HAZARD IDENTIFICATION: THE STARTING POINT OF BOTH QUANTITATIVE RISK ASSESSMENT AND HACCP

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Abstract
Food safety can be controlled quantitatively by implementation of quantitative risk assessment in food safety management systems. Quantitative risk assessment starts with identification of the hazards. A procedure for hazard identification was developed and implemented as a computer program. This resulted in a decision support system for hazard identification. In this system hazards are identified at three levels of detail. First, a rough hazard identification is performed to identify the most obvious hazards for a product, before more detailed hazard identifications are performed. By this the main problems can be tackled first before focusing on less relevant problems. Combination of knowledge sources, expressed in the use of knowledge rules, supports the user in systematically selecting hazards which may indeed cause harm to the consumer. Due to the structured method and the clear definitions of the knowledge rules, the procedure is transparent and may if necessary be changed. In future the decision support system for hazard identification will be part of a decision support system for quantitative risk assessments.

Keywords: *quantitative risk assessment, hazard identification, HACCP*

Introduction

In the past years many food producing companies have been working on safety management systems to systematically prevent outbreaks of food infection and poisoning. A quantitative approach of food safety control can be created by development and implementation of quantitative risk assessment for food products in existing safety management systems. Quantitative risk assessment consists of four steps: (1) hazard identification, (2) exposure assessment, (3) dose response assessment, and (4) risk characterisation.

We have developed a framework for stepwise execution of quantitative risk assessment. This stepwise approach uses three levels of detail, ranging from qualitative, rough risk assessments to detailed quantitative risk assessments. This approach allows to tackle first the most relevant problems, before focusing on less important problems.

First the procedure has to be gone through roughly and mainly qualitatively (level 1) to get a first impression of the most important hazards, the risk determining parts of the production process, and of risks. The results of level 1 are used in level 2. Both very specific models and/or general models can be used to quantitatively describe the risk determining aspects. The results of these models can then be compared, to estimate risk on a broad basis. Also, in level 2 risks resulting from several failure scenarios are estimated. The results of level 2 can be used in level 3, which is the most detailed level, to perform calculations and simulations using for instance stochastic variables. This is useful if process variations determine risk to a great extent.

Hazard identification as a start for quantitative risk assessments

A stepwise and interactive identification procedure for foodborne microbial hazards has been developed (Van Gerwen *et al.*, 1997). In the stepwise approach use is made of several levels of detail ranging from rough hazard identification to very detailed hazard identification. The interactive character of the identification procedure is based on the use of various knowledge sources. Combination of knowledge sources, expressed in the use of knowledge rules, supports the user in systematically selecting hazards which may indeed cause harm to the consumer.

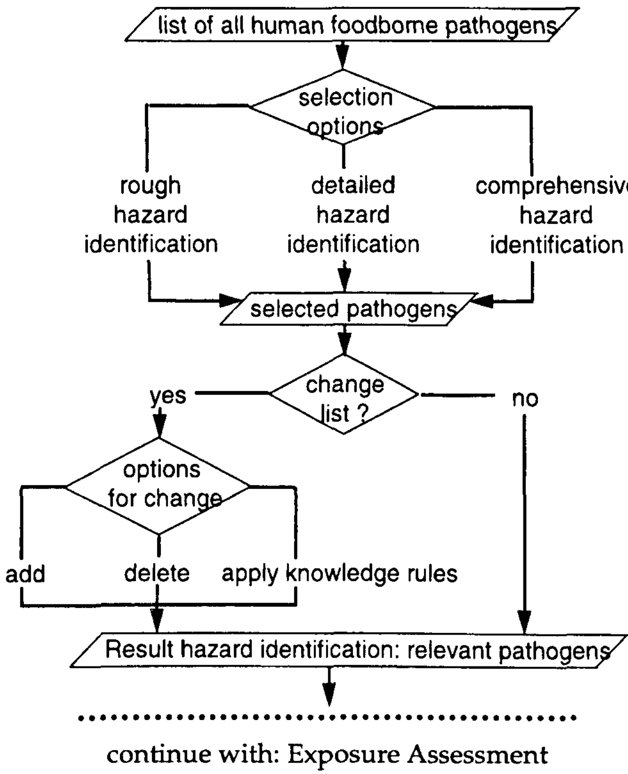

Figure 1. Schematic representation of the hazard identification procedure (Van Gerwen et al., 1997).

The hazard identification procedure is shown in Figure 1. Starting point of the hazard identification procedure is a list of microorganisms that are known to be pathogenic to man. Currently, the list contains about 200 names of pathogens. Then three options can be selected:

1. *Rough hazard identification.* The rough hazard identification selects pathogens that were reported to have caused foodborne outbreaks in the selected food product in the past. These pathogens are the most obvious since they have caused health problems via the specified product whereas other pathogens did not.
2. *Detailed hazard identification.* The detailed hazard identification selects pathogens that have been reported as being present in the ingredients of the specified product.
3. *Comprehensive hazard identification.* The comprehensive hazard identification identifies all pathogens as hazardous. It is based on the idea that everything is everywhere. By this means, pathogens that unexpectedly recontaminate the product can be included, and potential future problems can be evaluated.

First, the level of least detail should be used to determine the most obvious hazards. If risks for the most obvious hazards were shown to be acceptable, more detailed hazard identifications must be performed. The process of consecutively using the levels of detail is illustrated in Figure 2.

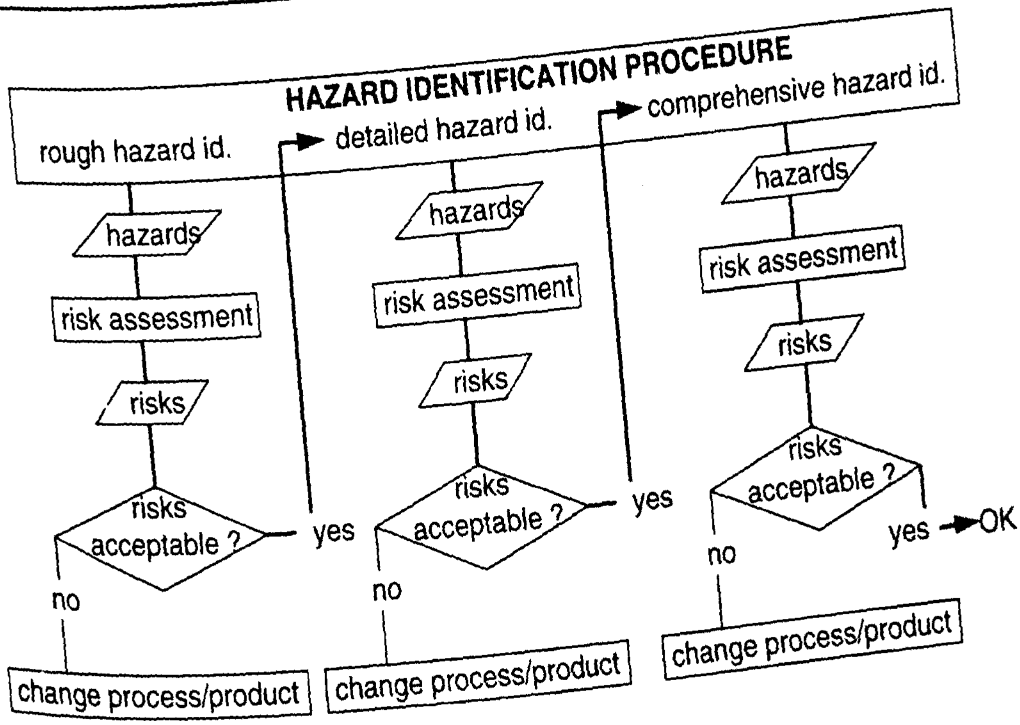

Fig. 2. Process of using several levels of detail in the hazard identification procedure (Van Gerwen et al., 1997).

The detailed and comprehensive hazard identification may result in a long list of pathogens that is impractical to work with. It is efficient to start with the most relevant hazards of this list. The user can be supported in selecting these pathogens by the use of literature and expert knowledge. Literature knowledge is useful for selection of theoretically hazardous pathogens, whereas expert knowledge is useful to treat theoretical predictions with relativism. Literature and expert knowledge have been captured in knowledge rules. The user decides which knowledge rules are applied in the hazard identification. It is this combination of various knowledge sources that provides the dynamic and interactive character to the hazard identification procedure. Three types of knowledge rules are used in the procedure (Table 1): 1. Rules concerning presence or absence of pathogens; 2. General and qualitative rules on pathogen characteristics; 3. Rules selecting the pathogens that are able to grow in the product.

Table 1
Some examples of the knowledge rules in the hazard identification procedure (Van Gerwen *et al.*, 1997)

Type 1: Rules concerning survival of pathogens:
- If pasteurisation occurs in the production process: remove all vegetative bacteria that contaminated the product before the inactivation
- If sterilisation or radappertisation occurs in the production process: remove all pathogens that contaminated the product before the inactivation
- If drying occurs: remove *Campylobacter spp.* and *Vibrio spp.* that contaminated the product before drying.

Type 2: Rules concerning general pathogen characteristics:
- Remove exotic pathogens that are not by nature present in your region. For the Netherlands these are: *Coxiella burnetii, Francisella tularensis, Vibrio parahaemolyticus, Vibrio vulnificus.*
- Remove micro-organisms of which foodborne pathogenicity is uncertain, for example: *Aeromonas caviae, Aeromonas hydrophila, Bacillus anthracis, Brucella spp., Brucella canis, Campylobacter fetus subsp. fetus, Citrobacter spp., Helicobacter pylori,* and others.
- Remove pathogens that rarely cause problems in man, for example: *Brucella canis, Listeria seeligeri, Pseudomonas cocovenenans, Streptococcus bovis* and others.

Type 3: Rules concerning growth opportunities of pathogens:
- Remove pathogens that, according to their growth characteristics (based on pH, temperature, and water activity), cannot grow or produce toxin in the end product, except for *Salmonella spp., Listeria spp., Shigella spp.* and others.

By using all types of rules, pathogens are selected that are potentially present and able to survive in the end product, and that are likely to cause health problems as a consequence of consuming the end product. For these pathogens it is important to perform risk assessments. If a first strict analysis to determine the most obvious hazards does not result in an answer, a less strict procedure is the next step. The user is free to choose which types of knowledge rules are used in the hazard identification, as there is no rank order of significance for the types of rules. Multiple runs using various options are necessary to reveal possible problems.
The result of the changing step is a practical list of pathogens, being the hazards for which risk assessments for a specified product have to be performed.

Decision supporting identification system for microbial hazards
For practical use it is very convenient to implement the interactive procedure into a decision support system. The literature and expert knowledge used in the hazard identification are captured in three databases: a food database, a pathogen database, and a knowledge database.
The computer program starts with selection of a product and product characteristics, and with construction of a process flowsheet. After this, the user must choose a level of detail for which the hazard identification procedure will be performed. A list of pathogens is the result of this first selection procedure. The list can be modified according to the userís demands. There are several options of changing the list: add pathogens, remove pathogens, and apply knowledge rules. Addition and removal of pathogens are purely based on the userís expertise. Knowledge rules can be used if the user needs support in shortening the list. The user decides which types of knowledge

rules he uses. The knowledge rules belonging to the chosen types appear one by one if appropriate. By acceptation of a knowledge rule, pathogens are deleted from the list.
The outcomes are derived by matching data from the databases. The process of matching data was described by Zwietering *et al.* (1992). If, for example, selection on growth characteristics (type 3 knowledge rule) is performed, the physical properties of the product in the food database are matched to the growth characteristics of pathogens in the pathogen database.
The final result of the hazard identification procedure is a list of pathogens, that, according to the user and the information from the databases, are hazardous.

The hazard identification procedure applied to vacuum packed cooked potatoes
The most obvious hazards for vacuum packed cooked potatoes were identified by the rough hazard identification. *Clostridium botulinum* type A is reported to have caused problems in the past in vacuum packed cooked potatoes. It is prudent to first evaluate the risk of this pathogen in the process.
Detailed hazard identification was based on the ingredients potatoes and water (water may contaminate the potatoes during washing). 33 pathogens were selected to be potentially present in the ingredients. Since this list is quite large it is useful to first start with the pathogens that are most likely to cause problems, by means of the knowledge rules. Application of type 1 rules resulted in a list of 9 pathogens, application of type 2 rules resulted in a list of 25 pathogens, and application of type 3 rules resulted in a list of 12 pathogens. For application of type 3 rules it was assumed that the pH of cooked potatoes is 6.5 ± 0.1, the water activity is 0.98 ± 0.01, and the temperature is 6 ± 1 ^{0}C, assuming that the potatoes are stored chilled. The ranges in pH, temperature, and water activity are used to compensate for uncertainties in pH, *T*, and a_w of the product and inaccuracies in determining the minimal pH, *T*, and a_w at which growth can occur.
The pathogens left after application of all knowledge rules are *Bacillus cereus, Clostridium botulinum* type B (non-proteolytic), type E, and type F. The four pathogens left can be present, and are able to survive and grow in the product. Moreover, they may well cause health problems as a result of consuming cooked potatoes in practice. Therefore, it is important to perform risk assessments for these three pathogens.
It is remarkable that *Clostridium botulinum type A*, which was identified as the most relevant pathogen, was not identified in the detailed hazard identification, when using all types of knowledge rules. *Clostridium botulinum type A* was identified in the detailed hazard identification as present on the ingredients, but it was removed from the list by type 3 knowledge rules. The fact is that *Clostridium botulinum type A* is not able to grow in vacuum packed cooked potatoes under normal conditions, in this case at a temperature of 7 ^{0}C. Its minimum growth temperature was reported to be 10 ^{0}C. The reported outbreak of botulism was most probably caused by abuse storage at temperatures higher than 10 ^{0}C. This type of problem can be identified in various failure scenarios. This example clearly shows the need to perform all kind of failure scenarios to identify possible problems and main determining parameters.
For every selected hazard it can be estimated whether it really is likely to cause food safety problems by exposure and dose-response analysis. Studies are momentary performed in these fields.

Discussion
A stepwise procedure for quantitative risk assessments has been developed, which allows to tackle the most relevant problems first, before focusing on less relevant problems. The stepwise approach is necessary in the complex field of food safety.
Quantitative risk assessments start with identification of the hazards. A procedure has

therefore been developed to systematically identify relevant hazards at three levels of detail. The levels of detail provide a way to first identify the most obvious hazards. If risks for the most obvious hazards are shown to be acceptable, more detailed hazard identifications must be performed. If detailed hazard identification results in an impractically long list of selected hazards, literature and expert knowledge can be used for well-founded reduction of the list. These knowledge sources are captured in knowledge rules. The knowledge rules are clearly defined in the hazard identification procedure, which makes the procedure clear. By this clear definition, the knowledge rules can be criticised, and changed if necessary. The user decides which knowledge rules should be applied. The combination of knowledge sources (literature, expert, user) makes the procedure interactive. The interactive character of the procedure implies that the procedure does not give definite answers on microbial hazards in food products. The hazard identification procedure is therefore best used by experienced microbiologists, who are supported in their decisions by the best use of literature and expert knowledge. By this, the most relevant hazards in a product are assessed efficiently, at three levels of detail.

The hazard identification procedure has been implemented as a computer program. This has resulted in a decision supporting identification system. The hazard identification procedure will be part of the procedure to systematically perform quantitative risk assessments for food products. Currently we are developing the other steps for quantitative risk assessment and implementing this into computer based systems. These developments will result in a decision support system for quantitative risk assessments.

References

Van Gerwen, S.J.C., De Wit, J.C., Notermans, S., Zwietering, M.H. (1997). An identification procedure for foodborne microbial hazards, *International Journal of Food Microbiology*, accepted for publication.

Zwietering, M.H., Wijtzes, T., De Wit, J.C., Van 't Riet, K. (1992) A decision support system for prediction of the microbial spoilage in foods, *Journal of Food Protection*, **55**, 973-979.