Effect of High Oxygen Modified Atmosphere Packaging on Fresh-Cut Onion Quality

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Abstract: The high oxygen modified atmosphere packaging is effective to the vegetable, but there is rare study about its effect to fresh-cut onion. This work investigates the effect of high oxygen modified atmosphere packaging on the quality of fresh-cut onion at room temperature. In order to study the effect of different oxygen concentration on the quality of fresh-cut onion, onion slices on the polypropylene (PP) trays were packaged in a package of $18\times24cm^2$ high-barrier film of 70 μ m thickness. Onion slices were stored in five different modified atmospheres which including 100% O_2, 95%O_2/5%CO_2, 80%O_2/20%CO_2, 75%O_2/25%CO_2 and air. The physics, chemistry and microbe characteristics were selected as primary quality indexes. The study showed that the weight loss and respiration rate of high oxygen modified atmosphere packagings were remarkable smaller than the air packaging during the storage; The total reducing sugar decreased during the storage, but the package with 80%O_2/20%CO_2 reduced slower relatively; The total titratable acid increased slower in the high oxygen than in the air; The total soluble solid content also reduced during the storage, but there was no remarkable difference in the different modified atmosphere packagings; The total bacterial count of all the packages increased slower in the first 2 days, after that the total bacterial count of fresh-cut onion in the high oxygen modified atmosphere packaging increased remarkable slowly compared with in the air. It showed that the total bacteria counts of the high oxygen modified atmosphere packaging with 80% O_2/20%CO_2 increased slowest relatively, and the total bacteria counts increased to 10^5 CFU/g after 7 days. All the fresh-cut onions besides the high oxygen modified atmosphere packagings with 80%O_2/20%CO_2 and 100% O_2 were gently rotten after 4 days. Summarizing all the primary quality indexes of the fresh-cut onion during the storage, the high oxygen modified atmosphere packaging with 80%O_2/20%CO_2 could obtain longer shelf-life at room temperature.

Keywords: high oxygen; fresh-cut onion; shelf life; microbial quality; sensory quality; modified atmosphere packaging

1. Introduction

Onions is the most widely available vegetables. Many people in the world like it because it has plentiful nutrition and tastes delicious. As the faster life rhythm of modern people, the fresh-cut fruits and vegetables are more and more welcome. However, good sensory quality is required for fresh-cut products and the vegetable processing industry requires the development of preservation techniques capable of keeping safe shelf-life and preserving the original organoleptic fresh-cut characteristics of fresh-cut onion.

Low O_2 modified atmospheres packaging has been used to extend the shelf-life of fresh-cut fruits and vegetables, helping to reduce respiration and ethylene production, inhibiting or delaying enzymatic reactions and preserving the product from quality losses. Atmosphere modification can also substantially delay the growth of most aerobic spoilage microorganisms. However ,under certain conditions, the growth of some anaerobic psychotrophic pathogens might be allowed or even stimulated [1], and excessively low O_2 levels are often detrimental to the fruits and vegetables shelf-life because anaerobic respiration is induced, leading to fermentation processes, and the subsequent production of undesirable metabolites [2]. At the present time, the key to successful low O_2 modified atmospheres packaging of fresh-cut fruits and vegetables is to establish equilibrium modified atmosphere, optimally 3-5% O_2 and 3-10% CO_2 (balance N2), by choosing the packaging film with the correct permeability for O_2 and CO_2. Due to the respiratory nature of fresh fruits and vegetables, the development of hazardous anaerobic conditions and undesirable fermentation reactions within low O_2 modified atmosphere packaging may occur when stored at higher temperatures. During retail of low O_2 modified atmosphere packaging, temperature fluctuations are unavoidable [3]. Moreover, as the respiration rate differs stronglu from vegetable to vegetable, packaging films with a different permeability for O_2 are necessary to package a range of vegetables [4]. This is, from a logistic point of view, not very convenient for producer.

A alternative for low O_2 modified atmosphere packaging, used for prolonging the shelf-life of respiring ready-to-eat vegetables, can be packaged under high Oxygen atmospheres(HOA) [5]. The application of high

O_2 concentration (i.e. ＞ 70% O_2) could overcome the disadvatages of low O2 modified atmosphere packaging for some fresh-cut vegetables. High O_2 was found to be particularly effective in inhibiting enzymatic discoloration, preventing anaerobic fermentation reactions and inhibiting microbial growth [6]. In addition, the high O_2 modified atmospheres packaging was found to be very effective at reducing decay of the fresh prouduce [7]. Under high O_2 modified atmospheres packaging, it is hypothesized that reactive oxygen species damage vital cellular macromoleccules and thereby inhibit microbial growth when oxidative stress overwhelm cellular antioxidant protection systems [8]. Amanatidou et al [9] studied the impact of high O_2 modified atmosphere packaging on microorganims associated with minimally-processed vegetables. When high O_2 was applied alone, the inhibitory effect on microbial growth was highly variable. Inhibition was more pronounced when the elevated O_2 concentration was combined with an elevated CO_2 concentration.

The high O_2 modified atmospheres packaging had been used to some vegetables and fruits, such as minimally processed carrots [10], strawberry [11], minimally processed baby spinach [12], fresh-cut mango [13], apple slices [14] and so on. It had been approved to be effective to prolong the shelf life of some fresh-cut vegetables and fruits.

In the present there are not enough cold chain systems in China supermarkets, many fresh-cut fruits and vegetables have to be preserved at room temperature. So the objective of this work was to study the effect of high O2 modified atmospheres packaging to fresh-cut onion at room temperature with four high O_2 modified atmosphere packaging systems: 100% O_2, 95%O_2/5%CO_2, 80%O_2/20%CO_2, 75%O_2/25%CO_2, and compare with air packaging.

2. Materials and methods

2.1. Materials

All the onions were bought from a local wholesale market on the day of their arrival, the onions were sorted to remove injured onions and to obtain onions of uniform size and color. First the onions were peeled and cut into slices with a sharp stainless steel knife, then the onions were washed for 1 minute in potable water and manually spin dried. The fresh-cut onions were packaged with 100 g on the polypropylene(PP) tray in a package of 18×24 cm^2 high barrier film of 70 μ m thickness and oxygen tansmission rate of 3.25 mLO_2 /m^2 24 h atm at 23 ℃ and 0% RH. All the fresh-cut onions were stored at room temperature.

During storage, the sensory quality and microbiological quality were regulary analyzed (day 0, 2, 4, 7, 9).

2.2. Packaging of the onions

The different gas mixed proportion in the packages was achieved actively by using a gas packaging unit composed of gas mixer (DZQ-F1, Deshun, China) and a vacum compensation chamber (DQB, Yongchang, China). The gas combinations were applied (balanced by CO_2) : 100% O_2 , 95% O_2 , 80% O_2 and 75% O_2 and air as reference. The packages were flushed for 1 min with the selected gas conbination in order to remove the intrinsic gas in the package. After flushing, the packages were heat sealed and stored at room temperature.

2.3. Weight loss

During storage, the weight loss due to transpiration and respiration of the fresh-cut onions were followed (expressed as a percentage of the original weight of the packaged fresh-cut onion), by weighing the fresh-cut onion each day of the experiment.

2.4. Determination of respiration rate

Respiration rate of fresh-cut onions was determined by static state method [15]. The fresh-cut onions and 0.4 N NaOH were put in the same obturation airer, the CO_2 due to respiration will go down and be absorbed by NaOH. The NaOH was broken out and counteracted with 0.1N oxalic acid, gained the respiration rate through the count formula. The respiration rate was expressed as CO_2 mg/kg h.

2.5. Determination of total reducing sugar, total titratable acidity, and total soluble solids

Fresh-cut onions (25 g) were homogenized and filtered, and the filtered pulp were analysed for total reducing sugar, total tiratable acidity and total soluble solids. The reducing sugar was determined by straight titration (GB5009.7-85). The total titratable acidity was determined by diluting each 5mL aliquot of fresh-cut onion filtered pulp in 50 mL distilled water and then titrating to pH 8.2 using 0.1N NaOH, total titratable acidity was expressed as grams of anhydrous citric acid in 100 g of fresh-cut onion weight. Soluble solids content was determined using refractometer.

2.6. Determination of microbial quality

Triplicate samples of each treatment were used to assess the quality attributes of the stored products. Aerobic bacteria growth, expressed in colony-forming units (CFU) per gram, were quantified as the major indices of microbial quality. Samples (25 g) of the fresh-cut onions were aseptically transferred into sterile stomacher bags, to which 75 mL of sterile 0.5% peptone water was then added. The samples were then homogenized in a stomacher for 4 mins. Aliquots of 1 mL were plated directly onto plate count agar for total bacteria counts.

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Table 1.Changes in weight loss (%) of fresh-cut onions during storage at room temperature

Storage time (days)	air (%)	75% O_2 (%)	80% O_2(%)	95% O_2(%)	100% O_2(%)
2	2.32	0.33	0.45	0.41	0.37
4	7.63	1.11	0.85	0.44	0.42
7	10.73	1.60	1.57	1.20	1.00
9	13.21	2.13	1.96	1.85	1.60

Table 2.Changes in respiration rate (CO^2 mg/kg h) of fresh-cut onions during storage at room temperature

Storage time (days)	air (CO_2 mg/kg h)	75% O_2 (CO_2 mg/kg h)	80% O_2 (CO_2 mg/kg h)	95% O_2 (CO_2 mg/kg h)	100% O_2 (CO_2mg/kg h)
0	440	440	440	440	440
2	460	306	263	246	224
4	483	416	374	314	211
7	602	591	552	422	418
9	342	283	264	218	332

2.7. Sensorial quality

The sensorial quality of the packaged fresh-cut onions was regularly evaluated by a trained taste panel consisting out of minimum six persons. Before the experiment started, the typical characteristics of the onion and the possibilities of deterioration were explained. All sensorial tests were performed in a special taste room with separated boxes and IR light. Organoleptical properties such as taste, flavour, odour and texture (perception of the mouthfeel) were evaluated under IR light to exclude influence of the visual characteristics. The visual properties(colour, dryness, general appearance) were judged under normal light. A numerical score between 1 (= excellent) and 10 (= extreme bad) was given for each property to describe the sensorial quality of the fresh-cut onions. The cut off score was defined at score 5. Below this score, the sample was still acceptable.

2.8. Statistical analysis

The storage experiment was conducted in duplicate (three packages per measurement). Results of quality indexes were given by the mean.

3. Results and discussion

3.1. Weight loss

During the 9 days of storage (Table 1), significant differences of the weight loss of fresh-cut onions were observed, the fresh-cut onions in all the air packages lost significantly more weight than all the high O_2 modified atmosphere packages fresh-cut onions, and the weight loss of all the high O_2 modified atmosphere packages were never exceed 3%,while the weight loss of the fresh-cut onions packaged with air lost more than 10%

Table 3. Changes in total reducing sugar, total titratable acidity and total soluble solids during storage at room temperature

Storage time (days)		total reducing sugar (g/100g)	total titratable acidity (g/100g)	total soluble solids (%)
0		4.78	0.036	1.37
2	Air	3.10	0.041	1.25
	75% O_2	3.32	0.038	1.33
	80% O_2	3.94	0.037	1.36
	95% O_2	3.46	0.038	1.32
	100% O_2	3.63	0.040	1.28
4	Air	2.37	0.048	0.90
	75% O_2	2.55	0.032	0.90
	80% O_2	3.30	0.032	1.01
	95% O_2	2.65	0.034	1.00
	100% O_2	3.10	0.037	1.00
7	Air	1.92	0.058	0.70
	75% O_2	2.24	0.040	0.80
	80% O_2	2.91	0.038	0.91
	95% O_2	2.30	0.040	0.90
	100% O_2	2.41	0.042	0.90
9	Air	1.84	0.062	0.60
	75% O_2	2.11	0.045	0.70
	80% O_2	2.80	0.042	0.80
	95% O_2	2.15	0.046	0.70
	100% O_2	2.56	0.049	0.70

Table 4.Changes in bacteria counts (log_{10} cfu g^{-1}) of fresh-cut onions during storage at room temperature; values > 10^5 cfu g^{-1} are indicated in bold[18]

Storage time (days)	air (log_{10} cfu g^{-1})	75% O_2 (log_{10} cfu g^{-1})	80% O_2 (log_{10} cfu g^{-1})	95% O_2 (log_{10} cfu g^{-1})	100% O_2 (log_{10} cfu g^{-1})
0	2.34	2.34	2.34	2.34	2.34
2	3.28	3.06	2.91	3.32	3.68
4	**5.62**	4.16	3.65	4.34	4.69
7	**6.87**	**5.71**	**5.03**	**5.92**	**6.24**
9	**8.42**	**7.53**	**6.21**	**7.63**	**7.87**

Table 5.Changes in sensorial quality score of fresh-cut onions during storage at room temperature

Storage time (days)	air	75% O_2	80% O_2	95% O_2	100% O_2
0	1.0	1.0	1.0	1.0	1.0
2	4.2	3.5	2.3	3.6	3.2
4	7.1	5.2	4.1	6.2	4.5
7	9.3	8.6	6.9	8.1	7.3
9	1 0	9.5	9.0	9.6	9.2

of their weight. The high O_2 modified atmosphere packages can effectively inhibit the weight loss of fresh-cut onions, but effection is not visible between different O_2 concentrations. Similar results were observed for fresh-cuts bell peppers storaged at 14℃[16]. These results indicate that the high O_2 modified atmosphere packages can effectively inhibit the weight loss of the fresh-cut onions at room temperature.

3.2. Respiration rate

The respiration rate of the fresh-cut onions is obviously increscent comparison to the whole onion because of the fresh-cut process. But significant differences in CO_2 production were found at different atmospheres (Table 2). Treatments under high O_2 modified atmosphere packages commonly showed smaller CO_2 production than the fresh-cut onions in the air. The result indicated that the high O_2 modified atmosphere packages can effectively effection was increased as the increase of the O_2 concentration. The respiration rate of all the packages with air or high O_2 concentration was increased from second day to seventh day during the storage due to the metabolic activity and apace decline after seventh day. On the one hand the O_2 concentration in the packages continuously declined and the inhibitory effect to respiration rate was depressed, so the respiration rate was increased from second day to seventh day. On the other hand the respiration substance was consumed with respiratory metabolism, so the respiration rate declined when the respiration substance was not enough.

3.3. Total reducing sugar, total titratable acidity, and total soluble solids

Total reducing sugar of the fresh-cut onions continuously decreased during 9 days of storage at room temperature (Table 3). However the degressive speed of the total reducing sugar with high O_2 modified atmosphere packages was correspondingly slower than the air-treated fresh-cut onions. The result indicated that the high O_2 modified atmosphere packages can aptly delay the decrease of total reducing sugar, and the effection of package with 80% O_2 /20% CO_2 is better.

3.4. microbial quality

Debever (1996) proposed microbiological criteria for minimally processed fruit [18]. The limit for yeast is fixed at 10^5 cfu g^{-1}, because above this number spoilage of products due to yeast growth becomes detectable for consumers. Table 4 gives an overview of the obtained results that bacteria counts of the fresh-cut onions changed during 9 days of storage at room temperature. The limit of 10^5 cfu $g^{-1}$was already exceeded at day 4 for air-treated fresh-cut onions and was exceeded at day 7 for high O_2 treated fresh-cut onions. The result indicated that the growth of bacteria counts was inhibited by the application of high O_2 levels : an increase in the lag phase and a reduction of the maximum specific growth rate were obtained. The limit for bacteria counts should be interpreted carefully, is not necessarily rejected by this index and both microbial and sensory evaluations are important[19].

3.5. Sensorial quality

The sensorial quality score of fresh-cut onions in all the five package systems was increased during the storage at room temperature (Table 5). The applied cut off score was fixed at 5. A score above 5 indicates an unacceptable sample. At the first two days all the fresh-cut onions were edible and the scores was under 5. After 4 days the fresh-cut onions with air-treated was obvious inesculent. The scores of high O_2 modified atmosphere packages with 75% O_2/25%CO_2 and 95% O_2/5%CO_2

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were exceeded the cut off score. The fresh-cut onions, packaged with 75% O_2/25%CO_2 and 95% O_2/5%CO_2 were rejected after 7 days of storage. The result indicated that the high O_2 modified atmosphere packages is beneficial to prolong the shelf life of fresh-cut onions, and the effection of package with 80% O_2 /20% CO_2 is best. However, the mechanisms by which high O_2 atmospheres inhibit decay are yet unclear.

4. Conclusion

The fresh-cut onions were packaged in air has a short shelf-life, because the respiration rate of fresh-cut onions was quickened due to mechanical damnification and the bacteria counts rise did not be inhibited.

Applying a high O_2 modified atmosphere packaging in a high-barrier film, had a beneficial effect on the fresh-cut onions, by inhibiting the development of respiration rate and bacteria counts rise. High O_2 modified atmosphere packaging can effectively reduce the weight loss, respiration rate, total reducing sugar loss, bacteria counts rise, total titrable acidity rise of the fresh-cut onions and maintaining fresher sensory properties. The sensory quality of high O_2 packaged fresh-cut onions was shown to be acceptable up to 5 days, while air packaged fresh-cut onions were not acceptable after 2 days of storage at room temperature.

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