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Postharvest Physiology, Storage and Keeping Quality of Green Asparagus: A Review

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Introduction

Asparagus (*Asparagus officinalis* L.) is one of the popular vegetables which has been used since ancient times. The edible portion of asparagus is it's stem commonly known as spear. *Asparagus officinalis* is originated in the eastern Mediterranean region and has been used for over 2000 years, first as a medicine and later as a food crop. It's cultivation is favoured by the presence of a cool winter season when the plant remains dormant and the developing shoots are harvested in the spring. However, in warmer regions, round-the-year cropping is possible, providing a balance is established between canopy and shoot development. Spears may be cut below ground (white or blanched asparagus) or above ground (green asparagus) before the shoot tip has expanded to form the fern. Young shoots may be boiled and served whole or made into soup. They may also be processed by freezing or canning and there are national differences in colour preference. Green asparagus is the more popular edible form in Japan, United States, Australia, Chile, Taiwan and New Zealand and is gaining increasing favour in Europe. However, the delight of eating fresh asparagus can turn into disappointment if the spears are tough instead of tender and bitter instead of sweet. This review summarizes recent advances in our knowledge of the postharvest physiology, storage and keeping quality of green asparagus, concentrating particularly on studies aimed at understanding the initiation and regulation of postharvest senescence.

Asparagus spears grow very rapidly in the field, as much as 70 mm per day at 20°C (Culpepper and Moon, 1939) and have a high rate of respiratory metabolism (9-40 μmol CO_2 $gFW^{-1}h^{-1}$ depending on tissue type; King *et al*., 1990; Lill *et al*., 1990; Bhowmik *et al*., 2000). As may be expected of such metabolically active tissue, the spears deteriorate rapidly after harvest becoming unsaleable after about 5 days at shelf temperature (20-25°C). Physiological changes which occur after harvest include reduced respiration rate, toughening, flavour changes and losses of chlorophyll, ascorbic acid, soluble carbohydrates, protein and amino acids (Lipton, 1990). Cellular integrity is lost (King *et al*., 1990) and the spears become discoloured, flaccid and susceptible to disease. Strict storage and handling procedures are dictated by the physiology of the asparagus spear and are aimed at minimizing the deteriorative changes.

Storage and Handling: Refrigeration (0-2.5°C) retards quality loss in harvested asparagus and allows 2-3 weeks storage life. Deterioration proceeds more slowly at lower temperatures, as clearly demonstrated by the strong relationship between the accumulated degree-hours after harvest and quality loss (King *et al*., 1988; Klieber and Wills, 1992; Bhowmik *et al*., 2002). This relationship provides an excellent tool for determining the loss of quality during each step of the handling chain. Recent experiments have shown that accumulated CO_2 production by spears is even more closely related to residual shelf-life than is the accumulated degree-hours. This emphasizes the tight linkage between metabolism and spear deterioration.

Controlled atmospheres have been used to retard deterioration of asparagus during cool storage, but the response has given little practical advantage over cool storage in air (Lipton, 1990). With the development of new semi-permeable plastic films, however and an upsurge in interest in commercial applications for these films, there have been further investigations into modified atmosphere packaging (MAP) for asparagus (Tomkins and Cumming, 1988; Gariepy *et al*., 1991; Everson *et al*., 1992). There is some promise for extending shelf-life of unchilled spears using this technology. Widespread commercial application of MAP will depend on the development of effective safety devices for preventing over-modification of the package atmosphere.

Research approaches to maintain quality in harvested spears: Two main research approaches are being used to maintain postharvest quality of asparagus. In the first, specific deteriorative changes are targeted for investigation, e.g. toughening (Saltveit, 1988; Waldorn and Selvendran, 1990). These two studies have contributed valuable information demonstrating that lignin synthesis and changes to cellwall polysaccharides are instrumental in the toughening of harvested asparagus spears.

An alternative approach is to study postharvest senescence of asparagus as an integrated phenomenon.

Identification of key processes in postharvest senescence may enable maintenance of quality and extension of postharvest life through traditional breeding, or by molecular genetic modification. Only a few studies have focused on changes occurring in asparagus spears within the first few hours after harvest. Early changes could be expected based on the stresses that are imposed on an actively growing tissue that is suddenly removed from its nutrient, water and cytokinin source (the roots) by harvest. An understanding of these changes is essential for accurate interpretation of subsequent postharvest physiology.

In asparagus, the pattern of postharvest senescence is influenced by the diversity of spear tissue: the tip comprises actively dividing meristematic cells grading into a zone of cellular elongation, whereas the bottom comprises mature tissue where cell elongation has ceased and the vascular tissue is lignifying (Culpepper and Moon, 1939; Waldron and Selvendran, 1990). Physiological gradients also occur within the spear tissues. Tips of harvested asparagus spears have high protein and low soluble carbohydrate content (Lill *et al*., 1990; Lipton, 1990) in comparison with bottom. Tips are usually the first part of the spear to show symptoms of deterioration and physiological decline (King *et al*., 1988,1990; Lill *et al*., 1990). Within 48 h after harvest at shelf temperatures, respiration rate of tips declines markedly, protein is lost, free amino acids increase and ammonia may start to accumulate (King *et al*., 1990). Subsequent tissue deterioration renders the tips unappealing to consumers. Tips may also act as a sink for metabolites translocated from other portions of the harvested spear (Saltveit and Kasmire, 1985), suggesting the tips may have a role in regulating spear postharvest physiology. An understanding of the underlying changes occurring in tips of harvested asparagus spears may contribute much to understanding the factors that sets the tissues on the developmental pathways leading to postharvest senescence.

Respiratory and carbohydrate metabolism: A remarkable feature of the physiology of asparagus is the very high respiratory rate in tips of growing spears (30-40 μmol CO_2 $gFW^{-1}h^{-1}$). Respiration rate declines immediately after harvest before stabilizing after 12-24 h at shelf temperature (King *et al*., 1990; Lill *et al*., 1990). Equally dramatic are the declines in the value of the respiratory gas exchange quotient and in the level of sucrose in the spear tips. There is also a respiratory decline in the bases of spears (mature tissue with a correspondingly lower respiration rate; Saltveit and Kasmire, 1985; Lill *et al*., 1990) and greater losses of soluble carbohydrates in apical than in basal tissues of harvested spears (Saltveit and Kasmire, 1985). This suggests that respiration and preharvest growth of asparagus spears are both closely tied to the supply of sucrose from the roots. We are investigating the activities of enzymes involved in sucrose breakdown to obtain information on potential control points for slowing tissue metabolism and extending postharvest life.

Asparagus has one of the highest respiratory rates of any horticultural crop and senesces rapidly after harvest. Refrigeration is currently the primary means of retarding quality loss and acts by slowing many of the deteriorative processes. While modified atmosphere packaging may have potential for maintaining quality longer at shelf temperatures, only small gains in the postharvest life of asparagus are likely from fine-tuning existing technology. A better understanding of the factors initiating and regulating postharvest senescence is required if major gains in extending the storage life of this highly perishable vegetable are to be achieved.

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