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Shelf-life of stored asparagus is strongly related to postharvest respiratory activity

Don W. Brash *, Chris M. Charles, Sandy Wright, Bruce L. Bycroft

New Zealand Institute for Crop and Food Research Ltd., Levin Research Centre, Private Bag 4005, Levin, New Zealand

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Abstract

The respiration rate of asparagus spears was measured at 0, 5, 10, 15 and 20°C at intervals over 105 hours after harvest. The spears were then stored at 20°C for visual assessment of residual shelf-life (expressed as days to become unacceptable for sale). There was a strong negative correlation between accumulated respiratory activity after harvest (as carbon dioxide production) and residual shelf-life (r^2 = 0.95). Accumulated heat units (expressed as degree-hours > 0°C) was similarly related to residual shelf-life (r^2 = 0.92). Accumulated carbon dioxide (CO_2) production after harvest could be a useful guide to the residual shelf-life of asparagus and perhaps other crops. Accumulated degree-hours after harvest is easier to measure and gave an accurate guide to CO_2 production.

Keywords: Asparagus; Respiration; Postharvest; Shelf life

1. Introduction

The rate of deterioration (perishability) of harvested commodities is generally proportional to the respiration rate and temperature is the environmental factor that most influences this deterioration rate (Kader, 1992). Asparagus spears contain actively growing tissue and have a high respiratory rate, typical of young tissue (Ryall and Lipton, 1979).

Asparagus respiration rates, measured as CO_2 production, vary with temperature and the time elapsed from harvest (Lipton, 1990). Lill et al. (1990) found asparagus respiration rates at 16°C were highest immediately after harvest and dropped to a constant 30% of peak rates 24 hours later.

* Corresponding author. Fax: 64 6368 7059.

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The rate of visual deterioration of asparagus after harvest is mainly determined by temperature (Lipton, 1990). King et al. (1988) measured the effect of a number of postharvest temperature regimes on shelf-life by varying delays between harvest and hydrocooling and by simulating various air transport regimes. They found a strong negative relationship between shelf-life and accumulated heat units (degree-hours > 0°C) experienced between harvest and post-transport handling. This relationship has been confirmed over a wide range of simulated transport regimes (D.W. Brash, unpublished data).

Our aim in this project was to find out whether the strong relationship between accumulated heat units after harvest and subsequent shelf-life identified by King et al. (1988) is based on a similar relationship between respiration and shelf-life.

2. Materials and methods

Plant material

Asparagus spears (*Asparagus officinalis* cv. Limbras 10) were collected from a commercial block near Levin, New Zealand (site latitude 40.2°S, longitude 175.5°E). Spears were harvested at 250 mm in length, trimmed to 180 mm and graded. Only straight undamaged spears with closed bracts and with no obvious symptoms of disease were used.

Storage procedure and respiration measurement

The experiment consisted of 90 bunches (plots) of asparagus with harvests arranged so that on three consecutive days (replicates) a bunch of asparagus was available for respiration measurement 3, 12, 30, 54, 78 and 102 hours after harvest (± 2 hours, with exact times noted).

For each respiration measurement time, five bunches of spears were weighed and hydrocooled at the appropriate storage temperature for 15 minutes in chlorinated water (initial concentration of 200 mg available chlorine/litre). After hydrocooling bunches were shaken dry and placed flat in perforated polythene bags in storage rooms held at 0, 5, 10, 15 and 20°C (five storage treatments). Bunches consisted of ten spears at 0, 5 and 10°C, seven spears at 15°C and five spears at 20°C. Bunch size had to be smaller at higher temperatures to keep respiration rates within the measuring limits of the equipment.

Respiration rates were measured using an ADC LCA2 infra-red gas analyser. Bunches were removed from their polythene bags and carefully placed into 1.7 l glass jars for one hour prior to measurement of the rate of CO_2 production. Spears were returned to their bags soon after measurement.

Shelf-life and visual assessment

After 105 hours storage each bag was moved to a room held at 20°C (± 1°C) to assess residual shelf-life.

The overall visual quality of asparagus in each bunch was rated by two observers using a 1–9 scale (Lill, 1980). An asparagus bunch with an average rating of 6 or greater was regarded as unacceptable for sale and this rating marked the end of shelf-life. Results are expressed as days at 20°C to reach a rating of 6, with times being obtained by interpolation when necessary.

Determination of accumulated heat units and respiratory activity

Accumulated heat units (degree-hours > 0°C) and respiratory activity (accumulated CO_2 production) were obtained by plotting storage temperature and respiration rates against time and by integrating each curve over the 105 hour storage period.

Statistical analyses

Statistical analyses were performed on three replicates by non-linear curve fitting and analysis of variance, using the SAS statistical package.

3. Results

The respiration data obtained in this experiment were best described by an exponential relationship between respiration rate and time from harvest (Fig. 1). The formula used is described in Eq. 1.

$$R = a + b\,e^{-ct} \qquad (1)$$

where R = respiration rate [μmol CO_2 (g FW)$^{-1}$ h^{-1}]; t = time after harvest (hours); and a, b and c are constants at each temperature.

From these data it is quite clear that the basal respiration rate (constant a) is dependent on temperature. This relationship can also be accurately represented by an exponential equation (Eq. 2):

$$a = 0.57\,e^{0.10T} \qquad (r^2 = 0.96,\ p < 0.001) \qquad (2)$$

where T = storage temperature (°C).

Shelf-life at 20°C after 105 hours storage was closely negatively related to CO_2 production during storage (Fig. 2). There was a similar strong negative correlation

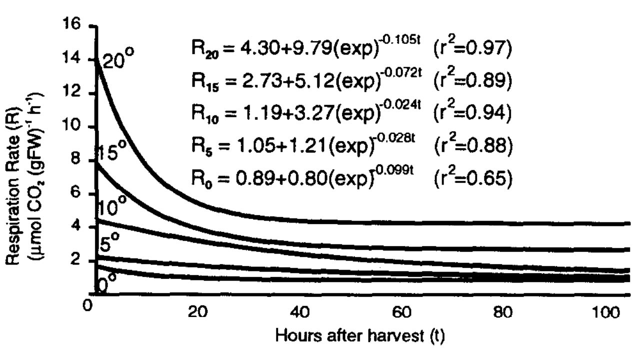

Fig. 1. The effect of storage temperature on the respiration rate of asparagus spears after harvest.

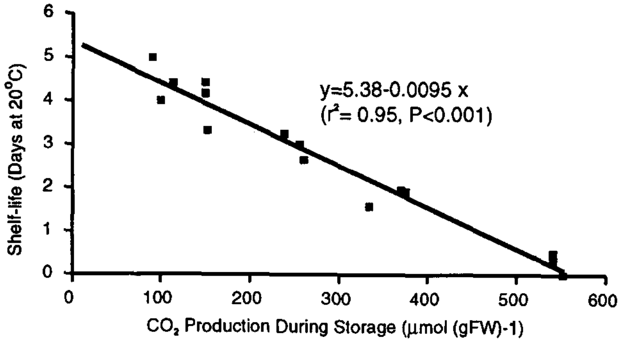

Fig. 2. The effect of total CO_2 production of stored asparagus spears on subsequent shelf-life. Each point represents CO_2 production during 105 hours of storage at 0, 5, 10, 15 or 20°C.

obtained between shelf-life and accumulated heat units (Eq. 3).

$$Y = 4.81 - 0.0021X \qquad (r^2 = 0.92, p < 0.001) \tag{3}$$

CO_2 production during storage was linearly related to accumulated heat units ($r^2 = 0.94$), although an exponential relationship gave a better fit ($r^2 = 0.99$).

We have estimated CO_2 production from harvest to the end of shelf-life by adding postharvest CO_2 production (from Fig. 2) to an estimate of the CO_2 production during the subsequent shelf-period (made by multiplying the hours of shelf-life by the basal respiration rate for 20°C from Fig. 1). Estimates for each temperature were not significantly different, with an overall mean of 560 ± 10 μmol (g FW)$^{-1}$.

4. Discussion

The patterns and rates of respiration shown in Fig. 1 are similar to those reported previously (Platenius, 1942; Lill et al., 1990; Lipton, 1990). The rate of respiration is affected not only by temperature, but also the amount of the time elapsed after harvest. The respiration rate at 20°C drops by over 50% in the first 24 hours after harvest.

Respiration, as a measure of metabolic activity, is reputed to be closely related to the rate of deterioration of fresh produce. Therefore, as respiration rate is not constant with time at a particular temperature, it seems likely that total production of CO_2 would give a closer relationship to shelf-life than accumulated heat units, as reported previously (King et al., 1988). CO_2 production, like accumulated heat units, gave a strong linear relationship for predicting residual shelf-life. The period during which the respiration rate is elevated substantially above the basal rate is relatively short (<24 hours). Subsequently respiration rate is very accurately described by spear temperature, and CO_2 production and heat units provide parallel measures of metabolic activity. It is perhaps not surprising, therefore, that cumulative CO_2 production gives only slightly better description of deterioration than accumulated heat units.

The total production of CO_2 by the spears between harvest and the end of shelf-life was remarkably constant, despite widely varying storage temperatures. There is a tight linkage between metabolism and perishability. The nature of the metabolic processes in an asparagus spear change with time after harvest (King et al., 1993). Our estimate of total CO_2 production suggests that although temperature alters the rate of metabolic processes it does not alter the nature of these processes.

The close relationships identified here probably apply to other crops with a predictable pattern of respiratory change after harvest and those where deterioration is primarily driven by the product's own tissue metabolism. Fungal pathogens, for example, may, in other crops, disrupt the tight relationships seen here in asparagus where fungal rots were not a problem.

The parameters of the equation describing the close relationship between accumulated heat units and shelf-life of asparagus are likely to vary with production factors such as cultivar (King et al., 1986), or harvest date (Klieber and Wills, 1992). It is also likely that observer interpretation will affect the parameters, because the visual assessment used requires a subjective response. Our results predict an end of shelf-life at 2290 heat units. The same relationship described by King et al. (1988) predicts 1900 heat units.

Acknowledgements

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