons

<table>
<thead>
<tr>
<th>Product</th>
<th>Availability</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberry</td>
<td>Jan</td>
<td>Feb</td>
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</tbody>
</table>
Strawberry supply chain sourcing areas and distribution center
General Chain (Strawberries)
General Chain (Strawberries)

Volume/day: ................
Picking speed per employee: .................
Boxing speed: .................
Stack size: .................

Temperature: .................

Growers

Spain
Egypt
Netherlands

contamination

picking

boxing

250/500g

10 boxes

16 boxes

cooling at farm level
General Chain (Strawberries)

Volume traded in auctions: .....%

Auctions

Temperature: ..............

Auction duration: ..............

Special Fruit, Meer, Belgium

Temperature: 1C, 10C (repacking)  Temperature: ..............

Volume traded in auctions: .....%

Auctions

Temperature: ..............

Auction duration: ..............

Wholesalers
Supermarkets (BAMA)

Retail shops

Households

Temperature: ..............

Transport

Temperature: ..............

Temperature: ..............

Temperature: ..............

Sale data from BAMA: # punnets per day per shop type or past sale data.

Shelf Temperature BAMA: ..............

Discuss consumption behavior.
Egypt - Netherlands Supply Chain
(Strawberries)
Egypt - Netherlands Supply Chain
(Strawberries)
Egypt - Netherlands Supply Chain (Strawberries)

Number of farmers: ...........
Location of farmers: ..........
Volume per day per farm: ............
Picking speed per employee: .............
Boxing speed: .................
Stack size: .................

Temperature: .................
Egypt - Netherlands Supply Chain
(Strawberries)

Transport to airport
Right frequency:............
min/max distance km:...........
cooled/uncooled truck? Temp:....

Transport to harbour
Cruise frequency:............

Temperature: ..............

Right time:............

Airport warehouse, uncooled customs operations, loading/unloading duration (min/max):............

Operator warehouse, cooled temperature:............

Transport to Meer: 11h
Temperature: ..............

Transport to Meer: 4/8h uniform delivery frequency:............

Transport to Meer: 1h
Temperature: ..............

Quality check

Wholesaler (daily)
Special Fruit, Meer, Belgium
Temperature: 1C, 10C (repacking)
% of volume repacked:............
typical repacking operation duration:............

Supermarkets
Local markets

Please provide a (representative) list of customers and shipping locations
Please provide (representative) daily volumes per customer
Please provide (representative) delivery frequencies per customer
Costs

• Transportation costs per ton of products
  – Boat
  – Plane
  – Truck

• Holding costs at producer, DC, retailers

• Boat is typically cheaper than plane but it is slower!
Problem parameters

- Costs (see previous slide)
- Transportation time (lead-time)
  - Boat
  - Plane
  - Truck
- Service level (non-stockout probability)
  - Retailers
  - Producer
- Backordering cost
  - Distributor
Quality (*Strawberries*)

- Botrytis cinerea in strawberries (Hertog et al 1999)

\[ Q_{t0} = 0.1 \]

- Model includes the effect of temperature \( (k_s) \) and storage atmosphere \( (Rel_{MR}) \).
Temperature profiles
Egypt - Netherlands Supply Chain (Strawberries)
Now or Later: A Simple Policy for Effective Dual Sourcing in Capacitated Systems

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We examine a possibly capacitated, periodically reviewed, single-stage inventory system where replenishment can be obtained either through a regular fixed lead time channel, or, for a premium, via a channel with a smaller fixed lead time. We consider the case when the unsatisfied demands are backordered over an infinite horizon, introducing the easily implementable, yet informationally rich dual-index policy. We show very general separability results for the optimal parameter values, providing a simulation-based optimization procedure that exploits these separability properties to calculate the optimal inventory parameters within seconds. We explore the performance of the dual-index policy under stationary demands as well as capacitated production environments, demonstrating when the dual-sourcing option is most valuable. We find that the optimal dual-index policy mimics the behavior of the complex, globally optimal state-dependent policy.
The constant-order policy

A comparison of the constant-order and dual-index policy for dual sourcing

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A R T I C L E   I N F O

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K e y w o r d s

A B S T R A C T

We analyze a single-product, periodic-review, stochastic demand inventory model with backorders and two supply options, a regular and a more expensive expedited one, with deterministic, offsetting lead times. Since the optimal policy for such a problem is generally unknown, several simpler policies have been proposed in the literature, e.g., the single-index (SIP), dual-index (DIP), or constant-order policy (COP). In previous research the DIP has been found to perform closely to the optimal policy in specific
Genetic Algorithms for Policy Parameter Computation

• JGAP (Java Genetic Algorithm Package)

• A policy can be encoded as a chromosome:
  – COP -> [Q,Sm,St,Sw,St,Sf]
  – DIP -> [Se,Sm,St,Sw,St,Sf]

• JGAP automatically computes “good” policy parameters by mutation and recombination.
Egypt - Netherlands Supply Chain
(Strawberries)
Chapter 3

Supply Chain Design: Safety Stock Placement and Supply Chain Configuration

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Safety Stock Positioning in Supply Chains with Stochastic Lead Times

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We study the safety stock positioning problem in single-product multistage supply chains with tree network structures, where each stage controls its inventory using an installation continuous-time base-stock policy. External demands follow independent Poisson processes, and unsatisfied demands at each stage are fully back-ordered. The processing (e.g., production) cycle times and transportation lead times are assumed to be stochastic, sequential, and exogenously determined. We derive recursive equations for the backorder delays (because of stockout) at all stages in the supply chain. Based on the recursive equations, we characterize the dependencies of the backorder delays across different stages in the network, and develop insights into the impact of safety stock positioning in various supply chain topologies. We present approximations and algorithms to coordinate...
Open issues

• Previous works deal with stock positioning w.r.t. costs and service levels

• There is no work that deals with the impact of stock positioning on product quality
Scenarios

• **Scenario 1 (base case COP):** This scenario constitutes the base case of our simulation analysis under a constant-order policy.

  The holding cost is set to 10 cents per punnet per day, the backordering cost is 50 cents per punnet per day, the cost of shipping 1 punnet by boat is 10 cents, the cost for shipping 1 punnet by plane is 30 cents. The solution obtained with GA sets the constant order quantity to $Q=24410$, and the order-up-to-levels for the expedite orders placed from Monday to Friday to $Se=[4065, 36471, 24434, 36626, 36632, 6800]$, respectively. This policy, when implemented at the distributor, has an expected total cost of 1405$ per day.

• **Scenario 2 (base case DIP):** This scenario constitutes the base case of our simulation analysis under a dual-index policy.

  The holding cost is set to 10 cents per punnet per day, the backordering cost is 50 cents per punnet per day, the cost of shipping 1 punnet by boat is 10 cents, the cost for shipping 1 punnet by plane is 30 cents. The solution obtained with GA sets the order-up-to-level for the regular order on Monday to $Sr=49625$, and the order-up-to-levels for the expedite orders placed from Monday to Friday to $Se=[24661, 17009, 25976, 36985, 36964, 17252]$, respectively. This policy, when implemented at the distributor, has an expected total cost of 1421.3$ per day.
Scenarios

• **Scenario 3 (climate change COP) & Scenario 4 (climate change DIP):** In these scenarios we assume that open-air temperature at the producer is impacted by climate change. We therefore consider an open-air temperature that is normally distributed with mean 16 °C and standard deviation of 3 °C. Scenario 3 implements a constant order policy, while scenario 4 implements a dual-index policy under these modified temperature conditions.

• **Scenario 5 (repacking COP) & Scenario 6 (repacking DIP):** In these scenarios we assume that repacking activities impact mean and standard deviation of storage temperature at the distributor. Repacking is carried out at a temperature of 10 °C. We therefore consider an overall storage temperature at the distributor that is Normally distributed with mean 3 °C and standard deviation of 0.75 °C. This modified temperature distribution accounts for the additional variation introduced by repacking activities. Scenario 5 implements a constant order policy, while scenario 6 implements a dual-index policy under these modified temperature conditions.
Scenarios

• **Scenario 7 (higher quality punnets COP) & Scenario 8 (higher quality punnets DIP):** In these scenarios we assume that the initial quality of a batch at \( t=0 \) is uniformly distributed in \( 0.3 \pm 0.250 \) as opposed \( 0.8 \pm 0.7 \) in the base case.

That is, we consider punnets in which 0.0005 up to 0.0055 percent of the strawberries are affected by Botrytis cinerea. We aim to assess the impact of higher quality products that enter the chain. Scenario 7 implements a constant order policy, while scenario 8 implements a dual-index policy under these modified initial quality conditions.

• **Scenario 9 (higher fuel costs COP) & Scenario 10 (higher fuel costs DIP):** In these scenarios, we assume that the expedite shipping cost per punnet rises to 50 cents, cost for regular transport is not affected.

Scenario 9 implements a constant order policy, while scenario 10 implements a dual-index policy under these modified shipping costs.
## Scenarios

Scenarios
1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
7 & 8 : Higher quality
9 & 10: Higher fuel costs

### Table 1: Simulation results

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<tr>
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<th>Age at consumption (hrs)</th>
<th>Retailer waste (punnets)</th>
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<tbody>
<tr>
<td></td>
<td>μ</td>
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<td>11.8</td>
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<td>21.4</td>
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<td>252</td>
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Scenarios

Heavy tailed system! Figures not very enlightening.

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Product quality at consumption

Scenarios
1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
7 & 8 : Higher quality
9 & 10: Higher fuel costs

Scenario 1
Product quality at consumption

Scenarios
1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
7 & 8 : Higher quality
9 & 10: Higher fuel costs

Scenario 2

2/8/17
Scenarios
1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
7 & 8 : Higher quality
9 & 10: Higher fuel costs

Product age at consumption

Scenario 1
Scenario 2

Product age at consumption

- Frequency
- age (hours)

Scenarios:
- 1 & 2: Base
- 3 & 4: Climate change
- 5 & 6: Repacking
- 7 & 8: Higher quality
- 9 & 10: Higher fuel costs
Quality at consumption

Scenarios
1 & 2 : Base
3 & 4 : Climate change
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Age at consumption

Scenarios
1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
7 & 8 : Higher quality
9 & 10: Higher fuel costs
Retailer waste

Scenarios
1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
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9 & 10: Higher fuel costs
Discussion

RQ1. Does a dual sourcing inventory control policy, whilst reducing costs, guarantee a sufficient quality at consumption and reasonable waste?

• A dual-index policy performs poorly compared to a constant order policy.

• Note that, as shown in (Klosterhalfen et al., 2011) none of these policies dominate the other from a cost perspective.

• the more constant inflow of fresh products ensured by a constant order policy guarantees higher quality at consumption and reduces waste at retailers.

• both the policies perform poorly with respect to the given acceptance criterion.
Discussion

RQ2. How sensitive is a dual sourcing policy to variations of initial quality and temperatures along the chain?

• an increase of the mean and of the standard deviation of the open-air temperature at the producer has only a marginal effect on the KPIs considered in this work.

• Repacking activities do impact product quality at consumption and retailer waste as demonstrated in scenario 5 and 6.
Discussion

RQ3. What is the impact of fuel cost variation on final product quality and on waste?

- an increase in transportation costs for expedited shipments has a detrimental effect on quality and waste.
  - The management should be aware that in such a situation, a mere optimization of the expected total cost of running the chain represents a poor strategy.
  - Any optimization model employed should carefully strike a balance between cost reduction and quality loss due to the increase of products shipped via regular orders.
Future work

• Impact of controlled atmosphere in the warehouse is not taken into account.
  – Products are typically stored under modified CO2 concentrations that tend to reduce or even stop mold growth.
  – Advanced model for strawberry quality include the effect of CO2 concentration. In this sense, results presented may be seen as worst-case scenarios, since in a modified atmosphere, mold growth will be significantly slower.

• the optimization algorithms adopted for computing near-optimal inventory control policy parameters are heuristics.
  – Future works may investigate difference observed when an optimal control policy is implemented.
  – a challenging area for further research is the development of optimization models for dual sourcing that include service level constraints involving product quality.
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A final remark...