Food preservation; map

Literature, Russian Literature

 Review of Literature: Modified Atmosphere Packaging of Minimally Processed Fruits and Vegetables The purpose of this literature review is to explore recent advances in modified atmosphere packaging (MAP) of fruits and vegetables. An examination of the impacts of minimal processing on fruits and vegetables highlights the importance of packaging as a preservation method to maintain quality and shelf life. From this foundation, literature on traditional MAP as a preservation method for minimally processed fruit and vegetables is analysed. In response to identified limitations and strengths within traditional technology, recent developments in MAP are identified and explored. In particular, high oxygen MAP is identified as a potential technology that addresses key shortcomings in traditional modified atmosphere packaging. What are Minimally Processed Fruits and Vegetables? Minimally processed fruit and vegetables can be classified as those fruit and vegetables which have been trimmed, peeled or cut into ready to use (RTU) products, can be pre-packaged, and offer consumers nutrition, convenience and flavour while maintaining freshness (Barry-Ryan & O'Beirne 1999; Lamikanra 2002). There has been significant growth in the production of minimally processed vegetables, due to demand for healthy convenient foods, and the known beneficial health effects of fruit and vegetables attributed to antioxidants such as ascorbic acid and -carotene (Kaur & Kapoor 2001; Rico, Martin-Diana, Barat & Berry-Ryan 2007). Additionally, consumers are more aware of synthetic additives and food preservation, signaling the need for minimal processing techniques that can replace traditional methods of preservation (Bruhn 2000). Ultimately, the finished product should remain preferable in terms of quality and safety for the consumer. Accordingly, quality evaluation concerning minimally processed fruit and vegetables will be examined in the following section.

Aspects of Minimally Processed Fruit and Vegetables that Affect Quality

Quality is a combination of factors involving appearance, texture, flavour and nutrition (Kader 2002). These factors vary with the type of commodity, but in general consumers judge quality of fresh-cut products at the time of purchase on appearance and freshness and their satisfaction in terms of texture, flavour nutritional quality and safety (Kader 2002). While the criterion for quality is highly subjective, there is ultimately a quality limit, below which is unacceptable to the consumer (Tijskens 2000). This limit is chiefly based on intrinsic properties such as colour, firmness and taste, which can be greatly affected by the product's shelf life (Tijskens 2000). Packaging can enhance shelf life and thus is a crucial factor when considering consumer acceptability of minimally processed fruits and vegetables. It is well established in the literature that the processing of fruits and vegetables in RTU products hastens physical and biochemical breakdown, resulting in colour, texture, and flavour degradation (Kabir 1994; O'Beirne & Francis 2003; Varoquaux & Wiley 1994). Physiological effects include but are not limited to: ethylene production; membrane deterioration; water loss; microbial spoilage; loss of chlorophyll; change in pH; increase in respiration; and formation of flavour volatiles (Toivonen & De-Ell 2002). Microbial growth on fresh produce and minimally processed fruit and vegetables occurs naturally, but also as a result of contamination from postharvest handling and processing (Beuchat 1996). This section describes in detail those aspects of minimally processed fruit and vegetables that influence consumer acceptability. As these aspects are important for the shelf life and quality of minimally processed fruits and vegetables, they form the criteria of effective packaging, including modified and controlled atmosphere packaging. Colour and Texture Colour is a primary consideration for consumers, affecting food choice, preference and acceptability of fruits and vegetables. This is due partly to its main role as an indicator of freshness and quality (Rico et al. 2007). Colour is also tightly linked with industry in determining time for harvest and predicting post-harvest life (Calero & Gomez 2003). The colour of fruit and vegetables is a result of the composition of the pigments it contains: chlorophyll, carotenoids, and phenolic compounds such as anthocyanins (Calero & Gomez 2003). Chlorophylls produce green, blue-green and olive brown colours, carotenoids produce red-yellow colours and anthocyanins are responsible for orange, red, blue, purple and black colours (Calero & Gomez 2003). Browning is the limiting factor for shelf life and marketability of lettuce, as well as several other surfaced-cut vegetables (Couture, Cantwell, Ke & Saltveit 1993). The processing of lettuce for minimally processed products includes cutting and breaking that cause induction and synthesis of enzymes (Ke & Saltveit 1989). The browning reaction is known to involve oxidation of polyphenol compounds by these enzymes such as polyphenol oxidase (Ke & Saltveit 1989). Other possible compounds influencing browning to a lesser extent include peroxidases, lipoxygenases, and lipases (Calero & Gomez 2003). Texture in minimally processed vegetables is an important consideration for consumer preference, and is associated with several types of enzymatic and non-enzymatic reactions (Rico et al. 2007). The degradation of pectins is closely linked with loss of texture in vegetables (Vu, Smout, Sila, LyNguyen, Van Loey & Hendrickx (2004). Lettuce undergoes an undesirable biochemical change upon processing associated with wounding (Brecht 1995). Low oxygen or high carbon dioxide concentrations can cause quicker textural changes in minimally processed vegetables and oxygen concentrations present in air cause quicker textural breakdown compared with modified atmospheres (Giminez, Olarte, Sans, Lomas, Echavarri & Ayala 2003). Textural degradation of vegetables may also be linked with high counts of psychrotrophic microorganisms that produce pectinolytic enzymes. Respiration and pH Aerobic respiration consists of the oxidative breakdown of complex organic molecules to simple organic molecules, with the release of energy (Fonseca, Oliveira & Brecht 2002). Minimally processed fruit and vegetables are still living tissues that continue to respire, sometimes at an increased rate (Fonseca et al. 2002). Through damage of the surfaces during processing, a stress response is induced, increasing respiration and ethylene production and thus increasing metabolism (Watada, Ko & Minott 1996). The respiration rate of minimally processed fruits and vegetables needs to be considered to extend the shelf life of these products. Minimally processed vegetables are generally low-acid foods with a pH of approximately 5-8-6. 0. Processing and storage conditions can influence pH such as significant increases in levels of carbon dioxide (Rico et al. 2007). An important quality consideration regarding pH is the browning reaction, with Rico et al. (2007) identifying that the activity of polyphenol oxidase is most effective at a neutral pH of 7. 0. Microbiology Minimally processed vegetables have a physical structure that lends itself to microbial contamination, due to the exposure of nutrients as a result of the breakdown of protective coatings (Ragaert, Devlieghere & Debevere 2007). Additionally, high water activity, neutral (vegetables) and low acid pH facilitates microbial contamination (O'Beirne & Francis 2003). Pathogens can become attached to processing equipment and once attached as biofilms, are very difficult to remove by chemicals (Nyugen-the & Carlin 1994). The five main factors determining pathogen survival are: storage temperature; product type/product combinations; minimal processing operations; packaging atmosphere; competition from natural microflora (O'Beirne & Francis 2003). Microorganisms are involved in the degradation of quality of minimally processed vegetables through visual defects, texture degradation, and off-flavours and odours (Ragaert et al. 2007). Natural populations of microorganisms on minimally processed vegetables range from 103 — 106 cfu/g (Ragaert et al. 2007). These include bacteria such as Pseudomonas, Lactic acid bacteria and Enterobacteriaceae, and several species of yeasts (Nyugen-the & Carlin 1994). Moulds play a lesser role due to the neutral pH that favours bacterial and yeast growth (Gimenez et al. 2003). There is limited research linking individual microbial species to specific off-flavours and odours including the link between microbial counts and textural degradation. However, there are strong links between high microbial counts and off-odours during storage (Ragaert, Devlieghere & Debevere 2007). Further research needs to be conducted for greater understanding of the impact of microorganisms on the sensorial quality of minimally processed vegetables. Nutritional Content Klein (1987) provides an in-depth review of the nutritional impact of processed fruit and vegetables. The processing of fruits and vegetables facilitates the loss of antioxidants. Levels of ascorbic acid, carotenoids, and polyphenols can reflect the capacity of antioxidants in fruit and vegetables (Klein 1987). Through the consideration of methods to improve the sensory characteristics of minimally processed fruits and vegetables, Klein (1987) suggested these methods would also preserve nutritional content. Through an understanding of the impacts of processing on colour, texture, respiration, pH, microorganisms and nutritional content, it's clear that treatments or packaging methods must be applied to minimise these effects and maintain the level of quality desired by the consumer. Treatments include the use of: chlorine; organic acids; hydrogen peroxide; calcium based solutions; ozone; electrolysed water; natural preservatives; heat; irradiation; ultraviolet light; hurdle technology; and MAP (Rico et al. 2007). The following sections will focus on MAP and recent advances and uses of this technology. Modified Atmosphere Packaging — What is it? MAP is a technique for preserving the quality of foods. It involves the alteration of the atmosphere within the package, adjusting the levels of oxygen and carbon dioxide (most commonly high carbon dioxide an low oxygen) to support an environment that reduces respiration, delays senescence and improves storage life (Rico et al.). There are two types of MAP techniques that exist: active and passive. Active packaging involves the removal of the natural atmosphere of the packaging with a vacuum and replacing it with the desired gas mixture (Kader, Zagory, Kerbel & Wang 1989). Passive packaging does not involve modification of the atmosphere directly; using instead the natural process of respiration of the commodity to alter the atmosphere and as such directly involves the ability of the packaging film to be permeable for certain gases (Kader et al. 1989). The type of packaging technique differs for the type of commodity, and in different products may have advantages and disadvantages. These advantages and disadvantages, taking into account the effect of MAP on some of the crucial aspects of minimally processed fruit and vegetables identified in Section Two, will be further discussed in the following sub-sections. Advantages and Disadvantages MAP poses several advantages for the consumer and producer. For the consumer, quality of produce is maintained with the extension of shelf life, reducing the need for harmful chemical preservatives (Han 2005). For the producer, increased shelf life allows a reduction in costs for distribution and transportation that allows products to be more readily available for distribution to more remote areas, increasing market range (Han 2005). MAP also poses several disadvantages. Different products require specific atmospheric concentrations (see Table 1 for detailed identification of some products), wherein specialised equipment is needed, and a substantial cost for the producer is incurred (Han 2005). Product safety is also questioned with the potential growth of harmful anaerobic organisms (Han 2005). The equilibrium modified-atmosphere is also difficult to obtain for each product, due to the difference in respiration rates of fruits and vegetables (Day 2003). Microbial Safety of MAP A major concern in regards to the safety of MAP is the microbiological safety of these products. This concern is associated with the inhibition of aerobic bacteria (and thus the ability for anaerobic bacteria to proliferate) and the growth of psychrotrophic organisms (Devlieghere & Debevere 2003). Specific foodborne microorganisms that give most concern include: Clostridium botulinum, Listeria monocytogenes, Yersinia enterocolitica and Aeromonas hydrophila. Vegetables are potential carriers of Clostridium botulinum, due to the possible contamination at the source during harvest or processing (O’Beirne & Francis 2003). Research has indicated that the likelihood of Clostridium botulinum to produce its toxin in the food before spoilage is relatively low (probability of 1 in 105) however a documented case of botulism was recorded in regards to a MAP dry coleslaw mix (O’Beirne & Francis 2003). L. monocytogenes has been found to occur on minimally processed produce at a relatively high occurrence (ranging from 0 — 44%), grows well at 1C and is a facultative anaerobe (O’Beirne & Francis 2003). These factors lead to the concern for the safety of minimally processed fruit and vegetables under modified atmospheric conditions. However, research suggests that strains of L. monocytogenes present in these modified atmospheres are not the same as the strains that cause normal food poisoning in humans (O’Beirne &

Francis 2003). Effect of Carbon Dioxide as an Anti-microbial Gas The three main gases used in MAP are oxygen, carbon dioxide, and nitrogen, with nitrogen acting primarily as a filler gas (Devlieghere & Debevere 2003). The main preservative gas is carbon dioxide and is generally used in the highest concentration (Devlieghere & Debevere 2003). Concentrations of oxygen, carbon dioxide and nitrogen for some common fruits and vegetables are outlined in Table 1. Table 1. Optimal Concentration of CO2 and O2 for Fruits and Vegetables Commodity | Temperature (C) | O2 (%) | CO2 (%) | Apple (whole) | 0-5 | 2-3 | 1-5 | Apple (sliced) | 0-5 | 10-12 | 8-11 | Avocado | 5-13 | 2-5 | 3-10 | Banana | 12-15 | 2-5 | 2-5 | Kiwifruit | 0-5 | 2 | 5 | Mango | 10-15 | 5 | 5 | Pineapple | 10-15 | 5 | 10 | Strawberry | 0-5 | 10 | 15-20 | Asparagus | 0-5 | 20 | 5-10 | Broccoli | 0-5 | 1-2 | 5-10 | Cabbage | 0-5 | 3-5 | 5-7 | Lettuce (head) | 0-5 | 2-5 | 0 | Lettuce (shredded) | 0-5 | 1-2 | 10-12 | Mushrooms | 0-5 | 21 | 10-15 | Spinach | 0-5 | 21 | 10-20 | Source: Han (2005) adapted from Kader (1986) While it is widely accepted that carbon dioxide is the anti-microbial gas in MAP, the mechanism is not generally understood in the scientific literature (O'Beirne & Francis 2003). The low temperature storage allows the carbon dioxide to dissolve and perform its antimicrobial action (O'Beirne & Francis 2003). Four possible mechanisms have been proposed: lowering of the pH of the food, penetration into the cell followed by a drop in cytoplasmic pH, specific actions on cytoplasmic enzymes and specific actions on biological membranes (Devlieghere & Debevere 2003). The first mechanism (lowering the pH of the food) depends on the buffering capacity of the food, and has not been related to large drops in the pH of food products (Devlieghere & Debevere 2003). This mechanism is unlikely to be the sole explanation for the antimicrobial properties of carbon dioxide. The following three mechanisms give a more accurate picture of the antimicrobial mechanism of carbon dioxide but the scope of this literature review does not allow a full analysis of these mechanisms. Generally speaking, gram-negative microorganisms (Shewanella, Pseudomonas, Aeromonas) are sensitive to carbon dioxide, gram-positive are less sensitive, and the lactic acid bacteria are the most resistant (Devlieghere & Debevere 2003). Additionally, yeasts and moulds are sensitive to carbon dioxide (Devlieghere & Debevere 2003). Effect of MAP on Nutritional Quality While there is no doubt that MAP extends shelf life by considerable time periods, the retention of nutrients in fruits and vegetables over these long time periods is not well understood (Devlieghere & Debevere 2003). Key nutrients in fruits and vegetables that are of importance to human health include ascorbic acid, carotenoids, phenolic compounds and glucosinolates (Devlieghere & Debevere 2003). It is difficult to provide a detailed account of the effect of MAP on nutritional quality, due to the fact that every fruit and vegetable has a different response. The susceptibility of fruits and vegetables to loss of ascorbic acid depends on factors such as pH, softness, and type of vegetable (for example, leafy vegetables or root vegetables). For intact fruits, controlled or modified atmospheres with lower oxygen and increased carbon dioxide tend to increase the retention of ascorbic acid, however, increased carbon dioxide beyond certain thresholds had an opposing effect on the retention of ascorbic acid in specific fruits (Devlieghere & Debevere 2003). The degradation of ascorbic acid in minimally processed fruits has also been associated with high levels of carbon dioxide (20-30%). Carbon dioxide concentrations of 5-20% have been shown to cause significant loss of ascorbic acid in fresh-cut kiwifruit slices (Agar, Massantini, Hess-Pierce & Kader 1999). Likewise, carbon dioxide concentrations of 20-30% in lettuce accelerated loss of ascorbic acid (Barry-Ryan & O'Beirne 1999). In contrast, no significant loss of ascorbic acid was seen in freshly cut strawberries, persimmons or cut broccoli florets (Barth, Kerbel, Perry & Schmidt 1993; Wright & Kader 1997a). Nevertheless, high concentrations of carbon dioxide appear to be detrimental to many fruits and vegetables. To determine the thresholds for specific commodities, further research should be undertaken. Carotenoids contribute to the nutritional quality of vegetables through provitamin A activity such as -carotene (Devlieghere & Debevere 2003). Plants contain no Vitamin A, although provitamin A can be converted to vitamin A in vivo (Devlieghere & Debevere 2003). Research, though limited, has shown that vitamin A content varies little for minimally processed fruits and vegetables under modified atmosphere conditions (Baskaran, Prasad & Shivaiah 2001; Paradis, Castaigne, Desrosiers, Fortin, Rodrigue & Willemot 1996; Petrel, Fernando, Romojaro & Martinez 1998). Within these studies, no significant change was observed for minimally processed pumpkins, oranges, broccoli, and green beans Glucosinolates and phenolic compounds are also important nutritional components of minimally processed fruits and vegetables. Browning can occur in fruits under low oxygen environments (Devlieghere & Debevere 2003), with carbon dioxide rich environments appearing to be detrimental for fruits due to the loss of phenolic compounds such as anthocyanin. Devlieghere and Debevere (2003) advise that there is a lack of research on the retention of glucosinates in minimally processed vegetables under MAP conditions, highlighting a potential area for further study. Colour Stability and MAP Anthocyanins, responsible for yellow and brownish pigments, are highly unstable molecules further destabilised through minimal processing (Calero & Gomez 2003). Increases in pH due to the high carbon dioxide concentration in MAP have adverse affects on anthocyanins (Calero & Gomez 2003). Likewise, key enzymes in the biosynthetic pathway of anthocyanins are inhibited by the high carbon dioxide concentrations during storage and thus contributing to levels of anthocyanin in fruits and vegetables (Calero & Gomez 2003). In the case of cut potatoes, browning was closely linked to concentrations of oxygen and carbon dioxide in the package (Gunes & Lee 1997), likewise for minimally processed apples (Soliva-Fortuny, Grigelmo-Miguel, Odriozola-Serrano, Gorinstein & Martin-Belloso 2001). Imperitively, Calero and Gomez (2003) note that colour responses as a result of MAP differ between types of fruits and vegetables although tolerance for high carbon dioxide environments is generally reduced for fruits and vegetables and retention of colour. In response to the limitations of tradition low oxygen MAP, new developments in MAP technology have emerged, and will be discussed in the following section. New Developments In MAP Technology Section Four identified and discussed limitations in MAP technology, including anaerobic microbial growth, and the tailoring of modified atmospheres to individual products. As a possible answer to many of MAP technology shortcomings, a new approach has been suggested, called high oxygen MAP (Day 2003). Some research is also being conducted on the use of argon (Ar) and nitrous oxide (N20) as potential gases for use in MAP technology. Claims have been made that Ar and N20 can inhibit fungal growth, reduce ethylene emission and slow sensory deteriation (Day 2003). However, further research must be conducted to strengthen these claims. Consequently, the remainder of this review will document applications of high oxygen MAP, as a significant level of research has been conducted using this new approach to MAP. High O2 MAP Research conducted from around the world has identified high oxygen MAP as a potential technology to inhibit enzymic discolouration, inhibit anaerobic fermentation reactions, reduce moisture loss, and inhibit aerobic as well as anaerobic microbial growth (Day 2003). Additionally, high oxygen was effective with traditional inexpensive plastic films and as a result, shelf life is extended considerably without the added cost for expensive micro-perforated packaging films (Day 2003). The finding that high oxygen MAP can inhibit both aerobic and anaerobic microbial growth is significant due to the safety concerns of traditional MAP on the growth of anaerobic organisms. The finding can be explained with an analysis of the growth profiles of aerobes and anaerobes (refer to Figure 1). The mechanism of antimicrobial action is hypothesised to be as a result of active oxygen radical species preventing microbial growth. Figure 1. Growth profiles of aerobes/anaerobes. Source: Day (2003) Another important finding is the ability of high oxygen MAP to inhibit enzymatic discolouration of fresh produce. Polyphenol oxidase is the key enzyme involved, causing the oxidation of phenolic compunds to colourless quinones and eventually to melanin compounds (McEvily, Iyengar & Otwell 1992). Day (2003) hypothesises that high oxygen may cause substrate inhibition of polyphenol oxidase. Alternatively, the production of high levels of colourless quinones may cause product inhibition of polyphenol oxidase (Day 2003). This process is shown in Figure 2. Figure 2. Product and substrate inhibition of polyphenol oxidase. Source: Day (2003). Testing High O2 MAP The CCFRA (Campden and Chorleywood Food Research Association) conducted experimental trials on the effect of novel MAP on freshly prepared produce, including a three-year EU-funded project in the period 1995-1999 (Day 2003). It was found that high oxygen MAP had odour and textural benefits for minimally processed potatoes and apples. Furthermore, most prepared produce items, under specific storage and packaging conditions, experienced beneficial sensory effects compared with low oxygen MAP. Shelf life was improved under high oxygen MAP of prepared lettuce, sliced mushrooms, broccoli florets, baby-spinach leaves, cubed swede, coriander, raspberries, strawberries, grapes and oranges. These findings by the CCFRA are highlighted in Table 2. Beneficial sensory effects were also found for fresh prepared tomato slices, pineapple cubes, honeydew melon cubes, sliced mixed peppers and sliced leeks (Day 2001a). Table 2. Achievable shelf life of fresh prepared produce Overall achievable shelf life (days) at 8C | Prepared Produce Items | Low O2 MAP | High O2 MAP | Iceberg lettuce | 2-4 | 4-11 | Sliced bananas | 2 | 4 | Broccoli florets | 2 | 9 | Cos lettuce | 3 | 7 | Strawberries | 1-2 | 4 | Baby spinach leaf | 7 | 9 | Lolla Rossa lettuce | 4 | 7 | Radicchio lettuce | 3 | 4 | Flat leaf parsley | 4 | 9 | Coriander | 4 | 7 | Cubed swede | 3 | 10 | Raspberries | 5-7 | 9 | Little Gem lettuce | 4-8 | 6-8 | Potatoes | 2-3 | 3-6 | Baton carrots | 3-4 | 4 | Sliced mushrooms | 2 | 6 | Source: Day (2003) In support of high oxygen MAP, the CCFRA found that high oxygen was successful in inhibiting a wide range of bacteria, yeasts and moulds, including foodborne pathogenic organisms such as Aeromonas hydrophila, Salmonella enteritidis, Penicillium roqueforti and Aspergillus niger. While high oxygen itself was not enough to inhibit the growth of other foodborne pathogens such as Bacillus cereus, Yersinia enterocolitica and Listeria monocytogenes, the addition of 10-30% carbon dioxide inhibited growth of all these pathogens in the CCFRA trial. High oxygen was found to be beneficial for the retention of ascorbic acid in prepared lettuce. However, high oxygen MAP was not found to decrease levels of the carotenoids (-carotene and lutein) in lettuce but did induce losses of some phenolic compounds. Jacxsens, Devlieghere, Van der Steen and Debevere (2001) studied the effect of high oxygen modified atmospheres, without the use of carbon dioxide, on minimally processed vegetables (shredded chicory endives, grated celeriac and sliced mushrooms). Oxygen concentrations ranging from 80-95% were found to be effective in reducing the mycelial growth of Aspergillus flavus and Bortrytis cinerea. In alignment with findings by the CCFRA, high oxygen by itself was not seen to inhibit the growth of Listeria monocytogenes, but a prolongation of the lag phase was identified. Jacxsens et al. (2001) found that grated celeriac and shredded chicory endive did not experience an increase or decrease in respiration as a result of high oxygen, compared with mushroom slices that had significant increases in respiration. The mechanism of increases in respiration in some processed fruits and vegetables is attributed to the inability of plant tissue to produce enough antioxidants to counter the large increases in radical oxygen species (Purvis 1997). In alignment with findings by the CCFRA, Jacxsens et al. (2001) found that the most significant improvement under high oxygen MAP compared with low oxygen MAP was the improvement in sensorial quality and thus shelf life. High oxygen was more effective at inhibiting enzymatic discolouration of all three vegetables, including the suppression of yeast growth, improving the shelf life of each considerably (Jacxsens et al. 2001). Implications of Findings An analysis of the findings on the effects of high oxygen MAP on minimally processed vegetables indicates the potential advantages over low oxygen MAP. Several shortcomings of low oxygen MAP identified in Section Three (microbial safety, retention of nutrients, and retention of colour) could be overcome with the use of high oxygen MAP. While an advancement in MAP technology, limitations of high oxygen MAP were still found in terms of respiration rates of specific fruits and vegetables (Day 2003; Jacxsens et al. 2001), indicating the continuing need to tailor conditions for individual plant types due to numerous variables (temperature, produce type, atmosphere, cultivar, severity of processing etc). High oxygen was not found to be solely capable of assuring microbial safety, with the use of carbon dioxide as an antimicrobial agent still necessary. It is unclear then, whether high oxygen concentrations counter the negative effects of high levels of carbon dioxide (> 10%) experienced under low oxygen atmospheres as discussed in Section Three. However, in consideration of the applications of high oxygen MAP in Section Four, maintaining a carbon dioxide concentration between 10-25% is suggested to maintain sensory and microbiological quality (Day 2003). The proper application of high oxygen MAP is imperative in gaining the maximum benefit from our current understanding of this technology. Application of High O2 MAP First and foremost, the safety of high oxygen MAP should be taken into account, considering the potential explosion hazard of oxygen concentrations greater than 25% (BCGA 1998). Additionally, recommended optimal gas levels, produce volume/gas volume ratio and temperature controls should be understood and applied to gain the greatest advantage from high oxygen MAP. The desired headspace levels in high oxygen MAP are > 40% O2 and CO2 between 10-25% (Day 2003). To achieve this, the highest level of oxygen should be introduced with the filler gas being nitrogen (Day 2003). The introduction of carbon dioxide is not necessary due to the natural build up of carbon dioxide during storage (Day 2003). Based on experiments undertaken by Day (2001a), the most effective concentrations for maximising sensory and microbiological benefits were 80-85% O2/15-20% CO2. In order to maintain the headspace levels indicated in the previous sub-section it is desirable to minimise the produce volume/gas volume ratio, achieved by either reducing the pack weight of fresh produce or increasing the gas volume (Day 2003). There is an obvious commercial limitation though, with consumers unlikely to accept products with too little pack weight and too much headspace gas volume (Day 2003). Testing is required to ensure practical produce volume/gas volume ratios for specific products. An obvious, but equally as important measure to maximise the benefits of high oxygen MAP, is the correct control of temperature during storage. It is recommended by Day (2003) that the temperature be maintained below 8C and preferably in the range 0-3C. Conclusion and Implications The purpose of this literature review was to explore recent advances in MAP of minimally processed fruits and vegetables. Quality impacts for fruits and vegetables as a result of minimal processing were identified, with the need for packaging as a preservation method highlighted. MAP was introduced as a crucial method for preservation of minimally processed fruit and vegetables to increase shelf life and maintain quality. Several key limitations of traditional MAP technology were identified (microbial safety, retention of nutrients, and retention of colour). Recent advances in MAP technology, in particular high oxygen MAP, are considered effective in overcoming these shortfalls. However, as some limitations of high oxygen MAP remain, it is advocated that further research is required to successfully develop this technology and utilise it to its full potential. List of References Agar I, Massantini, R, Hess-Pierce, B & Kader A 1999, ' Postharvest CO2 and ethylene production and quality maintenance of fresh-cut kiwifruit slices', Journal of Food Science, vol. 64, pp. 433 — 40. Barry-Ryan, C & O'Beirne, D 1999, ' Ascorbic acid retention in shredded iceberg lettuce as affected by minimal processing', Journal Food Science, vol. 64, pp. 498— 500. BCGA, 1998, The Safe Application of Oxygen Enriched Atmospheres When Packaging Food, British Compressed Gases Association, Hampshire, UK, p. 39. 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