Preservation: Current food preservation technologies

Accepted 11th June 2021

ABSTRACT

Foods deteriorate in quality due to a wide range of reactions including some that are physical, some that are chemical, some enzymic and some microbiological. This study aims to review the prospective of current preservation technologies with effectiveness of preservation and ensurance of safety. The various forms of spoilage and food poisoning caused by micro-organisms are preventable to a large degree by a number of preservation techniques, most of which act by preventing or slowing microbial growth. These include freezing, chilling, drying, curing, conserving, vacuum packing, modified atmosphere packing, acidifying, fermenting and adding preservatives. In contrast, a smaller number of techniques act by inactivating micro-organisms, predominantly heating (pasteurization and sterilization). Complementary techniques restrict access of micro-organisms to food products, e.g. aseptic processing and packaging. Major trends, reacting to consumers' needs, are towards the use of procedures that deliver food products that are less 'heavily' preserved, higher quality, more convenient, more 'natural', freer from additives, nutritionally healthier and still with high assurance of microbiological safety.

Key words: Current preservation, preservatives, reduction in water activity, low temperature, vacuum and modified atmosphere packaging, heat, acidification.

INTRODUCTION

Foods deteriorate in quality due to a wide range of reactions including some that are physical, some that are chemical, some enzymic and some microbiological. With few exceptions, all foods deteriorate in quality following harvest, slaughter or manufacture, in a manner that is dependent on food type and composition, formulation (of manufactured foods) and storage conditions. The principal quality deterioration reactions, which are, therefore, the principal targets for preservation, are well known and relatively few. They include some that are essentially microbiological, others that are chemical, enzymic or physical (Gould, 1989). When preservation fails the consequences ranges from extreme hazard eg. if any toxigenic micro-organisms are not controlled to relatively trivial loss of quality such as loss of colour or flavour. The most serious forms of quality deterioration include those due to micro-organisms, following the survival and/or growth of infectious pathogenic bacteria or the growth of toxigenic ones (Lund et al., 2000). Thus, an important challenge has been to ensure that current technologies retain or preferably improve on, the effectiveness of preservation and ensurance of safety that may otherwise be lost.

CURRENT PRESERVATION TECHNOLOGIES

Preservatives

Most of the preservatives that are used in foods are acids, such as the weak Hpophilic organic acids (sorbate, benzoate, propionate) or the inorganic ones (sulphite, nitrite). All are more effective at low rather than at high pH (Russell and Gould, 1991). Indeed, with the possible exceptions of the alkyl esters of p-hydroxybenzoate (‘parabens’), there are no wide-spectrum antimicrobial food preservatives that are effective at near-neutral pH. There is a well-established rationale for the effectiveness of the weak acids and for their synergy with hydrogen ions, that is, with low pH. This derives from the fact that in their unionized forms, which are favoured at low pH, they are...
able to readily equilibrate across the microbial cell membrane and access the cytoplasm of the cell.

The pK value of the common weak acid preservatives range from 4.2 (benzoic) to 4.87 (propionic), so that at pH values much above these activity is greatly reduced. At the pH of most foods, micro-organisms maintain an internal pH higher than that of their surroundings. Consequently, on entering the cytoplasm, the undissociated acids tend to dissociate, delivering hydrogen ions along with the particular anion. The additional hydrogen ions may be exported by the micro-organisms, but this is energy demanding, so cell growth is restricted. If the energy supply is overcome, then the pH of the cytoplasm eventually falls to a level that is too low for growth to continue. In addition, the accumulated anion may have specific antimicrobial effects (Eklund, 1983). From the point of view of practical food preservation, it is therefore sensible to include a weak organic acid whenever possible, then to acidify the food product as much as is organoleptically acceptable to capitalize on the weak acid-low pH synergy, then to vacuum pack it if possible because this will restrict the amount of energy that is available for the extrusion of hydrogen ions, then to reduce the aw as much as possible, because this will place additional energy requirements on the cell and so on. In this way, many empirical preservation ‘combination technologies’ can be rationalized and new logically-based ones sought.

Reduction in water activity

Water activity values (aw) are widely used to predict the stability of foods with respect to the growth of micro-organisms and the chemical, enzymic and physical changes that lead to quality deterioration (Christian, 2000). Values range from 1 (pure water) to zero (no water) and is equivalent to equilibrium relative humidities (ERH) on a scale from 100% to 0%. The water activity of foods is reduced by drying or by adding solutes such as salt, as in cured products, or sugars, as in conserves, or by combinations of these treatments. Small reductions, e.g. to about 0.97, are sufficient to prevent the growth of some important spoilage micro-organisms, e.g. Pseudomonas species that grow at high aw, and rapidly spoil foods such as fresh meat stored in air. Cured meats generally have aws sufficiently reduced to ensure longer Pseudomonas-free shelf-lives. Slow souring, caused by lactic acid bacteria occurs instead. If the aw is lower still, below about 0.95, as in some salamis and dry-cured meat products, even these are inhibited and slow spoilage by low aw-tolerant micrococci takes over. These and similar relationships are widely used to explain and predict the storage stability and safety of foods. Of the food poisoning micro-organisms, Staphylococcus aureus is the most tolerant, with a low aw limit for growth of about 0.86 in air, but only 0.91 anaerobically, so that it may grow and produce enterotoxin in relatively low aw foods if other conditions are conducive, e.g. temperature and time of storage.

At aw values below 0.86, few bacteria and no bacteria of public health concern can grow, and food is spoiled by yeasts or moulds, some of which can multiply slowly at aws as low as 0.6. Below this aw, no micro-organisms are able to grow. Shelf-stable dried foods are generally formulated around aw 0.3, where lipid oxidation and other chemical changes are minimal. An interesting extrapolation of aw-control of microbial growth into the clinical area was made by Herszage and his colleagues in Buenos Aires (Chirife et al., 1982). He built on the ancient uses of honey and other highly soluble solutes by promoting the treatment of infected wounds with cane sugar. The sucrose was not highly absorbed into underlying tissues, but served to reduce the aw within a wound, and apparently without interfering with macrophage activity, sufficiently to prevent the growth of pathogens, including Staph. aureus. Efficacy was demonstrated in a number of clinical studies (Sehvyn and Durodie 1985) and the procedure was said to have potential value, e.g. where particularly antibiotic-resistant micro-organisms were involved, or in third world countries where sugar is much cheaper than antibiotics.

Low temperature

As the temperature of a chilled food is reduced, the types of microorganisms and their rates of growth are reduced also. Two particularly important temperatures are around 12°C, which represents the lower limit for growth of the strict anaerobes, Clostridium perfringens and the proteolytic strains of Clostridium botulinum (types A and some types of B), and 3°C, which is the lower limit for non-proteolytic strains of C. botulinum (types E and some types of B and F). A few years ago, this would have been the chill storage temperature below which no food poisoning micro-organisms would have been expected to multiply. However, both Listeria monocytogenes and Yersinia enterocolitica can grow at temperatures below 1°C, so that indicated shelf-lives and sell-by dates can play an important role in ensuring safety, particularly when temperature control cannot be assured, e.g. in the home (Herbert and Sutherland, 2000). Many types of spoilage micro-organisms may continue to grow at sub-zero temperatures, multiplying slowly at temperatures down to about -7°C. Badly stored frozen foods may, therefore, slowly spoil through the activities of micro-organisms but not become dangerous if thawing has not occurred. At the temperature of properly stored frozen foods, nominally -18°C in many countries, microbial growth is completely prevented, although slow loss of quality may still occur through the activities of enzymes and through chemical reactions and physical changes.

Vacuum and modified atmosphere packaging (MAP)

The effectiveness of vacuum and MAP derive firstly from
Table 1: Major existing technologies for food preservation (Gould, 1995).

<table>
<thead>
<tr>
<th>Techniques that slow or prevent the growth of micro-organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in pH - acidification (eg use of acetic, citric acids, etc), fermentation</td>
</tr>
<tr>
<td>Reduction in temperature – chill storage, frozen storage</td>
</tr>
<tr>
<td>Reduction in water activity - drying, curing with added salt conserving with added sugar</td>
</tr>
<tr>
<td>Removal of oxygen - vacuum or modified atmosphere packaging</td>
</tr>
<tr>
<td>Modified atmosphere packaging - replacement of air with COy- O, N2 mixtures</td>
</tr>
<tr>
<td>Addition of preservatives - inorganic (eg sulphite, nitrite)</td>
</tr>
<tr>
<td>- organic (e.g propionate, sorbate, benzoate, parabens)</td>
</tr>
<tr>
<td>- bactenocin (e.g nisin)</td>
</tr>
<tr>
<td>- antmycotic (e.g natamycin)</td>
</tr>
<tr>
<td>Control of microstructure - in water-in-oil emulsion foods</td>
</tr>
</tbody>
</table>

Techniques that inactivate microorganisms

Heating - pasteurization

Techniques that restrict access of micro-organisms to products

Packaging

Aseptic processing

the removal of oxygen, with the consequent inhibition of strictly oxidative microorganisms. Fermentative organisms continue to multiply but they do so more slowly and for some types of foods, they have less unpleasant consequences for food quality. Special attention is always given to the possibility of encouraging the growth of strictly anaerobic food poisoning micro-organisms, such as C. botulinum, so that for foods such as 'sous vide' products, which are vacuum packed and pasteurized rather than sterilized, minimal heat treatments and tight temperature control in distribution are recommended (Notermans et al., 1990). Carbon dioxide is widely used in MAP foods because it has a specific antimicrobial activity, acting as a preservative that uniquely dissipates when the food pack is opened (Mohn, 2000). For example, much supermarket meat is packed in gas mixtures containing about 70% O2 and 30% CO2. The O2 maintains the meat in the bright red oxymyoglobin colour that consumers prefer, while the CO2 slows down the growth of Gram-negative spoilage bacteria so as to double the useful shelf-life.

Heat

Pasteurization at times and temperatures sufficient to inactivate vegetative micro-organisms and sterilization at times and temperatures sufficient to inactivate bacterial spores, remain the bases of large industries around the world (Pflug and Gould, 2000). With the slow acceptance of irradiation for food preservation in most countries, heat remains the only substantial means for inactivating micro-organisms in foods. However, most of the new and 'emerging' technologies that have been investigated and promoted in recent years act by inactivation, but without the need for substantial heating.

Acidification

Many yeasts and moulds are able to multiply at very low pH values, that is, well below pH 2, so that they predominate in the flora of spoiling acidified foods. Few bacteria grow below about pH 3.5 or so. Those that do are adapted to acid environments, e.g. the lactic acid bacteria and indeed are employed in numerous acid-generating food fermentations such as those for yoghurts, cheeses and salamis. A particularly important pH for food safety is pH 4.5, because it is the pH below which C. botulinum is unable to multiply. Consequently, in thermal processing, it is not necessary to heat foods that are more acid than this to the same extent as higher pH 'low acid' foods. Below about pH 4.2, other food poisoning and spoilage bacteria are mostly controlled. However, recently the spore-forming bacterium Alicyclobacillus acidoterrestris, capable of growth at pH values as low as 2, has caused spoilage problems ('disinfectant taints') in some low pH foods. Survival of micro-organisms at low pH may be important, even if they are unable to multiply. For example, Escherichia 0157 has an acid tolerance that may have contributed to some food poisoning outbreaks in which the vehicle was a low pH food, e.g. American (non-alcoholic) apple cider. Furthermore, acid tolerance may aid passage of such organisms through the stomach. Food processors are aware that acid tolerance may be increased by prior exposure to mild acidification, or even by seemingly unrelated stresses, such as mild heating (Wang and Doyle, 1998).

CONCLUSION

Preservation technologies have a long history of use, there is currently a real need for improved techniques, to meet
the developing needs of consumers. Some improvements are being derived from the use of established techniques in new combinations or under improved control and other improvements are being derived essentially from the development of new techniques. Generally, these are listed in Table 1, in such a way as to emphasize the fact that most of them act by slowing down, or in some cases by completely inhibiting, microbial growth.

REFERENCE


Cite this article as:
Submit your manuscript at http://www.academiapublishing.org/ajar