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Minimum level of processing for fresh fruits and vegetables

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Abstract
Minimal processing of raw fruits and vegetables are used for keeping the produce fresh, without losing its nutritional quality and ensuring a product shelf-life sufficient to make distribution feasible within a region of consumption. The present paper assesses the quality and safety aspects of minimally processed fruits and vegetables. It also discusses the key steps in the food chain, beginning with raw material and processing and ending with packaging, which affect the quality and shelf-life of minimally processed fruits and vegetables.

Keywords: fruits, vegetable, fresh, quality, food chain

Introduction

A precise definition, which situates minimal processing methods within the context of more conventional technologies, describes them as techniques that 'preserve foods but also retain to a greater extent their nutritional quality and sensory characteristics by reducing the reliance on heat as the main preservative action' (Fellows, 2000) [8]. Minimal processing can, therefore, be seen in the context of the traditional concern of food processing to extend the shelf-life of food. At the same time, whilst they value the convenience that increased shelf-life can bring, consumers have become more critical of the use of synthetic additives to preserve foods or enhance characteristics such as colour and flavour (Bruhn, 2000) [6]. They have also placed a greater premium on foods which retain their natural nutritional and sensory properties. Minimal processing techniques have emerged to meet this challenge of replacing traditional methods of preservation whilst retaining nutritional and sensory quality. The microbiological, sensory and nutritional shelf-life of minimally processed vegetables or fruits should be at least 4–7 days, but preferably up to 21 days depending on the market (Ahvenainen,2000) [3].

Changes during minimal processing

As a result of peeling, grating and shredding, produce will change from a relatively stable commodity with a shelf-life of several weeks or months to a perishable one that has only a very short shelf-life, as short as 1–3 days at chilled temperatures. During peeling and grating operations, many cells are broken and intracellular products, such as oxidising enzymes, are released. Minimally processed produce deteriorates owing to physiological ageing, biochemical changes and microbial spoilage, which may result in degradation of the colour, texture and flavour (Varoquaux *et al*., 1994) [15]. The most important enzyme in minimally processed fruits and vegetables is polyphenol oxidase which causes browning (Wiley, 1994) [18]. Another important enzyme is lipoxidase which catalyses peroxidation causing the formation of numerous bad-smelling aldehydes and ketones. Ethylene production can also increase and because ethylene contributes to the neosynthesis of enzymes involved in fruit maturation, it may play a part in physiological disorders of sliced fruits, such as softening (Varoquaux *et al*., 1994) [15].

With processing, the respiration activity of produce will increase by between 20% to as much as 700% or more depending on the produce, cutting grade and temperature (Varoquaux *et al*., 1994) [15]. If packaging conditions are anaerobic, this leads to anaerobic respiration causing the formation of ethanol, ketones and aldehydes (Powrie *et al*., 1991) [13]. During peeling, cutting and shredding, the surface of the produce is exposed to the air and to contamination with bacteria, yeasts and moulds. In minimally processed vegetables, most of which fall into the low acid range category (pH 5.8–6.0), high humidity and the large number of cut surfaces can provide ideal conditions for the growth of microorganisms (Willocx *et al*., 1994) [17]. Because minimally processed fresh fruits and vegetables are not heat treated, regardless of additives or packaging, they must be handled and stored at refrigerated temperatures, at 5 °C or under in order to achieve a sufficient shelf-life and microbiological safety.

Improving quality

If products are prepared today and consumed tomorrow, very simple and inexpensive processing methods can be used. Most fruits and vegetables are suitable for this kind of preparation. Such products may also be suitable for catering, where they will undergo further processing. If, however, products need a shelflife of several days, or up to one week and more, as is the case with the products intended for retailing, then more advanced processing methods and treatments are needed using the hurdle concept (Wiley, 1994) [18].

Raw materials

It is self evident that vegetables or fruits intended for prepeeling and cutting must be easily washable, peelable and their quality must be first class. The correct and proper storage of vegetables and careful trimming before processing are vital for the production of prepared vegetables of good quality (Wiley, 1994) [18]. The study of various cultivar varieties of eight different vegetables showed that not all varieties of the specified vegetable can be used for the manufacture of prepared vegetables. The correct choice of variety is particularly important for carrot, potato, swede and onion. For example, with carrot and swede, the variety which gives the most juicy grated product cannot be used in the production of grated products which should have a shelf-life of several days (Ahvenainen *et al*., 1994) [1]. Furthermore, the results showed that climatic conditions, soil conditions, agricultural practices, for example, fertilisation and harvesting conditions, can also significantly affect the behaviour of vegetables, particularly that of potatoes, in minimal processing (Ahvenainen *et al*., 1998) [2].

Peeling, cutting and shredding

Some vegetables or fruits, such as potatoes, carrots or apples, need peeling. There are several peeling methods available, but on an industrial scale the peeling is normally accomplished mechanically (e.g. rotating carborundum drums), chemically or in high-pressure steam peelers (Wiley, 1994) [18]. However, results have shown that peeling should be as gentle as possible. The ideal method would be hand peeling with a sharp knife. Carborundum-peeled potatoes must be treated with a browning inhibitor, whereas water washing is enough for hand-peeled potatoes. If mechanical peeling is used, it should resemble knife peeling. Carborundum, steam peeling or caustic acid disturb the cell walls of a vegetable enhancing the possibility of microbial growth and enzymatic changes. Carborundum and knife peeling can be combined with a first stage of rough peeling and then a second stage of finer knife peeling. Enzymatic peeling can be successful, for example in the case of oranges (Pretel *et al*., 1998) [14].

Many studies show that the cutting and shredding must be performed with knives or blades as sharp as possible and made from stainless steel. Carrots cut with a razor blade were more acceptable from a microbiological and sensory point of view than carrots cut with commercial slicing machines. It is clear that slicing with blunt knives impairs quality retention because of the increased breaking of cells and release of tissue fluid. A slicing machine must be installed solidly, because vibrating equipment may possibly impair the quality of sliced surfaces. Mats and blades used in slicing should also be disinfected, for example, with a 1% hypochlorite solution.

Cleaning, washing and drying

Incoming vegetables or fruits, which are covered with soil, mud and sand, should be carefully cleaned before processing. Asecond wash must usually be done after peeling and/or cutting (Wiley, 1994) [18]. For example, Chinese cabbage and white cabbage must be washed after shredding, whereas carrot must be washed before grating (Hurme *et al*., 1994). Washing after peeling and cutting removes microbes and tissue fluid, thus reducing microbial growth and enzymatic oxidation during storage. Washing in flowing or air-bubbling water is preferable to dipping into still water (Ohta *et al*., 1987) [12]. The microbiological quality of the washing water used must be good and its temperature low, preferably below 5°C. The recommended amount of water used is 5–10 l/kg of product before peeling/cutting (Huxsoll *et al*., 1989) [10] and 3 l/kg after peeling/cutting (Hurme *et al*., 1994).

Preservatives can be used in washing water to reduce microbial numbers and to retard enzymatic activity, thereby improving the shelf-life. 100–200mg of chlorine or citric acid per litre is effective in washing water before or after peeling and/or cutting to extend shelf-life (Wiley, 1994) [18]. However, when chlorine is used, vegetable material should be rinsed. Rinsing reduces the chlorine concentration to the level of that in drinking water and means that sensory quality is not compromised (Hurme *et al*., 1994) [9]. The effectiveness of chlorine can be enhanced by using a combination of low pH, high temperature, pure water and correct contact time (Wiley, 1994) [18]. It seems that chlorine compounds reduce counts of aerobic microbes at least in some leafy vegetables such as lettuce (Wiley, 1994) [18], but not necessarily in root vegetables or cabbages (Ahvenainen *et al*., 1994) [1].

Browning inhibition

A key quality problem for fruits and vegetables such as peeled and sliced apple and potato is enzymatic browning. Washing with water is not effective in preventing discoloration (Wiley, 1994) [18]. Traditionally, sulphites have been used to prevent browning. However, the use of sulphites has some disadvantages, in particular dangerous side effects for asthmatics. For this reason, the FDA (Food and Drug Administration) in the USA partly restricted the use of sulphites (Anon, 1991) [4]. At the same time, interest in substitutes for sulphites is increasing. Enzymatic browning requires four different components: oxygen, an enzyme, copper and a substrate. In order to prevent browning, at least one component must be removed from the system. In theory, 2,5-diphenyloxazole polyphenoloxidase (PPO)-catalysed browning of vegetables and fruits can be prevented by such factors as (Whitaker *et al*., 1995) [16]:

- heat or reaction inactivation of the enzyme
- exclusion or removal of one or both of the substrates (oxygen and phenols)
- lowering the pH to 2 or more units below the optimum
- adding compounds that prevent melanin formation.

Packaging and Storing

A key operation in producing minimally processed fruits and vegetables is packaging. The most studied packaging method for prepared raw fruits and vegetables is modified atmosphere packaging (MAP). The basic principle in MAP is that a modified atmosphere can be created passively by using suitable permeable packaging materials, or actively by using a specified gas mixture together with permeable packaging materials. The aim of both is to create an optimal gas balance inside the package, where the respiration activity of a product is as low as possible whilst ensuring that oxygen (O_2) concentration and carbon dioxide (CO_2) levels are not detrimental to the product. In general, the aim is to have a gas composition where there is 2–5% CO_2, 2–5% O_2 and the rest nitrogen (Day, 1994) [7]. One possible ‘packaging’ method for extending the post-harvest storage of minimally processed fruit and vegetables is the use of edible coatings. These are thin layers of material that can be eaten by the consumer as part of the whole food product. Coatings have the potential to reduce moisture loss, restrict oxygen entrance, lower respiration, retard ethylene production, seal in flavour volatiles and carry additives (such as antioxidants) that retard discoloration and microbial growth (Baldwin *et al*., 1995) [5].

Chilling is an important preservative hurdle, as is the control of humidity. Storage at 10 °C or above allows most bacterial pathogens to grow rapidly on fresh cut vegetables. Storage temperature is also important when MAP or vacuum packaging is used. Changes in temperature should be avoided. Higher temperatures speed up spoilage and facilitate pathogen growth. Fluctuating temperatures cause in-pack condensation which also accelerates spoilage. Temperature abuse is a widespread problem in the distribution chain, whether in storage, transportation, retail display and consumer handling. Where this is a significant problem, it may be necessary to restrict shelf-life, for example to 5–7 days at a temperature of 5–7 °C, when psychrotrophic pathogens have insufficient time to multiply and produce toxin. If the shelf-life of vacuum or MAP products is greater than 10 days, and there is a risk that the storage temperature will be over 3 °C, products should meet one or more of the following controlling factors:

- a minimum heat treatment such as 90 °C for 10min
- a pH of 5 or less throughout the food
- a salt level of 3.5% (aqueous) throughout the food
- *a*w, water activity value of 0.97 or less throughout the food.
- any combination of heat and preservative factors which has been shown to prevent growth of toxin production by *C. botulinum.*

Future trends

Much research is still to be done in order to develop minimally processed fruit and vegetable products with high sensory quality, microbiological safety and nutritional value. It is possible to reach 7–8 days’ shelf-life at refrigerated temperatures (5 °C), but for some products 2–3 weeks’ shelf-life may be necessary. More information about the growth of pathogenic bacteria or nutritional changes in minimally processed fruits and vegetables with long shelf-life is needed. A characteristic feature of minimal processing is the need for an integrated approach, where raw material, handling, processing, packaging and distribution must each be properly managed to make shelf-life extension possible. Hurdle technology using natural preservatives, for example, inhibitors produced by lactic acid bacteria, and the matching of correct processing methods and ingredients to each other, needs to be developed further in the minimal processing of fresh produce. It is probable that in the future fruits and vegetables intended for minimal processing will be cultivated under specified controlled conditions, and that plant geneticists will develop selected and created cultivars or hybrids adapted to the specific requirements of minimal processing (Martinez *et al*., 1995) [11]. Unit operations such as peeling and shredding need further development to make them more gentle. There is no sense in disturbing the quality of produce by rough treatment during processing and then trying to limit the damage by subsequent use of preservatives. Active packaging systems and edible films, as well as more permeable plastic films which better match with the respiration of fruits and vegetables, are particularly active areas for development.

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