LEI WAGENINGEN UR

Risk management in organic coffee supply chains

Testing the usefulness of Critical Risk Models

LEI – Wageningen UR

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Preface

This report documents the findings of the analysis of the supply chain of organic coffee from Uganda to the Netherlands using a Chain Risk Model (CRM). The CRM considers contamination of organic coffee with chemicals as a threat for the supply chain, and analyses the consequences of contamination in one stage of the supply chain for the subsequent stages. Next to this, CRM also analyses the effectiveness and efficiency of measures to avoid or detect contamination. In a subsequent phase of this research, the CRM can also be used to analyse the consequences of fraud (= mixing of organic coffee and non-organic coffee) and measures to tackle fraud.

The development of CRM, analysis of data and presentation of the conclusions was a responsibility of the LEI – Wageningen UR research team. However, this analysis would have been impossible without continuous guidance and data input of FAQ and Louis Bolk Institute. Their knowledge of- and contacts in the Ugandan (Organic) coffee sector were essential.

Also the inputs and insights provided during a workshop organised in early 2011 were very valuable. Hence, we would like to thank the attendants of this workshop: Ruth Nyagah (Africert), Charles Walaga (Ugocert), Albrecht Benzing (Ceres), Leen Janmaat (Louis Bolk Institute), Catherine van der Wees (Hivos), Frank Kraaijkamp (Van Weely BV), Jennie van der Mheen (LEI-Wageningen UR) and Michiel Schoenmakers (FAQ). The data used in our CRM of the Ugandan organic coffee supply chain were provided by Stanley Maniragaba, Ellyson Mwesigye, Nicodemus, and Ambrose Ahikire from ACPCU, Daniel Lutwama and Godfrey Sekabira from Kawacom, Charles Walaga and Martin Majanja from Ugocert, Jane Kyakyo (Jese), Heinrich Mukalazi (Katuka Development Trust) and David Kadocio (Bofo). Without their information we would not have been able to construct and analyse our model.

Lastly, the support of John van Duursen (HIVOS) is appreciated, as well as the financial means made available by HIVOS for this research. Together with financial contributions of the Dutch ministry of Economic Affairs, Agriculture and Innovation they made this research possible.

1. Context

The in 2007[1] and 2008[2] newly introduced EU organic standards require risk management, both in production and in external control. Article 27 of the 2007 regulation and Article 63 of the 2008 regulation express these requirements:

- Article 63 deals with control arrangements and undertaking by the operator:

  Organic production shall be based on management of biological processes based on ecological systems using natural resources which are internal to the system by methods that are based on risk assessment, and the use of precautionary and preventive measures. The operator shall draw up and subsequently maintain:
  - a full description of the unit and/or premises and/or activity;
  - all the practical measures to be taken at the level of the unit and/or premises and/or activity to ensure compliance with the organic production rules;
  - the precautionary measures to be taken in order to reduce the risk of contamination. The description and measures may be part of a quality system[3] as set up by the operator.

[1] Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91

[2] Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control

- Article 27 deals with the nature and frequency of the (external) controls:

  Control visits will be based on the evaluation of the risk of non-compliance with the organic production rules. The nature and frequency of the controls shall be determined on the basis of an assessment of the risk of occurrence of irregularities and infringements as regards compliance with the requirements laid down in the Regulation.

Both, certification bodies and operators are supposed to carry out risk assessments. The regulation, however, does not mention how to assess the risks, and does not describe minimum acceptable sample sizes in inspections to ensure compliance with the regulation. As a result, every certification body can use its own interpretation of the implementation rules. In fact this is already happening, different risk analysis systems are currently applied the sector. This potentially undermines the aim of the regulation to bring clarity and uniformity. Lack of uniformity may directly influence EU imports when competent authorities start applying different interpretations.

There are numerous reasons to push for risk management and modelling risk calculation in chains:

- Focus on high risk groups (often the poorest or most marginalized producers in a smallholder group)
- More transparency on effectiveness of proposed measures
- More control over proliferation of standards systems and related training programs

2. Problem

Consistency of the organic coffee supply chain needs to be improved. Consistency refers to the assurance of origin of the coffee. The organic label must guarantee that the coffee is produced according to the organic standards, thus it must be possible to check where the coffee is coming from. Improving consistency can be achieved through applied, risk based organic management systems. An optimal allocation of measures to control the hazards in organic supply chains is a condition to achieve this. Moreover, cost effectiveness of measurements has to be optimised.

Three main risks in organic supply chains have been brought up by various stakeholders:

1. Contamination by chemicals
2. Fraud: Fraud refers to the mixing Organic coffee with regular (non-Organic) coffee.
3. Effectiveness of chain measures (e.g. internal inspections and advice to farmers)

In this research, the specific case of organic coffee from Uganda is analyzed as case study. Preventive measures to control the hazards can be applied in the different stages of the supply chain. The first measure, for example, is the training and guidance of coffee farmers. When farmers are being trained how to produce organic coffee, the hazard in the first stage of the supply chain (i.e. production) will considerably decrease.

2.1 Contamination by chemicals

Organic coffee can get contaminated by chemicals in different parts of the supply chain. This contamination cannot spread itself through cross-infection. Contamination can only spread when coffee of contaminated bags is mixed with coffee of uncontaminated bags. There are not many methods available to detect contamination, and the costs and quality of the methods differ considerably. Cheap test are not (or less) suitable to detect light forms of contamination. More expensive tests, on the other hand, will be able to detect lighter forms of contamination. The challenge for supply chain actors is to decide on the most cost-efficient combination of detection methods and at which stage in the supply chain these detection methods should be used..

3. Method

A Chain Risk Model (CRM) developed by the Dutch Agricultural Economic Institute (LEI) optimizing phytosanitary measurements, is used. This model has been adapted to detect contaminations in organic product chains by chemicals. Fraud cannot be considered in this phase of the research, this is explained in a separate section of this report (See '6. Fraud'). The model can distinguish:

- Stages in the supply chain
- Flows of Organic coffee through the supply chain
- Contamination by chemicals
- Measures to detect chemicals

At the start of the CRM, we enter an anticipated level of production. This is the input of number of organic coffee bags for the first stage of the supply chain. From here on, the CRM will calculate for each stage in the supply chain how many coffee bags will enter and leave every stage.

The object defined in the model is one coffee bag. As mentioned, the coffee bags can get contaminated by chemicals in different stages of the supply chain. When we assume that a number of coffee bags are contaminated in a specific stage of the supply chain, a second assumption has to be made regarding the level of contamination. The CRM then calculates how the contaminated bags will move through the supply chain. Based upon assumptions, the model also calculates how and where contamination will spread over different bags. Contamination can only spread with the content of other bags, if different bags are mixed. Unlike diseases, contamination cannot generate more contamination by itself. Because chemicals of one bag are being spread over multiple bags, the level of contamination will decrease.

When all required data is entered in the CRM, it becomes possible to check per stage how many bags are contaminated as well as its concentration. At the end of the supply chain, the output presents the share of contaminated coffee bags in relation to the overall number of coffee bags. These contaminated bags thus become virtually visible in the CRM but they have not been detected by the actors of the supply chain. Since the contaminated bags at the end of the CRM are not yet detected, they have the same value as clean bags.

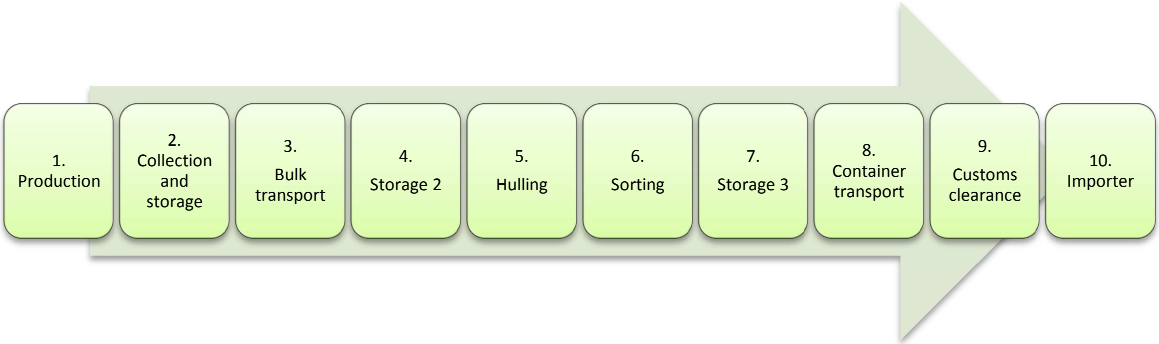
It is possible with CRM, to incorporate different detection methods in every stage of the supply chain. Per entered detection method, it is necessary to enter the costs and quality of the detection method. Cost of the measures are not only determined by the cost of the measure itself but also by the sample size to which a measure is applied. Bigger sample sizes entail higher costs. The quality refers to the level of contamination that the method can detect. When detection methods detect contaminated coffee bags, these bags are rejected. Within the virtual CRM, there is a possibility to send the contaminated bags immediately to one of the subsequent stages of the supply chain. This possibility is not used in the description of the Ugandan organic coffee supply chain however, as contaminated bags are immediately removed out of the supply chain. . Rejected bags can lose financial value (the price difference between organic and conventional coffee). Their value is called 'rejection value', and must be taken into account while considering the costs of a detection method.

4. Case study: Organic coffee from Uganda

This study focusses on the supply chain of Ugandan organic dry robusta coffee, which is presented in figure 1. In this flow diagram the arrow represents the volume of coffee running through the supply chain. The first step in this supply chain is "Production". Ugandan organic coffee is produced by smallholder coffee farmers. One organic coffee producer is assumed to produce 7 bags of coffee per year. The case study encompasses 5,000 smallholder farmers, thus a total production of 35,000 bags of organic coffee. This volume of coffee decreases in the production stage (due to first processing), during the hulling stage, and as a result of sorting. As a result of this volume loss, only 13,899 bags leave the end of the basic supply chain (if no measures to detect contaminated bags are applied). To check the numeric assumptions of these reductions (and of other assumptions), we refer to Annex 1 "Assumptions".

The key stage of the supply chain is 'hulling' (stage 5). During the hulling, bags of coffee are being mixed. In the current supply chain design, it is assumed that 1,000 bags of coffee are mixed per hulling process. Thus, contaminated coffee from one bag will spread itself over several other bags during the hulling. The level of contamination in the bags with hulled coffee will be considerably lower than the level of contamination in the contaminated bag of coffee before hulling.

Figure 1: Supply chain of Ugandan organic coffee



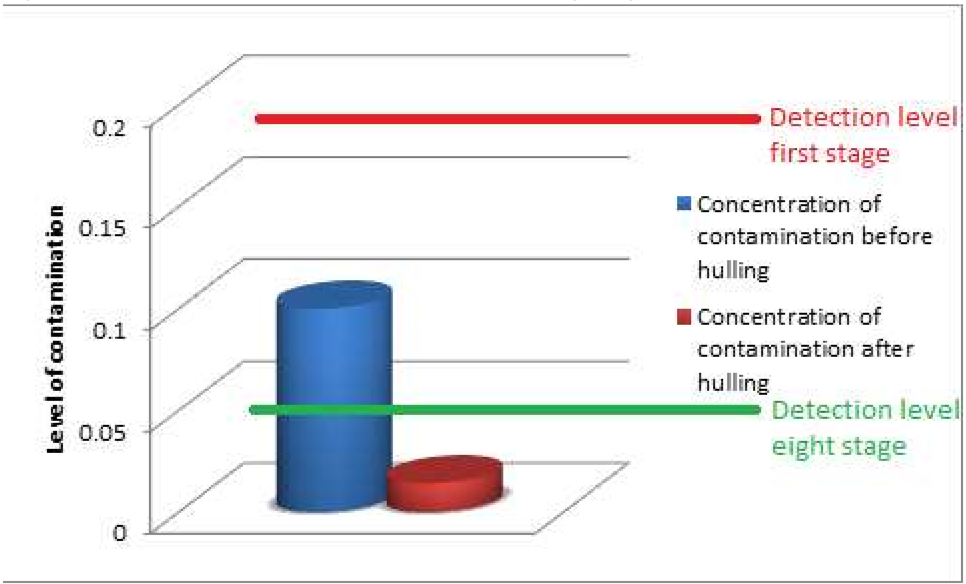
Two scenarios of contamination are considered in this research: one with a low number of contaminated bags, and a second scenario with a high number of contaminated bags. In the first stage of the supply chain, the same number of bags is contaminated in both scenarios. It is assumed that the production of 3 farmers (on a total of 5000 farmers) gets contaminated. Hence, a total of 21 bags gets contaminated in the first stage. In the subsequent stage, coffee bags can only get contaminated when they get into contact with chemicals "from outside" (e.g. when they are stored against a contaminated wall). This means that contamination cannot spread itself through cross-infection. In the first scenario, one additional bag of coffee gets contaminated in each stage with risk of contamination. In the second scenario, 10 additional bags get contaminated. The differences between the two scenarios are presented in table 1. The level of contamination concentration per bag is assumed to be 0,1 at the start of the supply chain and for every additional contamination coming from outside. The closer the level of contamination approaches to zero, the less severe the contamination of that bag. Contamination "from outside" can occur in stages 1, 2, 3, 4, 6, and 7. During hulling (stage 5), no additional contamination can occur, but present contamination can spread itself over other bags as the content of 1000 bags is being mixed. Hence, contaminated bags entering the hulling stage will spread their contaminated coffee over multiple coffee bags during hulling. It is assumed that the coffee of one contaminated bag spreads itself over 200 coffee bags and the end of the hulling stage. Consequently, the contamination concentration will decrease however. As mentioned the contamination of before hulling is 0,1. When contamination is spread during hulling, the contamination concentration of contaminated bags leaving the hulling stage will decrease to 0,0005 (=0,1/200).

Table 1: Level of contamination per supply chain location (Basic situation; scenario low versus scenario high)

Supply chain location	Level of contamination scenario 'low'	Level of contamination scenario 'high'
1.Production	3 farmer (=21 bags)	3 farmers (=21 bags)
2.Collection and storage (during storage)	1 additional bag	10 additional bags
3.Bulk transport (during transfer in new bag)	1 additional bag	10 additional bags
4.Storage 2 (during storage)	1 additional bag	10 additional bags
6.Sorting (during transfer in new bag)	1 additional bag	10 additional bags
7.Storage 3 (during storage)	1 additional bag	10 additional bags

Some detection methods are currently utilised in the organic coffee chain. The quality of these detection methods is presented in figure 2 in combination with the concentration of contamination before and after the hulling.

Figure 2: Concentration of contamination versus quality of detection methods



The first detection method is internal inspectors visiting all 5,000 coffee producers. The internal inspectors annually control the production sites visually, and interview the farmers. It is assumed that this measure can only detect concentration levels of contamination of 0,2. This means that, in figure 2, no contamination concentration below the red line (level of 0,2) can be detected. The current contamination concentration is just 0,1. This implies that the inspectors are not able to detect any contamination unless other visual evidence (e.g. packages of agro-chemicals) is present. Also, a second check occurs during the production phase. The company contracts a certification body, which sends an external inspector. The inspector has to check a sample that is as big as the square root of all producers. Thus of the 5,000 producers, the certification body checks 71 farmers. The check is comparable to the inspection of the internal inspector. In figure 2, it is obvious that the quality of the checks at production stage is not sufficient to detect the low levels of contamination that occur in this stage. A third check occurs at customs clearance. This check is more expensive but is of a better quality than the checks during the production stage. Figure 2 demonstrates that the quality of the check at customs clearance is sufficient to detect most of the contaminated bags at customs clearance. We assume that the check is able to detect 90 % of all contaminated bags. However, at customs clearance the coffee arrives in containers containing 350 bags of coffee. All of these containers are being controlled. But per container, just a sample of 5 bags is checked. As a consequence, this check is also not able to detect a lot of contaminated bags, despite the good quality of the check.

Current detection methods hardly detect contaminated coffee bags. If contaminated bags are discovered, these bags cannot proceed further through the organic supply chain, and consequently lose some of their value. In most stages the rejection value is 90 % of the value of an organic coffee bag (being the price of conventional coffee). Table 2 demonstrates the effect of different assumptions of contamination in the present situation (basic situation) and the course of the contamination throughout the chain. Please take note that in both scenarios 35,000 bags are being produced by smallholder farmers. The increase of contaminated bags - which pass the EC border - between the 'high' and 'low' scenario is 4,500 bags. The increase is a result of the hulling, where contamination of one bag can spread itself over 200 other bags of coffee.

Table 2: Output number of coffee bags and number of contaminated coffee bags per step in the supply chain. (production = 35,000 bags)

Scenario	Total output versus Contaminated bags	1. Production	2. Collection & storage	3. Bulk Transport	4. Storage 2	5. Hulling	6. Sorting	7. Storage 3	8. Container transport	9. Customs clearance	10. Importer
Low contamination	Total output	30447	30447	30447	30447	16746	13899	13899	13899	13899	13899
	Contaminated bags	24	25	26	27	5392	4476	4477	4477	4477	4477
High contamination	Total output	30447	30447	30447	30447	16746	13899	13899	13899	13899	13899
	Contaminated bags	24	34	44	54	10791	8967	8977	8977	8977	8977

As the number of coffee bags leaving the supply chain in stage 10 is the same for both the low and high scenario, it becomes obvious that the current checks are able to detect any contamination. As already mentioned above, the checks in the first stage of the supply chain are qualitatively not good enough. The checks at customs clearance are of better quality, but the concentration of contamination is either too low to be detected or too few bags are being controlled. This concentration has decreased considerably due to the hulling.

4.1 Costs of inspection in the current situation

Table 3 provides an overview of the costs per detection method. In addition, the detected contaminated bags represent "avoided damage". At this moment, it was not possible to quantify this avoided damage. Avoided damage includes abstract issues like 'consumer trust', this made it impossible to put an amount on it since it is a rather abstract issue. Once the avoided damage can be quantified, it is easily incorporated in the CRM however.

The other costs that occur in the supply chain due to losses at the production phase, hulling, or rejection due to sorting are not incorporated in this table as they cannot be seen as costs due to contamination..

Table 3: Cost of inspection in the basic model

Costs	Cost per unit/inspection ($)	Number of units/inspections	Total cost ($)
Company internal inspection costs	$26	5.000	$130.000
Certification inspection costs	Lump sum		$6.000
Inspection at customs clearance	$100/container	40	$4.000
Total costs of detection methods			**$140.000**

5. Additional measures

The CRM allows us to analyse what the effect of additional detection measures will be, given the current assumptions. Three different sets of additional measures are tested per scenario of low and high contamination.

5.1. Additional guidance at farmer level

When farmers are trained how to produce organic coffee, it can be expected that less contamination by chemicals and conventional coffee will occur in the production stage. In the current situation, the contaminated bags of 3 farmers are taken to the second stage of the supply chain. Due to better guidance and education, we assume that this number decreases to 1 farmer. It is assumed that this result can be achieved through the recruitment of one additional trainer. The costs of this additional trainer is equal to the wage of an additional inspector at the production stage ($1200). The output of the CRM for the basic scenario (as presented above) with the additional guidance of farmers is presented in table 4.

Table 4: Number of bags and contaminated bags at the end of the redesigned supply chain with reduced checks and additional guidance of the farmers

Scenario	Situation	Contaminated bags	Total number of bags
Low contamination	Basic situation & Additional guidance	1826	13900
	Basic situation	4477	13899
High contamination	*Basic situation & Additional guidance*	*6326*	*13899*
	Basic situation	*8977*	*13899*

Thus, with a small additional cost of $1200 before the hulling stage, the number of contaminated bags of coffee is considerably reduced compared to the basic situation (from 4477 to 1826 in low contamination scenario and from 8977 to 6326 in the high contamination scenario). The cost structure of all measures in this supply chain is presented in table 5. The benefits of this reduction of contaminated bags relates to the avoided damage. As explained before, avoided damage has not been quantified yet.

Table 5: Additional costs of redesigned supply chain with reduced checks and additional guidance

Costs	Cost per unit/inspection ($)	Number of units/inspections	Total cost ($)
Company inspection costs	$26	5.000	$130.000
Certification inspection costs	$1.2/inspection	5.000	$6.000
Inspection at customs clearance	$100/container	40	$4.000
Cost of extra trainer	$1200	1	$1.200
Total costs of detection methods			**$141.200**

5.2. Labelling and additional check at hulling

The second set of measures combines the labelling of the coffee bags until hulling and an additional check in the hulling stage. The additional check is a chemical check for contamination by chemicals. Table 6 presents the scope of the additional measures.

Table 6: Scope of additional measures

Type of additional measure	Number of units/producers checked	Number of bags checked per unit/producer	Additional information
Labelling	All coffee bags are labelled	NA	NA
Additional check	29,65% of the farmers	16,421% of a farmer's production	Check is of comparable quality as the current check at customs clearance

The labelling is necessary in order to be able to exclude all the bags produced by a producer if one contaminated bag is detected. It is assumed that the budget for this set of additional measures is 2% of the turnover. Hence, a budget of $289.000 is made available for this set of additional measures. A second assumption concerns the number of checked bags per producer. If one bag is checked per producer, it is possible to check 29,65% of the 5,000 producers.

Thanks to the labelling and additional check before hulling it is now possible to exclude contaminated bags out of the supply chain before the contamination spreads itself during the hulling. The effect of these measures is presented in table 7.

Table 7: Number of bags and contaminated bags at the end of the supply chain with additional measures (possibility 1)

Scenario	Situation	Number of contaminated bags	Detected contaminated bags (before hulling)	Total number of bags
Low contamination	Additional measures	3140	8	13848
	Basic situation	4477	0	13899
High contamination	*Additional measures*	*6281*	*16*	*13797*
	Basic situation	*8977*	*0*	*13899*

The additional set of measures is able to detect a number of contaminated bags before hulling. In no other stages, contaminated bags are detected. This considerably reduces the number of contaminated bags in the last stage of the supply chain. The difference for the 'low' scenario is 1337 contaminated bags less. In the 'high' scenario, the number of contaminated bags decreased by 2696. The overall costs of these additional measures are presented in table 8. As table 8 demonstrates, this results in a total cost of $ 288920, which is $80 less than the available budget. The costs of labelling are determined by the cost of RFID labelling, and electronic scanners to read the labels. RFID labelling is an electronic labelling method that allows its users to trace every single bag.

Table 8: Overview of additional costs and quality of additional set of measures

Additional measure	Type of cost (in unit)	Unit cost	Number of units	Cost
Labelling	Barcode scanner	$20 per year	10	$200
	Cost of labelling	$0,02 per bag	35000	$900
Additional check	Cost of chemical check	$195	1476	$287.820
Total cost for set of additional measures				**$288.920**

The possibilities of CRM can be illustrated by the following example. Assuming that the same budget ($289.000) is available for the additional checks, but in this case the additional check is already performed at the second stage (collection and storage). The results of this simulation are presented in table 9. If additional measures are organised in stage 2, a considerably higher number of contaminated coffee bags can be found at the end of supply chain, both in the 'high' and the 'low' scenario.

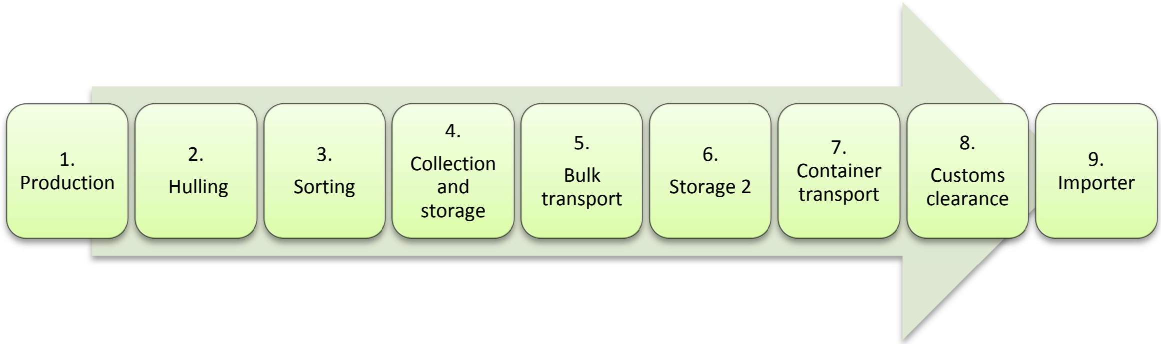
Table 9: Comparison additional measure in stage 2 or 4

Scenario	Stage of additional measure	Number of contaminated bags	Total number of bags
Low contamination	2	3252	13890
	4	3140	13848
High contamination	2	*7308*	*13890*
	4	*6281*	*13797*

5.3. Different chain design

Hulling is clearly a critical activity in the supply chain; both the spread of contamination can occur as well as the decrease of the contamination level can occur in this stage. In the current situation, coffee bags are untraceable after the first stage of the supply chain. Hence, when contaminated bags are detected, large numbers of coffee bags must be rejected. This increases the costs. Therefore, if we consider a redesign of the supply chain, more attention should be given to traceability in the 'hulling' stage. The resulting re-designed supply chain is presented in figure 3.

Figure 3: Re-designed supply chain of Ugandan organic coffee



This re-designed supply chain comprises of nine stages instead of ten. One mass storage stage is needed. Thus, after hulling, there is one stage less were contamination can occur. The CRM can be run under these changed circumstances. The current detection methods (company and certification body check at production, and test at customs clearance) are still incorporated in the model. The output of coffee bags at the end of the supply chain is presented in table 10. Table 10 also contains the output of the current supply chain (without additional measures) to allow comparison.

Table 10: Number of bags and contaminated bags at the end of the redesigned supply chain (possibility 2)

Scenario	Situation	Contaminated bags	Detected contaminated bags (before hulling)	Total number of bags
Low contamination	Different chain design	143	1	13899
	Basic situation	4477	0	13899
High contamination	*Different chain design*	*178*	*1*	*13899*
	Basic situation	*8977*	*0*	*13899*

The number of contaminated coffee bags decreased considerably, so the impact of the re-designed supply chain is big. However, there are some costs involved to re-design of the supply chain. These costs are presented in table 11. Table 11 does not contain the costs of the current measures. These measures are still incorporated in the CRM but are the same as in the basic situation (table3).

Table 11: Additional costs of redesigned supply chain

Type of cost	Cost per bag	Total cost
Additional cost of de-central hulling	$20,90	$636.342,3
Additional cost of transport	$14,93	$454.573,71
Overall cost of different chain design		**$ 1.090.916,01**

Compared to the costs of labelling until hulling in the current supply chain together with the additional check ($288.920), the costs of the different chain design ($ 1.090.916) are much higher. But the effects on the number of contaminated bags at the end of the supply chain is much bigger as well. Due to the different chain design, the number of contaminated bags is reduced to 143 or 178 bags (depending on the scenario), while this was still 3140 or 6281 bags with the previous additional measures. For the scenario with high contamination the contaminated bags represent almost half of the coffee bags at the end of the supply chain. The chain actors must decide what is most valuable for them: the damage avoided by almost reducing the number of contaminated bags at the end of the supply chain to nearly 1% or the costs of redesigning the supply chain.

5.4 Different chain design and reduced checks

The level of contamination decreases significantly if the chain is designed in an alternative way. In that situation reduced checks might be an interesting option. In the supply chain presented in figure 3, the current measures are still incorporated. Yet, previous analysis demonstrated that these measures are not all that efficient. Therefore the CRM also checked what happens if the supply chain of figure 3 is used but with reduced checks at customs clearance. It is assumed that instead of 100% of the containers, only 20% of the containers is checked for contamination by chemicals at customs clearance.

The number of contaminated (and total number) of coffee bags at the end of the supply chain is exactly the same as for the redesigned supply chain described in 5.2 "Different chain design". These results will not be presented here. But the reduction of checks at customs clearance means reduced costs. This is presented in table 12. The reduction of costs is not spectacular, but at the same time this analysis demonstrates the usefulness of the CRM: the two tested scenarios result in equal outputs at the end of the supply chain but thanks to the CRM, chain actors can test how this output can be achieved with minimal costs.

Table 12: Additional costs of redesigned supply chain with reduced checks

Type of cost	Cost per bag/unit	Total cost
Additional cost of de-central hulling	$20,90	$636.342,3
Additional cost of transport	$14,93	$454.573,71
Reduced costs at customs clearance	$100	-$3200
Overall cost of different chain design and reduced checks		**$ 1.087.716,01**

6. Fraud

As mentioned in the description of the problem, another risk in the supply chain is fraud. Fraud refers to the mixing of Organic coffee with conventional coffee. This endangers the consistency of the supply chain as it cannot be guaranteed that the output of the supply chain is 100% organic. The CRM can be used to also analyse the consequence of fraud. This has to be done in a separate analysis however, as it is not yet possible to consider two types of contamination (contamination by chemicals and contamination by conventional coffee) simultaneously.

Mixing of produce of conventional and organic origin results in contamination of the organic produce. For this risk model, the impact of fraud can be calculated in the same way as contamination by chemical substances. Again, it is possible to enter different levels of contamination. Just as contamination by chemicals, the contamination by fraud can spread itself over different bags during the hulling. What will differ however are the detection methods. Chemical test cannot be used anymore for example. Instead, fraud will have to be tracked by accountancy checks. These kind of measures are more time-costly and complex. Hence, it might be necessary to consider the possibility that measures cannot detect fraud immediately. When fraud is finally discovered, the bags might be in one of the subsequent stages already. Nevertheless, it is still possible to distinguish different quality levels for the different detection measures. As a consequence, it is necessary to decide on new assumptions for the entire supply chain prior to the analysis of the impact of fraud on the supply chain and measures to tackle the fraud. This can be done in subsequent research.

7. Conclusion

This research demonstrates the possibilities of the application of CRM in the analysis of organic supply chains. Firstly, the different scenarios allow to analyse the consequence of chemical contamination on the output of organic coffee bags at the end of the supply chain. Secondly, CRM also allows to analyse the effectiveness of measures to tackle the problem of contamination by chemicals. As demonstrated, there is doubt about the consistency and effectiveness of the current preventive and corrective measures used in organic coffee inspection. The cost effectiveness (and efficiency) of present measures is certainly low as they are unable to detect any contaminated bag. Results from the CRM suggest that other proposed measures can be more efficient. The outcomes of the different scenarios are presented in table 13.

Table 13: Overview of contaminated bags, detection, and costs per scenario and set of measures

Situation	Scenario	Total Costs (additional & current measures)	Number of detected contaminated bags	Contamination at the end of the supply chain
Basic scenario	Low contamination	$140.000	0	4477
	High contamination	$140.000	0	8977
Additional guidance	Low contamination	$141.200	0	1826
	High contamination	$141.200	0	6326
Labelling and additional check	Low contamination	$430.120	8	3140
	High contamination	$430.120	16	6281
Redesign of supply chain	Low contamination	$1.230.916,01	1	143
	High contamination	$1.230.916,01	1	178
Redesign of supply chain and reduced checks	Low contamination	$1.227.716,01	1	143
	High contamination	$1.227.716,01	1	178

The combination of labelling and an additional check before hulling was able to detect a considerable number of the contaminated bags. It was found that most contamination in the organic coffee supply chain occurs in the hulling stage. Hence, a different chain design appeared to be the most effective measure as it was able to almost eliminate spread of contamination. Consequently, the numbers of contaminated bags at the end of the supply chain was considerably reduced.

Next to the analysis of the number of contaminated bags at the end of the supply chain, CRM can also be used to analyse cost-effectiveness of the measures. For example, the effectiveness of different combinations (with equal budgets) can be compared. Hence, it is possible to look for the best combination of measures within a given budget. In this case study, we showed that a reduction of the checks at customs clearance for the redesigned supply chain did not affect the number of contaminated bags at the end of the chain. Therefore, the usefulness of this check (and expenditures) can be questioned.

Although this research focusses on contamination of organic coffee by chemicals, CRM can also be used to analyse other threats of the organic supply chain. Fraud can be analysed using the same rationale as contamination by chemicals for example. This analysis requires new discussions and agreement regarding the assumptions related to fraud. In this case, the severity of fraud will replace the level of contamination, and new detection methods (including assumptions on costs and quality) must be identified.

8. References

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Annex 1: Assumptions

Basic model

The basic model describes the situation when no detection methods are being used.

Step 1: Production

- Production = (5000 farmers) * (average production of 7 bags per farmer) = 35000
  Assumption: real average production is 6,7 but this is not convenient for calculations
- Reduction number of bags: 13 % of the bags disappears
- Contamination = 3 farmers = 21 bags
- Level of contamination = 0,1
  This level of contamination will remain stable for step 2,3, and 4 of the supply chain
- Surrounding damage factor = 7 (if one bag gets detected, all other bags or the farmer are rejected as well)
- Detection method 1 (company inspector):
  - Percentage of producers checked = 100%
  - Percentage of bags per producer checked = 100%
  - Quality of detection method (Technique) = 20 % of contaminated bags is found
  - Cost of detection method 1 = $1200 per year
- Detection method 2 (certification body inspector):
  - Percentage of producers checked = 1,42% (=71 farmers)
  - Percentage of bags per producer checked = 100%
  - Quality of detection method (Technique) = 20 % of contaminated bags is found
  - Cost of detection method 2 = $5 per inspection
- Value of one bag = ((15.54 Ush/kg) * 400) / 2879 = $2.15
- Value of a rejected bag = 0,9 * 2,15 = $1,94

Step 2: Collection and storage

- Contamination = 1 or 10 bags (according to the scenario)
- Value of one bag = (4313.38 Ush * 400) / 2879 =$599
- Value of a rejected bag = 0.9 * 599 = $539

Step 3: Bulk transport

- Contamination = 1 or 10 bags (according to the scenario)
- Value of one bag = (4313.38 Ush * 400) / 2879 = $599
- Value of a rejected bag = 0.9 * 599 = $539

Schakel 4: Storage 2

- Contamination = 1 or 10 bags (according to the scenario)
- Value of one bag = $635
- Value of a rejected bag = 0.9 * 635 = $572

Step 5: Hulling

- Spread factor = 200
  Contamination in one bag will spread itself over 200 coffee bags in this stage
- Level of contamination = (0,1 / 200) = 0,0005
  This level of contamination will not change for subsequent steps in the supply chain
- Reduction number of bags = 45% of the volume dissapears
- Value of one bag = $658
- Value of a rejected bag = $592

Step 6: Sorting

- Rejection thanks to sorting = 17%
- Contamination = 1 or 10 bags (according to the scenario)
- Value of one bag = $693
- Value of a rejected bag = $173,25

Step 7: Storage 3

- Contamination = 1 or 10 bags (according to the scenario)
- Value of one bag = $703
- Value of a rejected bag = $633

Step 8: Container transport

- No contamination
- Value of a bag = ($2.6/kg) * 400 kg = $1040
- Value of a rejected bag = $1040 – ($8000/350) = $1017
  When one contaminated bag is discovered the entire container is rejected, the cost of a rejected container is $8000
- Surrounding damage factor = 350 (if one bag gets detected, all other bags in the container are rejected as well)

Step 9: Customs Clearance

- No contamination
- Value of a bag = ($2.6/kg) * 400 kg = $1040
- Value of a rejected bag = $1040 – ($8000/350) = $1017
  When one contaminated bag is discovered the entire container is rejected, the cost of a rejected container is $8000
- Surrounding damage factor = 350 (if one bag gets detected, all other bags in the container are rejected as well)
- Detection method 3 (chemical check at customs clearance)
  - Percentage of shipment/containers checked = 100%
  - Percentage of bags per container checked = 1,428%
  - Quality of detection method (Technique) = 90 % of contaminated bags is found
  - Cost of detection method 1 = $100 per check

Step 10: importer

- No contamination
- Value of a bag = ($2.6/kg) * 400 kg = $1040
- Value of a rejected bag = $1040 – ($8000/350) = $1017
  When one contaminated bag is discovered the entire container is rejected, the cost of a rejected container is $8000
- Surrounding damage factor = 350 (if one bag gets detected, all other bags in the container are rejected as well)

Labelling and additional check at hulling

Cost of labelling:

- Cost of a scanner = $100
  - Scanners are only needed at storage and hulling
  - Scanner have a lifetime of 5 year
  - 10 Scanners are needed
  - (10* $100)/(5 years) = $200/year
- Cost of a label per bag = $0.02
- Total cost of labelling = $200 + ($0,02 * 35000) = $900

Cost of additional check

Cost per check = $ 195 (based upon information of Agriterra)[4]

- Budget = 2% of turnover = $289099,2
- Number of possible checks = ($289099,2 - $900)/$195 = 1478 checks

[4] Analyselijst pesticiden, Groen Agro Control (2011)

- Check 1 bag per producer after stage 4 (before hulling): 1478 / 5000 = 29.56 % of the producers is checked
- Output of stage 4 is 30447 bags; this makes 30447/5000 = 6.0894 bags per producer before hulling. When 1 bag can be checked; 1/6.0894 = 16.421 % of a producer's production is checked
- Change in step 4: Surrounding damage factor = 6 (if one bag gets detected, all other bags or the farmer are rejected as well)

Different chain design

Same characteristics per step in the supply chain, but ensure that:

Costs of different chain design

- Cost of de-central hulling per kg of Organic coffee in USH = USH 150,42
- Cost of transport to and extra handling cost of de-central hulling in USH per kg of Organic coffee = USH 107,45
- Additional cost of de-central hulling per kg of Organic coffee in USH = USH 257,87

Step 2: Hulling

- Spread of contamination over 6 bags in stage 2
- Level of contamination = (0.1 / 7) = 0.014286 (this remains unchanged during the subsequent stages)

Different chain design with reduced costs

Same characteristics as in "Different chain design", but with reduced checks in stage 8 ("Customs clearance"):

Step 8: Customs clearance

- Percentage of shipment/containers checked = 20%