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SHELF-LIFE PREDICTION OF MINIMALLY PROCESSED CHILLED FOODS

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Abstract: The prediction of shelf life of minimally processed chilled food is almost possible. To fulfill the demand of fresh natural food needing minimal processing has a substantial life. Minimal processing inactivate enzyme, self-decomposition of food and kill micro-organism up to some extent, which helps the produce to remain fresh without loss of nutritional quality and extend shelf- life for distribution of foods in hands of consumer.
Keywords: shelf-life, minimal processing, foods, micro-organism and food safety.

I. Introduction

I.1 Background

In recent years, two consumer-driven demands have arisen in the food industry. The first is for the provision of fresher, more natural foods requiring minimal preparation while the second is food safety. In particular, food safety considerations have rapidly become the primary consumer-driven concerns of the food industry. This is reflected in the emphasis now put on food safety by research funding agencies (Anon, 1999). To satisfy the first demand for fresh natural foods needing minimal preparation but which nevertheless have a substantial shelf life, minimal processing is becoming popular. Minimal processing is a somewhat vague concept and is a misleading term, as it usually involves substantial processing, but results in foods that have a fresh-like quality and contain only natural ingredients. Ahvenainen (1996) in a recent overview identifies two purposes for minimal processing: i) keeping the produce fresh, yet supplying it in a convenient form without loss of nutritional quality, ii) keeping the shelf life sufficient to make distribution to the consumer feasible.

The processing aspects of minimal processing can be invisible to the consumer and can be applied at various stages of the food processing and distribution chain (processing, storage, packaging) Ohlesson (1994). However significant and severe the processing, minimally processed products are rarely sterile and can undergo rapid deterioration. To counteract this, it is often associated with hurdle technology concepts where other systems (added salts,

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packaging systems, refrigeration systems) are used to inhibit spoilage. While not a new concept, hurdle technology has been given a new impetus by the requirements of minimal processing. Through it, existing and novel preservation techniques are combined to give a series of preservative factors which are called hurdles that cannot be overcome by micro-organisms. Leistner, and Gorris (1995). Common hurdles are temperature (heating, cooling), water activity, pH, redox potential, preservatives (chemical agents, bacteriocins). Novel preservative factors include gas packaging, ultra-high pressure treatment, edible coatings, use of bacteriocins (Leistner, and Gorris, L (1995). Hurdles are generally synergistic in their operation and use combinations of effects (e.g. the combination of pH and water activity). The concept of hurdle technology is widely used in the meat industry for the production of formulated products such as sausages, and can be used now also in the production of fruits and vegetables, bakery, dairy and fish products.

A particular form of minimal processing involving hurdle technology is sous-vide cooking or vacuum cooking in heat-stable vacuum pouches under controlled conditions of temperature and time Schellekens, (1996). It is especially suitable for ready-made meals and is claimed to give better sensory and nutritional quality than conventional processing. It is characterised by long heating times and relatively low heating temperatures to avoid thermal damage. However, the use of a low heating temperature gives a rather small pasteurizing effect so low temperature storage and distribution is essential. A major disadvantage is the limited shelf life that is available even at 0°C. To improve the microbiological safety of sous-vide cooked products, the concept of hurdle technology is used. Sous-vide cooking is normally a semi-continuous process and is used primarily in catering. Strict temperature control is essential Schellekens, (1996). With such products, the accurate estimation of their shelf life is essential but unfortunately, none of the previously available estimation systems are applicable. In fact, only frozen and sterilized foods had any mathematical estimation systems available.

I.2 Shelf life

Food products are usually non-equilibrium systems, i.e. are in a state of thermodynamic instability. While severe processing conditions can bring the food to a pseudo stable state, this is not possible with minimal processing and several forms of spoilage/deterioration have to be considered in predicting shelf life.

- *Microbial spoilage:* Foods must be safe from a microbiological point of view. Pathogenic micro-organisms (or sometimes their metabolites) should be removed or eliminated. However, it is spoilage organisms rather than pathogenic ones that limit the shelf life of foods and these should be inhibited. The most frequently used process in this respect is heating: pasteurization (the minimal heat treatment to ensure absence of pathogens) or sterilization (no micro-organisms left, complete microbial stability – unfortunately, rarely an option with minimal processing).

- *Chemical spoilage:* some chemical reactions may limit the shelf life of foods (e.g. non-enzymatic browning reactions, causing discoloration, off-flavours, loss of nutritional quality, perhaps formation of toxicologically suspect compounds, and fat oxidation causing off-flavours and loss of nutritional quality). Obviously, it is necessary to minimize such unwanted reactions as much as possible.
- *Biochemical spoilage:* enzymes present in raw materials from both plant and animal origin can cause deterioration, e.g. protein breakdown by proteases, fat breakdown by lipases, enzymatic browning by polyphenol oxidase. Destruction or inhibition of such enzymes is essential for significant shelf life.
- *Physical deterioration:* foods should be physically stable, that is to say, they should not show phase separation, should not dry out, have a certain consistency, etc. Migration of components within formulated products may determine a shelf-life limitation (e.g. moisture migration in a pasta product may make it tough and inedible).

Combine all these deterioration factors in multi-ingredient formulated foods and it quickly becomes obvious that shelf-life prediction becomes a very difficult problem for the processor. Trial and error shelf-life estimations became the norm and for safety considerations, the processor had to err on the side of caution and publish product expiry dates that were normally much earlier than the real one. Research has been limited in the area but in recent years the European Union and the funding agencies of several member states have invested significant funds in the subject (European union Copernicus project, 1994).

II. Shelf life prediction method

II.1 Methods

The European Union sponsored programme listed above involved 43 researchers from 17 countries covering both the EU member states and some Central and Eastern European states (Hungary, Poland, Bulgaria, Slovenia, Latvia). The research activities of the group covered three approaches to shelf-life modelling:

- Predictive modelling of shelf life
- Predictive modelling of microbial growth and decay
- Shelf-life estimation on specific individual products.

As the first of these, predictive modelling of shelf life, offers the best long-term benefits for the food processor, this paper will concentrate on this and on its inherent problems. The steps outlined below are those used by several research groups in seeking a solution:

- Select the product recipe and from a database estimate the probable microbial population and numbers of each species.
- Select the size and shape of the formulated product together with the container (if any) and package (if any) and the characteristics of both.
- Select the process conditions that will be used and the specific equipment types and characteristics (ovens, retorts, etc.).
- Select the shelf-life limiting factor. In most cases it will be when the average number of bacteria exceeds a given level.
- Use finite difference modelling to predict the heat transfer to/from the product during heating and cooling and estimate the temperature at selected nodes in the product at selected but short time intervals.
- Use predictive microbiology to estimate the bacteria numbers of each species at each time interval.
- Repeat the modeling exercise for the storage, distribution, retailing and home storage process (maximum home storage and conditions must be specified).
- When the predicted number exceeds the chosen limit, the end of safe shelf life has been reached.
- If suitable kinetic data are available, other limiting factors (enzyme activity, desired physical characteristics, etc.) can be easily incorporated into the software.

II.2 Limitations

While computer systems are quite capable of handling the complexities of the above system, a significant number of limitations exist and are considered below.

II.2.1 Product recipe and initial bacterial loads:

While there are some proprietary recipe formulation programmes, these are limited in nature and a company may have to prepare a database of its own ingredients and characteristics. This could be a major complication for the smaller company. A secondary important issue is the estimation of initial bacterial contamination levels. Only estimates can be given and for safety reasons these will error on the high side. Consequently, the predicted numbers will always be higher than the real ones (except in the rare case when sterility is achieved). In addition, there is currently no mechanism for estimating the effects of mixing ingredients on the initial bacterial population and loads.

II.2.2 Shape, size and characteristics of containers and equipment:

While container shapes and physical characteristics are available from the manufacturers, they are not in database form and will have to be entered manually in the system. However, for maximizing the shelf life of a product, an iterative process may be necessary with the procedure tested for different container shapes and materials (e.g. a thinner product in a metal foil container may permit greater heat penetration and bacterial killing than the same quantity of product in a deeper board container).

More serious is the lack of equipment characterization data. Often this is not known by the equipment manufacturers themselves. For example, while the temperature variation within an oven cavity may be specified by the manufacturer, they will seldom have measured the air flow rates and directions at various parts of the cavity nor can they provide data on how either temperature or flow characteristics will vary with the degree of product loading in the oven (obviously, air flow will be impeded by the degree of filling of the oven).

II.2.3 Process conditions

This is a simple matter for existing products where the set points of the process equipment have been determined by experience. However, for new products, modified products or shelf-life optimization, it remains a problem. Here again, several iterations of the programme will be necessary to determine the optimum conditions.

II.2.4 Shelf-life limiting factor

As previously stated, this is likely to be the number of bacteria present. Consequently, when shelf life is determined it is normally the 'safe shelf life' that is predicted. However, other factors often render the product inedible long before this safe limit is reached! Therefore, it is suggested that the concept of 'Total Quality Modelling' or TQM should be used with total quality as the controlling parameter in shelf-life prediction Nicolai and Baerdemeaker (1998); Mckenna, (1999).

***II.2.5* Modelling of temperature within the food at all stages of processing and distribution:**

Lack of data remains the major inhibiting factor at this stage in the programme. The lack of physical property data for foods has long been a problem in process calculations. Despite this, several modelling groups have been able to predict temperatures to within a few degrees. Sensitivity analysis of the input variables shows that the convective surface heat transfer coefficient during heating and cooling remains the variable of highest sensitivity. Values are never available in databases but are often calculated from dimension less number relationships.

A more serious deficiency is that the heat transfer coefficient relationships are normally for transfer of heat to or from inert surfaces. In the heating and cooling of foods, both evaporation from and condensation on the surface will change the effective heat transfer coefficient and lead to incorrect estimation of the internal temperatures. It is essential that values used allow for this mass transfer complication.

A third problem arises in predicting conditions that are outside the control of the processor, namely, the retailing, home storage and final heating/cooking conditions (if any). Here, the processor can do no more than specify the desired retail, home storage and final heating conditions and allow for the worst conditions of transfer between them (e.g. significant time in a hot car).

II. 2.6 Predictive microbiology

During minimal processing, distribution and use, foods will experience both microbial growth and decay at different stages. Consequently, both growth and decay kinetics are required. Once again, problems arise through the lack of suitable data. Predictive modelling has long been used in microbiology and database packages are available Food Micromodel database (1999). However, since safety has been the primary consideration in development of such models, pathogenic organisms are well represented but many common food spoilage organisms are missing.

A second problem is the limitation of growth and killing data to a small range of substrate conditions. For complete use in a shelf-life prediction system, kinetic growth and decay data are required on a wide range of pH values in the product, a range of moisture contents, a range of salt contents and, ideally, a vast range of ingredient contents.

A third problem is the variation in microbiological kinetic data. This is often the result of substrate variation but is also related to the inherent in exact nature of microbiological measurements. Consequently, it is difficult to put exact confidence limits of the kinetic data.

Yet a fourth problem arises from poor data at two stages in the growth and decay system. Variation in the lag phase has long been recognized and complicates the prediction process. Less obvious is the lack of data at the shoulder period when temperatures reach a level where growth is stopping but killing has not yet started. (for mesophilic bacteria in the temperature range 45 to 60°C).

II.2.7 Other shelf-life limiting factors

Kinetic data on texture variation with time and temperature are very limited. Similarly, diffusion will affect this (as it could also affect microbial kinetics) and while some diffusion kinetics is available for water and NaCl, it is deficient for many other components.

II.2.8 General

Computer systems are powerful enough to handle the computing complexities of the prediction systems. However, the systems developed to date (Nicolai, et al., 1995 ; Keane, G. 1997) require at least work-station power whereas the food industry is largely PC equipped. Acceptable running times are just now being achieved with Pentium III machines.

III. Conclusions

It might be concluded from the list of limitations in the above section that shelf-life prediction remains impossibility. This is not the case. Current computer systems are working well. The limitations certainly restrict their use to a small range of products. The main message is that the computer systems are working well but are being hindered by inadequate food and microbiological data. However, even in the short few years since the first developments, there have been significant improvements and these are continuing.

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