Tolerance of Sugar Snap Peas to Modified Atmospheres with High Concentrations of Carbon Dioxide

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Abstract

Current recommendations for maintaining quality of sugar snap peas in storage include low temperatures, but not modified atmospheres (MA). However, sugar snap peas may be unintentionally exposed to MA when shipped in 'bag in box' bulk packaging, or intentionally exposed when used as a component in fresh-cut vegetable trays. The aim of this research was to determine the tolerance of sugar peas to MA. Two experiments were conducted in which sugar snap peas ('Super Sugar Snap') were stored at 5°C for up to 21 days in air, 3% O_2 + 7, 12 or 18% CO_2, or 10% O_2 + 12% CO_2. Overall, storage in air resulted in the best quality based on subjective (overall visual quality, discoloration, aroma, decay) and objective measurements (sugar, ethanol, acetaldehyde, ammonia). The 3% O_2 with 12 or 18% CO_2 resulted in visible damage (discoloration) to the peas after 9 to 12 days. This was associated with changes in color (increased darkness, loss of greenness), and substantial increases in ammonia, ethanol and acetaldehyde; all indicative of stress. Quality changes in peas stored in 3% O_2 + 7% CO_2 or 10% O_2 + 12% CO_2 were intermediate between the stressful atmospheres and air. Further tests showed that peas ('Sugar Snap') maintained good quality at 5°C in air, 3% O_2, 3% O_2 + 6% CO_2 or 10% O_2 + 12% CO_2 atmospheres for 18 days. Best quality was maintained in air at 0°C for over 21 days. At 5°C for 18 days, some MA combinations provided slight benefit over air storage, and importantly did not result in increased concentrations of stress indicators. If peas have to be in MAP with other fresh-cut vegetables, the 3% O_2 + 6% CO_2 or 10% O_2 + 12% CO_2 atmospheres are probably the better options.

INTRODUCTION

Temperatures near 0°C, in combination with high humidity, are essential conditions to maintain freshness and quality of snow peas and sugar snap peas (Suslow and Cantwell, 1998; Morris and Joplin, 2004). At 0°C, peas can be maintained in excellent quality for at least 14 days, and good to very good quality for 21 days or longer. At 0°C, sugar loss is also minimized. At 5°C or higher, symptoms of water loss (wilting, increased appearance of 'white spots' in mechanically damaged areas), loss of sugar, and increased decay will occur after storage for 2 weeks. Peas produce little ethylene and are not considered to be sensitive to ethylene at typical low storage temperatures. At 10°C, however, ethylene can be detrimental, principally causing degreening of the calyx (M. Cantwell, unpublished).

Relatively little research has been done on responses of edible-pod peas to modified atmospheres (MA) and the research that does exist is somewhat contradictory. It is important to consider that there will be important temperature-atmosphere interactions. Ontai et al. (1992) stored sugar peas at 1 or 10°C in air or 2% O_2 plus 0, 3 or 5% CO_2 for up to 21 days. They did not report CO_2 injury, but found that the MAs were beneficial compared to air storage at 10°C. However, none of the MAs resulted in better quality than that obtained by storing in air at 1°C. Pariasca et al. (2000) reported that atmospheres of 5% O_2 plus 5 or 10% CO_2 at 5°C resulted in better visual and compositional quality than peas stored in air. They reported that atmospheres of 2.5% O_2 + 5% CO_2 or 5% O_2 +10%

CO_2 were detrimental, leading to off-flavors. Sugar snap peas have been successfully shipped in marine containers at 1 to 3°C from Peru to the US using an atmosphere of 1 to 2.5% O_2 and 5% CO_2 (M. van Ryn, pers. commun.). Peas are also packaged bulk in 5 kg 'bags in boxes' for marine container or air shipment. Damage (discoloration and deterioration) of some of the peas has been observed (R. Bernard, pers. commun.). Sugar snap peas are an increasingly popular vegetable and are often used as an ingredient in fresh-cut vegetable trays. These trays may produce an intentional or unintentional MA.

A reassessment of the tolerance of sugar snap peas to MA is needed because of the increased use of MA during their long distant transport, and the possible development of MA in value added products. Previous work has shown that stressed sugar snap peas can produce high concentrations of ammonia (Cantwell et al., 2010), and the usefulness of this stress indicator was compared to changes in fermentative volatiles.

MATERIALS AND METHODS

Three controlled atmosphere (CA) experiments were conducted on two cultivars of sugar snap peas. Product was shipped in 5 kg boxes in a refrigerated truck from Mexico, or air-shipped with gel ice packs from Peru. Peas were 2 to 5 days from harvest at the time of experimentation. Pods were sorted for defects (mainly mechanical damage) and maturity, rinsed in chlorinated water (150 ppm NaOCl pH 7.0), drained and air dried. The peas were stored at 5°C in vented polyethylene bags in chambers through which humidified gas mixtures flowed. Controlled atmospheres were prepared from mixing humidified gases and were maintained within 5% of the indicated concentrations.

Pods were evaluated by 3 trained evaluators for appearance quality, discoloration, dehydration, aroma, off-odors, and off-flavor within 30 min of removal from storage. Visual quality was scored on a 9 to 1 scale, where 9 = excellent, fresh appearance, 7 = good, 5 = fair, 3 = fair, 1 = unusable. Typical aroma, off-odors, and flavor were scored on 1 to 5 scales (1 = none, 2 = slight, 3 = moderate, 4 = almost typical aroma or moderately severe, and 5 = maximum or severe). Decay, discoloration or other defects were scored on 1 to 5 scales (1 = none, 2 = slight defect but product salable, 3 = moderate, product useable but not salable, 4 = moderately severe and 5 = severe, unusable).

Color values (L*a*b*) were determined on the midpoints of the pods using a Minolta Chroma Meter CR-200. Chroma (C) and hue angle (H) were calculated as $(a^{*2} + b^{*2})^{1/2}$ and $\tan^{-1}$ (b*/a*), respectively. Chopped samples were frozen at -20°C for subsequent extraction in ethanol for the determination of total sugars by a phenol-sulfuric colorimetric method (Buysse and Merckx, 1993) using glucose to construct a standard curve. For fermentative volatiles, 8 g of chopped tissue was frozen at -80°C in stoppered test tubes until analysis. Samples were incubated at 65°C and ethanol and acetaldehyde were determined from 1 ml head space samples by GC-FID. Vitamin C (ascorbic acid and dehydroascorbic acid) were determined on cold 2% oxalic acid extracts, filtered and frozen at -80°C for subsequent analysis by HPLC equipped with a UV detector based on a method modified from Tausz et al. (1996). Ammonia concentrations were determined from frozen tissue by homogenizing tissue in water, centrifugation and reaction of an aliquot with a phenol nitroprusside reagent and alkaline hypochlorite (Weatherburn, 1967; Beecher and Whitten, 1970), using ammonium sulfate to construct a standard curve.

Data are based on 3 replicates per treatment per evaluation with each replicate containing 12 pods. Data were analyzed by ANOVA with mean separation by calculation of LSD.05.

RESULTS AND DISCUSSION

The visual appearance of sugar snap peas was the same for all atmospheres up to day 6 for CA experiment 2 (Fig. 1). Some injury (discoloration, darkening) was observed in some of the pods stored in 3% O_2 + 18% CO_2 by day 9. By day 12 and 15, similar defects were observed in the peas stored in the 3% O_2 + 12% CO_2 atmosphere. Overall visual quality for up to 18 days was best maintained in air, followed by 3% O_2 +7% CO_2 and 10% O_2 + 12% CO_2. Quality changes were mainly due to discoloration and

dehydration (increased appearance of white areas associated with damage), and there was virtually no decay. Aroma, off-odor and off-flavor changes were first noticed in the 18% CO_2 atmosphere followed by the 3% O_2 + 12% CO_2 atmosphere, and these defects were serious by 15 days. The best scores for aroma were achieved with air storage. There was no indication of any off-odors or off-flavors after 21 days at 5°C. CA experiment 1 resulted in the same trends but notable injury and off-odor development in the high CO_2 atmospheres was delayed until day 9 (data not shown).

The visual discoloration of peas stored in 3% O_2 + 18% CO_2 was also reflected in changes in color values. L* values decreased as pods darkened (data not shown). Chroma values increased as browning occurred while hue values decreased by day 12 showing loss of green pigmentation (Fig. 2). Differences in objective color values occurred after visual differences in pea quality were observed.

The 3% O_2 + 18% CO_2 atmosphere resulted in substantial increases in ethanol and acetaldehyde by day 12 (Table 1) in CA experiment 1; indicating that this was a stressful atmosphere for the peas. The two CAs with 12% CO_2 also resulted in significant increases in ethanol and acetaldehyde. Minimal changes were observed in the peas stored in air or in 3% O_2 + 7% CO_2. Similar trends for ethanol and acetaldehyde occurred in CA experiment 2, but ethanol concentrations were generally lower (Table 2) while acetaldehyde concentrations were in the same range.

There were moderate increases in ammonia concentrations in the sugar snap peas. The largest increases occurred in peas stored in 3% O_2 + 18% CO_2, while minimal changes were observed in air-stored peas (Tables 1 and 2). Peas in CAs with 12% CO_2 generally had higher ammonia concentrations than those in air or 3% O_2 + 7% CO_2.

Although the same cultivar was used in CA experiments 1 and 2, there were significant differences in sugar concentrations between these two experiments (Tables 1 and 2). Sugars averaged a 5% decrease after 18 days in CA 1, but there was a much larger 15% decrease in peas held in the stressful 3% O_2 + 18% CO_2 atmosphere. Similar results were found in CA 2, but in this experiment differences in sugar concentrations were not significant over the 18 days of storage.

In CA experiment 3, the atmosphere conditions resulting in the best quality from the previous experiments were further evaluated along with 3% O_2 alone, and air at 0°C (Table 3). Visual quality changes were similar among all treatments, but pods held in air at 0°C retained the highest visual quality throughout (data not shown). There was no evidence of damage due to CO_2 for up to 24 days (data not shown) in any of the storage atmospheres. Ethanol and acetaldehyde concentrations increased significantly in the 3% O_2 + 6 or 12% CO_2 CAs while concentrations in other storage treatments remained low (Table 3). Ammonia concentrations increased slightly during storage for most atmospheres, but were consistently higher in the 5°C air and 10% O_2 + 12% CO_2 treatments at both 12 and 24 days. Sugar concentrations were higher in peas stored in air at 0°C than at 5°C after 24 days, but the differences were small. On average, the sugar and vitamin C concentrations decreased by 18 and 21%, respectively, over the 24 days, with no notable differences among storage conditions.

CONCLUSIONS

The visual and compositional quality of sugar snap peas can be maintained at 0 to 5°C in air for 18 to 24 days. Quality can also be maintained at 5°C for up to 21 days in CAs of 3% O_2 alone, or in combination with 6 to 7% CO_2 and in 10% O_2 + 12% CO_2. The 3% O_2 atmospheres with 12 and 18% CO_2 resulted in visible damage (discoloration) to the peas after 9 to 12 days. This was associated with changes in color (increased darkness, loss of greenness), and substantial increases in ammonia, ethanol and acetaldehyde; all indicative of stressful conditions. Peas stored in 3% O_2 + 7% CO_2 or 10% O_2 + 12% CO_2 resulted in changes intermediate between the very stressful CAs and air. Although not recommended, peas can tolerate a range of MAs that permits them to be packaged with other fresh-cut products. If MAs are used, the 3% O_2 + 6 to 7% CO_2 and 10% O_2 + 12% CO_2 atmospheres are probably the better options. Both measurement of fermentative

volatiles and ammonia were good indicators of stressful atmospheres for sugar snap peas.

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Tables

Table 1. CA experiment 1. Sugar, ethanol, acetaldehyde, and ammonia concentrations of sugar snap peas ('Super Sugar Snap') stored in air or controlled atmospheres at 5°C for 6, 12 and 18 days. Data are averages of 3 replicates of 12 pods.

Atmosphere % O_2 + % CO_2	Days	Sugar (mg/ml juice)	Ethanol (µmol/100 g)	Acetaldehyde (µmol/100 g)	Ammonia (µg/g)
Initial	0	59.1	1.9	2.8	7.2
Air	6	-	14.0	9.6	9.4
3 + 7	6	-	14.8	12.4	6.3
3 + 12	6	-	12.7	12.6	13.1
3 + 18	6	-	16.7	14.6	14.0
10 + 12	6	-	10.7	9.0	13.4
Air	12	59.3	38.5	16.6	6.2
3 + 7	12	58.9	40.2	29.1	5.4
3 + 12	12	59.8	121.6	30.8	17.7
3 + 18	12	59.6	504.5	84.6	24.5
10 + 12	12	60.2	212.9	27.4	5.5
Air	18	59.4	64.1	5.3	6.8
3 + 7	18	57.5	71.4	9.7	25.2
3 + 12	18	55.9	312.8	24.8	33.9
3 + 18	18	50.2	1202.4	86.1	45.9
10 + 12	18	57.4	421.7	14.2	29.9
LSD.05		5.3	139.0	5.8	4.9

Table 2. CA experiment 2. Sugar, ethanol, acetaldehyde, and ammonia concentrations of sugar snap peas ('Super Sugar Snap') stored in air or controlled atmospheres at 5°C for 12 and 18 days. Data are averages of 3 replicates of 12 pods.

Atmosphere % O_2 + % CO_2	Days	Sugar (mg/ml juice)	Ethanol (µmol/10 g)	Acetaldehyde (µmol/100 g)	Ammonia (µg/g)
Initial	0	67.5	10.4	11.3	8.2
Air	12	67.9	41.1	26.0	7.4
3 + 7	12	65.3	7.5	25.6	7.8
3 + 12	12	67.8	24.6	31.3	20.2
3 + 18	12	62.2	99.9	43.3	38.2
10 + 12	12	66.7	49.6	25.3	14.1
Air	18	66.6	86.0	19.4	7.0
3 + 7	18	63.0	18.2	30.4	7.3
3 + 12	18	62.4	89.8	34.8	18.3
3 + 18	18	58.6	355.4	69.8	48.8
10 + 12	18	59.9	130.8	29.4	11.8
LSD.05		ns	38.5	6.3	4.7

Table 3. CA experiment 3. Visual quality scores and concentrations of sugar, ethanol, acetaldehyde, ammonia, and vitamin C of sugar snap peas ('Sugar Snap') stored in air at 0 or 5°C or controlled atmospheres at 5°C for 12 and 24 days. Data are averages of 3 replicates of 12 pods.

Atmosphere % O_2 +% CO_2	Days	Sugar (mg/g)	Ethanol (µmol/10 g)	Acetaldehyde (µmol/10 g)	Ammonia (µg/g)	Vitamin C (mg/100 g)
Initial	0	54.4	2.5	2.2	1.2	71.7
Air 0°C	12	48.4	3.0	1.7	3.1	61.0
Air 5°C	12	46.6	3.2	1.8	4.7	58.7
3	12	49.2	6.6	3.2	2.4	66.7
3 + 6	12	50.8	9.4	4.0	2.8	63.3
3 + 12	12	49.2	3.0	2.0	5.9	54.4
10 + 12	12	51.7	3.0	2.1	8.0	55.6
Air 0°C	24	46.8	4.2	1.8	5.4	59.5
Air 5°C	24	41.1	3.4	1.7	6.6	56.7
3	24	43.3	11.8	5.0	3.5	64.5
3 + 6	24	46.7	62.2	8.5	3.4	53.8
3 + 12	24	47.7	49.6	6.9	3.7	55.6
10 + 12	24	43.9	6.2	2.4	6.1	48.4
LSD.05		4.7	30.0	2.4	1.4	7.0

Figures

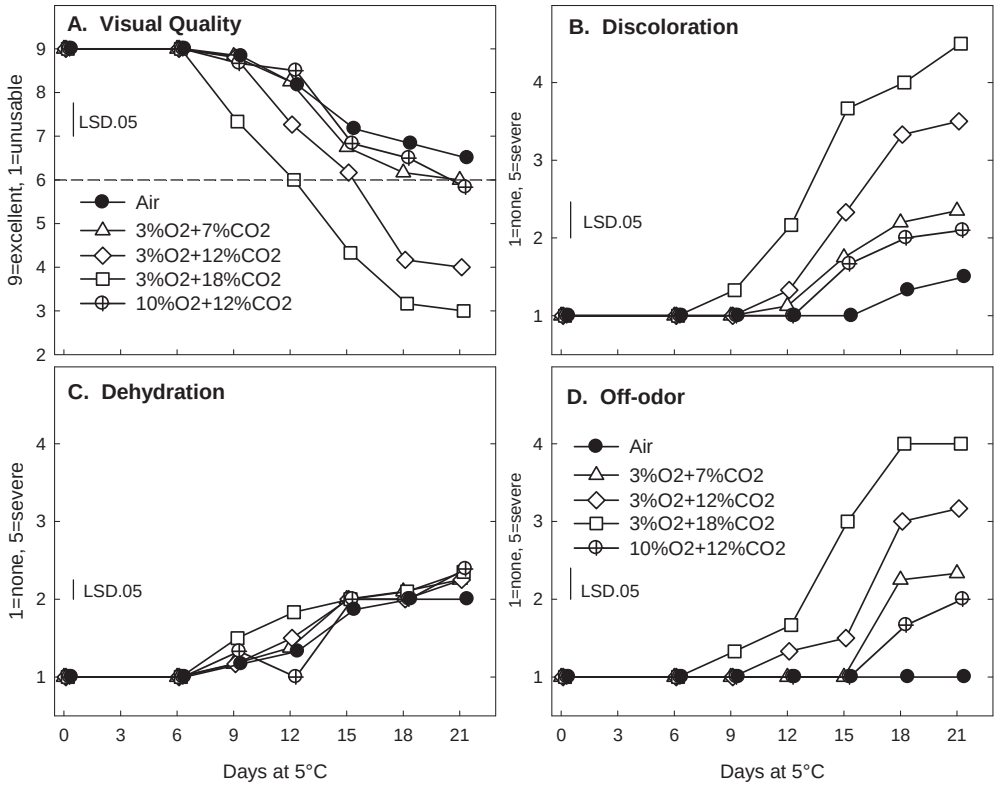

Fig. 1. Quality attributes of sugar snap peas ('Super Sugar Snap') stored in at 5°C in air or controlled atmospheres. A visual quality score of 6 indicates the limit of marketable quality. CA experiment 2. Data are averages of 3 replicates of 12 pods each. Vertical bars indicate LSD.05.

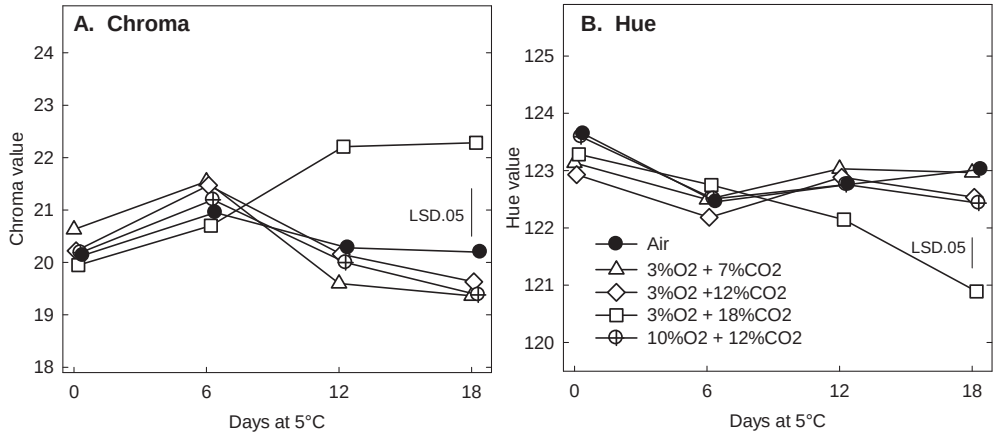

Fig. 2. Chroma and hue values of sugar snap peas ('Super Sugar Snap') stored in at 5°C in air or controlled atmospheres. CA experiment 2. Data are averages of 3 replicates of 12 pods each. Vertical bars indicate LSD.05.