Postharvest Handling and Packaging of Fresh Herbs

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Foreword

This report surveys, collates and reviews key aspects of Australia’s fast-growing culinary herbs industry, including all of the published scientific and industry literature on postharvest handling and packaging.

It identifies and analyses the reasons for the high wastage rate in shops and supermarkets and suggests ways to overcome the problems of dealing with such a wide range of temperate and tropical herbal plants.

The report also studies the export and international handling of Australian culinary herbs and shows how producers can improve their chances of reaching world markets.

This project is part of RIRDC’s culinary herbs, spices, teas and coffee program which fosters development of viable industries based on these products by investigating markets and commercial opportunities and by developing technology packages to support production.

Peter Core
Managing Director
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Executive summary

Culinary herbs is a growth industry. Yet expansion is curtailed by a distinct lack of understanding of the specific postharvest handling and packaging needs of the broad range of species and varieties generically labelled “culinary herbs”. Wastage on domestic markets is high with some suppliers to supermarkets having to rotate stock every 24 to 48 hours to assure quality at the time of purchase. Furthermore, many packers and exporters of herbs feel that their ability to export to overseas markets is severely limited by their lack of knowledge of handling and packaging requirements.

There are two sections contained in this report. The first is the results of a survey of the Australian culinary herb industry which identified the postharvest handling methods currently in use and the major postharvest factors limiting the expansion and sustainability of the industry. Based on the survey results, all the published scientific and industry literature on postharvest handling and packaging of herbs was collated and reviewed. This review comprises the second part of the report.

The survey identified poor postharvest handling and a lack of knowledge on suitable packaging systems for herbs as the major factors contributing to wastage, poor quality and limited market opportunities. In particular, poor temperature and humidity management during handling, distribution and marketing were identified as key issues which need to be addressed. Culinary herbs as a group comprise a very diverse range of plant species, cultivars and plant parts. Furthermore, fresh herbs may be of temperate or tropical origin. Consequently, their postharvest handling requirements are very diverse indeed. It appears that industry is unaware of the specific needs of different species and at present most varieties are simply branded “herbs” and all are treated the same after harvest.

After examining and critically reviewing the published literature on postharvest handling and packaging of herbs it became apparent that some information exists on how to address these issues and it will be useful to some sectors of the industry. This information is available in this report. However, a major finding of the review was how little research has been done on the postharvest handling and packaging of culinary herbs.

Data from the survey and the review has identified the priority areas for research inputs to address the problems faced by industry and has identified a substantial opportunity to add value to the herb industry. With the sudden increase in the production of minimally processed vegetables there is an opportunity to supply minimally processed herbs in their own right as well as additives to minimally processed vegetable mixes. These products will require specific postharvest handling and processing requirements and this information appears to be unavailable in the public domain at present.

A number of these research and development issues are being addressed in a new project which is being funded by RIRDC and the herb industry. This project will develop postharvest handling and packaging protocols for problem herbs such as sweet basil as well as new herb products.
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Background

In recent years an increasing number of enquires have been made to IHD on the postharvest handling and packaging of culinary herbs for both domestic and export markets. In responding to these requests for information it became increasingly clear that little knowledge was readily available and that growers, packers, retailers and exporters were quite confused as to how to handle and package different herb species. This was resulting in high levels of wastage on domestic markets and a lack of confidence in developing export markets. These observations were supported by the recommendations of the inaugural Australian Herb Industry Workshop where packaging technology was identified as a high priority area for research and development inputs (RIRDC Project No. FHC-1A).

However, it was decided that the problem should be properly identified before it could be addressed. To this end, a survey of the herb industry was undertaken to identify which crops and products have the highest priority and what are the major postharvest handling and packaging issues which need to be addressed. In addition to this, the published information on the postharvest handling and packaging of herbs was collated and reviewed. The results of these investigations comprise the basis for this report.

Objectives

To identify new and emerging postharvest packaging and handling technologies which will enable the fresh herb industry to overcome existing barriers to market expansion. Using the results of an industry survey and a desk-top review of existing literature, research priorities will be identified.
1. Introduction

Demand for fresh culinary herbs in Australia and overseas has increased rapidly over recent years. Although local production has grown to meet this demand, the potential for further market expansion, at both domestic and export level is considerable. For example, the local hospitality industry requires increasing volumes of high quality product that can be stored and used as required. Niche export markets are available to growers who can provide sufficient quantities of quality product, particularly "out-of-season" herbs to Northern hemisphere markets.

Commercially, the majority of herbs produced are sold as dried products due to ease of transport, marketing and storage (Pruthi, 1980). Although freshly harvested herbs are superior in flavour to dried herbs, their widespread commercialisation has been limited due to high perishability and a relatively short shelf-life (Cantwell and Reid, 1993).

The Australian herb industry currently supplies a number of domestic markets, fresh, wholesale, retail, food service and processing, with some growers supplying niche markets in South-East Asia. Despite some expansion and diversification of markets, major marketing and handling problems associated with fresh herbs still exist. Low daily turnover of fresh herbs at the local retail level leads to substantial wastage due to quality loss while further expansion into export markets is limited by low volumes, high air-freight costs and inadequate packaging. In most cases, due to a lack of postharvest handling information for individual species, herb growers and distributors use the same packaging and handling technology for species that are diverse in botanical origin and physiological characteristics. Similar problems exist at the end of the marketing chain, retailers selling herb bouquets that may combine an extremely perishable herb such as chervil with long-lasting rosemary and thyme or, displaying fresh herbs under incorrect environmental conditions.

A few growers and distributors have tried using modified atmosphere packaging (MAP) technologies to increase product shelf-life using packaging systems developed "in-house" or by packaging companies. A number of costly and time-consuming commercial trials have been unsuccessful in improving fresh herb shelf-life to any great extent. Inconsistent quality due to inappropriate packaging and poor postharvest handling has been a common outcome.

Design of proper MAP requires a better understanding of the postharvest physiology and storage requirements of each herb species. Complementing this technology with proper postharvest handling procedures throughout the distribution and marketing chain will result in a high quality product reaching domestic and overseas markets.
This report will focus on current postharvest handling and packaging practices through a local industry survey and reviews the latest research in this area. Major aims are to identify research opportunities to overcome existing problems and assess the potential of introducing new and emerging handling and packaging technologies into the Australian fresh herb industry.

2. Commercial herb species
Australian growers produce a variety of Mediterranean culinary herbs, salad herbs and increasingly a number of Japanese greens and Asian herbs such as mitsuba, shisho, mizuna, mibuna and tatsoi. The importance of these will increase as exports to South-East Asia become common practice.

A fresh herb industry survey determined that five of the major herb species grown in Australia are parsley, both continental and curled; chives, both onion and garlic; coriander, sweet basil and chervil. Many others would be grown in similar quantities and are listed in Table 1.

Table 1. Major fresh culinary herbs grown in Australia.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Botanical name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basil</td>
<td>Ocimum basilicum L.</td>
</tr>
<tr>
<td>Chervil</td>
<td>Anthriscus cerefolium L.</td>
</tr>
<tr>
<td>Chives</td>
<td>Allium schoenorasum L.</td>
</tr>
<tr>
<td>Coriander</td>
<td>Coriandrum sativum L.</td>
</tr>
<tr>
<td>Dill</td>
<td>Anethum graveolens L.</td>
</tr>
<tr>
<td>English mint</td>
<td>Mentha spp.</td>
</tr>
<tr>
<td>Mache</td>
<td>Valerianella locusta L.</td>
</tr>
<tr>
<td>Marjoram</td>
<td>Origanum marjorana L.</td>
</tr>
<tr>
<td>Mibuna</td>
<td>Brassica rapa japonica</td>
</tr>
<tr>
<td>Mitsuba</td>
<td>Cryptotaenia japonica Hassk.</td>
</tr>
<tr>
<td>Mizuna</td>
<td>Brassica rapa japonica</td>
</tr>
<tr>
<td>Oregano</td>
<td>Origanum vulgare L.</td>
</tr>
<tr>
<td>Parsley</td>
<td>Petroselinum crispum</td>
</tr>
<tr>
<td>Peppermint</td>
<td>Mentha piperita L.</td>
</tr>
<tr>
<td>Rosemary</td>
<td>Rosmarinus officinalis L.</td>
</tr>
<tr>
<td>Sage</td>
<td>Salvia officinalis L.</td>
</tr>
<tr>
<td>Shisho</td>
<td>Perilla frutescens crispa</td>
</tr>
<tr>
<td>Sorrel</td>
<td>Rumex acetosa L.</td>
</tr>
<tr>
<td>Spearmint</td>
<td>Mentha spicata L.</td>
</tr>
<tr>
<td>Tarragon</td>
<td>Artemisia dracunculus L.</td>
</tr>
<tr>
<td>Thyme</td>
<td>Thymus vulgaris L.</td>
</tr>
<tr>
<td>Watercress</td>
<td>Nasturtium officinale R.Br.</td>
</tr>
</tbody>
</table>

Many species have several varieties, for example, lemon thyme, onion and garlic chives, sweet or golden marjoram, French or Russian tarragon and curled or continental parsley.

Availability in many cases is dependent on the time of the year and fresh herb quality at harvest can also vary greatly depending on the time of the year they are grown.
Production of salad and herb mixes is increasing rapidly as growers seek to expand and diversify their markets. Salad and herb mixes, also known as mesclun, can be a combination of various leafy salad herbs, leafy vegetables and edible flowers. A common mix could include lettuce and spinach leaves, endive, herbs such as rocket, mibuna, mizuna and chervil and various edible flowers such as pansies, violets and chrysanthemum. These are usually packaged in bulk, in a similar manner to fresh herbs but increasingly are available in smaller, package branded consumer prepacks.

2.1 Major species by production and export

There are very few published statistics on herb production. Most likely, the bulk of Australia's production is still based on 'traditional' herbs such as parsley, thyme, chives, oregano, mint and rosemary. Recently, considerable new plantings of herbs are being grown for inclusion in salad mixes and these include chervil, mizuna, mibuna and rocket.

Fresh herb exports are increasing with major markets in South-East Asia, the Middle East and the Pacific region (Table 2). More than half of Australia's culinary herb exports are made up of parsley, which is one of the easiest to handle and store. Approximately 130 tonnes of parsley were exported during 1993/94. Exports of other individual herb species were less than 1 tonne each although 84.4 tonnes were exported as "herb other". All together, 217 tonnes of fresh culinary herbs were exported in 1993/94.

Table 2. Major fresh herb species by exports (1993/94) (Source: DPIE, AQIS).
<table>
<thead>
<tr>
<th>Herb</th>
<th>Major Destinations</th>
<th>Exports (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parsley</td>
<td>Hong Kong, UAEM, Taiwan, Bahrain</td>
<td>130.139</td>
</tr>
<tr>
<td>Chives</td>
<td>Fiji</td>
<td>0.151</td>
</tr>
<tr>
<td>Coriander</td>
<td>Singapore, French Polynesia</td>
<td>0.055</td>
</tr>
<tr>
<td>Basil</td>
<td>New Zealand, Singapore</td>
<td>0.993</td>
</tr>
<tr>
<td>Mint</td>
<td>New Zealand</td>
<td>0.186</td>
</tr>
<tr>
<td>Rosemary</td>
<td>Singapore</td>
<td>0.438</td>
</tr>
<tr>
<td>Dill</td>
<td>Phillipines, Malaysia, Hong Kong</td>
<td>0.118</td>
</tr>
<tr>
<td>Tarragon</td>
<td>Singapore, New Zealand</td>
<td>0.443</td>
</tr>
<tr>
<td>Sorell</td>
<td>Solomon Islands</td>
<td>0.005</td>
</tr>
<tr>
<td>Sage</td>
<td>Singapore</td>
<td>0.083</td>
</tr>
<tr>
<td>Herb (other)</td>
<td>Hong Kong, Singapore</td>
<td>84.360</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>216.971</strong></td>
</tr>
</tbody>
</table>

3. **Industry survey**
Existing postharvest handling practices in the Australian herb industry were determined through a short industry survey aimed at fresh culinary herb growers and distributors, a few of which were exporting some of their product.

3.1 Fresh herb industry participation

As has been noted in the past, the local fresh herb industry is fragmented, consisting of many small growers and distributors individually trying to find local and export markets (Fletcher and Fraser, 1993).

The fresh herb industry is relatively small and mainly geared to supplying local retail, wholesale and food service markets while a few producers are seeking to increase their export opportunities. More 'entrepreneurial' distributors have specific growers on contract to source produce from or they may grow the product themselves, giving them some control over supply and product quality. They then package the fresh herbs for retail and export markets.

The survey was sent out to 24 industry participants and included growers and distributors from every state. Many of the larger producers were surveyed and the final response rate of 65% was a good result considering the competitive nature of the industry. A few growers and/or distributors did not want to reveal too much of their postharvest handling practices, as they had spent many years building up their respective businesses. Discussions with smaller growers, distributors, wholesalers and retailers also provided useful information which was included in the survey results.

A copy of the questionnaire used in this survey is located at the end of this report. Industry participation in completing the survey was conditional on strict confidentiality being maintained.

3.2 Key survey results

The industry survey highlighted several deficiencies in the postharvest handling of fresh herbs.

3.2.1 Product handling
All growers surveyed managed to wash, bunch and package their herbs and begin cooling them within three hours of harvest, although during this time they remained at ambient temperatures, even during summer. Spraying or dipping herbs in water was a common method of preventing moisture loss. Only 14% of growers used a postharvest chemical treatment to reduce the microbial load present on harvested herbs. This is surprising as decay development is a major factor limiting shelf-life of most fresh herbs and the food service industry demands a low microbial load. Cool store temperatures used varied from 2 - 6°C with many growers and distributors stating that storing chilling-sensitive basil at these low temperatures was a major problem. Another problem the industry faces is that these temperatures are higher than the optimum for most herbs and because of the rudimentary cooling facilities usually available, field-heat removal may take many hours which compromises quality.

3.2.2 Packaging

Culinary herbs grown for the local wholesale and fresh retail market are packed in a variety of ways, the simplest being to wrap herb bunches in plastic film to provide some protection against water loss. The most common method is to bulk package fresh herbs (1-3 kg), either directly into a styrofoam box or waxed cartons which are covered with paper or plastic. Approximately 70% of growers and distributors packed their herbs inside perforated polyethylene or polypropylene bags which are then placed in waxed cartons. The few companies that export fresh herbs to South-East Asia use this bulk packaging method.

Producers supplying local retail outlets have made attempts at finding suitable packaging for a variety of fresh herbs by trial-and-error commercial testing methods. Currently, a number of methods for the retail market are being used including plastic punnets sealed with various plastic films and consumer-sized plastic film bags.

Quality and shelf-life improvements at the retail level have been marginal in many cases mainly due to a poor understanding of the packaging requirements for different species and the unreliability of the handling chain. Retail outlets displaying these perishable products at temperatures well above their optimum is just one example of the problems which need to be addressed.

Various claims have been made by distributors that their MA packaging can maintain herb quality for up to three weeks but without proper testing and assessment of various packaging materials, many unknowns still exist.

3.2.3 Distribution
Approximately 85% of growers and distributors have very little knowledge of how their product is transported and handled once it leaves the farm gate or their company. To ensure that correct storage temperatures are maintained during distribution a few companies use refrigerated transport but the majority of fresh herbs are transported at ambient temperatures with growers relying on quick turnover and short travel times to minimise warming and rapid quality loss. Even when refrigerated vans are used, poor handling and temperature management practices can still occur during the marketing chain. With little control over the temperature during distribution and lack of proper handling protocols fresh herb quality suffers and wastage is high. All fresh herb exporters felt that poor handling practices by air-freight companies and temperature fluctuations during air transport were major problems.

3.2.4 Shelf-life

The major factors cited by industry which limited fresh herb shelf-life were, in order of importance, poor temperature management and failure to maintain the cool chain during distribution, decay and disease development and moisture loss.

3.2.5 Quality

Three-quarters of survey respondents claimed that poor postharvest quality was the biggest problem facing the fresh herb industry.

With no industry quality standards or quality assurance systems in place, significant quantities of poor quality product is being marketed to the detriment of better herb growers. The survey also showed that industry sees pre-harvest management, good initial quality, good postharvest temperature management and reliable packaging to maintain quality as the keys to producing and distributing a quality product.

4. Literature Review

4.1 Fresh herb marketing and handling

4.1.1 Marketing

Each fresh herb market has individual distribution and packaging requirements which will have a large bearing on postharvest shelf-life. Wholesale markets require their fresh herbs in bulk so they
prefer them to be supplied in cardboard or polystyrene cartons with the bunches often placed in plastic bags. Market agents in Sydney and Melbourne will only deal with larger growers who can supply regular consignments of high quality product (Bagshaw, 1988).

At the retail level, chain stores have increased their sales of value added, package branded fresh herbs and require regular supplies of a very high quality product with an equally high standard of packaging. At the moment this packaging consists of either sealed plastic bags or sealed plastic punnets usually holding 10 to 50 grams and labelled to identify the grower or distributor.

A rapidly growing market sector is the hospitality and food service industry and again, continuity and reliability of supply are vital (Biggs, 1991).

All sectors of the wholesale and retail markets for fresh herbs demand long lines of high quality product. To meet these demands, producers and distributors are investigating improved postharvest handling practices, in particular packaging. However, at this stage, a lack of knowledge in how to achieve this is providing a substantial barrier to the industry achieving its aims of consistent supply and quality.

4.1.2 Export markets

Market research to determine the requirements of export markets is required by growers and distributors. Even though fresh herbs are now consistently exported, mainly into South-East Asia, the exact products, product specifications and packaging requirements demanded by these markets are poorly understood. In general terms, export markets require a regular supply of top-quality produce, attractively presented and packaged so that quality will be maintained throughout distribution and marketing (Bagshaw, 1988).

Costs of exporting are high due to requirements for cool storage throughout the handling chain to ensure freshness and a sole reliance on expensive air-freight. Consequently, growers must have an efficient production and marketing operation and many use a freight forwarder who is a vital component in the marketing chain.

4.1.3 New products

Large fresh herb growers have expanded their range of product lines over recent years to include salad or mesclun mixes. These contain a wide range of herbs and lettuce types. Commonly used herbs include a range of cresses and mustards such as mibuna, mizuna, rocket and chervil. Quality mixes may also include baby Chinese cabbage, snow pea tendrils and baby beet leaves. Many mixes also contain flowers such as nasturtiums, marigolds, carnations, calendulas and violas (Biggs, 1991). There is considerable debate in the industry at present as to whether all the flower
types and cultivars used are "edible" and furthermore, whether some may actually be toxic to humans if eaten in large amounts. There appear to be no restrictions on what type of flowers can be added to salad mixes and little information available on which types and cultivars are fit for human consumption. This issue needs to be addressed in the near future.

The use of minimally processed fresh herbs, and their use in other minimally processed products has also increased and will continue to do so. In most cases the packaging and handling techniques used are the same for all product, even though each product may have different postharvest handling requirements. The most commonly used fresh cut herbs are chives and parsley, both as a product in their own right and in salad, soup, stirfry and vegetable medley mixes.

An understanding of marketing requirements, handling and packaging, and close customer contact will ensure expansion of the industry, yet weaknesses exist in each area, particularly in distribution and packaging requirements.

4.2 Postharvest biology of fresh culinary herbs

The postharvest shelf-life of fresh herbs may be substantially affected before harvest. Factors such as genotype influences morphological and metabolic variability which impacts on shelf-life and handling requirements. Cultural and environmental factors during production can also have a significant role in determining the postharvest behaviour of fresh herb species.

4.2.1 Botany and development
Fresh culinary herbs are made up of many different species, harvested at different stages of development with most having similar physiological characteristics to green leafy vegetables. Lipton (1987) has documented cultivar differences in shelf-life between leeks, lettuce and cabbage. These differences in postharvest behaviour would be expected within herb species as well, although documented evidence of this is minimal. Cantwell and Reid (1993) report that differences in sensitivity to chilling injury have been found between basil cultivars and that rates of water loss are different between various mint species. Spence and Tucknott (1983) have found different rates of yellowing between watercress species.

Morphological differences can also account for differences in perishability. Salad herbs such as watercress, which have large, tender leaves, are very susceptible to rapid water loss while a perennial herb such as sage, with small, waxy leaves has better water-conserving characteristics (Cantwell and Reid, 1993). In this case each herb will require different handling and packaging systems.

Plant development may also affect postharvest shelf-life. Herbs are harvested at different stages of development, the most common being as a soft or semi-woody leafy stem but the plant can also include immature or mature flowers (dill, basil and oregano), developing leaves (sorrel) or intact leaves (coriander and mache) (Cantwell and Reid, 1993).

Effects of leaf age on the postharvest physiology of parsley was studied by Apeland (1971). At 5°C, it was found that respiration was initially higher in younger leaves than in older leaves but that after 30 days storage the total respired carbon dioxide was higher in the older leaves. This correlated with final quality, with only 34% of older leaves still marketable compared with 89% of young leaves.

In similar studies on mache, Cantwell and Reid (1993) found that young plants retained visual quality longer than mature plants. Differences in quality were associated with lower respiration and lower ethylene production rates by young mache plants.

Results of the local industry survey suggest that industry has a basic understanding of these morphological differences and their implications but they do not take them into account when harvesting, handling and packaging their product.

4.2.2 Cultural factors

The relationship between agronomic practice and postharvest shelf-life is poorly understood. It is likely that some variation of postharvest behaviour within herb species may be attributable to cultural practices such as irrigation and fertilisation regimes. It is known that these factors influence yield and essential oil composition of culinary herbs (Simon et al, 1989).
Seasonal factors such as temperature and day length may also have an effect. Rothwell and Robinson (1986) found these environmental factors had an effect on the rates of senescence of watercress after harvest. The shelf-life of winter-grown oregano has been shown to be significantly shorter than that of summer-grown product (Cantwell and Reid, 1993).

Within Australia, seasonal and cultural differences will almost certainly have a bearing on fresh herb shelf-life but to date, no information is available.

4.2.3 Physiology

Fresh herbs, like many green, leafy vegetables rapidly deteriorate after harvest. Senescence is caused by an increase in metabolic activity due to stresses caused by wounding, elevated temperature and water loss during postharvest handling procedures.

These stresses cause a change in the levels of hormones such as ethylene, cytokinins, abscisic acid (ABA) and gibberellins present in the leaves (Aharoni et al, 1993a).

Lipton (1987) found that senescence in leafy tissue was closely tied to the levels and interactions of these endogenous hormones and that the water status of the plant strongly influences the progress of senescence related events.

Biochemical breakdown in the form of protein degradation and lipid peroxidation also occurs, which is accompanied by a decrease in photosynthesis and increases in respiration rate and ethylene production (Cantwell and Reid, 1993; Meir et al, 1992a).

Visually, these changes are seen as chlorophyll loss and leaf yellowing and abscission. Senescing leaves lose their membrane integrity and become susceptible to mildly pathogenic bacteria that are usually harmless to the plant but under these conditions cause rapid decay (Cantwell and Reid, 1993).

Research into the physiological changes of leafy vegetables during senescence has been limited (Lipton, 1987). Research conducted using fresh herbs has been limited to the determination of ethylene's role in senescence processes, biochemical retarding effects of CO₂ and non-destructive methods of determining chlorophyll loss (Meir et al, 1992b).

Ethylene

Ethylene is an endogenous plant hormone which is believed to either initiate senescence or regulate it once it has begun (Lipton, 1987). It's synthesis by horticultural products generally increases during senescence.

Using parsley and watercress, Philosoph-Hadas et al (1989) found a positive correlation between levels of wound-ethylene production and the rate of senescence, suggesting that ethylene plays a
significant role in this process. In a later study, Philosoph-Hadas et al. (1993a) concluded that ethylene may have a limited role in the senescence of watercress and that stress due to wounding may have a more important effect on senescence of this tissue. It is likely that the senescence of leafy tissues involves a series of complex interactions between the plant and environment and the exact role of ethylene in this process is still unclear.

**Role of carbon dioxide**

Carbon dioxide is a competitive inhibitor of the mode of action of ethylene, and there is abundant evidence that carbon dioxide acts as an anti-ethylene agent (Philosoph-Hadas et al., 1989). The senescence-retarding effects of increased levels of carbon-dioxide on leafy vegetables and fresh herbs, particularly in reducing the rate of yellowing, has been well documented (Aharoni et al., 1989; Aharoni et al., 1993d; Hruschka and Wang, 1979; Ishii and Okubo, 1984; Kader et al., 1989; Umiecka, 1973; Zavgorodnyaaya et al., 1985). Philosoph-Hadas et al. (1993b) applied 10% CO₂ to chervil bunches in a flow-through system. An increase in cellular pH was noted due to the retention of the original levels of polyamines, naturally occurring senescence retardants, suggesting another mechanism by which carbon dioxide may retard senescence.

**Ethylene inhibitors**

Studies have demonstrated that various growth regulators such as cytokinins, gibberellins, aminoxy acetic acid (AOA) and aminooethoxyvinylglycine (AVG) retard ethylene biosynthesis and action in leafy tissue and therefore slow down the rate of senescence (Lipton, 1987). The mechanism by which this control occurs is not well understood and Cantwell and Reid (1993) suggest that the results are difficult to interpret. Treatment of leaves with ethylene or abscisic acid will accelerate yellowing yet ethylene inhibitors have inconsistent effects in preventing this yellowing.

One measure of senescence in fresh herbs is chlorophyll loss which can be retarded by the use of cytokinins and gibberellins (Lipton, 1987). Gibberellic acid (GA₃), was found to be very efficient in delaying yellowing, deterioration and decay of chives, dill, coriander, chervil and parsley when applied to herbs immediately prior to harvest (Aharoni et al., 1993a; Aharoni et al., 1993b). AOA
and AVG have been found to retard senescence in parsley and watercress (Philosoph-Hadas et al, 1989; Philosoph-Hadas et al, 1993a).

4.3 Postharvest handling of fresh culinary herbs

Fresh herb quality during marketing can only be maintained through proper postharvest handling practices. This cannot be achieved unless the factors that influence fresh herb shelf-life are known.

4.3.1 Physical damage

Mishandling of fresh herbs can result in damage and discoloration of tender leaves. This leads to increased respiration rates and ethylene production, provides opportunities for pathogenic invasion of damaged tissue and can speed up enzymatic deterioration (Bell, 1987). Small-scale production means that most handling operations are performed manually. Careful handling at harvest and during packaging will minimise physical injury. Rigid plastic containers are sometimes used during marketing for delicate herbs such as basil and coriander.

4.3.2 Respiration rate
Senescence of fresh herbs is an active metabolic process which is well correlated with respiration rate so respiration measurements can be used to determine the perishability of a product. Cantwell and Reid (1986) measured the respiration rates of selected fresh herbs at 0, 10 and 20°C (Table 3). They found herb respiration rates to be relatively high, often between 150 and 200 ml CO₂/kg/h which is comparable to highly perishable products such as mushrooms and asparagus.

The relationship between respiration rate and deterioration for parsley, indicated by chlorophyll loss, has been documented by Yamauchi and Watada (1993) and Apeland (1971). A clear correlation was shown between leaf yellowing and increasing amounts of CO₂ respired. Apeland (1971) also demonstrated that senescence of parsley could be monitored by changes in respiration patterns. Like many leafy vegetables, respiration decreased rapidly after harvest but subsequently rose again as senescence progressed (Figure 1). At 10 and 12.5°C, increased rates of respiration lead to rapid deterioration of the parsley.

Table 3. Postharvest respiratory activity of selected fresh culinary herbs. (Cantwell and Reid, 1986).

<table>
<thead>
<tr>
<th>Herb</th>
<th>Rate (μl CO₂/g/h)</th>
<th>Q₁₀ value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0°C</td>
<td>10°C</td>
</tr>
<tr>
<td>Basil</td>
<td>18</td>
<td>37</td>
</tr>
<tr>
<td>Chervil</td>
<td>6</td>
<td>42</td>
</tr>
<tr>
<td>Chives</td>
<td>11</td>
<td>58</td>
</tr>
<tr>
<td>Dill</td>
<td>11</td>
<td>54</td>
</tr>
<tr>
<td>Epazote</td>
<td>16</td>
<td>83</td>
</tr>
<tr>
<td>Mache</td>
<td>6</td>
<td>44</td>
</tr>
<tr>
<td>Marjoram</td>
<td>14</td>
<td>36</td>
</tr>
<tr>
<td>Mint</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Mitsuba</td>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td>Oregano</td>
<td>11</td>
<td>53</td>
</tr>
<tr>
<td>Parsley</td>
<td>11</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>54</td>
</tr>
<tr>
<td>--------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Sage</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>Shiso</td>
<td>20</td>
<td>52</td>
</tr>
<tr>
<td>Tarragon</td>
<td>19</td>
<td>43</td>
</tr>
<tr>
<td>Thyme</td>
<td>13</td>
<td>47</td>
</tr>
</tbody>
</table>

¹Measured 3 days after harvest and storage at indicated temperatures.

Published respiration data for fresh herbs over their storage lives is limited. Hruschka and Wang (1979) measured respiration rates of watercress, mint and parsley one day after harvest after the herbs were stored at six temperatures between 0 and 25°C (Figure 2).
Figure 1. Respiration patterns of parsley cv. bravour at 0, 5, 10 and 12.5°C (Apeland, 1971).
4.3.3 Temperature

Temperature control is the most important aspect of good postharvest management of fresh herbs (Bell, 1987; Cantwell, 1988; Joyce et al., 1986). The optimum storage conditions for most leafy vegetables and herbs is 0°C and 95-98% relative humidity (Aharoni et al., 1993a; Cantwell and Reid, 1992). Cantwell and Reid (1986) found that the best holding temperature for all herbs tested (except basil) was close to 0°C (Table 4) and under experimental conditions, they maintained excellent visual quality over 10-14 days and were still in good condition after 4 weeks.

Table 4. Effect of temperature on visual quality of fresh culinary herbs after 10 days. (Cantwell and Reid, 1992).

<table>
<thead>
<tr>
<th>Herb</th>
<th>Visual quality score after 10 days at indicated temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0°C</td>
</tr>
<tr>
<td>Basil</td>
<td>2</td>
</tr>
<tr>
<td>Chervil</td>
<td>8</td>
</tr>
<tr>
<td>Chives</td>
<td>9</td>
</tr>
<tr>
<td>Dill</td>
<td>9</td>
</tr>
<tr>
<td>Epazote</td>
<td>9</td>
</tr>
<tr>
<td>Mache</td>
<td>8</td>
</tr>
<tr>
<td>Marjoram</td>
<td>9</td>
</tr>
</tbody>
</table>
As temperature increases, biological reaction rates increase rapidly and so does deterioration. The Q₁₀ co-efficient is a factor which measures the increase in respiration rate over a 10°C range and can be used to demonstrate the perishability of herbs as temperature increases. Products with high respiration rates and short shelf-lives tend to have high Q₁₀ values (Cantwell and Reid, 1993). Highly perishable vegetables such as mushrooms and asparagus have Q₁₀ values of approximately 3 between 0-10°C.

Respiration rates of the fresh herbs studied increased by an average of 3.6 times between 0 and 10°C (Table 3) although there was considerable variation between herb species with 7.3 for mache compared to 2.0 for basil.

Storage

Cantwell and Reid (1992) used visual quality ratings to demonstrate the different physiological behaviour of fresh herbs during storage at different temperatures (Table 4). Over a 10 day simulated marketing period all herbs except for basil and shiso were in good to excellent condition at 0°C and most still had acceptable quality at 10°C although it is unlikely that fresh herbs having "acceptable" quality would be saleable.

Aharoni et al (1993a) evaluated the storage quality of mint, sage, tarragon, lovage and oregano stored for either 5 or 10 days, at temperatures ranging from 0.5-12°C, and then for 2 days at 12°C. All herbs were packed in folded perforated PE liners. At 0.5°C sage and tarragon remained in good condition after 5 and 10 days storage while the quality of mint and lovage decreased rapidly when stored for more than 5 days at this temperature and were barely saleable after 10 days storage. Oregano quality was not maintained at this temperature and was just saleable after 5 days storage. For all the herbs evaluated, quality decreased markedly with increasing storage temperature. Above 6°C only tarragon and lovage were still saleable after 5 days storage with decay being the major factor limiting the shelf-life of the herbs.

Hruschka and Wang (1979) demonstrated that mint, parsley and watercress bunches, top-iced and stored in waxed cartons at 0°C all remained in excellent condition after 2 weeks storage. Although

<table>
<thead>
<tr>
<th>Herb</th>
<th>Quality score</th>
<th>Location</th>
<th>Shelf-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mint</td>
<td>9</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Mitsuba</td>
<td>9</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Rosemary</td>
<td>9</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Sage</td>
<td>9</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>Shiso</td>
<td>6</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Tarragon</td>
<td>8</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Thyme</td>
<td>9</td>
<td>8</td>
<td>7</td>
</tr>
</tbody>
</table>

¹Quality score: 9 = excellent; 7 = good, minor defects; 5 = fair, moderate defects, limit of salability; 3 = poor, major defects; 1 = unusable.
the leaves of the herbs remained relatively green beyond this storage period decay over the third and fourth week of storage severely diminished overall appearance of the herbs and thus their saleability. Mint was found to have a shorter shelf-life than parsley or watercress, showing symptoms of severe decay after 3 weeks storage.

**Chilling injury**

Tropical and subtropical horticultural produce is susceptible to chilling injury which occurs if the produce is held below a critical temperature for too long. Symptoms can include surface and internal discolouration, pitting, water-soaked areas, increased susceptibility to pathogens and a reduced shelf-life (Bell, 1987). The critical temperature during storage for chilling sensitive species varies between products but is usually from 8 to 12°C (Cantwell and Reid, 1993). Symptoms often only become apparent when the product is transferred from the storage temperature to a higher temperature environment, such as during marketing.

Presently, basil, shiso and some species of oregano are known to be chilling sensitive. The critical temperatures for appearance of visual chilling symptoms in two basil cultivars were found to be 12.8 and 10.2°C (Meir et al., 1992b). Hopkirk et al. (1990) observed that symptoms of chilling injury in basil varied but included brown discolouration of the leaves and stem, wilting, loss of leaf glossiness and loss of characteristic aroma. It was also found that the severity of chilling injury symptoms was dependent on the period of exposure as well as on the specific storage temperature (Figure 3). Dostal (1990) has reported that holding basil at 10°C reduced its shelf-life to 8 days compared with 12 days shelf-life attained at 15°C.

The sensitivity of basil to chilling injury presents practical problems because it is usually included in shipments of mixed herbs. Lack of temperature compatibility with other herbs means that these shipments are usually held at a compromise temperature of between 5 and 10°C. However this temperature range can still cause chilling injury in basil and will substantially increase the rate of deterioration of the other herbs (Cantwell and Reid, 1992). This storage problem was also noted by some local growers in the industry survey.

Symptoms of chilling injury in oregano have been observed by Aharoni et al. (1993a). Storage for 3 weeks at 0.5°C resulted in darkening of basal and apical leaves. Cantwell and Reid (1986) suggest that leaf discolouration only occurs in oregano produced under a cool climate and that the optimum storage temperature for this herb is still 0°C.

Differences between species and cultivars may influence the development of chilling injury in basil. Hopkirk et al. (1990) has observed that chilling sensitivity varies between basil cultivars, with sweet basil being one of the least sensitive. Atmosphere modification, that is at 1% O₂ and 5% CO₂; and 5% O₂ and 16% CO₂, does not appear to reduce chilling injury (Cantwell and Reid, 1993; Dostal, 1990) but Aharoni et al. (1993a) suggests that the high humidity environment created by
film packaging may have an effect in ameliorating chilling injury. Further study is required to clarify the situation.

Figure 3. Development of chilling injury in sweet basil. (Hopkirk et al, 1990). Measured on green-house grown sprigs stored in the dark at indicated temperatures. Chilling injury score based on visual appearance where 0 = no injury and 8 = severe; a score of 3 was the limit of commercial acceptability.

Temperature management

Good temperature management of fresh herbs during distribution, storage and marketing begins with the rapid removal of field heat after harvest. The most efficient way to do this is by vacuum cooling the product but it is also the most expensive (Aharoni and Reuveni, 1989; Bell, 1987). Forced-air cooling (FAC) is very effective for tender herbs such as chives and coriander and can be economical as the equipment required can be incorporated into an existing cool room. To reduce the risk of wilting and to speed cooling during FAC the herbs should be sprinkled with clean water. Room cooling is a less effective process in which fresh herbs are placed in low temperature storage and field heat is slowly removed, a process that can take many hours. This final method is common in the local industry where small scale production means that cooling facilities are often
rudimentary. Growers can reduce their precooling requirements by harvesting during the coolest part of the day.

Fresh herbs such as mint, watercress and parsley are commonly cooled with ice (Hruschka and Wang, 1979; Seelig, 1974; Seelig, 1974). Top-icing can also be used during air shipment to export markets. Gel-ice packs are also used to reduce heat build-up during transport (Cantwell and Reid, 1992). Under simulated air transport conditions, refrigerated containers, cooled by solid carbon dioxide were capable of maintaining temperatures of 3 - 5°C for 2 days (Aharoni et al, 1993c). Bell (1987) notes that given sufficient surface moisture and moderate air velocity and humidity, evaporative cooling of leafy herbs can cause freezing injury even though the storage temperatures may be above 2°C.

4.3.4 Moisture loss

The high susceptibility of fresh leafy herbs to moisture loss results in loss of marketable weight, visual quality, causes physiological stress and may reduce the product's resistance to attack by pathogens (Bell, 1987; Cantwell and Reid, 1986; Hruschka and Wang, 1979).

The amount of water lost before fresh herbs become unsaleable ranges from 5% to 40% (Grierson and Wardowski, 1978). The amount of weight loss associated with a substantial degree of quality deterioration was found to be higher than expected for most major herb species. Hruschka and Wang (1979) reported that over a temperature range of 0 - 25°C, parsley, watercress and mint showed moderate to commercially significant wilt symptoms after losing approximately 40% of their weight. Cantwell and Reid (1993) studied water loss from herbs during storage and found that chives and thyme were still saleable after losing 25 and 40 percent of their fresh weight respectively, while similar losses in dill and mint rendered these herbs unsaleable. Further research is required to validate these results as it would be reasonable to expect that a moisture loss of greater than 10% would lead to rapid deterioration of most herbs.

Factors that influence the rate of water loss are surface-to-volume ratios, respiration rates, storage temperature and air humidity surrounding the herb. Moisture loss is minimised by low temperatures and relative humidities greater than 95% during storage, packing, transport and marketing (Bell, 1987; Cantwell and Reid, 1992).

One of the main reasons fresh herbs are packaged in plastic films is to prevent excessive water loss. Aharoni and Reuveni (1989) showed that both perforated and unperforated polyethylene bags reduced water and quality loss of salad herbs such as watercress, dill and chives. This was also demonstrated by Cantwell and Reid (1993) for chives, dill, mint and thyme. Unperforated bags were found to be most effective in both studies. Films that are partially permeable to water vapour can also be used (Cantwell, 1988).
Due to temperature fluctuations during handling, condensation may form inside plastic film packages which increases the risk of microbial growth. At local retail level, this free moisture problem occurs frequently with individually packaged fresh herbs and potentially is an important problem to be overcome in developing export opportunities for packaged fresh herbs.

4.3.5 Postharvest pathogens

The shelf-life of fresh herbs, particularly those packaged individually in film packaging, is frequently terminated by the growth of pathogens such as bacterial soft rot and grey mould (Cantwell, 1988). No research to date has been specifically aimed at finding the best methods of preventing disease and decay in fresh herbs. Like many leafy vegetables, postharvest stresses related to excessive heat or cold and incorrect mixes of gases, CO₂, O₂, and ethylene in the storage environment predispose herbs to attack from disease organisms. Other factors that influence susceptibility to disease include chilling and physical injury and poor plant nutrition during growth (Boyette et al., 1993).

Chemical treatments can be combined with correct postharvest handling practices to provide effective control of decay organisms such as Psuedomonas spp., a common bacteria causing soft rots in herbs such as chives. Chlorinated water is the safest and cheapest method of reducing the microbiological load on equipment and fresh produce (Bell, 1987).

Fresh herbs can be washed in chlorinated water before packaging but no information is available on rates and dipping times for any herbs. Surface-bleaching of delicate leaves may also occur if fresh herbs are kept in contact with chlorine for extended periods.

The extent to which local producers use chemical treatments is difficult to gauge with survey results demonstrating that sodium hypochlorite and chlorine dioxide are used by some growers. At this stage, the way these chemicals are used is determined by the grower as no specific guidelines for fresh herbs are available.

4.3.6 Ethylene

Leafy vegetables, including fresh herbs, are highly sensitive to low ethylene concentrations in the postharvest environment with threshold values as low as 0.1 ml/liter causing quality loss (Philosoph-Hadas et al. 1989; Kader, 1985). Physiological stresses due to poor temperature management or physical injury will increase the ethylene produced by fresh herbs. Responses to ethylene during storage can include accelerated leaf yellowing, leaf abscission and epinasty (downward growth of leaf and petiole which gives the herb a wilted look) leading to accelerated senescence.
Cantwell and Reid (1993) observed the responses of fresh herbs to ethylene exposure at 20°C and found that out of nine major herbs the most sensitive species were parsley, mint and marjoram, all showing leaf abscission, yellowing and epinasty when exposed to concentrations of 0.4 ppm ethylene. On the other hand, rosemary and sage were found to be insensitive to 30 ppm ethylene. Philosoph-Hadas et al. (1989) showed that exogenously applied ethylene (10 ppm, 20°C) in 5% CO₂ did not enhance chlorophyll loss in chives, a monocotyledonous species, but did negate the beneficial effects of high CO₂ for dicotyledonous herbs, such as dill and watercress.

Some studies have shown that lower temperatures may have an affect on ethylene response. Ethylene sensitive herbs such as parsley and mint were found to maintain visual quality when exposed to high ethylene concentrations (10 ppm) at 0°C (Cantwell and Reid, 1993). Apeland (1971) observed that the shelf-life of parsley was affected by ethylene contamination at 5°C but not at 0°C.
4.4 Packaging of fresh culinary herbs

Currently, the main reason fresh herbs are packaged and marketed in plastic bags or films is to reduce water loss with any atmospheric modification of O₂, CO₂ and C₂H₄ concentrations being incidental. Little information on the use of modified and controlled atmospheres for fresh herbs is available (Bell, 1987; Cantwell and Reid, 1993). Research in this area has been limited to studies of bulk packaging for air transport using polyethylene bags with little work done to determine optimum atmospheres for individual herb species to maximize shelf-life and storage time. Packaging and marketing problems faced by the local herb industry are to some extent due to this knowledge gap.

4.4.1 Atmosphere modification

The beneficial effects of controlled atmosphere (CA) and modified atmosphere (MA) storage in retarding deterioration of fresh, leafy vegetables is well documented (Kader et al, 1989; Kader, 1986; Brecht, 1980; Geeson, 1989). CA implies a greater degree of precision than MA in maintaining specific levels of O₂, CO₂ and other gases (Kader et al, 1989). Generally, increased
carbon dioxide levels and lowered oxygen levels retard chlorophyll loss and deterioration in green plant material by reducing respiration, ethylene synthesis and action, pathological breakdown and other undesirable metabolic changes (Kader, 1986).

Many fresh herbs would be expected to respond in a similar manner to green vegetables although little is actually known about most species, with the possible exception of parsley and watercress, which have been the focus of most research in this area, evidenced by the literature available on these species.

### 4.4.2 MA packaging

Aharoni et al (1989) examined the effect of modified atmospheres produced inside film packages on the keeping quality of yellowing-susceptible herbs such as chives, watercress, sorrel, coriander, dill and parsley. Under simulated air transport and marketing conditions it was found that bulk packaging (1 and 3 kg) in perforated polyethylene (P.PE) carton liners reduced water loss substantially but was not effective in retarding yellowing and decay of the fresh herbs.

Packaging of these herbs in non-perforated polyethylene (NP.PE) carton liners resulted in a large reduction of yellowing and decay. The best results were achieved by using sealed polyethylene (S.PE)-lined cartons although this type of packaging requires strict temperature control during storage and transport.

Packaging of chives in PE-lined cartons markedly reduced water loss and prevented any wilting when stored at 6°C for 5 days and 12°C for 2 days (Figure 4). Gas measurements inside the 1 kg packages revealed that accumulation of CO₂ (5.7%) rather than a decrease in O₂ (12%) could be the reason for retardation of senescence.

It was found that retardation of yellowing in watercress stored at 6°C for 6 days and 12°C for 2 days was only achieved using sealed PE bags in which CO₂ levels rose up to 7-10% and O₂ was reduced to 4-6% (Table 5). In this case, it seems that watercress quality was maintained due to an increase in CO₂ and also a reduction in O₂ below approximately 10%. Under this oxygen concentration decreasing O₂ levels did not seem to have any additional effect on the degree of yellowing in the herbs.
Figure 4. Effect of four packaging treatments on chive quality after 5 days storage at 6°C followed by 2 days at 12°C. Yellowing and decay indices: 1=none, 2=slight, 3=moderate, 4=severe. (Aharoni et al, 1989).

Table 5. Effect of the weight of watercress, 1 or 3 kg, packed in sealed and non-sealed polyethylene liners on CO₂ and O₂ concentrations and yellowing. Cartons were held at 6°C for 6 days followed by 2 days at 12°C. Yellowing index: 1=none, 5=severe. (Aharoni et al, 1989).

<table>
<thead>
<tr>
<th>Packed-carton weight (kg)</th>
<th>Package type</th>
<th>Gas concentrations (%)</th>
<th>Yellowing index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CO₂</td>
<td>O₂</td>
</tr>
<tr>
<td>1</td>
<td>non-sealed</td>
<td>0.5-3.0</td>
<td>18.1-20.5</td>
</tr>
<tr>
<td></td>
<td>sealed</td>
<td>7.4-8.9</td>
<td>8.3-12.0</td>
</tr>
<tr>
<td>3</td>
<td>non-sealed</td>
<td>4.0-5.0</td>
<td>15.5-15.8</td>
</tr>
<tr>
<td></td>
<td>sealed</td>
<td>7.0-10.0</td>
<td>4.0-6.0</td>
</tr>
</tbody>
</table>
Aharoni et al (1993a) found that elevated CO₂ levels in sealed packages completely overcame the senescence-promoting effect of ethylene on yellowing-susceptible herbs and that above average quality was maintained using these packages. The effect of package type on the quality of seven yellowing-susceptible herbs after 5 days at 6°C followed by 2 days at 12°C are shown in Table 6. Under constant temperature storage, anaerobic conditions were not produced but under simulated transport conditions where extreme temperature fluctuations were encountered, anaerobic conditions were only prevented through the use of micro-perforated PE liners. Specific information on the use of micro-perforated PE liners is not available although this research suggests that the number of micro-perforations required for a certain package is affected by the CO₂ and O₂ requirements of the herbs, film permeability, respiratory activity and the ratio between herb weight and film surface area.

Ishii and Okubo (1984) have maintained the quality of very perishable Chinese chives (Allium tuberosum Rottl. ex K. Spreng.) by packaging bundles in polyethylene bags and storing at 0°C and 10°C. After 3 days, the package atmospheres contained increased carbon dioxide levels (5% at 0°C and 7% at 10°C). Respiration levels were reduced, and chlorophyll, carotene, and Vitamin C levels were maintained longer under MA conditions compared to air storage at 10°C. No significant differences in visual quality were noted between samples stored in air and MA at 0°C.

### Table 6. Effects of package type on quality of fresh herbs after 5 days at 6°C followed by 2 days at 12°C. (Aharoni et al, 1993).

<table>
<thead>
<tr>
<th>Herb</th>
<th>PE liner</th>
<th>O₂ (%)</th>
<th>CO₂ (%)</th>
<th>Appearance</th>
<th>Yellowing</th>
<th>Decay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chervil</td>
<td>Perforated</td>
<td>-</td>
<td>-</td>
<td>2.8</td>
<td>2.2</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Non-Perf.</td>
<td>19.0</td>
<td>2.5</td>
<td>3.2</td>
<td>1.7</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Sealed</td>
<td>10.7</td>
<td>8.8</td>
<td>3.6</td>
<td>1.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Chives</td>
<td>Perforated</td>
<td>-</td>
<td>-</td>
<td>2.0</td>
<td>2.5</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Non-Perf.</td>
<td>18.8</td>
<td>1.8</td>
<td>3.0</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Sealed</td>
<td>15.9</td>
<td>5.7</td>
<td>3.6</td>
<td>1.4</td>
<td>1.3</td>
</tr>
</tbody>
</table>
### Appearance index:

5 = excellent, 1 = complete deterioration

### Yellowing and decay index:

5 = very severe, 1 = none

Umiecka (1973) studied quality loss in chives, parsley and dill when they were packed in either perforated or non-perforated polyethylene bags and stored at 2, 5, 10, 15, 20°C. It was found that the longest satisfactory storage of dill (9 - 12 days) and parsley and chives (14 - 21 days) was obtained in non-perforated bags at 2°C. Hruschka and Wang (1979) conducted storage and shelf-life tests using watercress, mint and parsley. Watercress and mint retained acceptable quality at 0°C and 95% relative humidity for up to 4 weeks in perforated polyethylene bags but for only 4 days in naked bunches. At 20°C and 60% RH they were unmarketable after only 2 and 4 days respectively in polyethylene bags and 1 day or less in naked bunches.

One of the few published studies that attempted to determine the optimum CO$_2$ and O$_2$ levels for fresh herbs was conducted by Apeland (1971). He observed that lowered oxygen levels alone, or in combination with elevated carbon dioxide, reduced colour loss in parsley and that a combination of 10% O$_2$ and 11% CO$_2$ seemed to give the best result (Table 7). It was concluded that parsley could be stored at 0°C under these atmospheres for up to 4 - 5 months with minimal chlorophyll loss. Saltveit (1989) recommends 8 - 10% O$_2$ and 8 - 10% CO$_2$ at 0 - 5°C as being the optimum atmosphere for storage of parsley.

<table>
<thead>
<tr>
<th></th>
<th>Perforated</th>
<th>Non-Perf.</th>
<th>Sealed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dill</strong></td>
<td>-</td>
<td>19.9</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>5.1</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>2.8</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>3.2</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>2.8</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>Coriander</strong></td>
<td>-</td>
<td>20.0</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>1.7</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>1.9</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Watercress</strong></td>
<td>-</td>
<td>16.5</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>6.2</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>1.7</td>
<td>3.6</td>
</tr>
<tr>
<td><strong>Parsley</strong></td>
<td>-</td>
<td>19.3</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>4.1</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>2.8</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>3.5</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Sorrel</strong></td>
<td>-</td>
<td>13.7</td>
<td>9.3</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>4.0</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>2.3</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>3.1</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Table 7. Effect of various modified atmospheres on the colour and saleability of parsley stored for 45 and 75 days at 5°C. (Apeland, 1971).
As determined for parsley cv. Bravour stored at 5°C. Colour rated on a hedonic scale where 9 = dark green and; 1 = yellow. The percent of saleable product was based on the proportion of plant material having a colour score of 7 to 9.
Gill (1988) studied the effect of various film packages and initial atmospheres on watercress quality. Packages containing 200 grams of watercress made from 35 μm thick Propafilm® and 25 μm and 78 μm thick Low-density polyethylene (LDPE) films were used to store watercress and flushed with different atmospheres, 5% CO₂ : 10% O₂, 5% CO₂ : 5% O₂ and air before they were sealed. Each package had a total surface area of 1800 cm² and an unpackage control was also used in the experiment. It was found that using 35 μm Propafilm bags flushed with 5% carbon dioxide and 10% oxygen resulted in equilibrium levels of 11-12% CO₂ and 2% O₂ between day 8 and day 15 of storage at 1°C. All gas flushed and packaged samples had a superior appearance to that of unpackage watercress which by day 8 was yellow. It was concluded that all the film and gas combinations studied resulted in a product of fresher appearance up until 7 to 8 days of storage when dark patches on the leaves and signs of product breakdown began to appear. These observations coincided with a decline in the percentage of oxygen within the pack. Beyond this period, the oxygen levels in some packages fell below 3% which in some cases, caused the watercress to undergo anaerobic fermentation. Table 8 summarises the results of the watercress packaging trials.

Table 8. Maximum shelf-life achieved for watercress using various films and atmospheres at 1°C. (Gill, 1988).

<table>
<thead>
<tr>
<th>Film</th>
<th>Atmosphere¹ (%CO₂:%O₂)</th>
<th>Storage days before initial signs of quality loss</th>
<th>Gas concentration³ (%CO₂:%O₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yellowing</td>
<td>Breakdown²</td>
</tr>
<tr>
<td>25 μm LDPE</td>
<td>5% : 5%</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Air</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>35 μm Propafilm</td>
<td>5% : 5%</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Air</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>78 μm LDPE</td>
<td>5% : 5%</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Air</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>5% : 5%</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>35 μm Propafilm</td>
<td>10% : 5%</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

¹Initial atmosphere flushed into package.
²Breakdown in the form of small dark patches and brown edged holes.
³Concentration on day before initial signs of quality loss.
4.4.3 Light

Fresh culinary herbs are commonly marketed under lighted retail conditions. The effect of exposure to light on respiration rate, colour and general senescence of herbs has not been studied to any great extent. Light is generally considered to slow senescence and retard chlorophyll loss of leafy tissues and the level and quality of light may also be an influence on quality (Lipton, 1987). Under lighted conditions, photosynthesis may reduce carbon dioxide levels inside fresh herb packages, making it difficult to maintain a desirable atmosphere (Cantwell and Reid, 1992).

Preliminary results from experiments where unpackaged herbs were stored in the light or dark indicate that the quality of dill, basil and thyme remained better under illuminated conditions while there was no difference in the visual quality of sage stored in the light or dark. In the dark at 10°C, respiration rates declined and subsequently increased during tissue senescence. It was found that the initial rate of ethylene production was similar under both storage conditions but that in the dark a major increase in ethylene production was associated with the final stages of senescence and loss of visual quality (Cantwell and Reid, 1993). In experiments where film packages of fresh herbs were exposed to light and dark conditions at 10°C, the visual quality of oregano was found to be the same under both conditions but the quality of dill and tarragon was noticeably reduced when stored under light. Accumulated carbon dioxide levels in packages of herbs kept in the light were only a fraction of those kept in the dark, probably due to the photosynthetic fixation of carbon dioxide.

When watercress was stored in the light and in the dark it was found that intense flourescent lighting partially bleached the chlorophyll pigment of the leaves compared to product stored in the dark. The watercress was packaged in 50 μm Propafilm® packages at 1°C for 8 days. There was no significant difference in the equilibrium atmospheres inside packages stored in the light or dark after 8 days storage (Gill, 1988).

The interplay between carbon dioxide, ethylene and light in plant senescence is complex and predicting the effect of light on gas levels inside herb packages is difficult. Even so, it has been recommended that when designing plastic film packaging for retail marketing, light should be a major variable to be considered (Bell, 1987).
5. Conclusions and Recommendations

A survey of the herb industry has identified many factors contributing to poor herb quality that is limiting market expansion. Attempts by growers to maintain quality are usually compromised by poor product handling such as storage at incorrect temperatures and no postharvest chemical treatments. Packaging for short-term storage and transport seems to be adequate but is unsatisfactory if a greater extension in storage life is required. Film packaging has been largely unsuccessful in extending shelf-life due to inconsistent quality and a lack of information on packaging requirements of individual herb species.

The main herb species presently grown in Australia have been listed previously. With the growth in product lines such as salad and herb mixes, for example mesclun mixes, postharvest handling and packaging research should be geared towards salad herbs such as mibuna, mizuna, rocket, chervil, cresses and mustards. Other herbs that are gaining in importance and should be given priority include sweet basil, chives and coriander. Discussions with industry have identified a number of opportunities to use packaging to add value, expand markets and decrease the rate of deterioration of 'problem' crops. These mixes and minimally processed herbs are relatively new products and substantial potential exists for market expansion both nationally and internationally if suitable packaging systems are developed.

A review of past fresh herb research has identified a lack of information in many areas concerning postharvest handling and packaging of herb species. Unknowns such as optimum atmospheres, chemical treatments and behaviour under retail conditions still exist for the majority of fresh herbs.

Bulk packaging trials have demonstrated the benefits of polyethylene liners in increasing the shelf-life of parsley and watercress and this packaging method is now common practice. Study of other packaging technologies has been minimal and the results have been inconsistent.

There is a wide scope for research into many aspects of fresh herb handling and packaging. Industry requires more information and access to effective packaging methods that are currently unavailable. A research program is required that will determine optimum handling protocols for the major herb species and for herb mixes. These can then be used to develop packaging technologies that are cost-effective and readily available to growers and distributors. Close interaction with local
industry will be required to ensure that packaging is used under the correct environmental conditions.

6. Future research requirements

A survey of the fresh culinary herb industry and review of current postharvest practices and research has demonstrated a need for further development of packaging technologies and postharvest handling protocols. Future research should be aimed at increasing the storage and shelf-life of fresh herbs by:

* Developing optimum postharvest handling and packaging protocols for the major herb species.

* Identifying the optimum harvest maturity and storage environment (including temperature, humidity, levels of CO₂ and O₂ and ethylene) for each herb species.

* Developing protocols for chemical dips and disinfection of herbs to control bacteria and fungi.

* Determining respiration rates of products under simulated storage, transport and marketing conditions.

* Designing prototype packages for each herb to be tested under laboratory and commercial conditions.

* Make prototype packages available to industry for evaluation including information on postharvest handling protocols.

* Developing quality standards for major fresh herb species and optimum distribution procedures to maintain quality.
7. Literature cited


8. Appendix

8.1 Postharvest handling and packaging of fresh herbs industry survey

1. What are the major species that you grow/pack/distribute?

2. What postharvest handling protocols do you use for your herbs? (Tick appropriate boxes)

- Water washing/spraying
- Chemical dips
- Precooling

Harvest-to-storage time
Moisture-loss prevention
Distribution temperature
Storage temperature and time
Other

3. If you package your herbs before distribution, what type of packaging do you use?

- Polyethylene bags
- Retail plastic packaging/films
- Styrofoam/polystyrene containers
- Rigid plastic packs
- Waxed cartons

Perforated
No
Other packaging

4a. How are the herbs transported from your farm/distribution centre to different markets?

<table>
<thead>
<tr>
<th>Refrigerated vehicle</th>
<th>Yes □</th>
<th>Distances (local, interstate etc.)</th>
<th>No □</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature.</td>
<td></td>
<td>Air freight</td>
<td>Yes □</td>
</tr>
<tr>
<td>Moisture-loss prevention</td>
<td></td>
<td></td>
<td>No □</td>
</tr>
</tbody>
</table>

4b. Do you know how well herb quality is maintained or how they are managed once they leave the farm or once they are packed and distributed i.e correct temperature management?

5. What are your major markets (general answers only)?
(Tick appropriate boxes)

- Fresh market □
- Food service industry (hospitality) □
- Retail □
- Food industry □
- Interstate □
- Export □
- Countries.............................................
6. What do you think are the major problems the herb industry faces at the moment?

- Marketing strategy
- Industry fragmentation
- Product perishability
- Quality
- Handling chain
- Other

7. What do you think are the major factors that limit quality and shelf-life of herbs?

- Poor temperature management
- Moisture loss
- Disease/rots
- Physical injury
- Current packaging
- Pre-harvest factors
- Other

8. What do you think is the key to producing and/or distributing a high-quality product?

- Pre-harvest management
- Proper postharvest handling
- Quick turn-over
- Quality assurance
- Initial quality
- Other

Thank you for your assistance.
Dear Sir/Madam,

My name is John Lopresti and I am a researcher at the Institute for Horticultural Development (Vic. Dept. of Agriculture) in Melbourne and am currently working on a project titled **Postharvest Handling and Packaging of Culinary Herbs. A review.**

This project is being funded by RIRDC and the institute, and is aimed at helping the Australian fresh herb industry overcome existing barriers to market expansion by describing current postharvest handling and packaging practices and identifying research opportunities to overcome existing problems and introduce new and emerging technologies.

An important component of this study is the completion of an **industry survey**, this information forming the basis of a broad summary of current postharvest handling practices in Australia.

Your assistance in this matter, by completing and returning this survey as soon as possible, would be greatly appreciated. As an industry member I am sure you understand the importance of this information to the future of the fresh herb industry.

All information supplied will be treated in strictest confidence and only composite information will be released in the final report which will be made available to industry members. If you require more information or want to know more about my work I can be contacted on (03) 210 9277 or by fax on (03) 800 3521.

I thank you for your assistance and look forward to receiving your reply.

Yours sincerely,

John Lopresti

Institute for Horticultural Development.
9. **Product index**

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