# A NEW RATING SCALE FOR ETHYLENE ACTION ON POSTHARVEST FRUIT AND VEGETABLES


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**ABSTRACT**

Ethylene is physiologically active on many postharvest fruit and vegetables at levels above 0.005 μL/L, concentrations which are invariably present in marketing and storage situations. The concept of maximum potential postharvest life at 0.005 μL/L is utilised to generate a new rating scale for what constitutes low and high levels of ethylene based on 10% and 30% loss of potential postharvest life as being acceptable and unacceptable, respectively.


## INTRODUCTION

Ethylene is well known to affect the postharvest behaviour of fruit and vegetables. While many studies have examined the effect of relatively high concentrations of ethylene, it is of considerable importance to know the effect on produce of low concentrations in order to determine what constitutes a safe level of ethylene in which fruit and vegetables can be held during storage, transport and marketing without harmful effect. A concentration of 0.1 μL/L achieved some credibility as the threshold ethylene level of activity. While this is no longer accepted in the scientific community, no alternative rating scale for ethylene action has gained any acceptance and 0.1 μL/L is still used as a reference point. This paper reports on studies conducted in Australia over the last 10 years which have examined the effect of atmospheric ethylene concentrations down to very low levels on postharvest behaviour and determined the levels present during a range of marketing situations (Kim and Wills 1995; Wills and Kim 1995, 1996; Wills and Wong 1996; Wills and Gibbons 1998; Wills et al 1999; Wills, Harris and Seberry 1999; Wills, Warton and Ku 2000). This data is used to propose a new rating scale for the definition of high and low concentrations of ethylene in the atmosphere around non-climacteric fruit and vegetables and pre-climacteric fruits.

## MATERIALS AND METHODS

The effects of ethylene on postharvest behaviour was examined by placing produce into sealed containers that were held at 20˚C or a lower temperature and flushed at 20L/hr with air containing ethylene over the range of 0-10 μL/L. Ethylene levels were obtained by mixing and ethylene/air gas mixture with air in the required proportions. A zero ethylene concentration was attained by passing air through a column containing potassium permanganate absorbed onto alumina beads. Flame ionisation gas chromatography was used to ensure the desired gas mixtures were attained and were present in the containers holding the produce. The sensitivity of the GC meant that 0.005 μL/L was the limit of detection and hence a "0" concentration is denoted as <0.005 μL/L. The quality of produce was monitored over time using quality parameters appropriate to specific non-climacteric produce and ripening for climacteric fruit. The time for produce to become unacceptable for marketing or fully ripe was taken as the postharvest life.


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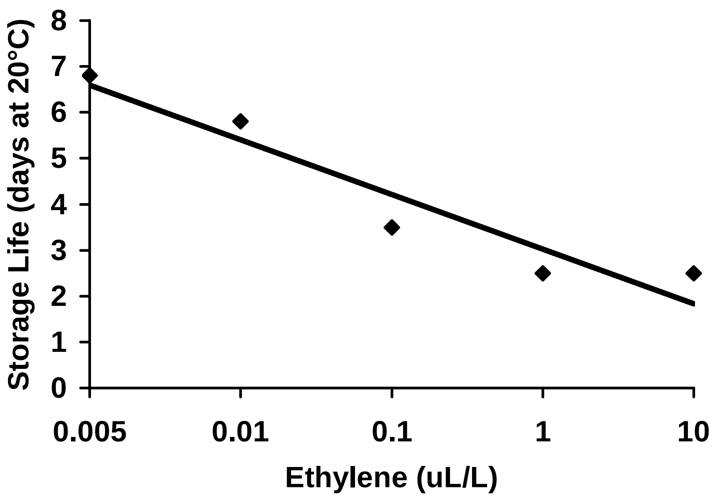
The level of ethylene that accumulates around produce during marketing was determined by taking a sample of the atmosphere inside packages held in wholesale markets and supply distribution centres, and from the atmosphere in the receival, storage and display areas of supermarket stores and the crisper section of domestic refrigerators. The ethylene content of the samples was determined by gas chromatography.

## RESULTS AND DISCUSSION

For a wide range of climacteric and non-climacteric produce, a common effect was for the postharvest life to increase linearly with logarithmic decrease in the ethylene concentration in the atmosphere. Figure 1 shows the effect with Chinese cabbage. The linear relationship was maintained over the whole range hence no threshold level for ethylene action was found. Any threshold level must therefore be lower than 0.005 µL/L. This means that maximum postharvest life of fruit and vegetables is attained when the ethylene concentration is held at <0.005 µL/L.

**Figure 1. Relationship between storage life of Chinese cabbage and logarithmic atmospheric ethylene concentration**




The ethylene level that accumulated in packages of non-climacteric produce held in the Sydney wholesale markets ranged from 0.03-0.38 µL/L with a mean value of 0.06 µL/L which was similar to that present in the ambient atmosphere of markets. For climacteric fruit, the corresponding levels were a range of 0.014-4.9 µL/L and a mean of 0.2 µL/L which indicates a reasonable proportion of fruit were post-climacteric which while not a problem for these produce is adding to the total ethylene loading into the atmosphere at the markets. It seemed that the primary sources of ethylene in the markets came from climacteric fruit and exhaust emissions from the many motor vehicles in the markets. The levels around non-climacteric produce were considered to be mainly derived from diffusion of the atmosphere into packages. For the distribution centres which mainly supply the supermarket chains, the ethylene level in the fruit storage centre was quite high in all rooms including where pre-climacteric fruit can be held for long periods and in empty rooms (Table 1). The constant production of ethylene thus appears to readily diffuse throughout the centre. The centre with mixed storage contained ethylene at about 0.08 µL/L. Much lower ethylene levels were present in supermarket retail stores with mean values of 0.023, 0.035 and 0.017 µL/L in receival, storage and display areas, respectively. The lower levels are probably due to greater movement of air in the air conditioned stores and produce throughput. Ethylene levels in the crisper section of domestic refrigerators varied widely with a range of 0.01-0.6. However, the presence of apples had a major effect with all values >0.1 µL/L being from apple-containing refrigerators with a mean value of 0.2 µL/L while those without apples had a mean value of 0.003 µL/L.

It was concluded that in most market situations, ethylene is always present at greater than 0.005 µL/L and is often in order 0.1µL/L or higher. Considered in conjunction with the laboratory generated data on individual produce, there would seem to be substantial loss in potential postharvest life in fruit and vegetables during marketing. This raises the question as to what level of ethylene should the industry aim to achieve during marketing. While this will depend on the length and delays in any marketing chain and expectations of quality by the buyer, we would like to suggest a method for establishing target ethylene concentrations. For any single produce, a linear regression equation relating postharvest life to log ethylene concentration can be generated. If it is assumed that 0.005 µL/L is the lowest possible concentration that can be achieved in a commercial situation, then holding produce in air at this concentration will give 100% of the potential postharvest life. From the equation, the reduction in postharvest life can be calculated for any higher ethylene concentration. By nominating the desired postharvest life, the maximum ethylene concentration that can be tolerated during marketing can then be determined.

**Table 1. Ethylene in the atmosphere of storage chambers in produce distribution centres**

| Centre | Area | n | Temp (°C) | Ethylene (µL/L±SD) |
|---|---|---|---|---|
| 1 | Kiwifruit storage room | 7 | 0 | 0.233±0.055 |
| | Avocado arrival room | 4 | 5 | 0.588±0.340 |
| | Avocado ripening room | 5 | 20 | 0.896±0.383 |
| | Avocado holding room | 6 | 7 | 1.412±0.506 |
| | Empty room | 3 | 17 | 0.288±0.105 |
| | Ambient air | 4 | 17 | 0.068±0.058 |
| 2 | Cold room 1 | 5 | 6 | 0.081±0.036 |
| | Cold room 2 | 5 | 2 | 0.080±0.006 |
| | Ambient air | 5 | 15 | 0.031±0.008 |

n = number of occasions an atmosphere sample was collected

For general or mixed storage situations, acceptable ethylene levels that apply to groups of produce need to be assigned. It was found that while non-climacteric produce can be grouped into those that are sensitive and those less sensitive to ethylene, the differences were not that great that a common rating scale could not have some application (Wills et al 1999; Wills, Warton and Ku 2000). If it is assumed that the industry can accept a 10% loss in potential postharvest life, but finds a 30% loss is unacceptable, from a combined regression equation for non-climacteric produce of $y = 9.8 - 4.2 \log_{10}x$ (where y = % postharvest life and x = ethylene concentration), the ethylene levels that equate to these % losses are about 0.015 and 0.1 µL/L, respectively. A suggested general rating scale for ethylene then is for a low level to be <0.015 µL/L and a high level to be >0.10 µL/L, and levels 0.015-0.1 µL/L to be intermediate. It is noted that the limit for a high level is the previously considered threshold level. Applying this rating scale to ethylene found in the marketing situations, Table 2 shows that levels in supermarket stores would give low-medium loss in postharvest life to produce while those in distribution centres would result in medium-high loss. Domestic refrigerators without apples would have a low-medium loss while those with apples would have a high loss in postharvest life.

**Table 2. Rating of ethylene levels in marketing situations where storage of mixed climacteric and non-climacteric produce occurs**

| Market | Situation | n | % of Measurements<br>Low<br>≤0.015 | <br>Medium<br>>0.015-<br><0.10 | <br>High<br>≥0.10<br>μL/L |
|---|---|---|---|---|---|
| Wholesale | Air | 36 | 5 | 78 | 17 |
| | Non-climacteric | 389 | 10 | 74 | 16 |
| Distribution | Air | 13 | 0 | 85 | 15 |
| centre | Storage room | 35 | 0 | 40 | 60 |
| Supermarket | Receival | 49 | 47 | 53 | 0 |
| | Storage | 49 | 8 | 90 | 2 |
| | Display | 49 | 39 | 61 | 0 |
| Consumer | Refrigerator | 30 | 17 | 53 | 30 |

While ripening of climacteric fruit is often not a problem and can be desirable in many marketing situations, particularly towards the retail marketing sector, suitable rating scales would be beneficial for situations where a delay in ripening is required. Applying this rating scale to climacteric fruit, the data in Table 3 show a much wider range in sensitivity to ethylene. Banana and kiwifruit were much more sensitive to ethylene than the other fruit with peach the least sensitive. A rating scale for climacteric fruit may need to categories of low, medium and high ethylene sensitivity each with a different set of ethylene standards.

**Table 3. Effect of ethylene rating levels on time to ripen of climacteric fruit at ambient temperature**

| Fruit | Ethylene concentration(μL/L)<br>10% loss | <br>30% loss |
|---|---|---|
| Banana | 0.009 | 0.03 |
| Kiwifruit | 0.014 | 0.11 |
| Custard apple | 0.026 | 0.65 |
| Mango | 0.027 | 0.89 |
| **Tomato** | **0.048** | **4.05** |
| Avocado | 0.047 | 5.05 |
| Peach | 0.132 | >10 |
| *Mean* | *0.043* | *2.97* |

It is concluded that there is no safe level of ethylene for fruit and vegetables and there is considerable commercial benefit to be gained through reducing atmospheric ethylene concentrations below current levels. It is suggested that ethylene standards should be set for each type of produce of commercial importance with the probability that many produce will share a common standard. The application of such standards would require the monitoring of ethylene in postharvest situations and taking appropriate market decisions if the standards are exceeded for any length of time.

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