Szent István University
Faculty of Food Sciences
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THE ROLE OF RISK ANALYSIS IN THE FOOD QUALITY & SAFETY MANAGEMENT SYSTEMS

Thesis of Ph.D. Dissertation

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Approval of Head of the School Approval of Supervisor

Introduction

The most important quality parameter within the food/agri sector is food-safety. In contradiction with the rapid and continuous development of food processing technologies, applied quality control- and analytical methods, the number of food safety incidents (world-wide) are increasing too. Due to the expanding global economy and the international trading of foodstuffs, there is an increasing demand to ensure worldwide safe food.
The most significant driving force for increased attention to food safety has been the continued surge in new food borne pathogens, chemical contaminants and different food borne accidents.

HACCP *(Hazard Analysis Critical Control Point)* is the most accepted, recognized method to achieve food safety objectives effectively.
The objective of HACCP is to ensure food safety throughout the entire food chain.

The most effective industrial application of the Food Safety Management system is condition of the scientific evaluation of the related food borne hazards and their adequate control measures throughout the food chain.
Although the principles and methodology of Risk Analysis has been introduced for many years within different socio-economic fields, until recently the risk based concept within the food-industry was used „ad-hoc". In the last few years, due to the occurence of several significant food safety related hazards and their adverse health effects, a formal food industrial Risk Analysis methodology was developed.
Protection of human health is the main target of food industrial Risk Analysis, thus during the determination of acceptable risk level all related health effects must be taken into consideration.
Beyond, controlling human health and food borne diseases, Risk Analysis can be used as a tool within different areas, like optimalization of quality costs, increasing productivity, research & development, technical installations within food processing and risk based approach might be used in the daily business too.

During my research work I've assessed the opportunities of industrial application of food industrial Risk Analysis. The associated research work was conducted within the field of beverage processing. The beverage industry and related

processing and bottling technology is rapidly developing and the number of microbiologically sensitive products in the category are continuously increasing. The microbiological sensitivity of the new beverage portfolio cannot be compared to the classical beverage products, which are mainly preserved and carbonated.
In my research analysis I've applied the methods of food industrial Risk Analysis at the food safety- and the general microbiological quality levels too.

Research objectives

The objective of my research work was to establish a microbiological risk assessment method applied in the beverage industry.
Related to the research objective I was in search of certain answers.

- How could the available risk assessment methods applied in the food industry?
- What kind of predictive microbiological model fits the most for the aseptic PET beverage technology? Within this field I've conducted the following research work:
  - Frequency of occurence of *Klebsiella oxytoca* in the Water Treatment Process,
  - Probability of survival of *Alicyclobacillus acidoterrestris*, *Bacillus subtilis*, *Aspergillus ochraceus* and *Cladosporium cladosporoides* strains in the PET bottles chemical decontamination system.
- Is the Monte-Carlo method suitable to model different processes within the aseptic PET technology?
- Are the available validation methods and tools providing an adequate background for the industrial application of risk assessment?
- To define adequate microbiological criteria in order to measure the effectiveness of the PET bottle decontamination system?

During the design of my research work one of the main focus points were to provide scientifically based answers to the frequently referred questions, presented by food business operators: what is the probability to manufacture products in compliance with the related and required quality standards, at a given hygiene level in the processing environment? How can the risk assessment based approach – defined by the Codex Alimentarius Commission – applied at Company level?

Materials and methods

The scope of my research work covers the following areas:

- Water Treatment process,
- Chemical decontamination of PET bottles.

Microbiological analytical methods

Standard membrane filtration and pour plating methods were applied during the applied microbiological analysis.

Within the first test series i.e. Water Treatment process, a member of the Coliform group - *Kbsiella oxytoca* – was selected as a test strain.

In the second test series i.e. PET decontamination process, 4 test micro-organisms were selected (*Alicyclobacillus acidoterrestris, Bacillus subtilis, Aspergillus ochraceus, Cladosporium cladosporoides)*.

The role of the above described indicator and spoilage micro-organisms are proved throughout many different food hygiene indicators and spoilage problems across the beverage industry.

Determination of the destruction kinetics - Klebsiella oxytoca

Experiments were carried out at room temperature (22-24 °C) using different chlorine concentrations (4, 6, 8, 10, 12 mg/l). As a disinfectant agent commercial bleach was used in a pilot plant (active chlorine concentration: 90g/l). One ml of the basal suspension of *Klebsiella oxytoca* was added to 12.5 ml of water samples with different chlorine concentrations. The suspension was prepared from *Klebsiella oxytoca* cells, which were incubated for 24 hours. The living cell numbers (cfu) were determined at 10, 20, 30, 40 and 50 minutes after the addition of the basal bacterial suspension to the chlorinated water samples. The destruction rate coefficients (k) belonging to the different chlorine concentrations (c) were calculated from the linear regression equations of the surviving curves ($\log_{10}$ N vs. time).

Plotting the $\log_{10}$ k values against $\log_{10}$ c values, from the linear relationship, the concentration exponent (n) could be determined as the slope of the curve. With the concentration exponent the effect of the concentration on the destruction rate (k) or decimal reduction time (D) was calculated.

Modeling of *Klebsiella oxytoca* survival in the Water Treatment technology

The Water Treatment process consists of the following process elements:

- from the raw water storage/buffer tank (1 m^3 - in the pilot plant) the water is supplied onto the sand-filter for mechanical filtration.
- from the sand filter the water goes into the reaction tanks, where chlorine is injected into the water flow. The chlorine is dosed into the pipe section just before the reaction tanks.
- removal of the chlorine is performed by filtration of the water supply via carbon-filters.
- as a final step the water is filtered through a 10 μm mesh filter, i.e. polisher.

The *Klebsiella oxytoca* suspension was injected into the raw water supply system. The introduced cell number - N_0 [cfu/ml] – value was determined by preparing dilution series. The initial cell concentration was kept constant for a period of 10 days. Followed by the completion of the 10 days period, new inoculum initial cell concentration level was selected. The level of contamination followed by the polisher filtration - N_1 [cfu/ml] - was measured on a daily basis.

Operation of the Water Treatment pilot plant was conducted according to the relevant industrial standards, i.e. chlorination dose: 6-8 mg/l (target value: 7mg/l); contact time: 50 min. Enumeration of *Klebsiella oxytoca* strains was performed on Endo-agar (MERCK), by applying the following incubation conditions:

temperature: 37 °C; incubation period: 24 (48) hours.

Minimum level of detection was defined as: $4 \cdot 10^{-3}$ cfu/ml (1 cfu/250ml), logarithm value lgN = -2,4.

The end-point of the microbiological risk assessment was selected as: lgN = -2,4.

PET bottles decontamination experiment

At the aseptic PET bottles decontamination process step as a chemical sterilant agent, in most cases Oxonia type of disinfectant is applied. This chemical consists of Peracetic-acid (=PAA) (5,8%) and hydrogen-peroxid (27,5%) 1:4 ratio mixture. The applied concentration of the chemical during bottle decontamination is: 1500 mg/l (PAA). During the first step of the decontamination cycle all bottles are inverted by a rotary rinser, operated at a speed of 28,000 bottles/hour. Followed by this step, the

chemical disinfectant is injected into the bottles by using 3,5 bar pressure. The objective of this step is to create an Oxonia layer inside the entire bottle surface.
The temperature of the desinfectant at the point of appication: 52 °C, contact time: 8 sec. Removal of the residual chemical desinfectant is performed by sterile water rinsing. (Maximum residue level of chemical agent in the PET bottle: 0,5 mg/l)
The test series was performed in the pilot plant applying 4 repeats, where 24 bottles were contaminated/test micro-organisms. The Pet bottles were decontaminated according to the routine industrial operations requirements, desribed above.
Total number of analysed PET bottles:
96 contaminated PET bottles / test microbe + 4 positive control + 4 negative control.

Teszt-micro-organizms:

Alicyclobacillus acidoterrestris
Bacillus subtilis
Cladosporium cladosporoides
Aspergillus ochraceus

The inoculum used to test the bottle decontamination system consisted of approximately 90% spores versus vegetative cells. The initial cell concentration was adjusted to the value of 10^6 cfu/bottle.
1 ml of suspension was added in the 0,5 l PET bottles and distributed evenly. The bottles were dryed at room temperature (20-24 °C) for a period of 48 hours.
All test bottles were decontaminated according to the above described technology.

The end-point of the microbiological risk assessment was determined as: 1 cfu/bottle contamination value.

Mathematical modelling of the microbial survival

The risk associated with survival of test microorganisms were accordingly modelled taking into consideration the relevant destruction kinetics parameters, level of initial contamination and it's variation where Monte-Carlo modelling was used as a risk assessment tool. The relevant destruction kinetics parameters were calculated with STATGRAPHICS 5.1 (Statistical Graphics Corporation, USA) software.

The Monte-Carlo simulation was performed by using Microsoft Excel 2002 (Microsoft Corporation) és @Risk 4.5 for Excel (Palisade Corporation, Newfield, New York) software. In most experimental models described in my dissertation 10,000 iterations were applied.

Results

Results of *Klebsiella oxytoca* chemical destruction

The different survival curves associated to the different chlorine level, have been determined.

Based on the slopes of the curves (m) the destruction rates (k) and decimal reduction times (D) are defined.

Table 1. *Klebsiella oxytoca* destruction kinetics parameters due to chlorination

chlorine ($mg\ l^{-1}$)	k (min^{-1})	D (min)
4	0.135	17.0
6	0.195	11.8
8	0.328	7.02
10	0.393	5.87
12	0.583	3.95

The results of linear regression:

$$\lg k = -1{,}689 + 1{,}317 \cdot \lg c, \qquad R^2 = 0{,}979$$

This is in good agreement with the n = 1 value of hypochlorous acid reported by Odlaug, (1981).

Calculating the destruction rate belonging to the chlorine concentration of 7 mg l^{-1}, which is a mean value in the industrial chlorination:

$$k = 0.265 \text{ min}^{-1}.$$

Modelling of survival of *Klebsiella oxytoca* in the Water Treatment Process

The initial - N_0 [cfu/ml] - contamination value is decreased - N [cfu/ml] - by dosing chlorine in the reaction tanks. If the coliform cells are surviving the chlorination in the reaction tanks, the risk is high that coliform positive water samples are detected in the system, which have a direct influence on the water quality used for the syrup manufacturing as well as for beverage filling. I've calculated the living cell concentration (N_t) value based on the related destruction kinetics equation, where k(c) is the destruction rate related to the given chlorine concentration, (t) is the contact time related to the chlorination process. (t) has been estimated by using the contact times in the reaction tanks.

In the mathematical model the analysed parameters are considered as probability density functions, which are represented by the relevant distribution parameters (μ; σ). The variation of the factors (N_0, c, t), which are directly influencing the number survivals cannot be considered as explicit parameters, thus Monte-Carlo simulation was used.

The estimated values used in the Monte-Carlo model are summarized in table 2.

Table. 2. The estimated values used in the Monte-Carlo model

Input parameter	Type of distribution	Parameters of distribution
Initial cell concentration	Normal x = log N	μ =-2 – 6 σ = 0.5
Chlorine concentration in the reaction tanks	Normal x = c	μ = 7.0 (mg/l) σ = 0.5 (mg/l)
Contact time in reaction tank I.	Exponential x = t $\beta = \bar{t}$	- β = 25 (min)
Contact time in reaction tank II.	Exponetial x = t $\beta = \bar{t}$	- β = 25 (min)

In alignment with the determined risk assessment end-point, the probability of survival and detection is defined based on the distribution function resulted from the Monte-Carlo simulation [lgN_t>-2,4], where the probability values are defined from the [$P(lgN_t$>-2.4)] risk estimate.

The initial cell concentration [lgN_0] was adjusted between -2 – 6 and at each value 10.000 iteration was performed in order to determine [lgN_t] values. Followed by this step – by using the MC software – I've calculated the probabilities [$P(lgN_t$>-2.4)] associated with the [lgN_t>-2,4] values, based on the [lgN_t] values distribution functions. The resulted probabilities are illustrated in the function of the initial cell concentration (lgN_0). On Figure 1. it can be seen that within the traditional Water Treatment systems even in case of the lowest detectable contamination level the risk of survival and detection of 1 *Klebsiella oxytoca* cell is approximately 3-4%.

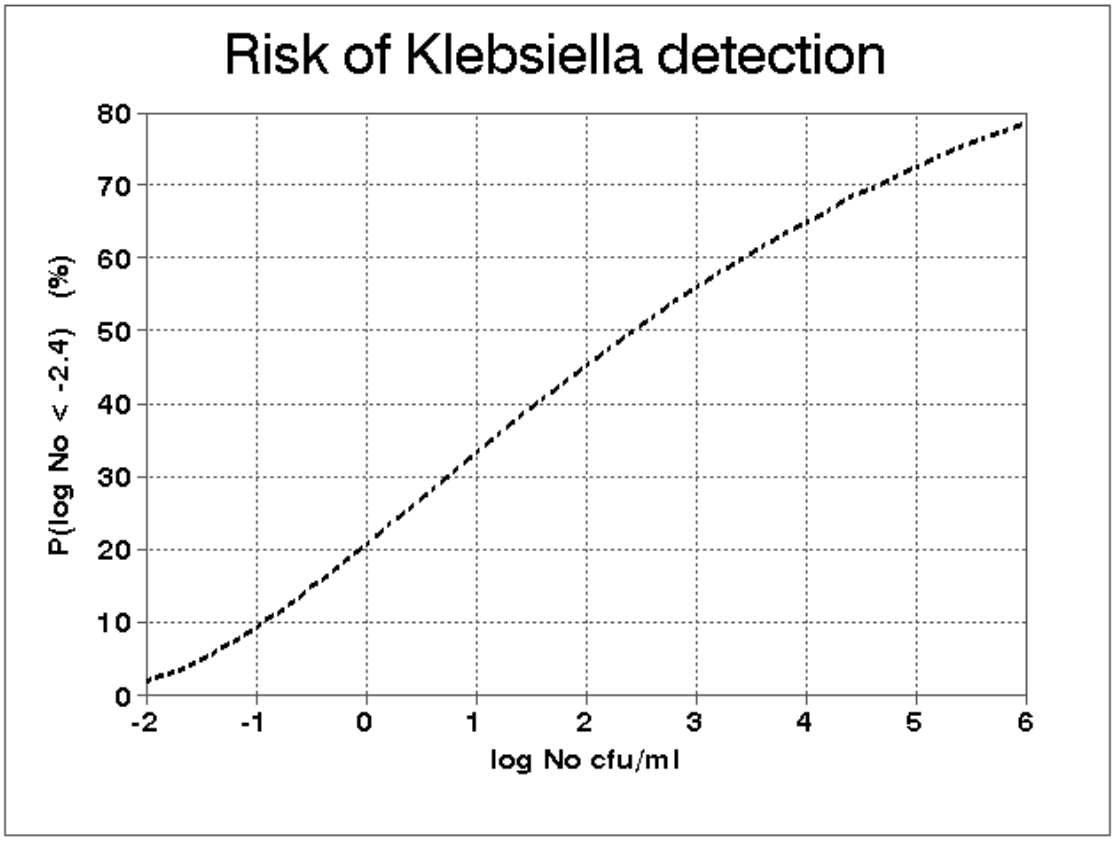

Figure 1. Probability of detection of *Klebsiella oxytoca* cells surviving the Water Treatment Process, in the function of the initial raw water contamination level

Validation of the *Klebsiella oxytoca* survival and detection model

The validation of the above described microbiological risk assessment model was carried out in a R&D pilot plant department (SIDEL beverage filling division/France). The validation period was defined as 180 days (10 decades). The *Klebsiella oxytoca* contamination level was analysed on a daily basis, by applying membrane filtration method. The results are summarized in table 3.

Table 3. Validation of the *Klebsiella oxytoca* survival and detection model

Decade	log N_0	P(lg N_t>-2.4) (%)	Detection (%)
1.	-0.49	15	10
2.	-1.40	6	10
3.	-	0	0
4.	-0.50	15	20
5.	0.48	26	30
6.	0.30	25	20
7.	3.04	56	50
8.	0.70	31	30
9.	4.08	66	70
10.	1.99	45	40
11.	0.00	20	30
12.	-1.00	9	10
13.	-0.82	11	0
14.	-0.52	14	20
15.	-1.70	4	10
16.	0.08	21	20
17.	1.23	36	30
18.	-0.60	14	10

Based on the analysis I've conducted the linear regression equation was determined, which describes the correlation between the observed and predicted values. Of the survived and detected *Klebsiella oxytoca* contamination levels. Detected contamination level (%) = -1,28 + 1.091 · predicted probability (%)

Data pairs = 18

Determination coefficient: R^2 = 0,905

Results of the PET bottles decontamination experiment

The initial cell concentration was determined by pour plating and preparation of dilution series of the inoculum.

Followed by the 8 sec. contact time the residual microbial contamination level in the PET bottles were determined in lg values. During my experimanetal work, significant survival was detected only in case of *Alicyclobacillus acidoterrestris.* In most cases the residual cfu level was below 10. Survival rates are summarized in table 4.

Table 4. Survival rates – PET bottles decontamination experiment

Teszt strain	PET bottles pieces	Survival measured pieces	Level of contamination cfu/bottle 1-10	11-100
Alicyclobacillus acidoterrestris	96	90 (94%)	85 (94%)	5 (6%)
Bacillus subtilis	96	20 (21%)	20 (100%)	0
Cladosporium cladosporoides	96	1 (1%)	1 (100%)	0
Aspergillus ochraceus	96	0	0	0

By calculating the destruction rates, it was considered that the decontamination treatment might result in higher destruction rate.

The initial cell – determined by pour plating from the positive control bottles - concentration was considered as reference parameter.

Table 5. Details of survival rates – PET bottles decontamination experiment

Teszt strain	lgN_0	Nr. of contaminated bottles				lg N_o/N_t	D* (s)
		1.	2.	3.	4.		
A. acidoterrestris	**5,82**	24	23	23	20	4,59->5,82	1,37
B. subtilis	6,34	0	9	10	1	5,39- >6,34	1,26
C. cladosporoides	6,32	0	0	1	0	6,02- >6,23	1,26
A. ochraceus	6,15	0	0	0	0	>6,15	1,30

(Decontaminated bottles: 96/strain/repeat)

* 8 sec. contact time

There were significant differences detected by measuring the survival rates related to the different micro-organisms. While *A. ochraceus* and *C. cladosporoides* cells were to a large extent destroyed, *B. subtilis* and (especially) *A. acidoterrestris* resulted in significant survival rates by applying large, i.e.10^6 cfu/bottle dose initial cell concentrations in the experiments.

Probability model of the PET bottle decontamination process

The probability of detecting contaminated Pet bottles followed by the sterilization process was simulated by Monte-Carlo modelling.

The statistical parameters taken into consideration during the simulation were as follows:

Input parameter: $\lg N_0$, $\sigma = 0{,}5$.

The input parameter (initial cell concentration) was adjusted between $\lg N_0 = 1–7$ (scale parameter 0,5)

Contact time (chemical treatment): $t = 8$ s $\sigma = 0{,}5$ s

Destruction rate: $D = 1.3$ s $\sigma = 0{,}2$ s

Model describing the survival: $\lg N_t = \lg N_0 - t/D$

Model output parameter:

Risk of beverage spoilage: The probability of surviving test micro-organisms detected in more then 1 bottle: $P(\lg N_t \geq 0)$.

The results based on the Monte-Carlo simulation are summarized in table 6. (10.000 iteration)

Table 6. Probability of PET bottle contamination in the function of the initial cell concentration level

	Classical Estimation			**Monte Carlo**
$\lg N_o$	**$\lg Nt = \lg N_0 - 8/1{,}3$**	**N_t**	**$P = 1 - e^{-N}t$ (%)**	**$P(\lg N_t \geq 0)$ (%)**
7	0,85	7	99,9	74,5
6,5	0,35	2,2	88,9	60,7
6	-0,15	0,71	50,4	43,2
5,5	-0,65	0,22	19,8	26,3
5	-1,15	$7 \cdot 10^{-2}$	6,78	12,1
4,5	-1,65	$2 \cdot 10^{-2}$	2,00	4,32
4	-2,15	$7 \cdot 10^{-3}$	0,69	1,14
3,5	-2,65	$2 \cdot 10^{-3}$	0,20	0,17
3	-3,15	$7 \cdot 10^{-4}$	0,07	0,02
2,5	-3,65	$2 \cdot 10^{-4}$	0,02	0,0015
2	-4,15	$7 \cdot 10^{-5}$	0,007	<0,001

The classical prediction (estimation) of probability values of beverage spoilage were determined based on the observed cfu numbers in the relevant destruction kinetics equation.

The probability of detection survival cells in the PET bottles:

$$P = 1 – \exp (-N_t)$$

The N_t values determined by the classical estimation - destruction kinetics equation is not taking into consideration the variation of the related statistic parameters, thus they are not reflected in the probability values. In table 6. the comparison values based on the classical estimation and the Monte-Carlo simulation are reflected.

Conclusions

Microbiological risk assessment modelling is proved to be a very effective tool to predict microbiological quality parameters in food processing. Based the evaluation of the experiments carried out in my thesis the following conclusions are made:

- The effectiveness of the applied chemical treatment in the traditional water treatment processes is very limited. The risk associated with the survival and detection of *Klebsiella oxytoca* in the treated water is high.
- The analysed and applied Monte-Carlo method provided suitable good performing risk estimates, related to the probabilities of survival of *Klebsiella* spp. especially in low dose applied cases, which cases were validated successfully, by pilot plant experiments (180 days).
- In case of large dose applied in the aseptic PET bottle decontamination system the Monte-Carlo simulation didn't provide as precise prediction risk estimates as the classical model, which has been defined based on the relevant destruction kinetics equation.

- The application of the classical model for determining microbiological quality parameters in the aseptic technology is further recommended. The microbiological criteria to be used for the maximum tolerable contamination level / PET bottle is recommended as:

$$N_0 \leq 100 \text{ cfu/palack}$$

This value is ensures that the commercial sterility rate (0,01%), from a bottle decontamination effectiveness point of view.

Summary

During my thesis I've reviewed the specific aspects of the Food Quality Management systems, with a special focus on the role of HACCP within the field of food safety. In compliance with the objective of my research work, followed by the review of food chemical- and physical risk analysis processes, I've investigated and described the structure and methods of microbiological risk analysis. The qualitative and quantitative aspects of the microbiological risk assessment as one of the most important elements of the risk analysis process were explained, based on the review of related activities at national and international level. Although, the overall risk assessment projects were reviewed in detail, the experiments, related to my thesis were designed in order to investigate the opportunities of food industrial application of these methods.

The industrial experiments related to the microbiological risk assessment process were carried out in the beverage industry, which is one of the most rapidly developing fields within the food industry. Aseptic PET technology represents the latest strategical and technological development within the beverage industry. The aseptic PET filling technology is described in depth in my study.

Experiments were carried out at two process elements – water treatment & PET bottle decontamination system – both elements have a critical impact on the microbiological safety and quality of the product. The objectives of the experiments were to estimate the risk level associated with the occurrence of determined microbiological hazards.

Based on the scope of the assessment, quantitative risk assessment (QRA) was used as a process by which the results of the hazard analyses were applied to support business decisions, which might not necessarily impact the food safety parameters of beverage products, but all other quality parameters.

During the first set of experiments, simulation of probability of occurance and detection of the most resistant member of the Coliform group, Klebsiella oxytoca was carried out. The QRA process was used in order to estimate the probability of the test micro-organism in the treated water as a function of the initial contamination level of the raw water. The risk assessment end-point was determined as: coliform bacteria level of treated water sample $\geq$ 1 cfu/250 ml. The water treatment process is based on chlorination and operated according to the industrial standards. The QRA process was based on the assumption of the initial viable cell concentration and the mathematical modelling of the effect of chlorine on the destruction rate, taking into account the

probability distribution of the contamination, chlorine concentration and the residence time distribution during disinfection. For evaluation, the Monte Carlo simulation was applied. The model was validated in a Pilot Plant for a period of six months and the linear relationship between the predicted and observed probability of *Klebsiella*-detection was characterized with a determination coefficient of R^2= 0.905.

During the second set of experiments the risk of microbiological contamination rate was simulated at the aseptic filling bottle decontamination system. Four different test strains were applied in the experiment. The importance and role of the strains being clearly proved in the beverage industry. The PET bottles were contaminated by using the suspension of the given test strain and followed by the routine decontamination cycle the residual contamination was measured. We determined the probability of occurrence of the bottle contamination after the sterilization cycle as a function of the input cell concentration. The uncertainty related to the probability distribution was taken into consideration by using the Monte-Carlo simulation. A comparison was established between the Monte-Carlo method and the classical exponential model, which is calculated from the microbial destruction kinetics associated to the theoretical considerations. Microbiological criteria were recommended in order to measure the sterilization effectiveness of the bottle decontamination system.

Newly achieved scientific results:

- Application of the available risk assessment methods and their importance in the decision supporting system is verified by food industrial trials.
- The advantages of the Monte-Carlo methods in the field of microbiological risk-assessment are verified by relatively long term pilot-plant trials.
- Predictive model is established in order to support the quality control system.
- The differences between the Monte-Carlo and traditional theoretical models are described in case of low dose occurrence.
- Recommendation is made for introduction of microbiological criteria, to measure the effectiveness of the PET bottle decontamination system.

List of publications related to the subject of the dissertation

I. Publications in International Journals

1. Journals with impact factors

Dióspatonyi I., **Syposs Z.**- Viczián Zs., Kollár G. Láng-Lázi M. (2000): Quality assurance aspects in biochemical and chemical information technology. Computers and Chemical Engineering 24 pp. 1031-1036.

Kollár G., Viczián Zs., **Syposs Z.,** Füstös Zs., Dióspatonyi I. (2000): Quality assurance, information technology and bioindustry. Hungarian Journal of Industrial Chemistry. Veszprém, Vol. 28. pp. 317-320.

Kollár G., **Syposs Z.**, Viczián G., Mészáros L., Kollár-Hunek K. (2001): Quality Management System as a tool of process control for food and agri industries. Hungarian Journal of Industrial Chemistry. Veszprém, Vol. 29. pp. 135-138.

Z. Syposs, O. Reichart, L. Mészáros (2003): Microbiological risk assessment in the beverage industry. Food Control-Elsevier Sciences Publishers. Jóváhagyott folyóiratcikk. Megjelenés várható időpontja: 2003 szeptember.

2. Journals without impact factors

Kollár G., Füstös Zs., **Syposs Z.**, Viczián Zs. (1999): The effect of Quality Assurance on the Postharvest processes. New Economy of Horticulture, 31/4. Budapest p. 128-130.

Kollár G., Füstös Zs., **Syposs Z.**, Viczián Zs. (1999): The effect of Quality Assurance of the Postharvest processes. Seed, Research, Cultivation, Commercelization, XIII. Nr.6. p.29-30.

Syposs Z., Kollár G. (2000): Quality Assurance & Food Safety systems. New Economy of Horticulture. 32/1. pp. 48-52.

Syposs Z. (2000): The application levels of quality system audits. Mineral Water, Beverages, Fruit Juices. Budapest, I. 1. p. 21-22.

Syposs Z. (2000): The structure and specialties of the ISO 9001:2000 quality system standard in the Food Industry. Mineral Water, Beverages, Fruit Juices. Budapest, I. 2. p. 53-54.

Syposs Z., Lakner Z. (2000): Quality related challenges faced by the Hungarian Food economics in the globlaization. Mineral Water, Beverages, Fruit Juices. Budapest, I. 3. p. 63-69.

II. Conference - full papers, abstracts & posters

1. Full paper - Hungarian

Syposs Z. (2001): Applied methods in the Risk Assessment & HACCP. Hungalimentária 2001., Budapest, P 15.

2. Abstract - Hungarian

Kollár G., Viczián Zs., Füstös Zs., **Syposs Z.** (1999): Quality Assurance & Information Technology. Chemical engineering. Hungary, Veszprém, p. 105.

3. Full paper – International Conference

Z. Syposs, Z. Lakner (2000): The Role of Quality Certification in the European Market. The effect of quality strategy on competitiveness in the Hungarian Food Chain. 44th EOQ International Congress Budapest, Hungary. pp 419-433.

Kollár G., Viczián G., **Syposs Z.**, Mészáros L., Hunek K. (2001): Postharvest aspects in Quality Management System engineering for fruit and vegetable production. Proceedings of 6th International Symposium on Fruit, Nut, and Vegetable Production Engineering, Potsdam. pp. 351-357.

Z. Syposs, G. Kollár (2001): Applied Risk Assessment Methods in the Food Industry. 45th EOQ Congress 19-21 September 2001. Istanbul, Turkey. D3 pp.1-8.

Z. Syposs, G. Kollár (2002): Microbiological risk assessment in the beverage industry. Fifth International Food Safety and HACCP Conference, Noordwijk, the Netherlands. Lectures pp. 37-38.

4. Abstract – International Conference

Z. Syposs, M. Erdélyi (1999): DNV experiences on independent industrial HACCP self assessment in Hungary. Third International Food Safety and HACCP Conference, Noordwijk, the Netherlands. P5. pp. 50.

M. Erdélyi, L. Lelik, **Z. Syposs** (1999): Sensory and analytical tests on recyclable bottles (PRB) used for saturated soft drinks. Third International Food Safety and HACCP Conference, Noordwijk, the Netherlands. P10. pp. 57-58.

Z. Syposs (2000): DNV experiences on supplier chain auditing in Hungary. Food Hygiene Europe 2000 Conference, Amsterdam, the Netherlands. P4. pp.68.

Kollár G., **Syposs Z.** (2000): Experiences of QA & Food Safety Systems Audits. Lippay János-Vas Károly Scientific conference. Szent István University Budai Campus Publications. Bp. pp.116-117.

Z. Syposs, J. Tornai-Lehoczki (2003): Application of acidified? (pH 4,5) Linden Grain Medium as a microbiological validation tool in the Aseptic Beverage PET Technology. 23rd International Specialised Symposium on Yeasts, Budapest, Hungary. Jóváhagyott absztrakt a konferencia kiadványban. Megjelenés várható időpontja: 2003 augusztus.