Food Safety Objective: An Integral Part of Food Chain Modelling

P.K. Malakar* and G.C. Barker

Institute of Food Research, Norwich Research Park, Colney, Norwich, NR4 7UA, UK

Abstract: The supply and maintenance of safe and wholesome foods to a population is a complex system involving multiple stakeholders. An organizational scheme for representing this complexity is a food chain. A food chain also provides the appropriate structure for the management and communication of food risks. A natural extension of this framework is the concept of a food safety objective. The mathematical form of the food safety objective is a mathematical inequality which consistently incorporates a mechanism for combining objective and subjective risk in a single framework. Additionally, the food safety objective mathematical inequality can be adapted to include uncertainty, when information is imprecise or unknown. This extension involves the use of statistical distribution to represent quantitative terms in the expression. Food chain modeling using the FSO framework provides a useful tool for managing the complexity inherent in the supply of safe foods.

Keywords: Food safety objective, food chain, modeling.

INTRODUCTION

Although almost all foods have an agricultural origin it is clear that, in general, many other steps precede food consumption. These steps include the procurement of raw materials, primary production processes, manufacturing practices and retailing. This chain has developed in order to maintain an appropriate food supply for growing populations but it is also the framework which supports innovations and developments that improve the eating experience. The food chain is also the main structure from which food safety is assessed and managed.

The safety concept for a particular food and hazard combination bridges many levels of understanding and concern and involves multiple stakeholders. A food chain is an organizational scheme for this complexity and the appropriate structure for the management and communication of food risks. A risk based approach to food safety is a relatively new concept. It explicitly expresses food safety in terms of burden of disease in a population. If food safety is improved, the burden of disease in a population decreases. In this framework, it is possible to decrease the burden of disease to an absolute minimum but then the cost involved in achieving this reduction could be prohibitive. A risk based approach incorporates a mechanism for a trade off between burden of disease and cost to society and therefore explicitly involves multiple stakeholders.

In a quantitative microbial risk assessment, the risk is expressed as a mathematical statement combining the chance and severity of illness (or other outcome) after exposure to the pathogen. Risk in this context includes the propagation of the uncertainty and variability of events in a food safety domain. Therefore in quantitative microbial risk assessment the organizational scheme implicit in a food chain is used to link foodborne illness, the food consumed and the hazard contained in the food. Translating this link to multiple stakeholders can be problematic because of the specialist knowledge involved in preparing a quantitative microbial risk assessment.

A quantitative tool related to microbial risk assessment which is communicable to multiple stakeholders, and recommended by the International Commission on Microbiological Specifications for Foods, ICMSF, is the concept of a food safety objective (FSO). The FSO is a concept for translating objective risk into a definable goal for establishing food safety management (ICMSF 2002) [1]. FSOs provide the scientific basis for selection and implementation of measures that control the hazards of concern in specific foods or food operations and they bring together apparently disparate streams from process control and public health into a structured approach for managing food safety (Gorris 2005) [2]. A FSO therefore combines objective and subjective methodologies in a single framework and provides a basis for regulators to connect quantitative aspects of food safety with the setting of public health goals.

FOOD SAFETY OBJECTIVE

Food safety objectives can be translated into a mathematical form using the following inequality

$$H_0' \times \frac{f_a}{f_b} \le 10^F$$

where H_0' is the initial strength of a hazardous agent, f_a is a factor which increases H_0', f_b is a factor which decreases H_0' and F is an agreed or established criterion which meets the objectives of multiple stakeholders. Using this inequality, we explicitly state that if the left hand side is not greater than the right hand side then the food safety objective is met. The food safety objective in this inequality is the magnitude of F. The inequality also constrains the units of H_0' and F and consideration must be given to the units of the FSO when assessing safety. The general form of the inequality can be easily adapted to assess the safety of a food chain.

Usually a food chain can be partitioned as a sequence of modules that represent distinct processes or events along the

*Address correspondence to this author at the Institute of Food Research, Norwich Research Park, Colney, Norwich, NR4 7UA, UK;
E-mail: pradeep.malakar@BBSRC.AC.UK

1874-2564/07 2007 Bentham Science Publishers Ltd.

timeline from primary food production to food consumption. Typical food chain modules include the rearing of broiler chickens, pasteurization of dairy produce, retail storage of ready to eat meals and the preparation of salad in a fast food restaurant. The processes or events in a food chain involve process parameters whose specifications can either directly or indirectly increase or decrease the strength of the hazardous agent in that module. For example washing vegetables in clean water is a direct method for reducing the bacterial load and this process can be parameterized by the duration. In contrast low temperature storage for chilled foods is an indirect method, since it reduces the ability of pathogenic microorganisms to reproduce and this process can be parameterized by the storage temperature. In general, the effects of the process parameters on the strength of the hazard are adequately approximated by a multiplicative process along the food chain. Therefore the general form for expressing the FSO concept is

$$H_0' \times \prod_i \frac{f_{ai}}{f_{bi}} \leq 10^F$$

where H_0' denotes the strength of the hazard at the beginning and i denotes the stages, or distinct processes, in the food chain. This safety assessment across sequential element of food chain assumes that reintroduction of the hazardous agent does not occur at any of the stages.

Reintroduction or recontamination is an important process in most food chains and since this is an additive process, as opposed to multiplicative, the above inequality is inappropriate. However we may refine the FSO concept to include potential additive contamination at the beginning of each sequential element of the food chain structure. For a 3 stage process the inequality can be expressed as

$$\left(\left(H_1' \frac{f_{a1}}{f_{b1}} + H_2'\right)\frac{f_{a2}}{f_{b2}} + H_3'\right)\frac{f_{a3}}{f_{b3}} \leq 10^F$$

where H_i' is the hazard strength (e.g. agent concentration) at the beginning of each stage in this food chain. Note that H_0' is not distinctive from H_1'. Generalizing to N stages gives

$$\sum_{j=1}^{N} H_j' \prod_{i=j}^{N} \frac{f_{ai}}{f_{bi}} \leq 10^F$$

This compact formulation of a food safety objective can easily be encoded in a computer program or spreadsheet. However a more readable form of this result is obtained by taking logarithms, to base 10, for both sides of the inequality and this gives

$$\log_{10} \sum_{j=1}^{N} H_j' \prod_{i=j}^{N} \frac{f_{ai}}{f_{bi}} \leq F$$

Note that when no recontamination occurs this inequality reduces to arithmetic sums

$$H_0 - \sum R + \sum I \leq FSO$$

where H_0 is the logarithm to base 10 of the initial strength of the hazard, ΣR is the sum of the logarithms of f_{bi} and ΣI is the sum of the logarithms of f_{ai}. This is the most common form of the inequality and is presented in the ICMSF document. A practical application of using food safety objectives is given in Zwietering 2005 [3].

The sequential nature of the food chain enables isolation of the elements and an analysis which leads to the relative contribution to safety for each chain element. When an element or elements which contribute most to safety is identified, it leads to a further partitioning of the left side of FSO inequality. The hazard strength in these elements needs to be reduced to an acceptable level in order to ensure the overall safety of the food chain. This level is defined as a performance objective, PO, and the technology or methodology to achieve the performance objective is defined as a process criterion (PC). These definitions have been explored further by Gorris 2005 [2].

Since FSOs are a relatively new concept, only one FSO has been proposed to date. This relates to the foodborne pathogen *Listeria monocytogenes*. The proposed FSO for this pathogenic bacterium is the presence of less than 100 CFU/g in ready-to-eat (RTE) products at the time of consumption [4]. However, the FSO concept, and in particular its representation in terms of an inequality, has value even in the absence of a detailed value of F. By adhering to the best possible hygienic practice, it is possible to explore a range of values for the left hand side of the inequality. It is then a subjective decision for stakeholders to agree on an appropriate FSO.

CONCLUSION

The food safety objective mathematical inequality consistently incorporates a mechanism for combining objective and subjective risk in a single framework. Additionally, the food safety objective mathematical inequality can be adapted to include uncertainty, when information is imprecise or unknown. This extension involves the use of statistical distribution to represent quantitative terms in the expression. Food chain modeling using the FSO framework is a useful tool for managing the complexity inherent in the supply of safe foods.

ACKNOWLEDGEMENTS

This work was supported by the United Kingdom Rural Economy and Land Use Program (RELU).

REFERENCES

[1] ICMSF (2002). International Commission on Microbiological Specifications for Foods. Micro-organisms in foods 7. Microbiological testing in food safety management. New York: Kluwer Academic/ Plenum Publishers.

[2] Gorris LGM. Food safety objective: An integral part of food chain management. Food Control 2005; 16(9): 801-809.

[3] Zwietering MH. Practical considerations on food safety objectives. Food Control 2005; 16(9): 817-823.

[4] Szabo EA, Simons L, Coventry MJ, Cole MB. Assessment of control measures to achieve a food safety objective of less than 100 CFU of *Listeria monocytogenes* per gram at the point of consumption for fresh precut iceberg lettuce. J Food Prot 2003; 66(2): 256-264.

Received: August 07, 2007 Revised: October 02, 2007 Accepted: October 29, 2007