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CA - STORAGE OF FRUITS AND VEGETABLES

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Abstract

Appropriate CA-conditions using a lower oxygen and a higher carbon dioxide content are presently available as a means to control ripening and aging of fruits and vegetables, and to reduce the metabolic activity. Specific beneficial effects of proper CA-storage conditions on the presentation of quality and nutritional value are: delayed softening and mealiness (apples, pears, tomatoes), delayed toughening (asparagus), chlorophyll retention (apples, pears, leaf vegetables), inhibition of anthocyanin formation (gooseberries, sweet peppers), inhibition of the browning of cut surface (cut vegetables), better flavour retention (cabbage), reduction of disorders (scald, core flush) and decay (berries), higher nutritional value after storage (vitamin C). Caution must be used with too low oxygen atmospheres (near 1% O_2) because of the risk of anaerobic respiration. This causes high levels of ethanol and acetaldehyde in the fruit which give rise to breakdown and develop off-flavours. A too high CO_2 content can also have deleterious effects such as external discolouration, off-flavours and breakdown (cavities, internal breakdown).

KEYWORDS:

C.A.-STORAGE, QUALITY, DISORDERS, DECAY

PHYSIOLOGICAL EFFECTS OF CA STORAGE

CA storage has a retarding effect on different morphological and enzymatic changes at a cellular level: respiratory intensity, breakdown of membrane phospholipids and decrease of the volume of cytoplasma and mitochondria are all inhibited.

The effects of reduced oxygen and elevated carbon dioxide on metabolic changes and respiratory activity are additive. A 10% CO_2 added to the air influences respiratory metabolism to about the same extent as 2 % O_2; a combination of 2% O_2 + 10% CO_2 has approximately twice the effect of either component (Burg et al., 1967). Although the oxygen level at which anaerobic respiration occurs may be as low as 0.2 % O_2 within the plant cell, the gradient of oxygen concentrations from that point to the external atmospheres necessitates maintenance of about 1 to 3% oxygen around the commodity.

The anaerobic compensation point (A.C.P.) differs from variety to variety. In unripe pears the A.C.P. is 1.6 to 1.7 % O_2, while in ripe pears it is 2 to 5 % O_2 (Schulz, 1989).

CA storage helps to achieve more easily the optimum quality characteristics demanded by the consumer. This is the case for the optimal firmness, refractometer value and acidity of Jonagold apples, demanded by the European consumers (Pladdet et al., 1991).

Preservation of firmness by CA - storage

The softening and cell separation in many fruits is associated with the increased proportion of readily soluble pectins. There are two stages of cell wall breakdown during the ripening of apples. In the first stage fruit firmness declines slowly and wall galactans decrease. In the second stage, firmness decreases more rapidly and soluble polyuronides increase.

Reduction of the oxygen concentration to 2% O_2 delays the beginning of the second stage considerably (Knee, 1974).

In CA storage Jonagold apples have a higher firmness than in regular storage (RS) or modified atmosphere (MA) storage (Table 1).

Table 1: Firmness of Jonagold apples (kg/cm^2) (Herregods et al., 1989)

Storage System	17 weeks	17 weeks and 10 days, 18° C
RS (0.5° C, 21% O_2 0.03% CO_2)	4.0	3.4
MA (0.5° C, 17% O_2 4 % CO_2)	4.3	3.5
CA (0.5° C, 1.3% O_2 0.8% CO_2)	4.6	4.2

The influence of a high CO_2 level is greater at higher (3% O_2) than at lower (1.5% O_2) oxygen concentrations (Dewey, 1982) The effect of low O_2 on firmness also depends on variety and picking time (Table 2).

Table 2: Firmness after 10 months of storage (Curry, 1989).

		Storage			Storage + 10 days		
Species	Date	2% O_2	1% O_2	0,5% O_2	2% O_2	1% O_2	0,5% O_2
Granny Smith	11. Sept.	a	A	a	c	b	a
	26. Sept.	b	A	a	c	b	a
	08. Oct.	c	b	a	c	b	a
Criterion	11.Sept.	a	a	a	a	a	a
	26. Sept.	b	a	b	b	a	b
	08. Oct.	b	a	b	b	a	b

Inhibition of toughening by CA-storage

The degree of toughening of asparagus as measured by rupture force after 3 weeks at 1° C 95% R.H. was lower in CA conditions (3-5% O_2,16-18% CO_2) than in normal air (Herregods, internal report, 1988).

Preservation of colour by CA-storage

Loss of chlorophyll and biosynthesis of carotenoids are slowed down in horticultural crops kept in CA. The green colouring of the yellow protochlorophyll of chicory endives is strongly inhibited at 8 to 12% CO_2.

After storage in CA circumstances the ground colour of Jonagold apples stays greener (Table 3).

Table 3: Ground colour of Jonagold apples after storage (1=green, 8= yellow) (Herregods et al., 1989).

Storage System	17 weeks	17 weeks and 10 days, 18° C
RS (0.5° C, 21% O_2 0.03% CO_2)	7.8	8.0
MA (0.5° C, 17% O_2 4 % CO_2)	6.2	7.5
CA (0.5° C, 1.3% O_2 0.8% CO_2)	5.9	7.2

Next to a high CO_2, a low O_2 has also a positive effect on green colour preservation (Sharpler, 1982).

Elevated CO_2 can result in detrimental effects on colour such as:

- uneven red colouring of tomatoes (>5% CO_2)
- grayish-yellow colour on cauliflowers upon cooking (>15% CO_2)
- darkening of the red colour of strawberries (>25% CO_2)
- brown discoloration of external and internal tissues (>2 to 20% CO_2)

A too low oxygen content (0.2 to 0.8 % O_2) can stimulate a brown discoloration of the internal tissue.

Odor-active volatiles in CA-storage

Apple flavour is a complex combination of several taste and odor sensations. About 300 volatiles have been reported to be produced by apples, but only some have significant sensory impact on the fruit (Yahia, 1989).

CA-storage changed the rate of production of some aroma compounds. Some volatiles were completely suppressed in CA but when apples were transferred to air, some were produced in normal amounts, some were suppressed while others were produced in higher amounts (Table 4).

Table 4: Variation of volatiles production in apples ripened in air at 20° C after CA-storage (E.M. Yahia, 1989).

similar amounts of	- ethyl butanoate - propyl 2-methylbutanoate - butyl pentanoate
less amounts of	- hexanal - E-2-hexenal - methyl butanoate - propyl butanoate - butyl 2- methylbutanoate - hexyl 2-methyl butanoate - methyl hexanoate
very small amounts of	- hexyl acetate - butyl hexanoate - hexyl hexanoate

Dirinck et al. (1990) showed that at low O_2 concentrations the production of unbranched aroma compounds as butylacetate and hexylacetate are strongly inhibited; there is no effect on the production of branched compounds as 2-methylbutylesters and 2-methylbutanoate, originated from the amino-acid metabolism.

When loss of volatiles production in apples stored for long periods under low oxygen is of concern, Lidster et al. (1987) suggested the use of low oxygen (1-2% O_2) for the first few months and 2-3% O_2 for final months. De Poorter (1991) suggests to apply short periods of regular storage to reactivate the changes from carbon acids and aldehydes to alcohols and esters. At higher CO_2 concentrations there seems to be an inhibition of lipid metabolism and a shortage of carbon acids.

Danger of off-flavour in CA-storage

As CA storage takes place in gas-tight rooms, then, after a certain time, there is a significant increase of volatiles. These arise not only from the fruits, but also of resin-terpenes from insufficiently dried wooden bins, and musty odours from moulds growing on the bins, when insufficiently treated with specific fungicides such as azaconazole (Scomrid 50 AZ Pallox). In more ventilated rooms with more air changes, the concentration of volatiles in the room is lower (Herregods, et al., 1989).

The concentration of volatiles is lower when an activated charcoal scrubber is used.

The new store technique of regularly flushing with nitrogen (N_2), produced with a membrane separator or PSA system, strongly reduced the volatile concentration in the room.

After a period of storage in a too low oxygen atmosphere, acetaldehyde and ethanol can concentrate in the fruit. These fermentation volatiles can diffuse out of the fruit again by applying a proper ventilation in normal air for several weeks (Henze, 1989).

Preservation of nutritional value by CA-storage

Sugars

Soluble carbohydrates increase more in regular storage than in CA storage. The increase of fructose and glucose are partly due to the hydrolysis of sucrose.

Acids

Total acidity declines less in CA than in regular atmosphere. The change in total acidity is attributed to the decline in malic acid.

Ascorbic acid

CA storage results in a better retention of ascorbic acid in fresh fruits and vegetables than in air.

Quality measured by taste panel after CA-storage

The optimum O_2 concentration for any variety will depend on the balance, which is required between its aromatic and textural attributes (19). Taste panelists found apples from U.L.O. more crisp, more acid and less sweet than apples stored in MA or RS (Table 5).

Table 5: Value measured by taste panel (Dirinck et al., 1990)

	Crispness	Acid taste	Sweet taste
RS (0.5° C, 21% O_2 0.03% CO_2)	1.3 - 1.7	1.4 - 1.8	2.3 – 2.7
MA (0.5° C, 17% O_2 4 % CO_2)	1.8 - 2.2	1.7 - 2.1	1.7 - 2.1
CA (0.5° C, 1.3% O_2 0.8% CO_2)	2.3 - 2.7	2.3 - 2.7	1.4 - 1.7

Overall acceptability of Cox's Orange in 1.25% O_2 was slightly greater than that from 2% O_2, but this preference was more marked among younger people (Sharples, 1982).

Inhibition of growth and development by CA

The cap opening of mushrooms is prevented by exposure to 1% O_2 (A.A. Kader, 1985). Also the growth of asparagus and chicory endives is inhibited by 5% CO_2.

Inhibition of disorders by CA-storage

Scald and core flush are two disorders reduced by CA storage. Environmentally unfriendly postharvest chemical treatments against scald could be replaced by using CA storage. In CA storage the content of alfa-farnesene and of conjugated triene hydroxyperoxydes in scald sensitive apple varieties is strongly inhibited.

Decay is strongly inhibited with 20% CO_2 for currant berries and blackberries, also for strawberries with 10 to 15 % CO_2. Lowering O_2 from 1.25 to 0.75 % O_2 tended to reduce rotting caused by Penicillium and Monilia, but tended to increase the incidence of Nectria rots in fruits infected naturally (Johnson, 1992).

Suppression of growth (in terms of fungal colony diameter) of all three strains of *Botrytis* cinerea by a 2 percent O_2 atmosphere is modest, and about 15 percent below the rate of growth in air (21% O_2). More growth reductions can be obtained when the O_2 is lowered from 2% but that, unfortunately, is generally considered too low for commodity safety.

Air commonly contains about 0.03 % CO_2. Elevation of CO_2 above about 5% noticeably suppresses growth (only in terms of fungal dry weight, but not colony diameter) and respiration rate of all three strains of B. cinerea. When the concentration of CO_2 is excessive, (in this study it was 40 % CO_2), the growth (both colony diameter and dry weight) and respiration rate of the fungi tested are completely inhibited (Jaenakson, 1991).

Quality of fruits after processing stored in CA-circumstances

Aroma intensity and sourness were the two characteristics which did differ, depending on cultivar and storage type (table 6).

Table 6: Effect of CA storage on sensory characteristics of processed apples (Massy, 1985).

	Aroma	Smoothness	Grain	Sourness	Desirability
Empire	x	NS	NS	xx	NS
Red Delicious	xx	NS	NS	NS	NS
Idared	NS	NS	NS	xx	NS

The incidence of discoloration of broken pods of snap beans held at 27° C for 24 hours declined with increasing concentrations of CO_2 (20% CO_2).

The reduction in discoloration was attributed to reduced phenolase activity and the reductions of phenolic compounds (Buescher et al., 1977). The same was found with cut lettuce stored at 3° C with 20% CO_2.

CONCLUSIONS

A strong preservation of quality and nutritional value is demonstrated by CA storage with a lowering of O_2 and an enhancement of the CO_2 concentrations. This results in:

- better quality after storage
- a longer storage period
- a longer shelf-life period after storage
- a higher nutritional value after storage (vitamin C)
- a more environmental friendly storage (no postharvest chemical treatments against scald are needed).

A too low O_2 and/or too high CO_2 content can have deleterious effect. Oxygen is in reality poison stimulating aging and senescence but in small amounts it is necessary for life (Beby et al., 1988).

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