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Effect of Ultra Low Oxygen on the Storage and Quality of Some Vegetables

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Abstract. **The effects of ultra low oxygen concentration in combination with high and low level of CO_2 on the storage and quality of butter-head lettuce, mature-green tomatoes, bell pepper, Chinese cabbage and onions were studied. Butter-head lettuce stored in CA containing 1% O_2 - 3% CO_2 retained green colour of leaves and higher content of vitamin C during 21 days at 1°C. Development of red colour during 7 weeks storage of mature-green tomatoes was suppressed by low O_2 (1% O_2 - 0% CO_2) or high CO_2 (5%). Tomato fruits stored at ultra low oxygen concentration retained a better taste and flavour than at other CA treatments. For both cultivars tested, the highest percentage marketable bell pepper fruits after 6 weeks storage at 8°C was obtained at 0% CO_2 and 3% O_2. Controlled atmosphere containing 5% CO_2 - 3% O_2 led to increase decay of pepper fruits during storage and shelf-life at 20°C. The Chinese cabbage after 100 days storage at 0°C in low concentration O_2 (1.5% and 3%) and 2.5% CO_2 were still in saleable condition with slight trimming losses. Low O_2 content in combination with low CO_2 delayed the loss of chlorophyll and yellowing of the leaves and reduced the incidence of decay. Ultra low concentration of O_2 (0.75 and 1%) with 2% CO_2 appeared to maintained onion quality much better than other CA treatments. A controlled atmosphere with reduced level of O_2 suppressed sprouting and rooting of onion bulbs during a long period of storage. These CA combinations were also very effective in extending shelf-life of onion bulbs at 20°C.**

Although a number of studies have been conducted to evaluate the effect of controlled and modified atmospheres on the quality and storage ability of vegetables, not so much work has been done on the influence of ultra low oxygen on quality maintaining, delay of ripening, chlorophyll degradation, reduction of decay, sprout inhibition and occurring of physiological damage in vegetables. Storage of vegetables at low O_2 has been shown to reduce respiration and other metabolic processes (Kader, 1986). The minimum oxygen level required to avoid fermentation and ensure aerobic metabolism depends on the kind of crop as well as the duration of storage (Weichmann, 1987).

Low concentrations of O_2 (1-3%) reduced senescence, respiration and physiological disorders of crisp-head lettuce (Saltveit, 1993), however combination of high CO_2(> 2%) with low O_2(1%) increases severity of physiological disorders. The quality of butter-head lettuce was maintained better at CA containing 1% O_2 -3 % CO_2, and no injury was found at CO_2 level up to 10% at 1°C during 3 weeks storage (Adamicki, 1989).

The beneficial effect of controlled atmosphere containing 3 - 5 % O_2 and 2 - 3 % CO_2 on the delaying ripening and reducing decay of mature-green tomatoes have been reported(Dennis et al., 1979). Saltveit (1993) described that for mature-green tomatoes the injurious level of O_2 is below 2%, while it is above 3% CO_2, and that it depends on the length of exposure.

Polderdijk et al.(1993) observed that CA storage of bell pepper at 3 % CO_2 - 3 % O_2 for 15 days at 8°C reduced the incidence of fruit decay during shelf-life compared with storage in air. Luo et al.(1996) suggested that low respiration and ethylene synthesis rates may be the primary factors in quality retention in low O_2 storage of pepper fruits.

Results of CA storage of Chinese cabbage are variable (Weichmann, 1977; Wang, 1982; Apeland, 1984; Pertierra et al. 1993; Balvoll, 1995). Most researchers showed that (1-2%) O_2 with 2 - 6% CO_2 was very effective in extending the storage life of Chinese cabbage. Cultivar differences in storage ability were mainly depends on their susceptibility to chilling injury.

Controlled atmosphere gave the best results when onions were stored at 5 % CO_2 - 3 % O_2 (Adamicki, 1974; Smittle, 1988).Onions response to low oxygen concentrations has not been extensively investigated and only Mikitzel et al.(1993) stated that sweet onions stored for 15 weeks at 0°C maintained better quality at 1 % O_2 with 5 or 10 % CO_2 than at other storage gas mixtures. High concentration of CO_2 (above 5%) should be avoided in CA storage of onions, because they may cause some physiological disorders e.g. translucent fleshy scales inside the bulbs(Adamicki, 1974; Adamicki,1977). The objective of this study was to evaluate the effects of ultra low oxygen concentration on the storage ability and quality of some vegetables.

Materials and Methods

Freshly harvested butter-head lettuce (cv. Królowa Majowych) was obtained from commercial fields in June, while tomatoes (Modena F_1 and cv. Rody F_1) , bell pepper (cv. Cadice F_1 and Stano from greenhouse) and Chinese cabbage (cv. Kigndom F_1 and Parkin F_1 from open field) in October-November. Before storage, peppers and tomatoes were cleaned and washed in chlorinated water. Onions (cv. B³oñska, Dinaro F_1 and Sochaczewska) were harvested in August and after drying selected for experiments.

Samples were stored in gas-tight 450-L steel chambers. Each CA treatments consisted of 4 to 6 replicates. The desired level of oxygen and carbon dioxide in each chamber was established within 24 hours by flushing with compressed nitrogen or adding CO_2. The gas composition was monitored two times a day by infrared analyzer for CO_2 and a paramagnetic analyzer for O_2 and maintained within 0.2% of the desired level (701 Fruit Store Analyzer; David Bishop Instr.). Carbon dioxide produced by vegetables during storage was absorbed with a KOH scrubber.

Samples of butter-head lettuce were stored for 21 days at 1°C, mature-green tomatoes for 7 weeks at 12.5°C, bell pepper for 6 weeks at 8°C, Chinese cabbage for 100 days at 0°C and onions for 33 weeks at 0°C. After storage, the vegetables were sorted into marketable and, depends on the crop, two or three other grades. The visual quality of vegetables was scored on a 9 to 1 scale, where 9 = excellent and 1 = unusable. Ripening of tomatoes was scored on 6 to 1 scale, where 6 = red, fully ripe and 1 = mature-green. The colour of the leaves (lettuce and Chinese cabbage) was evaluated on 9 to 1 scale, where 9 = green and 1 = completely yellow. Shelf-life of vegetables was evaluated at 18°C(tomatoes) and 20°C(other vegetables). Fifty onion bulbs from each CA treatment were held at 20°C and examined for signs of decay and sprouting twice a week. The quality of vegetables from different CA treatments was also estimated on the basis of chemical

analysis and subjective evaluation of several morphological and structural parameters. Data were analysed by a standard analysis of variance test. Means were compared using Newman-Keuls's test at significance level $\alpha = 0.05$.

Results

Lettuce stored at 3-5% CO_2 and 1% O_2 had much greener leaves and smaller trim losses than from other CA conditions, however there were significant differences among CA treatments (Table 1). After 21 days storage at 3% CO_2 - 1% O_2 lettuce contained higher amount of vitamin C and had better overall quality (fresh, crisp and juicy leaves) in comparison to other CA treatments.

Mature-green tomatoes could be stored in CA at 12.5°C and about 90% RH for 8 - 10 weeks. Colouring of fruits was greatly retarded especially at 1% O_2 (Table 2). Colour developments of tested cultivars at different composition of CA was similar, but some differences in susceptibility to CO_2 damage have been observed. Losses of dry matter, total sugar and vitamin C were lower during storage in comparison to the air. Tomato fruits stored at oxygen retained a better taste and flavour than at the other CA treatments.

Low level of O_2 increased the percentage of marketable fruits for both investigated bell pepper cultivars (Fig.1). 5% CO_2 - 3% O_2 CA led to increase decay during storage, as well as shelf-life at 20°C. The content of vitamin C and vitamin E was greatly increased after storage in the all studied CA treatments and was closely correlated with a degree of ripening.

The highest quantity of marketable Chinese cabbage was obtained after storage at low concentration of O_2 (1.5% - 3%) and 2.5% CO_2 (Fig. 2). There were significant differences between CA treatments only with Parkin F_1 cultivar. The lowest losses (weight and trim) were recorded during storage under 1.5% O_2 combined with low CO_2. In standard CA (5% CO_2 - 3% O_2) and in air, total weight losses increased up to 26% and 36%, respectively, while in low O_2 and CO_2 losses did not exceeded 10%.

Significant differences in the number of marketable onions between CA treatments and control (air) were found (Table 3). Ultra low concentration of O_2 (0.75 and 1%) appeared to maintain onion quality much better than the other CA treatments. CA suppressed sprouting and rooting of onion bulbs during 33 weeks of storage at 0°C. Quality of onion bulbs, especially bulb firmness, colour and retention of dry skin were much better during storage in CA. Quality as measured by pungency and sugar contents decreased during prolonged storage due to an increase in pungency of onions. Pungency of onions stored 8 months at 2% CO_2 - 3% O_2 increased to 11.9 $\mu M \cdot g^{-1}$, at standard CA (5% CO_2 - 3% O_2) to 12.6 $\mu M \cdot g^{-1}$ and in air to 16.3 $\mu M \cdot g^{-1}$. Ultra low concentration of O_2 and CO_2 had also influence on onion sprouting during shelf-life at 20°C (Fig.3). Percentage of sprouted onions after 21 days at 20°C, previously stored in ultra low oxygen concentration, did not increased over 20%, while from standard CA (5% CO_2 - 3% O_2) reached 50%. CA could be used to control sprouting of onion bulbs during long storage as well as shelf-life instead of Maleic Hydrazide.

Discussion

Atmosphere containing 3 %CO_2 - 1% O_2 effectively reduce senescence and retarded colour loss and decay of butter-head lettuce stored at 1°C. These results confirmed the previous finding

of Adamicki (1989) and are similar to those reported for crisp-lettuce (Kader, 1986: Saltveit, 1993). Physiological disorders of butter-head lettuce, appeared as browning of leaf tissue followed by a breakdown that was observed at 10% concentration CO_2. These observations are not in agreement with results for crisp-head lettuce (Saltveit, 1993).

A similar interaction between CO_2 and O_2 content as well as length of the storage period on the ripening and quality of mature-green tomatoes was also reported by Dennis et al.(1979). Our investigations showed that physiological injury of tomatoes usually appeared at higher concentration of CO_2 (>5%), however in some cultivars CO_2 damage have been observed even at 3% CO_2. Saltveit (1993) stated, that injurious level of O_2 is below 2%, while in our experiments we didn't observe any damage of tomato fruits stored 7 weeks at 1% O_2 and 0 % CO_2. This might be explained by different susceptibility of tomato cultivars to physiological damage caused by O_2 and CO_2.

A CA of 0% CO_2 with 3% O_2 was the best for maintaining storage ability and quality of pepper fruits. These observations are not in agreement with that reported by Polderdijk et al.(1993) and Saltveit (1993) who recommended 2 - 5% CO_2 and 3 - 5% O_2. Those differences might be explained by cultivars keeping ability, initial ripening stage of the fruits and various length of storage period.

The results obtained with storage of Chinese cabbage in and 1.5 % O_2 -2.5 % CO_2 are similar to those reported by Weichmann (1977), Apeland (1984), Pertierra et al. (1993). Atmospheres containing 1.5 % to 3 % O_2 and 2.5 % CO_2 effectively retained green colour of the leaves and decrease decay development in Chinese cabbage stored at 0°C for over 3 months.

Controlled atmosphere has been used in practice to store onion cultivars with good keeping quality for up to 8-9 months. Many researchers recommended 5% CO_2 - 3% O_2 as a optimal concentrations for inhibition of rooting and sprouting as well as development disease organisms (Adamicki,1974; Smittle, 1988). Onions stored in CA containing 10% CO_2 and 3 to 5% O_2 showed physiological disorders of the bulbs (Adamicki,1974). Microscopic study of the epidermis and parenchyma of fleshy scales have indicated a process of destruction in walls of the onion cells and an increase of free amino acid content in physiological damaged of the onion bulbs (Adamicki et al. 1977). Mikitzel et al.(1993) reported that storage of sweet onions in 1% O_2 with 5% CO_2 or 10% CO_2 gave better results than other CA conditions. Our data indicated that it is possible to store onions at ultra low oxygen concentration 0.75% or 1% O_2 and 2% CO_2 without any physiological injury of the bulbs and obtained a very high percentage of marketable onions after long period of storage.

Literature Cited

Adamicki, F., B. Dyki, and W. Malewski. 1977. Effects of carbon dioxide on the physiological disorders observed in onion bulbs during CA storage. Qual. Plant. Pl. Fds. Hum. Nutr. XXVII (3-4):239-248.

Adamicki, F. 1974. Storage of onions in controlled atmospheres. Acta Hort. 38:53-74.

Adamicki, F. 1989. Storage of vegetables in controlled atmospheres. Biul.Warzywn.107-113.

Apeland, J. 1984. Storage of Chinese cabbage- Brassica campestris L. Pekinensis(Lour) Olsson- in controlled atmosphere. Acta Hort.157:185-197.

Balvoll, G. 1995. Production of Chinese cabbage in Norway: Problems and possibilities. J. Veg. Crop Prod. 1(1):3-7.

Dennis, C., K.M. Browne, and F. Adamicki. 1979. Controlled atmosphere storage of tomatoes. Acta Hort. 93:75-83.

Kader, A.A. 1986. Biochemical and biophysical basis for effects of controlled and modified atmospheres on fruits and vegetables. Food Technol. 40:99-104.

Luo, Y., L.J. Mikitzel. 1996. Extension of postharvest life of bell peppers with low oxygen. J. Sci. Food and Agr. 70(1):115-119.

Mikitzel, L.J., M.E. Patterson, and H. Waelti. The effect of CA storage on the postharvest life of sweet onions, p. 789-796. In: CA'93 Proc. 6 th Intl. Controlled Atmospheres Res. Conf. NRAES-71,vol.2.

Pertierra, R., H. J .Weichmann. 1993. Das Lagerverhalten von Chinakohl. Gemuse 10:505-507.

Polderdijk, J.J., H.A.M. Boerrigter, E.C. Wilkinson, J.G.Meijer, M.F.M. Janssens. 1993. The effects of controlled atmosphere storage at varying levels of relative humidity on weight loss, softening and decay of red bell peppers. Scientia Hort. 55:315-321.

Saltveit, M.E.Jr. 1993. A summary of CA and MA requirements and recommendations for the storage of harvested vegetables, p. 805-818. In: CA'93 Proc 6th Intl. Controlled Atmospheres Res. Conf. NRAES-71, vol.2.

Smittle, D.A. 1988. Evaluation of storage methods for „Granex" onions. J. Amer. Soc. Hort. Sci. 113(6):877-880.

Wang, C.Y. 1982. Effect of high CO_2 and low O_2 on the storage quality of Chinese cabbage. Hort. Science 17(3):526.

Weichmann, J. 1977. CA storage of Chinese cabbage. Acta Hort. 62:119-129.

Weichmann, J. 1987. Postharvest physiology of vegetables. Marcell Dekker, Inc. N.J.