SMART Tomato Supply Chain analysis for Rwanda: identifying opportunities for minimizing food losses
This report was written by:

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1. Introduction

1.1 Background

Agriculture is a significant driver of Rwanda’s economy. Agriculture accounts for 32% of the GDP and employs more than 70% of the country’s population. However, Rwandan agriculture is very fragile. A major subsector is horticulture which compromises among others the production of fresh fruit, vegetables, and flowers. Sustainable development of the horticultural sector in Rwanda is important to realize food security, reduce poverty, and sustain the environment.

Tomatoes are an important horticultural crop in Rwanda. Tomatoes are produced on a total area of 6,800 ha, primarily in the open field. The production is bound by seasonality. As a result, Rwanda is a net importer of tomatoes, mainly from neighboring countries, such as Uganda. In addition, the demand for fresh tomatoes is increasing due to the economic growth and the rise of urban middle class.

Most smallholders lack essential resources and have problems to realize high yields and maintain quality while handling and storing their produce. The value chain is organized in an informal matter, with a dominant position for (travelling) middlemen. They buy early in the morning from the smallholders and sell at the wholesale markets in the city. During this process, tomatoes are badly stored or hardly cooled which is leading to a significant decrease in the quality of the tomatoes and high post harvest losses in the supply chain.

In light of the SMART project, this report analyses the post-harvest processes in the tomato value chain in Rwanda, and provides suggestions for practical improvements in post-harvest handling.

1.2 SMART project

The Dutch horticulture sector occupies a prominent position in worldwide greenhouse technology. The Dutch Horticultural Trade Board (DHTB) is a cooperation of 39 organizations and companies aiming to stimulate the export of horticulture supply products and technology. Besides export of high tech greenhouse technology, a growth is expected in the demand and need for medium and low tech greenhouses in the horticulture market. DHTB has taken the initiative to design a new concept for medium and low tech greenhouses adapted to local climatic and economic circumstances. This project idea has developed into the SMART (Smart Adaptive Sustainable Horticulture) project.

The SMART project is a public private partnership between Dutch leading horticulture companies, Dutch knowledge institutions, and local companies. The objective of the program is to make innovative horticulture technologies available for smallholders in Rwanda and South-Africa and in this way contribute to food security.
The challenge is offering technologies and practices that fit the local growing conditions and that are affordable for local producers. Within the SMART project a pilot venture is realized with a local partner to test and operate the SMART greenhouse. The partner is committed to share technologies within its value chain and beyond. In the case of Rwanda, the local partner is Rwanda Best Company.

1.3 Rwanda Best Company (RBC)

The company of Jean Claude Ruzibiza (RBC) is a mixed farm with approximately 10,000 chickens with a weekly supply of 65,000-85,000 eggs and horticulture production of various fruits, vegetables and flowers. Main vegetables produced are tomatoes, peppers and onions. For this two greenhouses are available, but the greenhouses are poorly designed, and will be replaced by newly designed greenhouses in fall 2015 in light of the SMART project. This will also be the starting point for RBC to increase the production of tomatoes significantly. RBC has produced tomatoes in the past and from this period still has good contact with various hotels and high end retailers in Kigali. This offers good opportunities to supply them.

1.4 Value chain analysis

This report is limited to the value chain of tomatoes in Rwanda (Work Package 3). The objective of this Work Package (WP) is to improve the value chain for tomatoes and to support the implementation of practical solutions in order to reduce the post-harvest losses along the value chain. The following activities are part of this WP:
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1. Diagnose
2. Mission and workshop
3. Design and final reporting
4. Support and implementation
5. Monitoring

Activity 1: Diagnose
This activity identifies the current situation of the value chain and supply chain in relation to:

- Logistic- and information processes in relation to the supply chain, including:
  - Presence of cold chain
  - Storage
  - Lead time (time to market)
  - Loading factor
  - Current post-harvest losses
  - Conditions and limitations for transportation
  - Role of out growers

- Economic aspects of the value chain, including:
  - Margin division between actors
  - Market segments
  - Price difference between qualities

- Stakeholders
  - Identification of the key stakeholder
  - Role of the stakeholders

Special attention is paid to open field tomato farming versus greenhouse farming and especially to the situation of Rwanda Best Company (RBC). In addition, post-harvest practices applied in other African countries and The Netherlands are considered, and opportunities to reduce current post harvest losses are analysed.

Activity 2: Fact finding mission
A short mission was organized in November 2014. An important part of the mission was to interview the key stakeholders in order to collect information on the dynamics, bottlenecks and opportunities in the tomato value chain.

Activity 3: Design and final reporting
This activity is related to the final design of the possible interventions that contribute to an improved value chain for tomatoes in Rwanda. The design will address recommendations for the main bottlenecks in order to reduce the post-harvest losses.

Activity 4: Support and implementation
Some of the recommendations can be implemented by key stakeholders during the project. As part of WP 3, we will assist RBC and other key stakeholders in the tomato value chain in order to imple-
ment the recommendations in order to improve the value chain performance.

Activity 5: Monitoring (2017)
During activity 1 the current post-harvest losses are identified, based on desk research and validated during our field research. Depending on the possible implementation of post-harvest interventions (which was not foreseen in the SMART work plan and budget) the losses will be monitored. The aforementioned data on post-harvest losses will then serve as a baseline for this monitoring.
2. Problem analysis of current situation

In this chapter the current value chain with regard to the tomato production and the logistic processes from farmers to markets are described. It gives insight into existing dynamics and bottlenecks.

2.1 Horticulture Rwanda

Horticulture is still a rather small sector within the agricultural sector. However the Rwandan government wishes to accelerate the development of horticulture in Rwanda, given its relatively high productivity per m², and higher value per kg.

The total area under vegetable production was about 95,000 ha in 2013 (Table 1). The total area of vegetables has almost doubled compared to the 2008 figures. The total production volume of vegetables was 678,000 tonnes. Production of tomatoes in 2013 was only 123,000 tonnes realised on a total area of 6,300 ha. The productivity of the tomato production in Rwanda has increased with almost 300% since 2008. It is estimated that around 239,000 households are involved in tomato production.

With regard to protected cultivation (e.g. production in a greenhouse) of vegetables, this is still very limited and no official figures are known. Currently, only one type of greenhouse is sold by the company Balton. Since its start in 2010, the company has sold about 400 greenhouses, what would roughly indicate that less than 7 hectares is currently under greenhouse cultivation in Rwanda.

Table 1: Area (in 1,000 ha) and production (tonnes x1,000) of different vegetable crops. Source: FAOSTAT
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**Seasons in Rwanda**
Rwanda has two rainy seasons (A and B seasons) - the long rainy season (B) from mid-February up to May and the short rainy season (A) starting with mid-September to mid-December. A dry season or season C starts from the beginning of June to the beginning of September. This season is usually used for planting in marshlands. The rainfall and temperatures vary in different parts of the country. In general it is drier and warmer in the interior and East whereas there is heavier rain and lower average temperatures in the North and West.

**Pest and diseases during the rainy season**
For growing tomatoes in the open field the influences of the seasons can have a strong influence on the disease pressure on the tomato plants. Tomatoes suffer drought stress during the dry season as well as pests and diseases which pose serious problems on production. During the wet season there are even more problems with pests and diseases. For instance, late blight and Downey can damage tomatoes in the field during rainy season. For farmers in Rwanda these climatological conditions lead to low productivity. But also give high risks, a low return on investments and a low income. In general it is drier and warmer in the interior and East whereas there is heavier rain and lower average temperatures in the North and West.

**Tomato yields and revenues**
The table below gives an overview of potential revenues for a year of tomato production in Rwanda for open field production. Figures are based on interviews with stakeholders and represent a dry and wet season, the stakeholders indicated that possible yields are slightly higher compared to the national average. The difference in the perception of these stakeholders and the actual yields realized could be explained by the incidence of pests, dry spells and other natural factors mentioned above, that play an important role in tomato cultivation. The effects of many of these influences can be moderated by applying greenhouse production.

In the dry season a yield of about 20 tons per hectare are reported (2 kg per m²) and in the wet season a yield of 40 tons per hectare are reported (4 kg per m²). Most farmers in Rwanda only cultivate a single acre with tomatoes so that means that from the estimated revenues of RWF 10 million only RWF 4 million is possible (Table x). However during the dry sea-

![Figure 1: Tomato planting schedule. Source: Ntirushwamaboko, 2013](image-url)
son many smallholder farmers do not produce tomatoes due to difficulties with obtaining sufficient water for irrigation.

<table>
<thead>
<tr>
<th>Dry season</th>
<th>Wet season</th>
<th>Total per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>20,000 kg per ha production</td>
<td>40,000 kg per ha production</td>
<td>60,000 kg per ha production</td>
</tr>
<tr>
<td>200 RWF per kg average sales price</td>
<td>150 RWF per kg average sales price</td>
<td></td>
</tr>
<tr>
<td>4,000,000 RWF per ha average revenue</td>
<td>6,000,000 RWF per ha average revenue</td>
<td>10,000,000 RWF per ha average revenue</td>
</tr>
</tbody>
</table>

*Table 2: Estimation of production (kg), selling price (RWF) and revenue (RWF) in the dry and wet season*

It is difficult to present precise calculations about the exact costs that occur during the production of tomatoes. As a consequence we are not able to calculate the actual profitability. However, it is clear that losses during production and post-harvest losses further up in the value chain have a substantial effect on the income of the farmers and other value chain actors. We will discuss this in more detail in the following paragraphs.

### 2.2 The value chain

The current value chain of tomatoes is presented in the figure below. We found a strong dominance of traders (middlemen) and wholesale traders. The lion share of all vegetables are traded via different wholesale traders. There are only a few farmers that directly supply to retail.

*Figure 2. The current supply chain of tomatoes in Rwanda*
A typical supply process, from tomato harvests to the market is as follows:

- Harvest on day 1;
- In the night storage of tomatoes on plastic on the ground;
- In the early morning (04:00) sale to the traders at the farm; transport from the farm to the market in a large traditional basket (20 kg) facilitated by the traders;
- Market sales from the basket in other smaller traditional baskets to the customer.

Of course different small variations in this process occur. For example traders that buy the tomatoes at the rural markets instead at the farm gate. The average time to market from farmer to market is approximately 24 hours.

**Production**

Subsistence farming is dominant. As discussed before, the current productivity is well below potential, and income levels in agriculture are low. Most farmers are organized in cooperatives throughout the country. However most cooperatives do not provide support in activities such as marketing, sorting, storing and grading. This leads to limited bargaining power towards traders. In addition individual farmers don’t have the capacity to trade directly on the wholesale market, since they are not able to organize transportation and they lack the time and skills to do business at the wholesale markets.
**Wholesale markets**

Traveling wholesale traders buy the tomatoes directly from the farmers along the road or at rural markets. They know exactly where the produce can be sourced during a certain period of the year, and to be more precise, during which day of the week. Due to lack of capacity of farmer to trade directly on the market farmers receive a low price for their produce, a farmer is paid between 150-200RWF per kg by the trader and at the wholesale market the tomatoes are sold by the trader for 300-400RWF per kg. However costs for collection and transportation are expected to represent a large share of the price difference.

Almost all tomatoes are sold on daily spot markets, where there are no facilities to cool and store tomatoes. In Kigali there are a number of large wholesale markets. One of the leading markets is Kimisagara. Here travelling wholesale traders bring their goods in the early morning. On the market, the tomatoes (also some leftovers from the day before) are sold to retailers. Often small shop owners that sell fruit and vegetables to consumers. However also restaurant owners buy their produce at these markets. The tomatoes are traded on stands that have basic sun covers. Often the produce is lying unsorted and unpacked on plastic sheets. Along the corridors of the market, there are cupboards where the sales ladies store the produce that they didn’t sell the day before. They simply pick up the plastic sheets on which the tomatoes are lying, and then putting this all together in the cupboards. At the moment of our visit the volume of tomatoes was limited and the observed quality was poor.

**Retail and other market segments**

Rural consumers mostly buy at the local markets or consume their own production. Urban consumers buy at the larger open air markets, or in small shops and stalls. There is an upcoming middle class in Kigali but the high end market remains small and mainly focusses on expatriates. As a result, the more modern retail outlets are gaining importance, such as supermarket chain Nakumatt, but also independent supermarkets such as Frulep. This market segment has higher quality standards compared to the traditional local markets.

Nakumatt is the main supermarket in Kigali and is part of the Nakumatt Holdings from Kenya. They have various shops in Kenya and the East African region. In Rwanda Nakumatt is considered to be very expensive and mainly serves the upper class. Nakumatt is one of the few stake-
holders that works directly with the farmers. On average they deal with 5-6 farmers, but there are fluctuations during the year. The vegetables are sourced from different areas in Rwanda, as far as Gisenyi (in the North on the border with the DRC), if the price is more attractive. The farmer arranges the transport to Kigali, and covers the transport costs and risks. Nakumatt also visits farmers frequently for quality assurance.

After delivery, the tomatoes are sorted at the supermarket loading area, and then repacked by Nakumatt staff in plastic crates. Clients can pick the tomatoes themselves and pack in small paper bags. This makes a number of “repacking” moment, which are not favourable for the quality of the tomatoes.

Other segments of the market with high quality standards are the upscale hotels in Kigali such as Hotel Des Milles Collines and Hotel Umubano, who both require high volumes of quality tomatoes. The tomatoes are delivered daily by truck in plastic crates and are supplied by a single trader. Umubano works with a single supplier with a half year / year contract. In general, the quality of the tomatoes is acceptable. Rejections of supplied tomatoes only happens occasionally.

When the season is low (in the dry season the supply of vegetables such as tomatoes is very low) and sourcing of high quality tomatoes is a challenge, the hotel is willing to pay a higher price in such circumstances. At the hotel kitchen the tomatoes are stored in cooled conditions. This is the first moment that tomatoes are cooled after harvest. However the tomatoes have already lost quality before they enter the cold store of the hotel.

Cross border trade
The export of tomatoes to neighbouring countries or further (by airfreight) is negligible for the moment. It is mainly limited on cross border trading activities with DRC and these trade flows are not documented in the official statistics. There are various reasons for the limited export, including the low quality of the tomatoes, the lack of a cold chain and high costs of airfreight. As a whole the tomatoes from Rwanda do not have very strong competitive position compared to other countries in the region, like Uganda and Tanzania. Where quality is high and prices low.

During times of undersupply of tomatoes in the market (for instance during the low season), there are large quantities of imported tomatoes from neighbouring countries, mostly from Uganda and Tanzania.
**Table 3. Import of tomatoes in Rwanda in 1,000 tons. Source: UN Comtrade.**

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uganda</td>
<td>9</td>
<td>888</td>
<td>3,266</td>
<td>1,027</td>
<td></td>
</tr>
<tr>
<td>Tanzania</td>
<td>89</td>
<td>1,280</td>
<td>1,361</td>
<td>631</td>
<td></td>
</tr>
<tr>
<td>Burundi</td>
<td>0</td>
<td>11</td>
<td>117</td>
<td>236</td>
<td></td>
</tr>
<tr>
<td>Kenya</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>79</strong></td>
<td><strong>2,179</strong></td>
<td><strong>4,747</strong></td>
<td><strong>1,900</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Transport**

The tomatoes are transported from farmers to wholesale markets in Kigali or directly to the customers in case of the hotels and supermarkets. The transport is facilitated by the traders. They generally use small (pick-up) trucks with a capacity varying from 0.75 ton (small pick-up truck) to 3 tons (small truck), e.g. ISUZU ELF truck 2-tons.

There is no cold chain, and tomatoes are transported to the market in open or closed trucks. The load factor of the trucks is high (see picture above) creating serious damage and losses. For transport to hotels, the regulations (equivalent to HACCP) require crates; cooling is being advised, but is not required, and in general is lacking.
The transport from farmers to the rural market is by foot or bicycle. Packaging is done in all sorts of baskets (plastic, organic material), which are carried on the head or on the back of the bike (often heavily overloaded with direct exposure to the sun), see pictures below. These baskets carry up to 20kg of tomatoes and provide no protection during transport.

Besides the poor protection provided by the baskets, in the entire logistic chain the tomatoes are repacked with each transaction that takes place in the chain. These numerous handling activities are also a cause for post-harvest losses and low quality of tomatoes at the end of the chain.

**Storage**

At the farm and the market there are no cold storage facilities available. The tomatoes are stored on the ground if needed covered by canvas. At these markets the shelf life for tomatoes is only about 1 to 3 days. Supermarkets and hotels store fruit and vegetables in cold storage facilities. The stock lifetime for tomatoes at the supermarkets and hotels can go up to 10 days, depending on the quality of the tomatoes.

Looking at the enabling environment of the tomato value chain, cold storage facility is available at the airport of Kigali, which has a capacity of 45 tons divided over three cold storage rooms. This storage is for export purposes. The cold storage facility at the airport is used little, because of the high additional costs and little added value in the process of exporting vegetables and fruit by air. The current export of fresh fruit and vegetable is very low and when used the goods are delivered at the airport just 2 hours before take-off, which provides sufficient time for the required administrative processes and handling processes and doesn’t require cooling. As a result, under the current conditions there seems no need for storing perishable goods at the airport for a longer time. In addition to this, four smaller cold storage facilities (capacity 5 tons) are available at logistic hubs distributed over the country (2 in the West at the border with Congo; 1 in the North and 1 in the South) to facilitate cross-border trade, but we could not verify whether these facilities are operational.

**Post-harvest losses**

When talking about post-harvest losses, reference is not only made to the loss of produce. Losses also refer to any decrease in the mass, appearance, caloric and/or nutritional value of edible food intended for human consumption at any stage in the food value chain. A loss of economic value happens, often reflected in the price per kg that a seller can get from a buyer (qualitative losses), or
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in the total volume that a seller can offer (quantitative losses). For instance, directly after harvest, the weight (volume) of vegetables can decrease because of evaporation due to high temperatures. During handling and storage food can get degraded by, damage, pests or diseases. During processing and packaging, vegetables can get damaged or bruised. Preventing such qualitative or quantitative losses can greatly benefit both farmers (less loss of economic value) as well as customers (more nutritious food available because of retention of quality).

An extensive study by WFLO (2010) gives detailed information about post-harvest losses in Rwanda (physical losses, sorted out before sales). They range from 7.8% for tomatoes at farm level to 14.7% at retail level (see table below for more details). In total about 33% of the tomatoes are sorted out before sales, however the sorted out share is often sold at lower prices (one-third of market price). However in Rwanda even highly bruised or dried out tomatoes still have an economic value and used for own consumption, sold to consumers hat have little money to spend, or used as animal feed.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Air temp.</th>
<th>Pulp temp.</th>
<th>Time from harvest (hrs)</th>
<th>% decay</th>
<th>% damage</th>
<th>Cumulative % of decay and damage</th>
<th>Actual % sorted out before sale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm</td>
<td>10</td>
<td>25.9</td>
<td>29.8</td>
<td>6.0</td>
<td>2.0</td>
<td>8.0</td>
<td>7.8</td>
<td>7.8</td>
</tr>
<tr>
<td>Wholesale</td>
<td>10</td>
<td>24.6</td>
<td>22.1</td>
<td>32.3</td>
<td>2.9</td>
<td>9.9</td>
<td>10.7</td>
<td>10.7</td>
</tr>
<tr>
<td>Retail</td>
<td>10</td>
<td>26.1</td>
<td>23.3</td>
<td>60.0</td>
<td>6.5</td>
<td>12.5</td>
<td>19.0</td>
<td>14.7</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>15.4</td>
<td>21.5</td>
<td>36.9</td>
<td>33.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Tomato postharvest losses in Rwanda at the farm level. Source: WFLO, 2010

**Processing**

In general, there is little processing of vegetables taking place in Rwanda, one of the main reasons for this being that it is difficult to compete with imports of cheap processed products such as tomato sauce and ketchup. On a large scale, the company Sorwatom has been struggling for years to become financially sustainable in the production of processed tomatoes (i.e. for ketchup), and is so far not succeeding. Also other, more small-scale initiatives in processing have been identified (such as Mayaga Processing company for tomatoes and Shekina for Cassava leaves and other vegetable products) but all these initiative struggle to reach a financially sustainable scale and/or to meet the quality criteria set by the government.
2.3 Conclusions

Concluding remarks on the main problems and bottlenecks in the value chain from farmers to the end-customers which lead to the high degree of post-harvest losses are summarized below:

- There is no cold chain storage, transport means and facilities in the logistic chain available;
- Tomatoes are packed in baskets and transported by trucks. The trucks are often overloaded and this seriously affects the quality of the tomatoes and can reduces the shelf life;
- Tomatoes are passed and re-packed from one means of packaging to another means of packaging too many times in the logistic chain;
- Lead time from harvest at farmers to end-customers is approximately one day, leaving enough remaining shelf life for the tomato (2 to 3 days). However, if this lead time is delayed in any way it quickly leads to additional post-harvest losses due to the short shelf life and bad temperature conditions for the tomatoes in the entire logistic chain.
- Proper storage directly after harvest (at the farm) and improved coordination between supply and demand could minimize losses early in the value chain.
- There is little recent information on exact post-harvest losses, but based on the literature estimations are between 30 and 40%.
- Post-harvest losses can be decreased by promoting improved post-harvest practices. E.g. by introducing sorting and grading and improved utilization of the current storage facilities.
- There is an upcoming middle class in Rwanda but the high end market remains small and mainly focusses on expatriates. There are only 3 supermarkets that demand small quantities of tomatoes. Compared to the total market for tomatoes the high end market constitutes less than 1% so (market) incentives to minimize losses and increase quality are very limited.
- Individual farmers don’t have the skills and capacity to trade directly on the wholesale market.
- Farmers are badly organized leading to limited bargaining power towards traders.
- As a result the biggest margins at traders / middlemen. However they also fulfil an important role in the value chain by aggregating tomatoes and providing transportation to the market.
3. Survey of Best Practice solutions for existing bottlenecks

3.1 Small-scale post harvest technologies

In the following part of the text, some post-harvest technologies will be highlighted, that can help prevent losses in the tomato value chain in Rwanda.

Why small scale?

The horticulture sector in Rwanda is a relatively small sector, both in terms of total volume as well as in terms of the size of the average farming operation. It therefore does not make sense to focus this report on large scale solutions, as the capital that is needed to implement these, is often not available with the farmers.

Next to that, research by Lisa Kitinoja (for references, see reference list at end of document) has shown that large scale post-harvest solutions (such as pack houses, coldstores) often are less successful because of:

- Problem with selection of sites (poor location for growers makes access difficult)
- High costs of energy for operation (electricity, fossil fuels) and unreliable electricity supply
- Lack of trained local personnel needed for successful management.

Especially the first two factors could be an explanation for the low use of the current airport’s cold store facilities as was observed during a site visit. Similar interventions that are planned by the Rwandan government (such as the Kigali Wholesale Market and the Kigali Logistics Platform) could also encounter this challenge if the importance of appropriate scaling is not taking into consideration in the final design of these interventions.

Small scale solutions for the various phases of the post-harvest process

A number of publications on small(er) scale solutions for post-harvest losses have been studied. Interestingly, the majority of the publications dealing with post-harvest solutions in Africa were written by the Horticulture Innovation Lab project implemented by UC Davis from the US, and funded...
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by the Feed the Future program of USAID. Most notably Dr. Lisa Kitinoja has issued a number of interesting publications on the topics. The following analysis is primarily drawn from the publications on her field work in countries such as Tanzania, Ghana and India. The analysis is focused on the different steps in the post-harvest process, from harvesting and handling until processing in the form of drying and mixing.

For each of the technologies, a cost-benefit analysis has been made. The results of this can be found in detail in Annex 1, and a summary of the analysis can be found in the technology descriptions below.

### 3.2 Harvesting and handling

**The problem**

Reducing losses already starts at the harvest itself. One of the key issues in harvesting is the loss of quality of the product due to temperature: high temperatures are well known to result in increased rates of respiration, deterioration and water loss in fresh produce. Often products are harvested at the wrong time of the day and/or under wrong conditions, leading to a very high temperature in the pulp of the product immediately after harvesting. Depending on time of day, this pulp temperature can vary more than 10 °C. This can already diminish the shelf life of the product with up to 50%.

In a 2010 research in Rwanda, the following average temperature in tomato was found (versus ideal temperature of around 15 °C) Farm: 30.1 °C Wholesale market 22.1 °C Retail market 23.4 °C [3]. These temperature differences show the need for a decrease in temperature during the harvesting, handling, storing and transporting of tomatoes in Rwanda. Temperature differences are practically not preventable but by harvesting at cooler times, shaded storing and transport can reduce temperature increase and increase shelf life.

As a general rule of thumb, a decrease in produce temperature of 10°C will extend potential shelf life by 100%. For example, tomatoes handled at ambient temperature of 35°C will have a shelf life of 3 days, while at 25°C they will maintain good quality for 6 days. The perfect temperature for a tomato to be conserved is 15°C. The maximum shelf life then is 14 days, so up to 5 times longer than the shelf life at 35°C.
What's the solution?
Time of harvesting is an important, simple solution. Harvesting early in the morning when temperature is still moderate can help, but what can also help is minimizing the direct effect of sunlight on the process of harvesting, by performing the handling (i.e. putting the tomatoes in crates/baskets) under a cover so as to provide shade during the process. This can be done relatively simple by providing shading through covers. An example of this can be seen in the image on the previous page.

During the trials for the Horti CRSP project, a shade structure was constructed at the AVRDC site in Tanzania. The total costs for the construction were $150 USD. A particular green 60% PolyNet shade cloth (from India) was used. [5] In a similar trial in Cape Verde, the total costs for the shade cover (with lower quality cloth material), were only $ 33. It is estimated that the relative costs in Rwanda to construct a similar shade cover with lower quality cloth material, are in line with the Cape Verde experiences.

What are the costs?
$ 33 - $150 (See above)

What are the benefits?
Trials using the shade covers in Cape Verde have demonstrated that for tomatoes, the losses in the product can be diminished by 30%. From the cost-benefit analysis it can be derived that the investment can be repaid within 5 weeks if an average harvest of 100 kg of tomatoes per week is realized. After those 5 weeks, an additional $ 6,75 per kg can be earned using this simple technology.

Additional measures
In addition to shade covers sorting of the harvested crop of tomatoes into first class high quality tomatoes and second class lower quality tomatoes can also improve the total value in the supply chain of tomatoes. First class high quality tomatoes can be sold for a higher price to the high end market segment and should be handled throughout the entire supply chain with more care. The second class lower quality tomatoes can be sold at local markets for a lower price. Using the local markets ensures a short time to market and prevents further quality loss in the supply chain.

3.3 Packaging and transport

The problem
A lot of different packaging modalities can be observed in Rwanda to transport fresh produce, ranging from traditional baskets to wooden crates to no packing at all. For tomatoes, the common mode of packaging for transport seems to be a basket. Frequently, it even serves as a metric unit for transactions: one basket is x amount of francs. What can be observed is that there are two big risks for quality loss of tomatoes in this mode of transport.

One is that the volumes packed in one basket is simply too high. Experience from research in Tanzania (where they use big wooden crates that can hold up to 50kg for transporting tomatoes) shows
that replacing the large crates that are normally used with smaller and/or plastic crates, can bring down damage from 50% (normal with big crates) to only 5%.

The other is that the baskets might last only a few times because they break easily since natural materials are used and the baskets are often overloaded. Next to that, they are difficult to clean, leading to a higher risk of infection for the tomatoes that are transported.

**The solution**
The introduction of plastic crates could be a good solution to combat this. Because the crates have a much lower height than the baskets, the damage to the lowest tomato’s by the weight of the overlying tomato’s is less. These crates (even though more expensive in purchase) can be cleaned easier, last longer (can be used 100+ times) and minimize the loss of quality/damage to the tomatoes. Crates can be stacked without getting additional pressure on the lowest tomato’s in the lowest crate. Crates can be bought in Kenya for an average prices of USD 6. The Kenyan company Kenpoly seems to be the best opportunity for this.

Not only can the crates themselves prevent losses, an efficient use of the crates in the chain can also minimize the number of times the tomatoes are repacked in different crates, if the crate can be exchanged by different partners, in other words, the crate circulates through the chain. However the use of plastic crates in the logistic chain in this circulatory way, requires collaboration of all the partners involved in the logistic chain to achieve a closed loop logistic chain for plastic crates. Otherwise, the plastic crates will soon disappear, because they are valuable assets for all sorts of logistic processes. From experiences in the Netherlands with plastic crates for distribution of vegetables in supermarkets the following suggestions are recommended:

- formation of a foundation for the management and control of a mutual pool of jointly owned plastic crates;
- all partners using the plastic crates should be part of the foundations (mainly the farmers and retailers, traders, hotels);
- set up and operate a registration system for keeping track of number of crates in use by various partners;
- set up and operate a mutual cleaning facility for cleaning of the plastic crates;
SMART Tomato Supply Chain analysis for Rwanda

- mutually agree on responsibilities and roles in the management and control of the plastic crates; (example responsibilities for traders and/or transporters: picking up excess crates from supermarkets and/or farmers);
- develop a manifest with rules for proper use of the plastic crates; (example rules for farmers and/or supermarkets, hotels: maximum number of crates at hand; maximum number of days to keep crates at location);
- mutually agree on a fixed membership fee and a fee per crate (for the rent of the plastic crates) to cover the costs of management and control and cleaning of the crates;

Such a system clearly needs the involvement of a central organization within the sector. The government could take up such a role in Rwanda, but also sector organizations such as RHIO could take the lead in this.

What can even further improve the effect of better packaging during transport is the use of isolation material as is depicted below. Here, a cover made out of a material called reflectix is used to fully cover three stacked plastic crates, herewith bringing down the average temperature in the crates. This cover reflects sunlight and insulates, thus keeping cool products longer cool and reduces heating up. Preventing direct sun radiation is beneficial anyway. Care has to be taken on locking up of moisture inside the packaging that cause spoilage. Small ventilation openings on top will prevent this. The exact effect of this is currently being studies by the HortiCRSP team, hence no concrete results can yet be identified.

**What are the costs?**

This depends a bit on import duties, transport costs etc. Assuming that the plastic crates are not directly available in Rwanda, the best option is to import from Kenya. The company Kenpoly offers plastic crates at a price of $5 per crate. However a minimum order of $3000 is required. This would imply an intermediary company is needed, importing the crates from Kenya. It is not clear what the reflectix cover would cost, so this option is not included in the costs/benefits analysis.

**What are the benefits?**

A study in Cape Verde indicated that by simply using plastic crates instead of wooden, 30-50% loss can be prevented. Working with the conservative figure of 30%, an investment in 10 crates (total $90) can be repaid in 10 weeks, assuming an average harvest of 100 kg of tomatoes per week. After those 10 weeks, an additional income of $9 per week/per 100 kg can be earned.

### 3.4 Packaging and transport

**The problem**

Tomatoes cannot always be sold directly on the market. Sometimes it is more beneficial to properly time the sales of tomatoes to fetch a higher price, if the market allows and sometimes it is required to store tomatoes until a full truckload is achieved. However, temperature and conditions (as was discussed above) are not beneficial to storing tomatoes in Rwanda. Also, large scale cooling soluti-
ons (such as cold stores) are simply too expensive for farmers (and often not available).

The solution

A low cost solution can be found in so-called evaporative cooling. Evaporative cooling extends the shelf life of tomatoes, and avoids spoilage by keeping food at lower-than-room temperatures without having to use electricity. Evaporative cooling can be realized by building a special cooling chamber with regular addition of water.

The basic structure of the cooling chamber can be built from bricks and sand. First the floor is built from a single layer of bricks, then a cavity wall is constructed of brick around the outer edge of the floor with a gap of about 75mm (3”) between the inner wall and outer wall. This cavity is then filled with sand. The whole structure should be protected from the sun by making a roof to provide shade. After construction the walls, sand in the cavity is thoroughly saturated with water. Once the chamber is completely wet, a twice-daily sprinkling of water is enough to maintain the moisture and temperature of the chamber. Such an evaporative cool chamber is also known as a ZECC (Zero Emission Cold Chamber). From different pilots by the Horti CRSP program and the organization Practical Action, information is gathered on construction that can hold around 100 kg in 6 medium sized plastic crates. Measures against wild and domestic animals eating the stored tomatoes have to be taken.
This storage structure works especially well in arid and semi-arid regions, during the dry season in other regions, and in locations where night time temperatures are much lower than day time temperatures (mountain zones or at higher altitudes), which makes it well-suited for Rwandan context.

Alternative, low-cost solutions for the ZECC can be found in different renewable-energy based technologies. The Dutch company Mueller has developed a solar-powered small scale cooling facility in Ethiopia for the dairy sector. This cooling facility could also facilitate the cooling of tomatoes in a decentralized way. The sales price of this cooler is not yet clear as the product is still in the R&D phase. Another opportunity is the WAKATI, another evaporative cooling solution powered by solar energy. This option is however more easy to construct than a ZECC, as it can be set-up like a tent construction around a number of crates. See the picture below. The sales price of a Wakati is $100 dollar and measures 150cm by 80cm by 80cm and can contain between 100-200 kg of produce (depending on product).

Lastly, a cold storage facility that might be more relevant for the large scale open markets (so for the marketwomen instead of the farmers) could be the ColdHubs system which is currently being piloted in Nigeria. In this system, a solar-powered cooling facility near markets is centrally operated by the ColdHubs company. Marketwomen, traders/hawkers could store their fresh produce there overnight for a fixed fee of $0.50 per crate per night.

**The costs**
Different (and various) amounts have been found about pilots in different parts of the world, but after consulting NAEB Expert, an average amount of $250 is needed to construct this with bricks and a thatched roof made of local materials. The Wakati is a cheaper alternative at $100. The ColdHubs use a completely different model where there are no upfront investment costs for users, but rather you pay for use.

**The benefits**
For the Wakati we cannot define the financial benefits, as there are not yet research results on the prevention of losses in tomato with the Wakati. Same thing holds for the ColdHubs. For the ZECC, with an investment of $250, the investment can be repaid in 83 weeks by preventing losses (if an average of 100kg per week is harvested and handled). After those 83 weeks, an average of $3 can additionally be earned per week/per 100 kg. This is without the financial benefits that might come from being better able to deal with market prices fluctuations and general market dynamics (by being able to extend the shelf life with 4-5 days).

### 3.5 Packaging and transport

**The problem**
Why dry or process a product that is sold on the fresh market on a daily basis? The main reason is the seasonal oversupply on the market in times of peak harvests. As open field cultivation of tomatoes has its seasonal peaks and drops (in Rwanda mainly in the dry season) in total production quantities,
often an oversupply of the market is occurring during which prices for tomatoes can fall consider-ably. Difference in sales price for farmers (farm gate price) can be as high as 100 to 200 RWF per kg, thus considerably lowering the potential income for farmers. By drying or processing tomato based products are made that are shelf stable for a longer time and can thus be sold (or used) long after the peak harvest.

The solution
By extending the shelf life of the tomato (through drying) or by processing the tomato (through juicing/paste making) a farmer can tap into the right moment for sales, when market prices are high (with drying) and/or can add value to the product (with juicing/paste making). If packed properly, dried tomatoes can be stored for months, and tinned or canned tomatoes can even be stored lon-ger than a year.

Different alternatives for both drying and processing can be observed. With regard to drying, two typical practices can be observed. One is a fairly low-cost alternative in which a solar dryer is built with simple materials. The size can vary from around 1 m2 dryer surface to many dozens of m2 in greenhouse type solar dryers. Examples of this have been found in the LEAF project by the NGO ADRA, who distributed 60 solar driers amongst 50 farmer cooperatives in Kayonza and Gatsibo dis-trict, and by Oxfam GB and Duterimbere MFI.

A larger alternative for this would be a hot air dryer, in which heated air is used to dry the tomatoes instead of using the sun. Also, this alternative relies more strongly on the availability of fuel and electricity. The investment costs are higher, but the volumes that can be handled this way are also
SMART Tomato Supply Chain analysis for Rwanda

higher and drying times are much more predictable. So it is a solution for larger farmers, aggregators or cooperatives in which farmers bundle forces.

Next to drying, with regard to processing into juice, paste or sauce, a lot of different options can be discussed such as canning, pureeing, smoking, pureeing, sterilizing, canning and ranging in solution-size from simple household juicing machines to entire factories. There are only a few examples in Rwanda that are not well documented. The Sorwatom case is the largest tomato processing factory that has been set up in Rwanda, but struggles to get to break-even point. Other cases encountered were the one of Mayaga Processing Company in Nyanza, who were shut down by the Rwanda Bureau of Standards because of poor hygiene practices.

The start of any type of tomato processing is often the pulping of tomato. This can be done with a simple pestle and mortar (100% manual) or with some type of mill. Simple mills or grinders are available in Kenya, for instance at Mixa Food & Beverages. These products are packed in cans or bottles, closed properly and sterilized afterwards.

**What are the costs?**

With regard to the solar dryers, enquiries with ADRA learned that the average costs to have a local manufacturer make a solar dryer are around $220. With regard to the hot air dryers, the most affordable solution seems to be the one of the South-African company Dryers for Africa, which have a container-based hot air dryer available that has a cost (without shipping) of $28600. Rwandan company Shekina uses such a container based hot air dryer for its drying of cassava leaves.
SMART Tomato Supply Chain analysis for Rwanda

The local costs for the different processing opportunities are too difficult to calculate given the wide range of opportunities (from simple household operations to complete factories) and have therefore been left out of this study.

**What are the benefits?**

In contrast with the other post-harvest solutions for which we made an extensive cost-benefit analysis (see annex 1) it is very difficult to make a solid cost-benefit analysis for these processing and drying technologies. This has mainly to do with the fact that price setting for processed products is unclear, and the price fluctuations in the market for fresh tomatoes make it difficult to calculate the average price difference between 1 kg of processed/dried tomatoes and 1 kg of fresh tomatoes.

It can however be said that the more expensive solutions (such as the hot air dryers and the processing lines) will not be achievable for individual smaller farmers, and are only solutions for large scale cooperatives.

### 3.6 Conclusions

As can also be observed in the costs benefit analysis in annex 1, the costs for low tech post-harvest solutions can greatly vary. Obviously, the more expensive solutions (most notably the drying technology and the ZECC) have a higher investment cost and also have a longer pay-back time, making an investment in such solutions less attractive on the short term. To add to this, the average price for fresh tomatoes on the Rwandan market is relatively low, compared to other countries. Because of this low price, it is difficult for these more expensive post-harvest solutions, to earn back the investment. This further limits the incentives in the market to invest in post-harvest technologies.

It can be said however, that these solutions offer an additional potential economic benefits. By being able to preserve and store the produce for a longer period of time, the farmer/producer can benefit from fluctuations in the market prices. This is also a way to reduce post harvest losses of tomatoes, but it is difficult to calculate the exact added value of this.

Next to that, there seems to be a clear need for training on the topic. Again, the HortiCRSP program has gained extensive experience with this, by setting up a dedicated training center in Tanzania together with AVRDC. Several Rwandese students have had trainings at this center, and it seems to be worthwhile to have more Rwandese farmers, policy makers and others attend this training, or to start a similar training center in Rwanda.

It is clear that fresh tomatoes are in high demand in the Rwandan market. However, with solutions that change the nature of the product, such as drying and processing, it is more difficult to connect these products to the market, and to capitalize on the longer shelf life of the product. For example, it is unclear whether there is a market for dried tomatoes, because the dried tomatoes do not seem to typically fit in the dietary habits of the average Rwandan. And so far, no tomato processing company in Rwanda has demonstrated its ability to compete on price with products (such as ketchup) that have been imported.
Another limitation with drying is that the dried produce has to be properly packed, often in plastic packaging. The environmental authority REMA does not very often issue permits for the use of such packaging. That’s also why the prices for these plastic products are relatively high, which adds to the investment costs. Glass bottles or jars or tin cans can be an alternative.
4. Conclusions and recommendations

The current situation with regard to the value chain of tomato production and logistics processes from farmers to the local markets proofs to be troublesome. Many problems occur in the production and the logistics processes which lead to high losses of tomatoes throughout the entire value chain. The most challenging problems are: the unpredictable weather conditions in open field production, the lack of a cold chain logistics process and the lack of good stackable crates. Besides these problems, the lack of a good organised cooperation between farmers prevents them from earning a good price for the produce. This is a barrier for a growing business model and investments in better production facilities (e.g. greenhouses) and logistics means (e.g. stackable crates, cold storage facilities and cooled transport trucks).

Because of the lack of large scale horticulture the most promising solutions are found in small scale postharvest technologies, such as:
- harvesting in the early morning hours when temperature is still moderate and handling of tomatoes under sunshine covers that provide shade;
SMART Tomato Supply Chain analysis for Rwanda

- packaging and transport of tomatoes in stackable (plastic) crates, potentially in combination with isolation material;
- low cost storing solutions for tomatoes which provide cooling, e.g. evaporative cooling by means of a cooling chamber with sprinkling of water (Zero Emission Cold Chamber);

The above mentioned small scale postharvest solutions proof to enable a limited return on investment (ROI) period, varying from 5 weeks (sunshine covers), 10 weeks (plastic crates) to 83 weeks (ZECC).

The introduction of re-usable (plastic) crates in the supply chain of tomatoes requires a closed loop system for the crates. To prevent the loss (theft) of crates in the supply chain, this can only be realised by an active managing and control system for the crates. This should be supported (and financed!) by all business partners in the tomato supply chain (producers / suppliers, transporters / traders and end customers). The system should provide a reliable registration of the whereabouts of all crates in the supply chain (tracking and tracing).

Processing of tomatoes into longer tenable and more durable products does not seem to be profitable because of the required investment and need for large scale processing. Against the current low prices of imported processed tomato products, this will be very difficult to realize in a competitive way.
Alternatively the SMART greenhouse will be installed and operated at Rwanda Best Company. This will considerably increase the yield of production of tomatoes at the farm. Without adequate improvements in the logistic chain from production to end customers (supermarket, hotel, market) a large part of this improvement will be lost in the logistics process. In this study some simple small scale postharvest solutions are provided. It is recommended that a tailored advice for Rwanda Best Company is provided, based on the general findings in this report and the specific situation of the SMART greenhouse and the partners in the logistics chain for Rwanda Best Company.
5. References

- FAOSTAT (http://faostat.fao.org/)


- Makunike, 2007


- Wachira, J (2012) COMPARATIVE ANALYSIS OF GREENHOUSE VERSUS OPEN-FIELD SMALL-SCALE TOMATO PRODUCTION IN NAKURU-NORTH DISTRICT, KENYA WACHIRA JOHN
In this annex, 4 post-harvest solutions are analyzed in more depth. Plastic crates, ZECC and shade cover have cost-benefit analysis and 4A adoption analysis (based on the Growing Prosperity report of Bain & Company). For the drying and processing opportunities, only a 4A adoption analysis is done, as we don’t have any scientific evidence of the cost/benefits of these technologies. With regard to the 4A analysis, the 4 solutions are analyzed based on the following aspects:

**Awareness**: Awareness is the knowledge that a farmer possesses about a product or service. This includes knowledge of a product or service “category” (e.g., a microfinance loan or microdrip irrigation), the knowledge of a specific company’s offerings as well as the knowledge of how the product or service should be used.

**Advantage**: Farmers will be motivated to adopt an innovation if they are convinced that the product or service will provide better outcomes than current practices—if an innovation promises to increase their wealth with higher crop yields or better prices for their outputs. Benefits may also take the form of reduction of income risk or in the form of improved social standing within the community.

**Affordable**: Affordability is the extent to which farmers are financially able to purchase a product or service. The innovation must be affordable not just in terms of the absolute price; it must also be available for purchase at that price when farmers have money in their pockets based on their cash-flow cycles.

**Access**: Access is defined by the ease, distance and timing of the procurement and sale of an agricultural innovation. Farmers have good access if the product or service is available, when they need it, at a location that they can easily get to.

### 1. Using crates for tomatoes

**Assumptions**:
- crates cost $ usd 9 (can be cheaper in Rwanda, thus lowering pay-back time).
- 1 crate holds 10 kg of tomatoes
- 100 kg harvest per week (harvest 1x per week)
- % losses based on study in Cape Verde on replacing baskets for plastic crates in tomato transport (See WFLO 2010 research in references)
### SMART Tomato Supply Chain analysis for Rwanda

<table>
<thead>
<tr>
<th>Current practice</th>
<th>New practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baskets used as containers. Tomatoes are bruised and damaged during packing, transport and marketing, suffer from decay</td>
<td>Plastic crates: smooth inside surfaces and vented sides prevent damage and allow tomatoes to have adequate ventilation</td>
</tr>
</tbody>
</table>

#### Costs

| 10 plastic crates, shallow size for delicate crops ($ usd 9 per piece) | $ usd 90 |

#### Expected benefits

| % losses | 30% | 10% |
| Amount for sale | 70 kg | 90 kg |
| Value per kg | $ 0,45 (300 RWF) | $ 0,45 (300 RWF) |
| Total market value of one load | $ 31,50 | $ 40,50 |
| Relative profit | 90/9 = 10 | + $ 9 |

After these 10 weeks, the farmers would earn an additional $ 9 per week/load of 100kg

<table>
<thead>
<tr>
<th>Type of A</th>
<th>Assessment</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness</td>
<td>Medium</td>
<td>Awareness is average. Plastic crates are scarcely available and used, so people can be aware of its existence. Possible distributor of plastic crates should invest (heavily) in marketing to demonstrate.</td>
</tr>
<tr>
<td>Advantage</td>
<td>Medium</td>
<td>Difficult to assess whether farmers see advantage of using plastic crates, also because use of baskets is very common, and baskets are also used as metric unit in sales. Behavioural change here is needed.</td>
</tr>
<tr>
<td>Affordability</td>
<td>High</td>
<td>Affordability (also in relation to other technologies) is relatively high, as buying a plastic crate is relatively cheap and has a high return. Also, plastic crates can be reused many times, whereas the alternative (baskets) quickly break and quickly need repairs or replacement.</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Low</td>
<td>This is low, as the availability of plastic crates is low. It is not a common mode of packing for farmers, and there are little to no operators selling these crates. The involvement of a central organization organizing the procurement and use of crates would improve accessibility.</td>
</tr>
</tbody>
</table>
2. **Using shade during packing (on field)**

Same assumptions as with plastic crates. Average costs for constructing shade cover come from Cape Verde research, as well as expected losses.

<table>
<thead>
<tr>
<th></th>
<th>Current practice</th>
<th>New practice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No shade: Vegetables must be sold on the day of harvest regardless of farm gate price or market price.</td>
<td>Use of shade: Vegetables can be held for a day if needed before sale, temperatures are cooler during sorting and packing.</td>
</tr>
<tr>
<td>Costs</td>
<td>Shade cover built by growers on farm.</td>
<td>$ usd 33</td>
</tr>
<tr>
<td>% losses</td>
<td>30%</td>
<td>15%</td>
</tr>
<tr>
<td>Amount for sale</td>
<td>70 kg</td>
<td>85 kg</td>
</tr>
<tr>
<td>Value per kg</td>
<td>$ 0,45 (300 RWF)</td>
<td>$ 0,45 (300 RWF)</td>
</tr>
<tr>
<td>Total market value of one load</td>
<td>$ 31,50</td>
<td>$ 38,25</td>
</tr>
<tr>
<td>Relative profit</td>
<td></td>
<td>+ $ 6,75</td>
</tr>
<tr>
<td></td>
<td>33/6,75 = +/- 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The investment repays itself in 5 weeks, if 100 kg of tomatoes is harvested and packed per week</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of A</th>
<th>Assessment</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness</td>
<td>High</td>
<td>Awareness is relatively high. These kind of covers can be found at many different place. It can however be questioned whether the farmer/middlemen is aware of the importance of shade for fresh produce handling.</td>
</tr>
<tr>
<td>Advantage</td>
<td>Medium</td>
<td>Difficult to assess whether farmers (and middlemen) see the advantage, as there seems to be relatively little awareness of the high impact of (too high) temperatures on the quality of the produce.</td>
</tr>
<tr>
<td>Affordability</td>
<td>Medium</td>
<td>As it is relatively easy to construct a cover, farmers can do it themselves, also local labour is relatively cheap. If locally available materials can be used, costs can be kept low. Repayment period is very short. However, these constructions (also because of weather conditions in Rwanda) tend to damage quickly, so additional costs for repairs can be expected.</td>
</tr>
<tr>
<td>Accessibility</td>
<td>High</td>
<td>Accessibility is high as the cover can be built with locally available materials.</td>
</tr>
</tbody>
</table>

SMART Tomato Supply Chain analysis for Rwanda
SMART Tomato Supply Chain analysis for Rwanda

3. Using a ZECC cold chamber

- Assumptions from India research on losses (see WFLO 2010 report)
- Assumptions from NAEB Rwanda official for construction cost of ZECC
- 100 kg capacity of ZECC in 6 different plastic crates.
- Losses are based on a 6 day preservation period.

<table>
<thead>
<tr>
<th>Current practice</th>
<th>New practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>No storage: Tomatoes are sold on the day of harvest regardless of farm gate price or market price.</td>
<td>Cool storage in ZECC: Tomatoes are stored for 6 days if needed before sale.</td>
</tr>
</tbody>
</table>

**Costs**

<table>
<thead>
<tr>
<th></th>
<th>Current practice</th>
<th>New practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building a ZECC</td>
<td></td>
<td>$ USD 250</td>
</tr>
<tr>
<td>Buying 5 plastic crates</td>
<td></td>
<td>$ 45</td>
</tr>
</tbody>
</table>

**Expected benefits**

<table>
<thead>
<tr>
<th></th>
<th>Current practice</th>
<th>New practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>% losses</td>
<td>8.4%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Amount for sale</td>
<td>91.6 kg</td>
<td>98.2 kg</td>
</tr>
<tr>
<td>Value per kg</td>
<td>$ 0.45 (300 RWF)</td>
<td>$ 0.45 (300 RWF)</td>
</tr>
<tr>
<td>Total market value of one load</td>
<td>$ 41.22</td>
<td>$ 44.19</td>
</tr>
<tr>
<td>Relative profit</td>
<td></td>
<td>+ $ 3</td>
</tr>
</tbody>
</table>

\[
\frac{295}{3} = 98 \\
\text{The investment repays itself in 98 weeks, if 100 kg of tomatoes is harvested and packed per week.}
\]

After these 98 weeks, farmers will earn an additional $3 per week.

<table>
<thead>
<tr>
<th>Type of A</th>
<th>Assessment</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness</td>
<td>Low</td>
<td>Awareness is low. There are very few of these ZECC’s built in Rwanda, and there is little awareness raising being done by NGO’s and government on the added value of low-cost evaporative cooling.</td>
</tr>
<tr>
<td>Advantage</td>
<td>Medium</td>
<td>Difficult to assess whether farmers (and middlemen) see the advantage, as there seems to be relatively little awareness of the high impact of (too high) temperatures on the quality of the produce.</td>
</tr>
<tr>
<td>Affordability</td>
<td>Low</td>
<td>In total, the costs for constructing a ZECC are quite high, which also translate into quite a long repayment period. Having said this, the life span of a ZECC is very long.</td>
</tr>
<tr>
<td>Accessibility</td>
<td>High</td>
<td>Accessibility is high as the ZECC can be built with locally available materials, that are easy to obtain.</td>
</tr>
</tbody>
</table>
4. **Using drying or processing technology**

It is very difficult to make a solid cost-benefit analysis for these processing and drying technologies. This has mainly to do with the fact that price setting for processed products is unclear, and the price fluctuations in the market for fresh tomatoes make it difficult to calculate the average price difference between 1 kg of processed/dried tomatoes and 1 kg of fresh tomatoes. Therefore, no cost-benefit analysis is done in the scope of this study.

With regard to the 4A analysis, we distinguish between solar drying, hot air drying, and pulping/processing:

**Solar drying:**

<table>
<thead>
<tr>
<th>Type of A</th>
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<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness</td>
<td>High</td>
<td>Awareness is high, because of the different NGO’s introducing low cost solar drying equipment in Rwanda.</td>
</tr>
<tr>
<td>Advantage</td>
<td>Low</td>
<td>Advantage perceived by farmers will be low, as there is little to no market demand for dried tomatoes. Any introduction of these dryers will need to be accompanied by strong marketing efforts and market research.</td>
</tr>
<tr>
<td>Affordability</td>
<td>Medium</td>
<td>In total, the costs for constructing a solar dryer (even the most basic version) are relatively high. Also, because it is not clear what the market potential is for dried tomatoes, it is difficult to assess what the potential sales price could be hence also difficult to assess repayment period. Also, these dryers tend to damage easily, so life span is not that long.</td>
</tr>
<tr>
<td>Accessibility</td>
<td>High</td>
<td>Accessibility is high as the solar dryers can be built with locally available materials, that are easy to obtain. Also drawings and instructions on how to construct and use are widely available</td>
</tr>
</tbody>
</table>
### SMART Tomato Supply Chain analysis for Rwanda

#### Hot air drying:

<table>
<thead>
<tr>
<th>Type of A</th>
<th>Assessment</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness</td>
<td>Low</td>
<td>Awareness is low, because there are very few of these dryers in Rwanda, and the ones that are used, are used by larger operations/companies.</td>
</tr>
<tr>
<td>Advantage</td>
<td>Low</td>
<td>Advantage perceived by farmers will be low, as there is little to no market demand for dried tomatoes. Any introduction of these dryers will need to be accompanied by strong marketing efforts and market research.</td>
</tr>
<tr>
<td>Affordability</td>
<td>Low</td>
<td>Investment cost are high for individual farmers, even for cooperatives, so basically only affordable for companies.</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Medium</td>
<td>The hot air dryers are not produced in Rwanda, but can be relatively easy be imported. The container based dryers are also easy to install and operate.</td>
</tr>
</tbody>
</table>

#### Pulping / processing

<table>
<thead>
<tr>
<th>Type of A</th>
<th>Assessment</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness</td>
<td>Medium</td>
<td>Awareness is present, as many farmers know of the possibility of the processing of tomatoes. Knowledge on how to operate processing technology however, will be limited.</td>
</tr>
<tr>
<td>Advantage</td>
<td>Low</td>
<td>Advantage perceived by farmers will be low, as it is difficult to compete with cheap imports of processed tomato products, such as ketchup</td>
</tr>
<tr>
<td>Affordability</td>
<td>Medium</td>
<td>Investment costs very much depend on the scale of operations. Example of Sorwatom has shown that large-scale processing is difficult to break-even.</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Low</td>
<td>There is little processing equipment available in Rwanda, all needs to be imported. No specific companies offering the equipment.</td>
</tr>
</tbody>
</table>