Development and application of a Safety Monitoring and Assurance System (SMAS) for chilled meat products

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Introduction

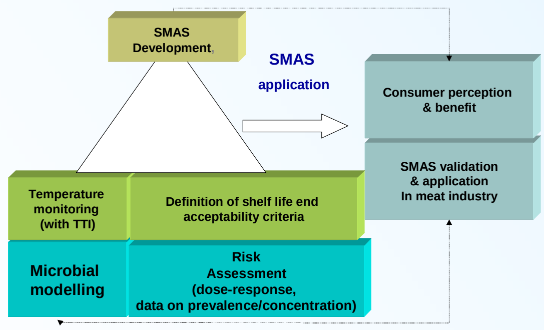
It is generally recognized by the European industry, retailers, food authorities and even consumers that the weakest link that affects directly safety and quality of chilled products is the actual ***chill chain***. A significant percentage of foodborne disease is due to temperature abuse, at some point within product chill distribution from producer to consumer.

Meat products are perishable and unless processed, packaged, distributed and stored appropriately can spoil in relatively short time. Overgrowth of incidental pathogenic bacteria like *Listeria monocytogenes*, *Salmonella sp.* and *Escherichia coli* followed by undercooking or inadequate preparation may pause a potential hazard for the consumer. Despite the proliferation of food safety regulations and the introduction of safety management ststems, such as HACCP, risk assessment studies show that foodborne disease has remained a main concern in the last decade.

Application of an optimized **quality and safety assurance system** for the chilled distribution of chilled food products requires continuous monitoring and control of storage conditions, from production to consumption. In the present study, the principles of development of an intelligent Safety Monitoring and Assurance System (SMAS) are presented. The SMAS is an effective chill chain management tool that leads to optimised distribution of risk at consumption time. It integrates kinetic models for food pathogens, variation in the intrinsic characteristics (eg. pH, a_w) of products and the capacity to continuously monitor temperature history with Time Temperature Integrators (TTI). The applicability and effectiveness of SMAS compared to the First In-First Out (FIFO) approach is demonstrated by comparing the risk of food products at consumer's end.

Methodological approach

The main cornerstones of the system include (a) validated models of microbial growth of pathogens and Specific Spoilage Organisms (SSO) for each different meat product, (b) information on the initial prevalence and distribution of the SSO, N_o (c) continuous temperature monitoring of the chill chain with Time Temperature Indicators and (d) correlation of sensory acceptability to a specific level of microbial load, N_S, that signals the end of the product shelf life (**Fig. 1**). These elements are integrated in the SMAS algorithm, allowing for the estimation of the actual remaining shelf life and the risk assessment of each product unit, at selected points of the chill chain.



The basic principles of TTI application are detailed by Taoukis (2001) and Taoukis and Labuza (1989). The reliable implementation of SMAS system requires the development and study of an assortment of Time Temperature Integrators suitable for meat safety. This step includes kinetic modeling of TTI response at a wide range of temperature conditions, and subsequent validation of the established models. Accurate, validated mathematical equations were also used for safety and quality related microorganisms of ready to cook meat products. The essence of TTI application scheme is summarized in Fig 2, and lies on the prediction of the time-temperature history of the product, at any point of its distribution, expressed as a time-integral, or, equivalently by an effective temperature (T_{eff}: the constant temperature, equal exposure to which, results in the microbial level as the variable temperature distribution, T(t)). A significant requirement for this algorithm reliability is the selected TTI response and the meat deterioration mode under study to have a similar temperature dependence (expressed as activation energies, E_{afood} and $E_{A(TTI)}$, for the food and the TTI, respectively)

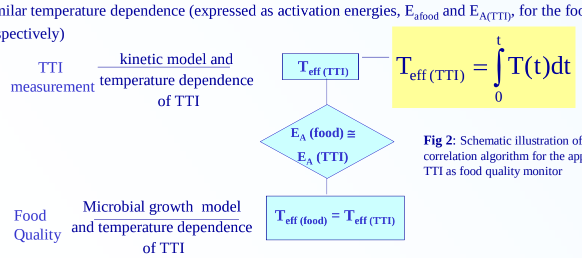


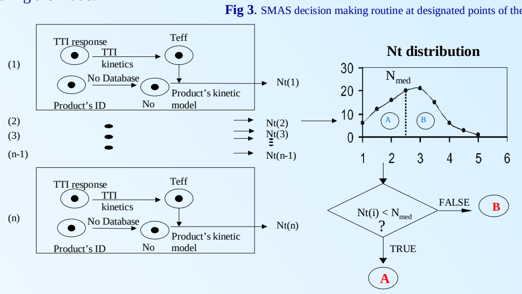
Fig 2: Schematic illustration of the correlation algorithm for the application of TTI as food quality monitor

Results & Discussion

In order to prove the effectiveness of the **SMAS system**, simulation of the results obtained through its application with regards the risk of the products at their final destination was generated, using Monte Carlo simulation technique. This numerical approach has been recently extensively applied for microbial risk assessment of food products. It is based on the generation of hypothetical, realistic "scenarios" in terms of the values attributed to the identified factors during all the segments of the chill chain from production to final consumption. In the approach used in this work, data and information provided by surveys on the conditions of the distribution chain were used and values of controlling parameters (e.g. temperature or distribution of a_w values) are treated as probability distributions. The procedure, repeated several times, requires the random selection of a value from each of the probability distributions assigned for the input parameters, in order to calculate a mathematical solution, defined by mathematical models used. At each iteration, a value is drawn from the defined distribution, i.e. values of higher probability are selected more frequently, calculations are performed and the results are stored. Eventually, the analysis provides a frequency distribution for the output of interest (risk), that has taken into account the probability distribution of the input factors, instead of using a single-point estimate.

The SMAS decision making routine at a hypothetical control point of the chill chain is based on the growth of the pathogen occurred within the period between production and arrival of the product at the control point (Fig 3). For example, at any point of chilled chain e.g. a distribution center, product from the same initial shipment is split in half and is forwarded to two different retail markets, a close and a distant one that requires long transportation. The split could be random according to conventional, currently used FIFO (First In First Out) practice or it can be based on the actual risk of the product units and the developed decision system. For all units, the product's identity is input (possibly through the scanning of a bar code). Also the response of the TTI, cumulatively expressing the temperature exposure of the product, is input either electronically as a signal of a suitable optical reader or as a keyed in visual reading. This information directly fed into a portable unit with the SMAS software, is translated to microbiological status of the food, based on the kinetics of the used TTI, which integrates the time-temperature history of each product into an effective temperature value, T_{eff}, and the growth models of the pathogen of concern. Having calculated the microbial level for all the n product units ($N(t)_i$), the actual risk distribution for the products at the decision point is constructed. Based on the risk of each product unit relative to this distribution, decisions about its further handling are made.

Fig 3. SMAS decision making routine at designated points of the distribution chain



When considering realistic alternative temperature scenarios for meat circuit in the chill chain, the objective of SMAS application is to demonstrate the optimization of final risk with SMAS compared to the conventional FIFO based random practice. Two decision points are used to apply the SMAS approach in this case. At the first decision point, the main distribution center, products are appropriately split and sent to the close local market or the distant export market based on product's risk. At the second decision point, units are classified into 3 groups for successive stocking of the retail cabinets every 6 h with the products with higher pathogenic growth promoted first. Without the use of SMAS, product split at the above two points with the common FIFO approach is random, since time in the chill chain for all products in consideration is the same. The contribution of SMAS in the chill chain management can be visualized as a minimization of risk of illness and optimization of meat product quality at the time of consumption (Fig 4)

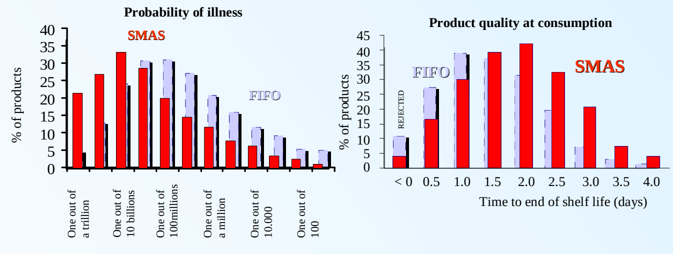


Fig 4: Distribution (a) of probability of illness associated with the consumption of one serving of meat and (b) of quality for products distributed to the export market based on SMAS and FIFO approach

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