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Effect of Controlled Atmosphere Storage on Quality of Harvested Asparagus

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CA 저장이 아스파라가스의 품질에 미치는 영향

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Abstract

Harvested asparagus, *Viking* variety, was stored in normal and controlled atmosphere with and without 'Butts in water' to extend shelf life of fresh asparagus.

Controlled atmosphere storage significantly reduced bacterial soft rot of asparagus. When asparagus was stored in controlled atmosphere in combination with 'Butts in water', asparagus spears could be stored over 3 weeks without noticeable soft rot.

Texture of stored asparagus, as measured by Instron and fiber analysis, became tougher as the storage time was extended. Increase of fiber content in asparagus was significantly reduced by controlled atmosphere storage and fiber content actually decreased in asparagus stored in controlled atmosphere in combination with 'Butts in water'.

Asparagus stored in controlled atmosphere had markedly less chlorophyll destruction than that in normal atmosphere. Reflectance color values of stored asparagus were closely associated with chlorophyll content in asparagus.

Considering all quality factors of stored asparagus, controlled atmosphere in combination with 'Butts in water' was the best storage method to maintain overall quality of harvested asparagus over 3 weeks.

Introduction

Asparagus respires more rapidly than other vegetables at a given temperature and this causes rapid quality deterioration of cut asparagus during storage. Respiration can be controlled by temperature, carbon dioxide and oxygen[1].

Thornton[2] found that carbon dioxide in the atmosphere lowered the oxygen uptake, and the oxygen uptake was decreased significantly when the CO_2 concentration was 10% or higher. Barker and Morris[3] found that the storage life of asparagus could be extended up to 35 days at 34°F in 5 to 10% carben dioxide with either 5 or 10% oxygen. Lipton[4] revealed that increasing levels of CO_2 reduced the incidence and severity of bacterial soft rot infection at the tip and cut end of the spear.

As in many vegetables, fibrous materials are objectionable due to their deleterious effect on palatability. Studies by Bitting[5] and Morse[6] showed that the fiber content rose as the storage period and

the storage temperature were increased. Objective methods for measuring fibrousness of asparagus spears have been developed by many researchers. Recently, Instron has been used to evaluate texture of asparagus[7]. Increase in the fiber is attributed to utilization of sugars in lignification in the pericycle and the vascular bundles[8].

One of the important quality loss of excised asparagus is yellowing which is a normal procedure of plant senescence. Wang[9] studied chlorophyll degradation during controlled atmosphere storage of asparagus and found that there was more retention of chlorophylls in controlled atmosphere stored asparagus. Gold and Weckel[10] showed that the percent of chlorophyll lost correlated very well with certain color functions, such as a/b (a function of hue) and $\sqrt{a^2+b^2}$ (a function of chroma) of reflectance color values measured by Hunterlab color difference meter.

The purpose of this study was to investigate methods to extend storage life of fresh asparagus with minimum quality deterioration during storage.

Materials and Methods

Asparagus

Viking variety hand harvested from 4~6 year old field was used for the experiment. Cut asparagus was washed and sorted according to diameter at 6 inches from tip of spears ranging 3/8 to 6/8 inch in diameter and 6 to 10 inches in length were used for the experiment. Sorted spears were divided into 4 lots, each lot weighing about 130 *lb*, and held in cold room at 35°F until transferred to the storage room.

Storage conditions

Storage rooms (8×10×8 feet: width×length×height) for normal atmosphere and controlled atmosphere were kept at 35°F and 90±5% relative humidity. A Tectrol generator was employed to maintain controlled atmosphere of 6.2% CO_2, 2.3% O_2 and 91.5% N_2.

Storage method

1. Control

Asparagus was held in wooden boxes.

2. Butts in water

Butt ends of asparagus were immersed in 2 inches of water in shallow pans.

Quality evaluation

1. Bacterial soft rot

On removal from storage, asparagus spears were carefully examined to determine soft rot. Observations were made in duplicate and expressed as percent of spoiled spears over total number of spears in each sample.

2. Texture measurement

Shear force in pounds to cut a spear at 7.5 inches from tip with single blade was recorded using Instorn. Ten spears from each treatment, diameter of spears ranging from 3/8 to 9/16 inch at 7.5 inches from tip, were used for measurement. Shear force was measured for each spear with a cutting speed of 4 inches/min.

3. Fiber determination

Fiber content was determined according to the procedures outlined by Smith and Kramer[11] and modified by Lipton[12]. Asparagus was cut into 4 inch sections (4 to 8 inches from tip) and sliced into small pieces. About 100 *g* of sample was weighed, filled in a No. 1 can and cooked in a steam kettle at 212°F for 15 min. The cooled sample with 70 *ml* of water was blended in a Waring blendor for 2 min. The fiber caught on 30 mesh screen was tranferred to filter paper in a Büchner funnel and then weighed fibrous residue after dried to a constant weight at 100°. Fiber content was expressed as percent based on corrected fresh weight of sample.

4. Chlorophyll determination

Asparagus with 3/8 to 4/8 inch diameter at 4 inches from tip was used for determination. Two inch cuts (2 to 4 inches from tip) were diced, and 20 *g* of weighed sample was homogenized with 80 *ml* of acetone in a Sorvall omni-mixer at high speed for 1.5 min and filtered through a sintered glass suction funnel. The residue was washed with 80% acetone and the volume of filtrate was made to 250 *ml*. The conversion sample was prepared by placing 3 *ml* of saturated oxalic acid in 80% acetone in a volumetric flask and diluting to 100 *ml* with

the filtered extract. The absorbances of samples were determined at 536, 645, 662, 666, and 750 *nm* and the chlorophyll content was calculated by the equation described by Vernon[13].

5. Reflectance color

Color of asparagus spears was determined using a Hunterlab Model D 25 color and color difference meter. Spears cut into 6 inches (2 to 8 inches from tip) were placed in a sample cell (6×6×2 inches: length×width×height) such that light would not pass through the sample. The cell was placed on the aperture and covered to exclude any room light from striking the photocells.

Results and Discussion

Bacterial soft rot

The results in Table 1 showed that controlled atmosphere(CA) was markedly effective in reducing bacterial soft rot of stored asparagus. 'Butts in water' stored in normal atmosphere (NA) and CA had significantly less bacterial soft rot than the corresponding control. 'Butts in water' in combination with CA was the best method to reduce bacterial soft rot of stored asparagus, extending the storage life to over 3 weeks.

Bacterial infection invariably caused the characteristic milky exudate of nauseating odor which degraded fresh quality of asparagus considerably. CA storage significantly reduced off-odor development of stored asparagus.

Table 1. Beacterial soft rot of stored asparagus

Storage period (Days)	Norml atmosphere		Controlled atmosphere	
	Control	Butts in water	Control	Butts in water
7	0%	0%	0%	0%
14	16	1	1	0.4
21	74	16	21	0.4
28	90	47	58	23
Mean	45[a]	16[b]	20[b]	6.2[c]

Note: Means with same letter are not significantly different from each other.

These findings were in agreement with Lipton's statement[14] that increasing levels of CO_2 reduced the incidence and severity of bacterial soft rot infection at the tip of the spear. He also found that O_2 concentration has little effect on soft rot either in the presence or absence of CO_2.

Changes in shear force

The results in Table 2 indicated that shear force generally increased during storage. Neither CA nor 'Butts in water' showed any noticeable effect on shear force of stored asparagus.

Researchers[12,15,16] found that texture of post harvest asparagus became tougher during storage and the level of crude fiber increased with time in storage.

Table 2. Changes in shear force (pounds) of asparagus pears during storage

Storage period (Days)	Normal atmosphere		Controlled atmosphere	
	Control	Butts in Water	Control	Butts in water
Initial	20.7	20.7	20.7	20.7
7	21.6	20.3	21.1	22.5
14	22.6	24.3	20.8	21.8
21	23.4	19.5	22.0	21.3
Mean	22.1[a]	21.2[a]	21.2[a]	21.6[a]

Note: Means with same letter are not significantly different from each other.

Fiber changes

Fiber content in asparagus generally increased with storage time, except CA in combination with 'Butts in water' (Table 3). Asparagus stored in CA had less fiber increase than that stored in NA. Fiber content in asparagus stored in CA with 'Butts in water' actually decreased during storage.

Table 3. Changes in fiber content(%) in asp-a ragus during storage

(Unit : $\times 10^{-3}$%)

Storage period (Days)	Normal atmosphere		Controlled atmosphere	
	Control	Butts in water	Control	Butts in water
Initial	21	21	21	21
7	19	18	18	21
14	24	18	17	17
21	42	29	34	19
28	38	23	35	15
Mean	29[a]	22[b]	25[b]	19[c]

Note: Means with same letter are not significantly different from each other.

Since there was some stem elongation during storage (1~2 inches), decrease in fiber content observed in asparagus stored in CA with 'Butts in water' might be partially due to sampling for fiber determination at a specific distance from the tip. Carolus *et al*[15] found that fiber levels in stored asparagus decreased with increasing CO_2 levels. Lougheed and Deway[16] indicated that most of the tenderizing effects appeared to be the result of a breakdown of inter cellular components.

Changes in chlorophyll content

Chlorophyll content in stored asparagus decreased as the storage was extended(Table 4). After 4 week storage, about 35% of chlorophyll was destroyed in asparagus stored in NA and about 29% in CA, and this difference was statistically significant.

Wang[9] reported that there was more retention of chlorophyll in the controlled atmosphere stored asparagus and that the degradation products of chlorophyll in CA stored asparagus was exclusively pheophytins.

The mechanism of chlorophyll retntion in CA was suggested by researchers[9,17,18]. James[17] suggested that chlorophyll became labile when the protein attached to the chlorophyll molecule within the chloroplast was degraded.

Table 4. Changes in chlorophyll content during post harvest storage of asparagus

(Unit: *mg* of total chlorophyll/100 *g* of fresh weight)

Storage period (Days)	Normal atmosphere		Controlled atmosphere	
	Control	Butts in water	Control	Butts in water
Initial	39.7	39.7	39.7	39.7
7	34.7	35.6	35.7	36.0
14	30.7	31.6	32.5	34.7
21	25.6	28.1	28.5	29.2
28	25.5	26.5	28.5	28.6
Mean	31.1[a]	32.3[b]	32.9[b]	33.7[c]

Note: Means with same letter are not significantly different from each other.

Degradation of protein in plant tisstes is a natural process in the plant senescence which is generally regulated by plant hormones. It could be assumed that the formation of hormones regulating the plant senscence would be decreased in atmosphere with low O_2 and high CO_2 concentrations.

Changes in reflectance color

A function of chroma, $\sqrt{a^2+b^2}$, increased during storage and this increase was mainly due to increase of b values (Table 5). This indicated that yellowness of stored asparagus increased during storage. Tristimulus values of Hunter color and

Table 5. Changes in reflectance color of asparagus during storage

Storage period (Days)	Normal atmosphere				Controlled atmosphere			
	Control		Butts in water		Control		Butts in water	
	$\sqrt{a^2+b^2}$	ΔE	$\sqrt{a^2+b^2}$	ΔE	$\sqrt{a^2+b^2}$	ΔE	$\sqrt{a^2+b^2}$	ΔE
Initial	19.8	0.0	19.8	0.0	19.8	0.0	19.8	0.0
7	19.4	0.03	20.1	1.3	18.9	1.1	19.7	1.3
14	21.1	1.8	19.8	1.3	18.7	1.1	20.6	1.3
21	20.7	1.7	20.1	1.6	20.2	0.5	21.2	2.0
28	21.7	3.1	19.9	1.7	20.2	1.5	21.0	1.8

Note : $\Delta E = \sqrt{\Delta L^2+\Delta a^2+\Delta b^2}$

color difference meter were further reduced to total color difference (ΔE). Tristimulus values of initial sample was taken as base values, and then color difference between the initial sample and stored samples were calculated. The results in Table 5 showed that ΔE generally increased as the storage period was extended, The increase of ΔE was mainly due to increase of L values (brightness) ane b values (yellowness), which suggested that the stored asparagus became more yellow and bright as the storage period was extended.

The relationship between reflectance color and

chlorophyll content was examined and the results are shown in Table 6. L, $\sqrt{a^2+b^2}$, and ΔE had statistically significant correlation with chlorophyll content in stored asparagus. Among reflectance color values evaluated, ΔE showed more reliable relationship with chlorophyll content in stored asparagus.

These results suggested that color changes in asparagus during storage could be evaluated by measuring reflectance color value, without time consuming chlorophyll analysis.

Table 6. The relationship between chlorophyll content and reflectance color of stored asparagus

Reflectance color	Linear regression equation	Correlation coefficient
L	$Y=-0.107\times44.61$	$r=-0.64^{**}$
$\sqrt{a^2+b^2}$	$Y=-0.105\times23.42$	$r=-0.56^{*}$
ΔE	$Y=-0.114\times4.92$	$r=-0.69^{**}$

Notes: Y : Reflectance color values
X : Chlorophyll content
*, ** : indicated statistical significance at 95% and 99% levels, respectivety.

요 약

생아스파라가스의 저장기간을 연장하기 위하여, 아스파라가스(*Viking* variety)를 정상 대기 저장과 C.A. 저장을 하였다. 이때, 밑부분을 물에 담근것과 물에담그지 않은 것으로 나누어 처리하였다.

CA 저장은 아스파라가스의 경우 박테리아에 의한 무름병이 발생하는 것을 현저하게 감소시켰으며, 밑부분을 물에 담그어 CA 저장을 한결과 무름병 없이 3주일이나 저장할 수 있었다.

섬유질의 분석과 인스트론(Instron)을 이용하여 저장한 아스파라가스의 조직변화를 관찰하였는바, 저장기간이 늘어남에 따라 차츰 질겨지는 것을 볼 수 있었다. 아스파라가스의 섬유질함량은 CA 저장에 의하여 그 증가폭이 훨씬 둔화되었고, 밑 부분을 담그어 CA 저장을 한 경우 섬유질의 양은 줄어드는 것으로 나타났다.

CA 저장에 의한 경우 정상 대기 저장에 비하여 아스파라가스 중의 엽록소 파괴는 훨씬 적게 나타났으며, Reflectance color value와 엽록소 양과는 서로 유의성 있는 상관관계를 나타내고 있다.

저장한 아스파라가스의 품질을 변화시키는 여러가지 요인을 고려할 때 밑부분을 물에 담그어 CA 저장을 하는 것이 아스파라가스의 품질을 3주일 이상 유지시켜 주는 가장 좋은 방법이라 할 수 있겠다.

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