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MANAGEMENT OF PROCESS SAFETY IN FOOD CHAIN

Abstract: *Food safety in all food industries gains increasing importance. Except health risks, diseases caused by spoiled food can significantly increase the economic costs, including medical treatment, absence from work, insurance payments and legal compensation. This paper considers the problem of determining the safety of production processes, and thus the products, in food chains using an expert system which is based on fuzzy logic. All the uncertainties and imprecisions that exist in a model properly are described using the theory of fuzzy sets. The quality goal values and the optimal management starategy are determined by proposed fuzzy expert system.*

Keywords: *food safety, food supply chain, process safety, fuzzy logic, expert system*

1. Introduction

Food safety and quality are of great importance for all participants in a long and very complex "food chain", although they are very important for society in general. Unfortunately, it must be noted that in the world with over 7 billion people, more than 1.2 billion don't have, or don't have enough food and water. An additional problem is the generally high prices of food products in the world, which is why the food is less accessible to a wider range of users. Serious problems also appear in terms of food safety, because only from diarrhea worldwide are diagnosed annually more than 1.5 billion people, with about 3 million deaths. Significant problems are appearing in terms of food quality, where due to different inconsistencies refund and cancellation of food products participate with about 9-12% of the total annual food trade in the world (Radovanovic& Djekic, 2011).

Ensuring high-quality food has been one of the major efforts of men since the first days of human existence. The safety of food is a basic requirement for the food quality and during the production, processing, storage and preservation food can be contaminated with a variety of substances from the environment (Tadic, 2009). For that reason, a new fuzzy expert system was developed, by which it can be relatively easy to determine the safety of processes and products in the food chain over a certain period.

The paper is organized as follows: Section 2 gives a summary of the literature dealing with the problem of determining the safety of processes and products in the food chain and the literature shows different approaches for calculating the weight of the items in a variety of management problems. Chapter 3 presents the problem statement and modeling of uncertainties by using fuzzy set theory.

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Chapter 4 presents a new fuzzy expert system built using Javascript programming language, which is used to evaluate the safety of products and processes in the food chain. In Section 5, the fuzzy expert system is illustrated by an example which uses the real data obtained from a food supply chain that operates in central Serbia. Also, the discussion of the results was showed. Conclusions are given in Chapter 6.

2. Literature review

For analyzing and monitoring processes and raw materials used in each stage of the process over time inherent safety index can be used. Based on the inherent safety index the safety during the process realization can be controlled and increased. This term was first widely expressed in the 1970's by Trevor Kletz. The basic principles are common sense, avoiding and minimizing the use and inventories of hazardous materials, and aiming for simpler processes (Kletz, 1984). Essentially, the safety should be considered and addressed in the whole life cycle of a process system or a facility (Greenberg and Cramer, 1991).

Considering that the HACCP (Hazard Analysis and Critical Control Points) has been accepted as an important tool for the identification and control of food safety, there is a lot of work that aims to provide guidance to the organizations involved in the food chain, to evaluate, and then verify the HACCP system. In the literature, there are many papers in which using HACCP system are presented (Toljagic-Milodanovic, 2009; Tadić, 2009; Henson and Caswell, 1999). The main goal of authors is to highlight those factors which are crucial for understanding of contemporaneous food safety controls in both the public and private spheres.

Determination of the weights of quality goals is a complex task and can be considered as a task in itself. Many papers determine the criteria weights using a procedure that is developed in the conventional AHP (Analytic Hierarchy Proces) (Galovic *et al*., 1997; Galovic, 2001; Tadić, D., Stanojević, 2005). The relative importance of criteria is in many papers (Gumus, 2009; Tadic, 2011; Chan and Kumar, 2007; Tadić *et al*., 2010; Chen, 2000; Chen *et al.* 2006; Tadic *et al*., 2007) given by a pair-wise comparison matrix, where the elements of the matrix are linguistic expressions. It is believed that this approach is close to the human way of thinking. It is assumed to be much fairer for the management team to presents their estimates using linguistic expressions. Chang (1996) has developed a method by which the weight vector of the considered goals is determined using the matrix of relative importance whose elements are described by fuzzy numbers.

Quality goal weights are in many previous works determined by combining the two approaches described. Zadeh (1965) assumed that pair-wise comparison matrix of criteria weights is constructed, and its elements are transformed to fuzzy numbers. Also, the relative importance of each of pair of entities can be described by five linguistic expressions.

Xiaojun *et al*. (2012) proposed a new risk assessment approach to perform structured analysis of aggregative food safety risk in the food supply chain. They used the concepts of fuzzy set theory and analytical hierarchy process, performed structured risk assessment and established an aggregative food safety risk indicator. In this paper a single value is representing the risk rating, and it can be efficiently employed in incorporating the safety objectives into operations planning.

Shi and Wang (2010) used the improved algorithm of membership degree transformation which includes three calculation steps. They can be summarized as “effective, comparison and composition”. Here, the new algorithm in fuzzy evaluation on the safety of foods is applied, and evaluation results show the validity of the improved model. Thus, the model can achieve the dynamic evaluation of the safety of foods in some country or some region.

According to some authors, the uncertain information can be in a much better way represented using the generalized fuzzy numbers than normal fuzzy numbers. Jianling and Yong (2010) proposed the model for food safety risk analysis using the generalized fuzzy numbers. First, they proposed a modified similarity measure. Then, step by step the food safety risk analysis model was presented and also the modified operation rules on generalized fuzzy numbers. Finally, the efficiency of the proposed method was showed using a risk analysis numerical example on food safety.

In a study (Kadir *et al*, 2011) to predict the grain security level authors used an Adaptive Neuro-Fuzzy Inference System (ANFIS). The inputs for this study are based on 3 categories, productive indexes, consumptive indexes, and disaster indexes. In total there are eleven input indexes to the system and each input has 2 membership functions. The system output is the level of the grain security.

For the early-stage risk assessment of microbial hazards in food chain Davidson *et al*. (2006) developed a Fuzzy Risk Assessment Tool (FRAT). Parameters to describe initial hazard level, potential changes during processing and consumer preparation as well as factors related to consumption and health impact are defined by user. Linguistic expressions were used to define the inputs and they were converted to fuzzy numbers. Also, the interval arithmetic was used to compute exposure and risk.

3. Problem statement

3.1 Basic assumptions

Managing food safety in a supply chain is a very complicated management assignment. In this paper, there are three main processes in the food supply chain: (1) primary production, (2) processing and (3) storing, serving and consuming.

Top management must ensure that on every level inside the organization and corresponding functions quality goals are established, including those that fulfill the products. Respecting the quality politic, management team sets the measurable quality goals. As a rule they are presented annually.

Discussed management problem is realized firstly by defining the quality goals for every process in the supply chain, and then defining relative importance of quality goals and values of quality goals in different periods of time.

Therefore, this problem can be decomposed on three sub-problems, with the following quality goals:

(1) Food safety management in a process of primary production: quality of materials, quality of processing, quality of environment, quality of verification and quality of human resources;
(2) Food safety management in a process of product processing: quality of materials, quality of processing, quality of equipment, quality of verification and quality of human resources;
(3) Food safety management in a process of storing, serving and consuming: fulfillment with prescribed storing, fulfillment with prescribed consuming and incomplete information during the consummation.

Parameters of which we measure the values of goals are determined to give us the clear state of the achievement of the goal. For products that are produced on a daily basis it is very important that quality goals are evaluated in short periods of time. In this paper, the time period in which the food safety management is measured is discretized into time periods of one month.

3.2 Modeling of relative importance of quality goals

Generally, it can be assumed that relative importance of quality goals in every part of supply chain is not equal. In this paper, quality goal weights on every level of supply chain are already given via pair-wise comparison matrix of relative importance of these goals (analog to Analytic Hierarchy Process). Also, modeling of linguistic expressions in this paper is based on theory of fuzzy sets respecting the rules which were defined by Klir and Folger (1988).

The total number of parts of supply chain is marked as I. Importance of quality goal q in part of supply chain i, $q, q' = 1,..,Q_i$; $i = 1,..,I$; is described by linguistic expressions which are modeled by triangular fuzzy numbers $\tilde{w}^i_{qq'}$. Lower, upper and modal value of this fuzzy numbers are marked as $l^i_{qq'}$, $u^i_{qq'}$ and $m^i_{qq'}$ respectively. Values in domain of these triangular fuzzy numbers belong to the set of real numbers in the interval [1-5]. Value 1, or value 5, says that the first member compared to the second member of considered pair has equal or extreme importance, respectively. If the importance of quality goal q' compared to quality goal q on level i of the supply chain is greater, then the element value inside the pair-wise comparison matrix of relative importance of these goals is presented as triangular fuzzy number:

$$\tilde{w}^i_{qq'} = \left(\frac{1}{u^i_{qq'}}, \frac{1}{m^i_{qq'}}, \frac{1}{l^i_{qq'}} \right) \qquad (3.13)$$

If relative importance of elements of earlier described matrix is equal, it is represented with fuzzy number (1,1,1). In this paper, fuzzy estimation by the management team is described via five linguistic expressions which are modeled by triangular fuzzy numbers, given in the following way:

Very low importance	$\tilde{R}_1 = (x;1,1,2)$
Low importance	$\tilde{R}_2 = (x;1,2,3)$
Moderate importance	$\tilde{R}_3 = (x;2,3,4)$
High importance	$\tilde{R}_4 = (x;3,4,5)$
Very high importance	$\tilde{R}_5 = (x;4,5,5)$

3.3 Modeling of quality goal values

As the values of quality goals are not measurable, it can be imported real assumption that it is closer to human way of thinking to describe these values using linguistic expresions. Therefore, quality goal values in every period of time t, t=1,..,T in part of supply chain i, i=1,..,I are evaluated by decision makers using linguistic expressions which are modeled using triangular fuzzy numbers. Number of these expressions is determined by management team taking care of the supply chain size.

Value of quality goal q^i in a supply chain part i, in time period t, is marked as $\tilde{v}^i_{qt}$, $i = 1,..,I$; $q = 1,..,Q^i$; $t = 1,..,T$;. Total number of quality goals in which food quality is evaluated in a supply chain part i is marked as Q_i. Time period in which food safety is monitored is T. Lower, upper, and modal value of triangular fuzzy numbers $\tilde{v}^i_{qt}$ are marked as L^i_{it}, U^i_{qt}, M^i_{qt}, respectively.

Values of quality goals within the each part of supply chain for each period of time are defined by using seven linguistic expresions which are modeled as triangular numbers shown below:

Very low value	(y;1,1,2)
Low value	(y;1,2,3)
Medium low value	(y;1.5,3,4.5)
Medium value	(y;3.5,5,6.5)
Medium high value	(y;5.5,7,8.5)
High value	(y;7,8,9)
Very high value	(y;8,9,9)

3.4 Proposed fuzzy model

Fuzzy analysis of food safety management in a supply chain in specific period of time is based on the aggregation of already defined quality goals for each part of the supply chain.

It is assumed that values of quality goals for each part of supply chain are not equal. Relative values of quality goals on every supply chain level are given via pair-wise comparison matrix. Elements of this matrix are linguistic expressions which are modeled using triangular fuzzy numbers $\tilde{w}^{i}_{qq'}$, $q, q' = 1,..,Q_i$; $i = 1,..,I$. Weight of a quality goal q, $q = 1,..,Q_i$ in the part of supply chain i, $i = 1,..,I$ is calculated as average of all estimated values of relative ratio of the observed goal inside of pair-wise comparison matrix. The resulting value is also a triangular fuzzy number, based on algebra (Klir and Folger, 1988; Zimmermann, 1996). Value of this triangular fuzzy number is defuzzed by using the method of maximal probability (Zimmermann, 1996). Representative scalar of fuzzy number $\tilde{w}^{i}_{qq'}$ is marked as w^{i}_{q}.

The weighted normalized value of each quality goal, in the part of supply chain i, in time period t, is calculated as a product of goal weight $\tilde{d}^{i}_{qt}$.

For the analysis of the success of food safety management in the supply chain following tasks are important.

(1) Decision in which time period t defined quality goal q on supply chain part i has the lowest value, $q = 1,..,Q_i$; $i = 1,..,I$; $t = 1,..,T$. Based on this value the management team can take appropriate actions to improve performance of that goal in period t, t=1,..,T.

(2) Evaluation of food safety management in supply chain part i, in time period t, respecting all defined quality goals and their weights, $\tilde{O}^{i}_{t}$; $i = 1,..,I$; $t = 1,..,T$.

Based on these values $\tilde{O}^{i}_{t}$, management team can define the rank of success of food safety management in supply chain part i, i=1,..,I in each time period t, t=1,..,T.

Rank is determined based on value of $\tilde{O}^{i}_{t}$, so that in first, and the last place, are periods of time t in which value $\tilde{O}^{i}_{t}$ has the lowest, and greatest value, respectively. Ranking of these values $\tilde{O}^{i}_{t}$ is done using method of comparison of continuous fuzzy numbers (Dubois and Prade, 1979; Bass and Kwakernaak, 1977). According to obtained rank decision on food safety management success in supply chain i, i=1,..,I can be made.

(3) Evaluation of measure of belief that management success in time period t' is worse than management in time period t^*. Measure of belief is done by using the method of fuzzy numbers comparison. Based on this calculated value management team should make a decision when to take actions for improving the performances of food safety management in every discretized time period t, t=1,..,T.

(4) Evaluation of food safety management success in supply chain part i, $\tilde{O}^{i}$, i=1,..,I in observed period of time T.

(5) Rank of evaluation of food safety management in time period t, t=1,..,T in every part of supply chain i, i=1,..I. Based on calculated rank management team can on exact way determine in which supply chain part management has the lowest characteristics. Respecting the obtained result, management team firstly has to take appropriate actions for improving performances of quality goals in specific part of supply chain where management has the

lowest characteristics.

(6) Measure of the belief that food safety management in the part of supply chain $i^{'}, i^{'}=1,..,I; i^{'} \neq i^{*}$ (i^{*} is a part of supply chain with the worst performance) has worse performance than the management in the part of supply chain i^{*}. According to the calculated values management team can determine the extent to which a food safety management is better in other parts of the supply chain than in part i^{*}.

(7) Determination of the food safety management evaluation for whole supply chain, $\tilde{O}$. Based on the obtained result $\tilde{O}$, the management team can determine whether the considered food supply chain has more secure management than the other food supply chains. The importance of food safety management effectiveness in the supply chain is very great for the management team, as well as for customers.

3.5 Algorithm of the proposed model

Furthermore, an algorithm of the proposed model is presented.

Step 1. Set the pair-wise comparison matrix of relative importances of quality goals in a part of supply chain, i

$$\left[\tilde{w}_{qq^{'}}^{i}\right], q, q^{'}=1,..,Q_i; i=1,..,I;$$

and then calculate the weight of quality goal q:

$$\tilde{w}_{q}^{i}=\frac{1}{Q_i}\cdot\sum_{1}^{Q_i}\tilde{w}_{qq^{'}}^{i}.$$

Step 2. Get the representative scalar of fuzzy number $\tilde{w}_{q}^{i}$, w_{q}^{i} using the moment method.

Step 3. Transform all linguistic expressions of quality goals, $\tilde{v}_{qt}^{i}=\left(y; L_{qt}^{i}, M_{qt}^{i}, U_{qt}^{i}\right)$ to $\tilde{r}_{qt}^{i}=\left(y; L_{qt}^{i}, M_{qt}^{i}, U_{qt}^{i}\right), z\in[0,1]$;

$i=1,..,I_g; g=1,..,G; p=1,...,P_f; f=1,..,F$

using the linear normalization method:

for the benefit type of indicator:

$$\tilde{r}_{qt}^{i}=\left(\frac{L_{qt}^{i}}{U_{qt}^{i\,*}},\frac{M_{qt}^{i}}{U_{qt}^{i\,*}},\frac{U_{qt}^{i}}{U_{qt}^{i\,*}}\right)$$

for the cost type of indicator:

$$\tilde{r}_{igp}^{f}=\left(\frac{L_{qt}^{i\,-}}{U_{qt}^{i}},\frac{L_{qt}^{i\,-}}{M_{qt}^{i}},\frac{L_{qt}^{i\,-}}{L_{qt}^{i}}\right)$$

where:

$$U_{qt}^{i\,*}=\max_{y=1,..,Y_{qt}^{i}} U_{qt}^{y}; L_{qt}^{i\,-}=\min_{y=1,..,Y_{qt}^{i}} L_{qt}^{y}.$$

Step 4. The weighted normalized value of quality goal q, in the part of supply chain i, in time period t:

$$\tilde{d}_{qt}^{i}=w_{q}^{i}\cdot\tilde{r}_{qt}^{i} \quad i=1,..,I; q=1,..,Q_i;$$

t=1,..,T

Step 5. Based on condition $\min_{t=t,..,T}\tilde{d}_{qt}^{i}=\tilde{d}_{qt^{*}}^{i}$ calculate the time period t^{*} in which the quality goal q, in the part of supply chain i, has the worst characteristics, $i=1,..,I; q=1,..,Q_i; t=1,..,T$.

Step 6. Calculate the evaluation of the food safety management success in the part of supply chain i, in time period t, respecting all values of defined quality goals for the part of supply chain i:

$$\tilde{O}_{t}^{i}=\frac{1}{Q_i}\cdot\sum_{q=1}^{Q_i}\tilde{d}_{qt}^{i}; i=1,..,I; q=1,..,Q_i;$$

t=1,..,T

Step 7. Determine the effectiveness rank of food safety management which is implemented in the part of supply chain i and throughout considered period T. Management with the worst performance is in first place in the ranking. In last place is management with the greatest value of evaluation $\tilde{O}_t^i$.

Step 8. Determine the measure of the belief that food safety management in period t, in the supply chain i, which is in the second place in rank has worse performance than the management that is in first place in the rank, $\tilde{O}_{t^*}^i$:

$$Bel\left(\tilde{O}_{t'}^i \geq \tilde{O}_{t^*}^i\right),$$

$$t' = 1,..,T; t' \neq t^*; i = 1,..,I$$

Step 9. Calculate the evaluation of success of food safety management for part i, throughout the time period T:

$$\tilde{O}^i = \frac{1}{T} \cdot \sum_{t=1}^{T} \tilde{O}_t^i \text{, t=1,..,T; } i = 1,..,I$$

Step 10. Determine the measure of the belief that food safety management in the part of supply chain i, during the time period T, has worse performance than the management in the part of supply chain i^* (which has the worst performance):

$$Bel\left(\tilde{O}^i \geq \tilde{O}^{i^*}\right), i = 1,..,I; i \neq i^*$$

Step 11. Finally, determine the evaluation of food safety management for whole supply chain during the time period T:

$$\tilde{O} = \sum_{i=1}^{I} \tilde{O}^i .$$

4. Computer program for management of process safety in the food chain and case study

The aim of this work is to create a new fuzzy expert system for processes and products safety management in the food chain. In this case, HTML and CSS were used to display the user interface, and JavaScript and jQuery were used for writing the algorithm. Therefore, to start the program you need to have a web browser. After running the file Index.html the web browser launches and you can start entering the information into the expert system.

First it's necessary to enter dimensions of pair-wise comparison matrix of relative importance of identified quality goals and values of triangular fuzzy numbers in the appropriate fields. After that, do the same for the time periods. All entered values are stored in the expert system's working memory. Then follows the entering of linguistic expressions, where you should enter their number, names and value. After that, select the type of each quality goal (benefit / cost), and then from the drop down menu choose the appropriate linguistic expressions. Now the program prints the results and performs an analysis of the quality goals, followed by management analysis by time periods. Here the program indicates critical quality goals and critical managing periods, which together with previous analyses represent the mechanism of inference of the expert system. Finally, the program calculates the performance evaluation of the whole process, and the results can be stored in the *.txt file.

5. Case study

In the food supply chain, which is discussed in this paper, we can discern three processes: (1) primary production, (2) processing, and (3) storing, serving and consuming. For each of these processes the goals upon which assesses the quality of the process are defined (Chapter 3.1). The program was tested using data from a company in central Serbia.

The relative importances of the quality goals are given in matrix form:

a) For the primary production process:

$$\begin{bmatrix} 1,1,1 & 1/\tilde{R}_3 & 1/\tilde{R}_2 & \tilde{R}_1 & 1/\tilde{R}_2 \\ \tilde{R}_3 & 1,1,1 & \tilde{R}_2 & \tilde{R}_1 & \tilde{R}_1 \\ \tilde{R}_2 & 1/\tilde{R}_2 & 1,1,1 & 1/\tilde{R}_2 & \tilde{R}_2 \\ 1/\tilde{R}_1 & 1/\tilde{R}_1 & \tilde{R}_2 & 1,1,1 & \tilde{R}_2 \\ \tilde{R}_2 & 1/\tilde{R}_1 & 1/\tilde{R}_2 & 1/\tilde{R}_2 & 1,1,1 \end{bmatrix}$$

c) For the product processing:

$$\begin{bmatrix} 1,1,1 & \tilde{R}_2 & \tilde{R}_3 & \tilde{R}_1 & \tilde{R}_1 \\ 1/\tilde{R}_2 & 1,1,1 & 1/\tilde{R}_2 & 1/\tilde{R}_1 & 1/\tilde{R}_2 \\ 1/\tilde{R}_3 & \tilde{R}_2 & 1,1,1 & \tilde{R}_1 & \tilde{R}_2 \\ 1/\tilde{R}_1 & \tilde{R}_1 & 1/\tilde{R}_1 & 1,1,1 & 1/\tilde{R}_2 \\ 1/\tilde{R}_1 & \tilde{R}_2 & 1/\tilde{R}_2 & \tilde{R}_2 & 1,1,1 \end{bmatrix}$$

b) For the process of storing, serving and consuming:

$$\begin{bmatrix} 1,1,1 & 1/\tilde{R}_3 & \tilde{R}_2 \\ \tilde{R}_3 & 1,1,1 & \tilde{R}_3 \\ 1/\tilde{R}_2 & 1/\tilde{R}_3 & 1,1,1 \end{bmatrix}$$

Evaluation of goals in each relevant time period (in this paper, one month) was estimated by the management team of the food supply chain.

As mentioned before, the developed fuzzy expert system is based on the model. The following pictures illustrate the work of this proposed fuzzy expert system for a given food supply chain in the process of primary production.

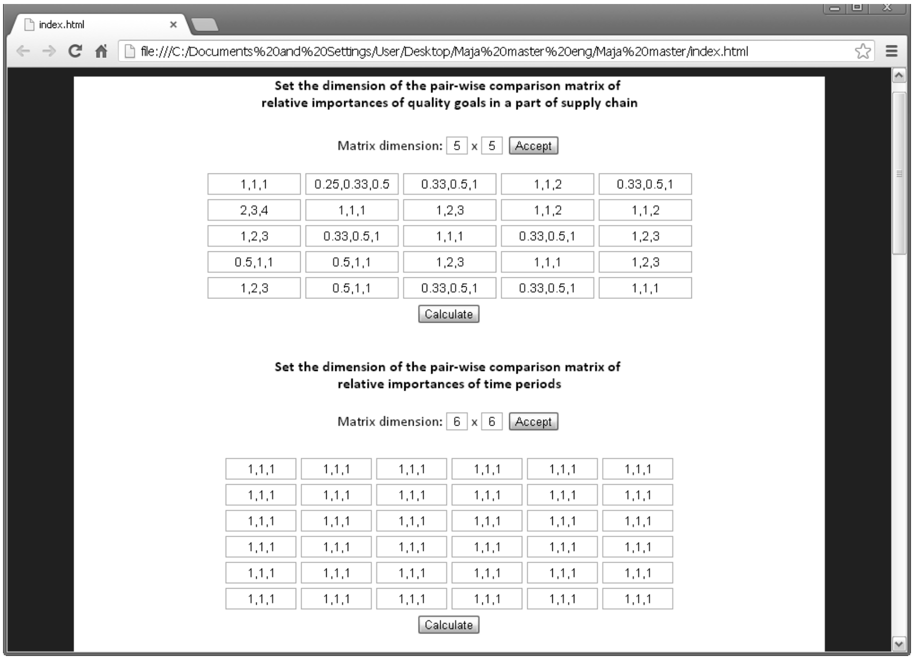

Figure 1. Setting the pair-wise comparison matrixes of relative importances of quality goals and time periods in which quality of primary production was considered

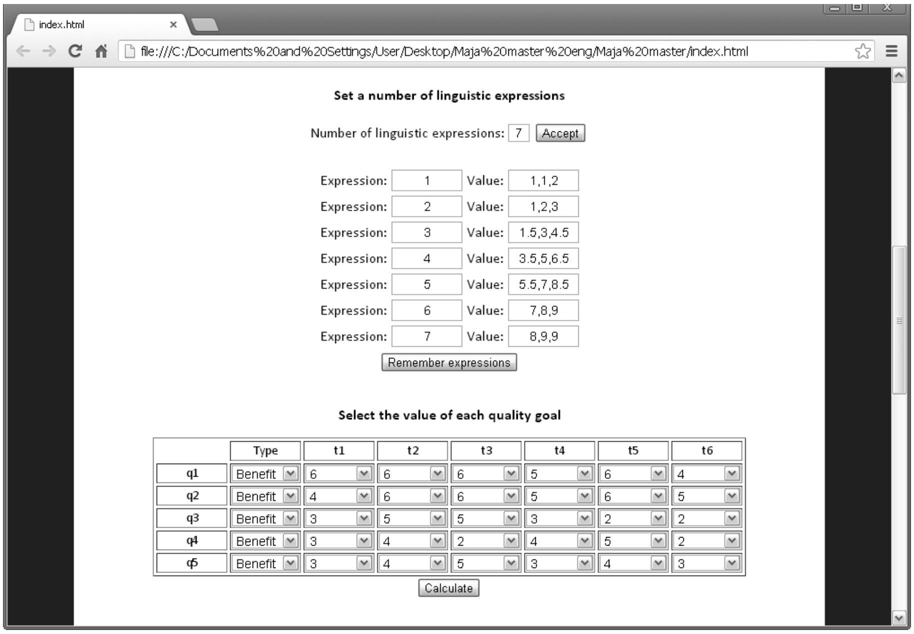

Figure 2. Setting the linguistic expressions, and evaluation of values of quality goals for each time period, in the process of primary production

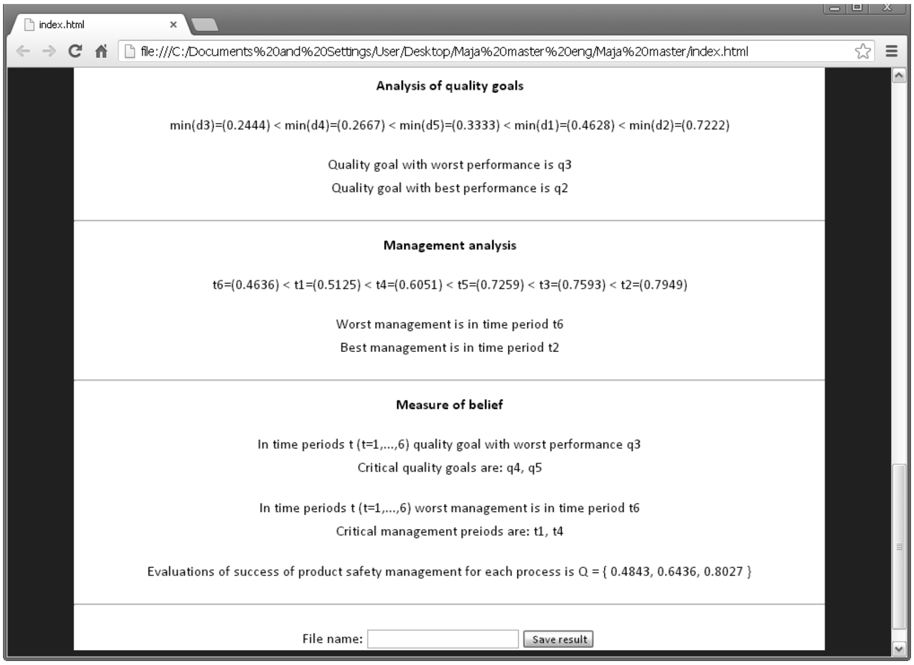

Figure 3. The results for the primary production process

In the same way, using this fuzzy expert system, were tested the processing and the process of storing, serving and eating.

5.1 Discussion of the results

For a process of primary production, during the considered time period T, quality goal with the worst performance is q_3 (quality of environment). This is because rigorous European regulations on water quality for drinking are not in place in Serbia, there are no explicit rules for recycling waste materials, etc. Most numbers of organizations don't have adopted standards that regulate environmental management as for example standard *ISO 14001* in the first place.

Beside these two quality goals, quality goal q_5 (quality of human resources) also has low performance. Quality of human resources results like this due to shortage of quality laborers and other experts which actively participate in process of food safety management in a supply chain. The period of the last twenty years has caused a lack of quality laborers because of poor economic state and general situation on a state level.

The worst product safety management in process of primary production is in the time period t=6. This month is the weakest link because of the increased quantity of food production in this period. This can condition lower level of food safety control and less production awareness than in previous months.

On the other side, best safety management of process and products in food supply chain is in the time period t=2. When this period is in question, large quantity of food are being imported in the first place, so there is a higher control of food quality.

Process of food processing is questioned in the same way, as well as process of storing, serving and consuming, and evaluations of success of product safety management for each process are:

$$\tilde{O}^{1} = 0.4843, 0.6436, 0.8027$$

$$\tilde{O}^{2} = 0.351, 0.483, 0.6283$$

$$\tilde{O}^{3} = 0.4077, 0.5917, 0.7966$$

$$\tilde{O}^{3} = 0.4077, 0.5917, 0.7966$$

$$\tilde{O}^{2} < \tilde{O}^{3} < \tilde{O}^{1}.$$

Using the given results of management success on every level of food supply chain, can be concluded that worst management is in process of food processing, and that management with best performance is in process of primary production. Also, it is possible to get evaluation of food safety management for whole supply chain, determined as:

$$\tilde{O} = \sum_{i=1}^{3} \tilde{O}^{i} = 1.243, 1.7183, 2.2276.$$

According to the results, for each part of supply chain the worst management is in the time period t=6. Therefore it is evident that trough the whole supply chain it is necessary to upgrade all processes in the sixth month. It assumes importing of activities of process reviewing. Reviewed results have to be corrective actions which have goal to improve business, and preventive actions that can ensure consistency on required quality level.

6. Conclusions

Unsafe food is harmful, costly and can lead to loss of consumer confidence. Therefore, ensuring the processes and products safety in the food industry is one of the most important and the most difficult management tasks.

In this paper, a fuzzy mathematical model was developed and also an expert system, which can be relatively easily used to determine the processes and products safety in the food chain during a given period of time. The time period is discretized into intervals of one month. Based on the good practices, it is considered that it is good to make a food safety control in every process of the food chain once a month. For each of the three processes discussed: (1) primary production, (2) processing, and (3) storing, serving and consuming the goals upon which assesses the quality of the processes were defined.

Inside of the knowledge base of the expert system are located linguistic expressions which are used to describe the relative importance of the goals in every process for each value of discreet period of time and their values. These linguistic expressions were modeled using triangular fuzzy numbers.

The inference mechanism contains the rules that are used to determine the ranking of goals within each process, the rules for determining the level of food safety management over time, and the rules for determining the level of the food chain process. These rules are based on the method of comparing continuous fuzzy numbers and mean value method, and the program has been tested using data from a company in central Serbia.

According to the results obtained, by using the proposed fuzzy expert system, the HACCP team can easily identify less secure processes and promptly react according to the procedures that are prescribed in the documents of ISO 22000:2005. HACCP team can take appropriate management actions at every stage of the production process, in order to increase the process safety, and also the safety of the product.

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