Risk management of unintended GMO contamination in the supply chain of maize and processed maize products

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Abstract. Production and processing of genetically modified organisms (GMO) in line with the European food safety and labelling regulations lead to an elevated risk of unintentional GMO contamination in food producing and processing companies. For these companies GMO contamination can lead to extensive losses such as decreased product value, recall expenses or decreased brand equity. The question that occurs in many food producing and processing companies is how to manage the risk of GMO contamination most effectively. The objective of this paper is to show how food companies manage the risk of GMO contamination. Because of the complexity of the German food sector the analysis focuses on one supply chain namely: the production, processing and trading of maize and maize products. Within this supply chain an assessment of potential losses and safety measures was conducted in a two-step analysis. At first personal interviews with executives or quality managers of companies along the whole supply chain were carried out. Then the results of these interviews were analyzed and used to create the framework for a second session of formalized online interviews within companies of the maize chain. The results of the survey in maize producing, processing and trading, companies show the risk of potential losses that can occur in case of GMO contamination. Additionally the results show the safety measures that can effectively reduce the risk of GMO contamination.

Keywords: Maize Chain, Genetically modified Organism, Risk Management

1. Introduction

The global acreage of genetically modified (GM) crops is steadily growing since the first introduction of GM plants in 1996. In 2008 over 120 million ha of GM crops were grown with total adoption rates of 70% in soybeans, 46% in cotton, 24% in maize and 20% in canola. But these figures conceal the fact that the allocation of GM crops is not uniform. While for example the USA, Argentina and Brazil account for more than 80% of all GM crops grown worldwide, the seven countries cultivating GM crops in the European Union have grown just 0,09% of the total cultivated GM crops in 2008 [1]. In Germany the adoption of GM crops was also low with about 3.000 ha bt-maize and came to a full stop in 2009 after the ministry of agriculture imposed a ban on growing bt-maize. Nevertheless, the risk that non-authorized genetically modified organism (GMO) is found in seeds, plants, food or feed still remains due to imports from GM growing countries. For food or feed processing companies the detection of GMO in food products can lead to extensive losses such as decreased product value, recall expenses, foregone profits due to business interruption, third party liabilities or decreasing brand equity; depending on the GMO authorization status, the thresholds for adventitious or technically unavoidable material and product labeling regulations. Therefore the question that occurs in many food processing companies is how to manage the risk of GMO contamination most effectively.

The enterprise risk management is a process, in which the GMO risks have to be addressed. First the risks have to be identified and assessed. Depending on the results of the risk assessment, it can be necessary for a company to impose certain risk avoiding, preventing or reducing measures. In general those risks have to be reduced with priority which have a larger impact and occur more frequently than others [2,3]. But for food processing companies that are faced by an ongoing risk of GMO contamination, it is difficult to impose an adequate risk management process. Since the GMO risk is relative new there are very few historical data on the impact and the frequency of GMO contaminations. The Rapid Alert System of Food and Feed of the European Union is one example of the very few institutions that provide data on GMO contaminations [4]. But taking the strong negative attitude of consumers into account [5], companies in general tend to keep GMO contaminations and associated losses secret as long as possible to avoid a negative impact of press coverage. Therefore statistics on the real amount and the frequency of losses caused by GMO contamination are not accessible. Besides the risk assessment; risk reduction is another difficult area of GMO risk management. Since the existence of GMO can only be detected in a reliable way by carrying out a PCR test, an analysis of all raw materials is not practicable for most companies. Therefore companies have to impose other food safety measures in order to reduce the risk of losses through a GMO contamination. In this field, studies show the paths through which GMO contamination can occur and give suggestions on how to reduce the risk of losses through a GMO contamination. However for the decision on an adequate set of risk reducing measures the companies should know how effective the different measures are. This subject was only of marginal objective in research until this point.

Based on the situation stated above the objective of the present paper is to analyze the risk of losses through a GMO contamination and furthermore the effectiveness of GMO risk reducing measures. The results of this analysis should provide additional information for the food and feed processing companies to impose adequate risk management measures. Because of the complexity of the German food sector the analysis focuses on one supply chain namely the production, processing and trading of maize and maize products. Within this supply chain an assessment of GMO risks and safety measures was conducted in a two-step analysis. At first personal interviews with executives and quality managers of companies along the whole supply chain were carried out. Then the results of these interviews were analyzed and used to create the framework for a second session of formalized online interviews within the same group. Several techniques are applicable for analyzing the characteristics of the GMO risk and the effectiveness of risk reducing measures. For the first aspect an extended Failure Mode and Effect Analysis and for the last aspect a self-explicated method was chosen.

2. Materials & Methods

2.1 Extended Failure mode and effect analysis

The adequate management of identified risks requires a risk assessment so that the decision maker can recognize the need for action. This in turn depends on the expected value of the risk which results as a product of the occurrence probability and the impact of an event [6]. As often applied in the manufacturing industry besides the probability of occurrence and the impact of a risk, the detection probability is added in order to analyze the risk of a product failure. This approach is called Failure Mode and Effect Analysis (FMEA). The FMEA is an engineering technique used to define, identify and eliminate known and potential product failures from the system. It is one of the most important early preventive actions in system, design, process or service which will prevent failures from occurring. In running an FMEA the existing or potential risks of a company have to be assessed by defining the value of the three components occurrence, impact and detection, while occurrence is the frequency of a failure, impact is the seriousness of the failure and detection is the ability to detect the failure before it reaches the customer. In ranking the components on a scale from 1 to 10 the results provide ease of interpretation, accuracy and precision in the quantification of the ranking. The priority of the risks is articulated in the Risk Priority Number (RPN). The RPN should be used to rank the order and concerns of a problem from minor risks, through moderate and high risks up to critical risks, where the thresholds of this classification has to be adapted depending on the problem and the surrounding conditions. However the exclusive use of the RPN can lead to a misinterpretation as shown by an example. When the value of the occurrence of a risk is very low (value 1), the value for the impact is very high (value 10) and the value for detection is very low (value 1) then the product of these values is 10, which is quite a low RPN. Nevertheless a risk with a very high impact value of 10 has to be addressed with priority. Therefore besides evaluating the RPN the three components of an FMEA have to be evaluated individually [7].

In order to use the FMEA in the context of risk management of GMO contaminations, the method has to be extended [8]. In this study the probability of occurrence of a GMO contamination relates to the frequency of GMO mixings and receiving of contaminated raw materials in a company within the next 12 month. The impact of a GMO contamination applies to the share of the risk that faces a company in total. The probability of detection corresponds to the probability that a GMO contamination is not detected within the company. If for example the non-detection probability within the company is high, the detection is rather taking place on a higher step of the supply chain. This usually enlarges the amount as well as the degree of processing of contaminated products. Therefore potential losses are increased for example due to expanded recalls and intensive media coverage. In case of a low non-detection probability it comes to a rather early detection and potential losses are reduced for example by early isolation of contaminated products. An exception of these characteristics is that there is no loss if a GMO contamination is not detected at all. In case of availability of sufficient quantitative historical data on the risk factors occurrence, impact and detection of a failure, the FMEA can be conducted by transforming these data into the above described ranking system. Since sufficient historical data for the risk of losses through a GMO contamination are not available the values are determined on the basis of an evaluation in food companies. In this evaluation the respondents have to rate the three risk factors on a quasi-interval scale from 1 to 10. In the cases "probability of a GMO contamination within the next 12 month" and "probability of non-detection of a GMO contamination within the company" the scale is specified with 1 = very unlikely, 4 = rather unlikely, 7 = rather likely and 10 = very likely. In the case "economic impact of a GMO contamination" the scale is specified with 1 = very low, 4 = rather low, 7 = rather high and 10 = very high. The extended Risk Priority Number is derived from these risk factors as shown in equation 1

$$RPN_k = Pc_k * Pd_k * I_k \tag{1}$$

with RPN_k = Risk Priority Number of a company k ($k = 1,K$), Pc_k = Probability of a GMO contamination in the company k within the next 12 month, Pd_k = Probability of non-detection of a GMO contamination within the company k and I_k = Economic impact of a GMO contamination in company k.

In addition to the analysis of the 3 main risk factors, the impact of a GMO contamination is analyzed in more detail. 7 tangible and intangible losses that potentially can be a consequence of a GMO contamination are evaluated on a scale from 1 to 10. The scale for these impact factors is specified with 1 = very low relevance, 4 = rather low relevance, 7 = rather high relevance and 10 = very high relevance.

2.2 Self-explicated model

Different measures are available for reducing the risk of losses through a GMO contamination. As an indicator for the effectiveness of these measures the preferences of food companies are evaluated. Analog preference analyses have been done for example in the field of food safety improvements within the dairy chain [9]. For preference analysis different compositional (product attributes are rated separately) and decompositional (paired full or partial product profiles are rated) approaches are available [10]. For this study the two most common instruments for each approach are compared: the self-explicated model, representing the compositional approach, and the conjoint measurement, representing the compositional approach. While both, the self-explicated approach and the conjoint measurement, have not shown evident predominance regarding the explanatory model as well as the reliability and the predictive validity[1], the decision on one of these instruments for the present research is more on practical questions. The advantages of the self-explicated model are less required cognition on the data providing capabilities of the respondents, greater ease in data collection, analysis, and research design as well as greater ability to handle a large number of attributes. The advantages of the conjoint measurement are greater similarity to real choice situations, greater chance of detecting real importance weights and greater range sensitivity. Relating to the design of this study with formalized online interviews of executives and quality managers from food companies, the advantages of the self-explicated model outweigh the advantages of the conjoint analysis. Since the number of respondents is expected to be relatively small and the subject at hand is relatively complex, the less required cognitive skills on the data providing capabilities of the respondents and the greater ease in data collection are advantageous in order to achieve a low break-off rate in online interviewing. Therefore the self-explicated preference measurement model, representing the compositional approach is chosen.

The basic objective of compositional approaches is to compose a utility function for objects or products out of empirical judgments for individual attributes and attribute levels of these objects or products as described in equation 2 [12],

$$U_{i_1 i_2 \ldots i_j k} = \sum_{j=1}^{J} w_{jk} u_{i_j k} \tag{2}$$

[1] SATTLER and HENSEL-BÖRNER [11] analyzed 23 empirical studies which compared the reliability and the predictive validity of self-explicated models and conjoint measurement. While 5 studies reported better results for self-explicated models, another 5 studies reported better results for conjoint measurement. The residual 13 studies reported no significant different results.

with $U_{i_1,i_2,\ldots i_j,k}$ = the respondents k's ($k = 1, K$) utility for level i_j ($i_j = 1, I_j$) of attribute j ($j = 1, J$) of a object or product, w_{jk} = the respondents k's self-explicated importance weights for attribute j, $u_{i_j k}$ = the respondents k's self-explicated scores for level i of attribute j. While the implementation of self-explicated approaches varies somewhat across authors, this paper follows on the method of GREEN and SRINIVASAN [13]. In a first step the measures for risk reduction of losses through a GMO contamination are structured and condensed by means of literature search[2] and interviews with experts from the maize chain. Within this process 4 attributes are identified that relate to the cause of a loss through a GMO contamination. These attributes are "control biological processes", "control technical processes", "control goods receiving" and "crisis management". Each of these attributes has 2 or more different levels. In a second step the levels of each attribute are evaluated by experts from food companies on an effectiveness scale from 1 to 10. The scale is specified with 1 = very ineffective, 4 = rather ineffective, 7 = rather effective and 10 = very effective. In a third step the experts are then asked to allocate 100 points across the attributes so as to reflect their relative importance for risk reduction. By multiplying the standardized attribute-level effectiveness for each respondent with the corresponding attribute weights, standardized part-worths for attribute-levels for each respondent are obtained which indicate the contribution of an attribute level to the main objective of reducing the risk of losses through GMO contaminations.

2.3 The Maize Supply Chain

The current research considers the independent actors in the German grain maize supply chain. As shown in figure 1 the maize chain includes the seed breeding companies, the maize producing farms, the grain collectors, the maize processing food industry and the food wholesale and retailing industry.

The feed production and other maize processing industries such as the oleo-chemical industry are not included in the following analysis. In the recent years the European Union established a series of regulations dealing with GMO of which the regulation (EC) 1829/2003 and 1830/2003 have special impact on the food and feed industry. According to these regulations conventional animal products which were produced with GM feed compounds, in contrast to other GM food products, do not have to be labeled [19,20]. Therefore the labeling regulations for conventional animal products reduce the risk of losses through a GMO contamination in the feed industry. A combined evaluation of GMO risk and risk reducing measures in food and feed companies is assumed to be inaccurate.

For the current research the maize supply chain is divided into three blocks: that is "seed" (the seed breeding companies), "farm" (maize producing farms) and "processing" (starch, milling and retail industry). The grain collectors are not represented with an individual block because only 1 grain collecting company took part in the online interview. The reason for this low participation was due to the simultaneous realization of the survey together with the beginning of the harvest season. Furthermore the food wholesale and retailing industry is included in the processing block. This is because the German retailing industry almost completely market own product brands and partly run own production and assembly lines. Therefore the quality and risk related structures are similar to other processing companies.

[2] To structure and condense the measures for risk reduction of losses through a GMO contamination the studies of BECK, A. et al. (2002) [14], WENK, N.; STEBLER, D.; BICKEL, R. (2001) [15], BOCK, A.-K. et al. (2002) [16], Lehmann, S. (2000) [17] and SCIMAC (Supply Chain Initiative on Modified Agricultural Crops) (1999) [18] are reviewed.

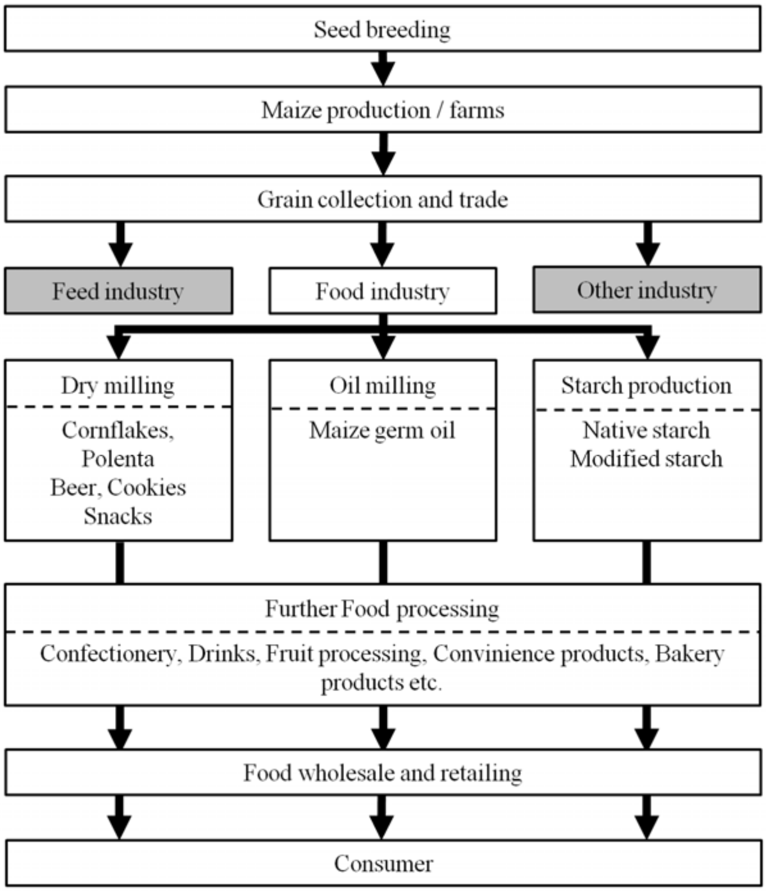

Figure 1. The maize supply chain for food consumption [21,22]

2.3 Data Collection

The data needed for analysing the risk of losses through a GMO contamination and risk reducing measures were gathered in two consecutive interview sessions. First, 11 guided personal interviews with executive and quality managers of typical companies of the German maize supply chain were carried out. The interviews, which took between 1 and 2.5 hours at a time, were conducted by visiting the particular companies. This procedure should ensure to get an insight in the internal structures of the companies and the local GMO risk situation. Second, the results of these interviews were analyzed and used to create a framework for a second session of formalized online interviews of companies within the German maize chain. Assisted by the associations of seed breeders, grain collectors and food processors about 450 invitations were extended via email. From about 80 respondents who visited the online interview homepage only 21 respondents completed the questionnaire. It can be assumed that the small sample size is due to the fact that in some sectors only a limited number of experienced individuals could be approached. While in the seed breeding industry the limited number of existing domestic companies lead to the small sample size, in farming the limited experience of farmers was the crucial factor. In fact, in conducting personal interviews with farmers it became clear that most of the farmers have no experience with management of GMO risks at all. Therefore only farmers were invited who either have cultivated GM plants on their farm or who at least farm in a geographical area where GM plants are used to be cultivated. The data of 3 respondents were rejected due to missing values. Finally 18 data sets were selected to build the basis for further analysis. The 18 data sets distribute to the 3 block as following: "seed" = 4 experts (22.2 %); "farm" = 3 experts (16.6 %) and "processing" = 11 experts (61.1 %).

2.4 Data Analysis

The data of the 18 respondents were analyzed by comparing the arithmetic means of different variables or attribute levels for the "seed", "farm" and "processing" block separately. When examining and interpreting the results it is important to have in mind, that all data are derived from quasi-interval 1 to 10 scales, which is a special form of an ordinal scale. An ordinal scale of measurement normally implies that the results can only be ranked, e.g. variable A (value 2) is better then variable B (value 4), with no information on the extent of difference, that is no information whether variable B is double as good as variable A. In order to analyzing the variables and attribute levels in more detail a quasi-interval scale of measurement was created [23]. This was done by arranging the scale descriptions in a symmetric way with approximate equal distances in regard to the content. Against this background the results have to be interpreted with caution. In statistically analyzing the data the Mann-Whitney-U-Test is used to compare mean values of variables between different blocks while the Wilcoxon signed-rank test is used to compare mean values of different variables within a block. The differences were considered statistically significant if the P value was less or equal to a level of 10% [24]. To examine the inter-respondent reliability of the data, Kendall's coefficient of concordance W was used. Basically, the coefficient of concordance is a function of the variance in the sums of ranks. It is used to evaluate the association among 3 or more sets of rankings [25].

3. Results and Discussion

3.1 Risk assessment

Table 1 shows the average GMO risk characteristics and the Risk Priority Number according to the opinion of the respondents from the "seed", "farm" and the "processing" block. In the respondents opinion "GMO contaminations within the next 12 month" seems to be not likely to occur (value 3.5 to 4.55) with no significant differences between the 3 blocks (P>0.10). The relatively high standard deviation in the farm block (4.4) indicates that either the farms are faced by different risk situations or the farmers had difficulties in evaluating the situation of GMO contamination for their company, which both could lead to deviating preferences. The risk factor "non-detection of a GMO contamination" appears to be not likely (values 3.6) in the "seed" block while in the "farm" and "processing" block the probability seems to be higher (value 5.91 to 6.0). However, the mean values of the three blocks show no significant differences (P>0.1). The "economic impact of a GMO contamination" as stated by the respondents is very low in "farm" block (value 1.25) and low in the "seed" and the "processing" blocks (value 4.73-4.8), whereas these results turn out to be significantly different (P<0.05 and P<0.01). The farmers opinion that a GMO contamination has a very low economic impact could be either due to the fact that on the farm level GM grain maize can be used alternatively in animal feeding or that the awareness of farmers regarding the economic impact of GMO contaminations is low because only a few losses have occurred until today. In sum, the mean risk characteristics reflect low or moderate levels of risk or risk awareness regarding GMO contamination. However the extreme values of the standard deviation in the "farm" block indicate difficulties in evaluating the risk situation in maize production.

Table 1. Mean risk factors and risk priority number per block (1 = very unlikely/very small, 10 = very likely/very large)

Risk characteristics	"Seed"[1] (n^2 = 4)	"Farm"[1] (n^2 = 3)	"Processing"[1] (n^2 = 11)
Probability of a GMO contamination within the next 12 month (Pc)	4.00 (2.2)	3.50 (4.4)	4.55 (2.7)
Probability of non-detection of a GMO contamination within the company (Pd)	3.60 (2.8)	6.00 (4.2)	5.91 (3.4)
Economic impact of a GMO contamination (I_k)	4.80 (1.6)	1.25 (0.5)	4.73 (1.9)
Risk Priority Number (RPN)[3]	80.80 (100.3)	27.25 (35.8)	95.36 (53.8)

[1] Risk factors stated as arithmetic mean $\overline{x}$ (standard deviation σ)

[2] n = number of respondents per block

[3] $RPN_k = Pc_k * Pd_k * I_k$

While the risk characteristics do not show clear differences in the risk of losses through GMO contamination between different blocks, the Risk Priority Number (RPN) suggests that the perceived total risk is significantly lower in the "farm" block (27.25) than in the "seed" (80.80) and in the "processing" (95.36) block ($P<0.1$). The relatively high value of the standard deviation of the RPN in the "seed" block (100.3), together with a relatively low standard deviation of the individual risk factors, indicates that in the "seed" block individual respondents rated the risk factors more simultaneous extreme low or high.

In table 2 the respondents' opinion on the economic impact of a GMO contamination is displayed in more detail. Mean values of 7 important tangible and intangible losses that can occur after a GMO contamination are shown in order to reflect the relative importance of each loss in relation to the total economic impact of a GMO contamination. In the "seed" and "farm" block no values are presented for the impact factor "delisting by food wholesale and retailers" because the "seed" and the "farm" block has no direct contact to the food wholesale and retailing industry. In the "seed" block the importance of the impact factors differs significantly ($P<0.1$), with "loss in value of contaminated products" (26.86%) being the most important impact factor, followed by "decreasing brand equity" (19.36%) and "costs of product withdrawal" (15.61%). In the "farm" block no significant differences could be detected ($P>0.1$), however the "liability for losses in other companies" (19.53%) seems to be more important than "costs of product withdrawal" (17.19%) and "loss in value of contaminated products" (17.19%). In the "processing" block "delisting by food wholesale and retailers" (18.24%) is the most important impact factor followed by "decreasing brand equity" (18.21%) and "reduction of profit due to business interruption" (16.62%), whereas significant differences between the impact factors could be detected ($P<0.01$). The values of Kendall's coefficient of concordance W indicates a moderate agreement of respondents in the "seed" block, but only fair agreement in the "farm" and "processing" block.

Table 2. Mean relative importance of different factors per block which are influencing the economic impact of a GMO contamination (%)

Impact factors	"Seed" ($n^1 = 4$)	"Farm" ($n^1 = 3$)	"Processing" ($n^1 = 11$)
Loss in value of contaminated products	26.86 (1)	17.19 (2)	8.08 (7)
Reduction of profit due to business interruption	12.23 (5)	15.63 (4)	16.62 (3)
Decreasing brand equity	19.36 (2)	14.84 (6)	18.21 (2)
Deprivation of certificates (e.g. organic or marketing programs)	10.75 (6)	15.63 (4)	8.87 (6)
Delisting by food wholesale and retailers	-	-	18.24 (1)
Costs of product withdrawal	15.61 (3)	17.19 (2)	14.21 (5)
Liability for losses in other companies (except costs of product withdrawal)	15.19 (4)	19.53 (1)	15.78 (4)
Total	100	100	100
	$W^2 = 0.502$, $P = 0.028$	$W^2 = 0.250$, $P = 0.416$	$W^2 = 0.290$, $P = 0.004$

[1]n = number of respondents per block
[2]W = Kendall's coefficient of concordance

When comparing the impact factors of the different blocks it becomes apparent that the product drawn losses such as the "loss in value of contaminated products" are of high importance in the "seed" (rank=1) and the "farm" (rank=2) block while in the "processing" block these losses are of only little importance (rank=7). In contrast the impact factors "delisting by food wholesale and retailers" and "decreasing brand equity" are highly important for respondents in the "processing" block (rank1, 2). By examining the impact factors for the farm block, the results for the overall "economic impact of a GMO contamination", which is shown in table 1, becomes easier to comprehend. Despite some damage events, e.g. GMO contamination in rape seed, no liability claims from food producing companies have reached farmers in Germany until now. Because the "liability for losses in other companies" is the most important impact factor in the "farm" block, it can be assumed that the awareness of farmers regarding the "economic impact of a GMO contamination" is very low.

3.2 Risk reducing measures

Table 3 to 5 show the relative effectiveness of risk reducing measures in the “seed”, “farm” and “processing” blocks. In the “seed” and ”farm” block the 4 attributes “control biological processes”, “control technical processes”, “control goods receiving” and “crisis management” were provided for response. In the “processing” block only 3 attributes were available for response because it can be assumed that food processing companies do not have special expertise and preferences in rating and comparing different risk reducing measures in the attribute “control biological processes”. Furthermore for the attribute “crisis management” no adequate data could be obtained in the “farm” block as most respondents replied with “no opinion”. Also no adequate data could be obtained for the attribute level “implement a system for withdrawing products from the market” in the “seed” block. The accumulated “no opinion” responds for the attribute “crisis management” as well as for the attribute level “implement a system for withdrawing products from the market” indicate the only very limited importance respectively the lack of knowledge regarding these attribute and attribute level to the respondents in the “farm” block for the first and the “seed” block for the latter.

In table 3 the mean relative effectiveness of 16 risk reducing measures are presented for the “seed” block according to the opinion of the respondents. The top 3 risk reducing measures are “cleaning of machines, transport- and storage containers” (15.83%), “spatial segregation of GM and conventional material flow” (14.17%) and “installing pollen barrier around GM planting areas” (10.86%). Together the top 3 measures account for 40.86% of the effectiveness of all risk reducing measures. Examining the allocation of the responses it appears that the attribute “control goods receiving”, which account for only 11.25%, are only of little importance to the respondents. This seems to be plausible because mostly the seed breeding companies are not depending on external seed supply. The value of Kendall’s coefficient of concordance W indicates for the mean relative effectiveness of risk reducing measures in the “seed” block a significant moderate agreement of respondents.

Table 3. Mean relative effectiveness of risk reducing measures in the “seed” block (%)

Measure	Effectiveness ($n^1 = 4$) ($k^2 = 16$)	Ranking
Control biological processes		
Change crop rotation of conventional plants	4.74	8
Installing pollen barrier around GM planting areas	10.86	3
Controlling secondary growth of GM plants	10.39	5
Advanced distances to GM planting areas (up to GM free zones)	4.43	9
Advanced information to neighbors of GM planting areas	10.83	4
Control technical processes		
Cleaning of machines, transport- and storage containers	14.17	2
Spatial segregation of GM and conventional material flow	15.83	1
Control goods receiving		
PCR analysis while receiving plant products or in supplying companies	2.57	15
Certificates on the non-existence of GMO in plant products	3.22	10
Quality management certificates of supplying companies	2.87	11
Personal examination of supplying companies	2.59	14
Crisis management		
Implementing a crisis handbook	2.68	12
Regular crisis practice	2.00	16
Implementing a crisis management group	2.68	12
Implement a system for withdrawing products from the market	-	-
Archiving retain samples of products sold	5.26	6
Implement a traceability system	4.87	7
Total	100	
	$W^3 = 0.458$, $P = 0.025$	

[1]n = number of respondents per block
[2]k = number of measures per case
[3]W = Kendall’s coefficient of concordance

Table 4 shows the mean relative effectiveness of the 11 residual risk reducing measures for the "farm" block according to the opinion of the respondents. The top 3 risk reducing measures are "personal examination of supplying companies" (21.11%), "certificates on the non-existence of GMO in plant products" (20.56%) and "PCR analysis while receiving plant products or in supplying companies" (18.61%). Together the top 3 measures account for 60.28% of the effectiveness of all risk reducing measures. Examining the allocation of the importance of all measures it appears that the attributes "control biological processes" is only of little importance to the respondents. The value of Kendall's coefficient of concordance W for the mean relative effectiveness of risk reducing measures in the "farm" block is moderate but not significant.

Table 4. Mean relative effectiveness of risk reducing measures in the "farm" block (%)

Measure	Effectiveness ($n^1 = 3$) ($k^2 = 11$)	Ranking
Control biological processes		
Change crop rotation of conventional plants	2.50	8
Installing pollen barrier	1.67	10
Controlling secondary growth of GM plants	2.50	8
Advanced distances to GM planting areas (up to GM free zones)	5.83	6
Advanced information to neighbors of GM planting areas	0.83	11
Control technical processes		
Cleaning of machines, transport- and storage containers	4.92	7
Spatial segregation of GM and conventional material flow	8.41	5
Control goods receiving		
PCR analysis while receiving plant products or in supplying companies	18.61	3
Certificates on the non-existence of GMO in plant products	20.56	2
Quality management certificates of supplying companies	13.06	4
Personal examination of supplying companies	21.11	1
Crisis management		
Implementing a crisis handbook	-	-
Regular crisis practice	-	-
Implementing a crisis management group	-	-
Implement a system for withdrawing products from the market	-	-
Archiving retain samples of products sold	-	-
Implement a traceability system	-	-
Total	100	
	$W^3 = 0{,}531$, $P = 0{,}102$	

[1]n = number of respondents per block
[2]k = number of measures per case
[3]W = Kendall's coefficient of concordance

In table 5 the mean relative effectiveness of risk reducing measures for the "processing" block is presented. According to the opinion of the respondents the 3 most effective measures are "PCR analysis while receiving plant products or in supplying companies" (20.70%), "personal examination of supplying companies" (17.88%) and "certificates on the non-existence of GMO in plant products" (14.05). Together these measures account for 52.63% of the effectiveness of all risk reducing measures. Considering the allocation of the importance of all measures it appears that the attribute "crisis management" is of relatively little importance. The value of Kendall's coefficient of concordance W for the mean relative effectiveness of risk reducing measures in the "processing" block indicates a significant moderate agreement of the respondents.

Table 5. Mean relative effectiveness of risk reducing measures in the "processing" block (%)

Measure	Effectiveness (n^1 = 11) (k^2 = 12)	Ranking
Control biological processes		
Change crop rotation of conventional plants	-	-
Installing pollen barrier	-	-
Controlling secondary growth of GM plants	-	-
Advanced distances to GM planting areas (up to GM free zones)	-	-
Advanced information to neighbors of GM planting areas	-	-
Control technical processes		
Cleaning of machines, transport- and storage containers	10.27	6
Spatial segregation of GM and conventional material flow	12.55	4
Control goods receiving		
PCR analysis while receiving plant products or in supplying companies	20.70	1
Certificates on the non-existence of GMO in plant products	14.05	3
Quality management certificates of supplying companies	11.51	5
Personal examination of supplying companies	17.88	2
Crisis management		
Implementing a crisis handbook	2.03	11
Regular crisis practice	2.12	10
Implementing a crisis management group	2.23	9
Implement a system for withdrawing products from the market	2.26	8
Archiving retain samples of products sold	1.99	12
Implement a traceability system	2.41	7
Total	100	
	W^3 = 0.475, P = 0.01	

[1]n = number of respondents per block
[2]k = number of measures per case
[3]W = Kendall's coefficient of concordance

In table 6 the mean relative attribute weights for each block are presented. The weights for the attribute "crisis management" in the "farm" block and for the attribute "control biological processes" in the "processing" block are omitted due to inadequate response for the first and missing relevance for the last one as described before. The relative weights show that in order to reduce the risk of losses through GMO contaminations, the measures of the attribute "control biological processes" seem to be more effective in the "seed" block then in the "farm" block. This result has to be interpreted against the background of the attribute "control goods receiving". While the companies in the "seed" block normally are not faced by the risk of receiving GM maize seeds, the focus in risk reduction is more on the attributes "control biological processes" and "control technical processes". In contrast the companies in the "farm" and the "processing" blocks mainly focus on risk reduction in the attributes "control goods receiving". The attribute "crisis management" is of relatively little importance for the "seed" and "processing" blocks, as well as for the "farm" block taking the responds "no opinion" into account. The value of Kendall's coefficient of concordance W indicates only for the "processing" block a fair agreement of the respondents.

Table 6. Relative weights of risk reducing measure attributes (%)

Measure group	seed (n^1 = 4) (k^2 = 4)	farm (n^1 = 3) (k^2 = 3)	processing (n^1 = 11) (k^2 = 3)
Control biological processes	41.25	13.33	-
Control technical processes	30.00	13.33	22.82
Control goods receiving	11.25	73.33	64.14
Crisis management	17.50	-	13.05
Total	100	100	100
	W^3 = 0.291, P = 0.32	W^3 = 0.233, P = 0.49	W^3 = 0.361, P = 0.01

[1]n = number of respondents per block
[2]k = number of measures per case
[3]W = Kendall's coefficient of concordance

Considering the results for risk reduction effectiveness for all blocks it became apparent that the approach of reducing the risk of losses through GMO contaminations is different for each stages of the supply chain. Since the biological and technical processes are of more importance in the seed breeding industry, the control of goods receiving is of exceptional importance to the farms and the processing industry. In comparison the crisis management measures are of only little importance. These results affirm the tendency to emphasize the control of risk origins in contrast to control the impact after a GMO contamination.

3.3 Significance of results

In general the results of this study are derived from opinions of executives and quality managers of typical companies in the maize chain. This means that the results depend on the subjective perception of respondents. Considering that only a few objective data are available right now, these results should be seen as an approximation of the objective risk characteristics and measures for risk reduction. Furthermore the presented results have to be interpreted against the background of partly not significant differences of mean values as well as respondent agreements. There are two reasons that probably lead to this lack in statistical significance. First, the small sample size in the “seed” (n = 4) and the “farm” block (n = 3) could have influenced the significance. Second, possible differences in underlying risk situations of the companies could have led to divergent results. Because of the small sample size the outcome does not demand to be representative for other companies or supply chains. However, the results are reasonable and therefore general trends can be used for risk management purposes.

5. Conclusion

The findings in this study provide a database of different quantitative factors regarding the risk of losses as a consequence of a GMO contamination. While the presented data are derived from experts – executives and quality managers of typical companies in the maize chain – the results are no facts but subjective opinions. However, given the fact, that at this moment no more accurate data on the subject are available, these results can serve as the best available estimation at hand.

The results cover the essential parts of an enterprise risk management planning, that is risk assessment and if needed risk reduction. For risk assessment the results indicate that the risk of losses through a GMO contamination is higher in the maize processing industry and the seed breeding industry than in maize cultivating farms. Looking in more detail to the potential impact of a GMO contamination the results suggest that seed breeding companies and farms are more concerned with product related factors such as losses in value of contaminated products, costs of product withdrawal and liability for losses in other companies, while maize processing companies are more concerned with intangible factors such as delisting by food wholesale and retailers, deprivation of organic or marketing certificates and decreasing brand value. For risk reduction the results show that in general there are significant differences in the effectiveness of different measures that reduce the risk of losses through a GMO contamination. Viewed in more depth, the results suggest that the seed breeding industry emphasis more the control of biological and technical processes while the farming and processing companies emphasizes more the control of products receiving. Furthermore crisis management as a tool for impact reduction is less important than the preventive measures.

Despite the fact that the analysis is limited to the relatively small sample size and a possible bias with respect to the selection of the experts, the results of this research have considerable implications for the companies dealing with GMO risk management. First the results allow to compare and classifying the risk factors depending to the stage of production or processing. Second the results allow prioritizing the more effective risk reducing measures so that companies can determine priority measures when advancing their enterprise risk management.

References

1. ISAAA (2008), *Global status of commercialized biotech/GM crops 2008. Executive summary*. ISAAA Brief 39-2008.
2. Dörner, Horvath, Kagermann (2000), *Praxis des Risikomanagements*. Schäffer-Poeschel Verlag, Stuttgart.
3. Skipper, H. D.; Kwon, W. J. (2007), *Risk Management and Insurance: Perspectives in a Global Economy*. Blackwell Publishing, Malden, MA, USA. p. 304ff.
4. European Commission (2008), *The Rapid Alert System for Food and Feed (RASFF). Annual Report 2008*. Retrieved from the internet, http://ec.europa.eu/food/food/rapidalert/report2008_en.pdf .
5. Bredahl, L. (2001), "Determinants of Consumer Attitudes and Purchase Intentions With Regard to Genetically Modified Foods – Results of a Cross-National Survey", Journal of Consumer Policy, Volume 24, Number 1, p. 23-61.
6. Garvey, Paul R. (2008), *Analytical Methods for Risk Management: A Systems Engineering Perspective*, CRC Press, Boca Raton.
7. Stamatis, D. H. (2003), *Failure Mode and Effect Analysis: FMEA from Theory to Execution*. ASQ Quality Press, Milwaukee, USA.
8. König, R. (2008), *Management betrieblicher Risiken bei produzierenden Unternehmen*. Diss. University of Aachen.
9. Valeeva, N. I. et al. (2005), "Improving Food Safety within the Dairy Chain: An Application of Conjoint Analysis", Journal of Dairy Science. p. 1601-1612.
10. Wittink, D. R.; Vries, M.; Burhenne, W. (1994), "Commercial use of conjoint analysis in Europe: Results and critical reflections", International Journal of Research in Marketing, 11, p. 41–52.
11. Sattler, H.; Hensel-Börner, S. (2000), *A comparison of Conjoint Measurement with Self-Explicated Approaches*. In: Conjoint Measurement: Methods and Applications. Springer Verlag, Berlin. p. 121-133.
12. Green, P. E. (1984), "Hybrid Models for Conjoint Analysis: An Expository Review", Journal of Marketing Research, Vol. XXI (May 1984), p. 155-169.
13. Green and Srinivasan (1990), "Conjoint Analysis in Marketing: New Development with Implication for Research and Practice", Journal of Marketing, 54, p. 3-19.
14. Beck, A. et al. (2002), *Bleibt in Deutschland bei zunehmendem Einsatz der Gentechnik in Landwirtschaft und Lebensmittelproduktion die Wahlfreiheit auf GVO-unbelastete Nahrung erhalten?* Research paper of the Forschungsinstitut für biologischen Landbau Berlin e.V. (FIBL).
15. Wenk, N.; Stebler, D.; Bickel, R. (2001), *Warenflusstrennung von GVO in Lebensmitteln. Untersuchung im Auftrag des Bundesamtes für Gesundheit.* Research paper oft he Prognos AG.
16. Bock, A.-K. et al. (2002), *Scenarios for co-existence of genetically modified, conventional and organic crops in European agriculture. A synthesis report of the joint research centre of the European commission.* Retrieved from the internet, http://www.jrc.cec.eu.int/download/GMCrops_ coexistence.pdf (05.07.2009).
17. Lehmann S. (2000), *Migrationswege von gentechnisch verändertem Raps in der Lebensmittelproduktion*. Diplomarbeit, Hochschule Fulda, Fachbereich Haushalt und Ernährung.
18. SCIMAC (Supply Chain Initiative on Modified Agricultural Crops) (1999), *Code of practice on the introduction of genetically modified crops, Guidelines for growing newly developed herbicide tolerant crops and the genetically modified crop management guide*. Cambs.
19. The European Parliament and the Council (2003a), *Regulation (EC) No 1829/2003 on genetically modified food and feed*. Official Journal of the European Union.
20. The European Parliament and the Council (2003b), *Regulation (EC) No 1830/2003 concerning the tracebility of genetically modified organisms and the tracability of food and feed products produced*

from genetically modified organisms and amending directive 2001/18/EC. Official Journal of the European Union.

21. Gawron, J. C.; Theuvsen, L. (2007), "Costs of Processing Modified Organisms: Analysis of the Rapeseed and Corn Industry", Conference Paper, 47th Annual Conference, German Association of Agricultural Economists (GEWISOLA), Freising/Weihenstephan, Germany, September 26-28, 2007

22. Fachverband der Stärkeindutrie (2009), *Zahlen und Daten zur Deutschen Stärkeindustrie*. Retrieved from the internet: http://www.staerkeverband.de/html/zahlen.html (12.07.2009).

23. Corbetta, P. (2003), *Social Research: Theory, Methods and Techniques.* Sage Pubn Inc, London.

24. Field. A. (2002), *Discovering Statistics Using SPSS for Windows*. SAGE Publications Ltd. London, UK.

25. Churchill, G.A. (1999): *Marketing Research. Methodological Foundations.* The Dryden Press, Fort Worth, TX.