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Analysis Of Present Commercial Packages Applied On Fresh Vegetables

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I. INTRODUCTION

Modified atmosphere packaging (MAP) which modifies the O_2 and CO_2 concentrations in the packages could prolong the shelf life of fresh produce [1]. Desired MAP is achieved through the interaction between two processes: the respiration of produce and the transfer of gases through the packaging material [2,3,4]. The suitable in-package atmosphere could prolong the shelf life of the fresh product. In present market, the plastic films are common used to package the fresh product. But whether they are suitable to the product or whether the atmospheres inside the packages could be modified by the interaction of gas permeability of the film and respiration rate of product is still unknown. Temperature plays a very important role in designing MAP for its dramatic influence on respiration rate and gas permeability. Respiration rate of fresh produce is influenced by temperature dramatically during the whole distribution and retailing procedures. Therefore, the analysis of the gas permeability and respiration rate which are influenced by temperature is very important for the establishment of the in-package atmosphere and should be researched.

The objective of this study is to investigate the effect of temperature on respiration rate of some selected vegetables, and analyze the adaptability of present plastic packages.

II. INVESTIGATION OF MAP OF SELECTED VEGETABLES

2.1 Produce and sample preparation

The samples in this study contained seven categories of vegetables: Shiitake mushroom, Maitake mushrooms, Enokitake mushrooms, Long bean, Green hot pepper, Edamame and Baby leaf (mixed young leaves). The samples were stored in the 10, 15 and 20℃ instant temperature and humidity storage rooms for 2 h till the core temperature reached to the storage room temperature. Then the gas concentration and respiration rate were detected.

2.2 Film identification, thickness detection and gas transmission rate detection

The package films unknown were identified by Fourier Transform Infrared Spectrometer (Magna-IR Spectrometer 560, Nicolet, USA) with the analysis software of OMNIC. And spectrums were compared with the reference spectrum and the film could be identified.

The film thickness was detected by digital thickness tester (0-25 mm, 0.001 mm, Mitutoyo, Japan). O_2 transmission rate (OTR) and CO_2 transmission rate (CTR) at 10, 15 and 20℃ with Gas Barrier Testing System (GTR-30X, GTR Tec Corporation, Japan) along with a Gas Chromatograph (GC 2700, Yanaco, Japan).

2.3 Determination of gas concentration and respiration rate

The O_2 and CO_2 concentrations were determined by a gas chromatograph (GC-8A, Shimadzu, Japan) with a thermal conductivity detector (TCD), and the packed column ZY-2 consisting of Molecular Sieve 5A column, Porapak Q column and Shimalite Q column. The carrier gas was helium with 0.67 $ml \cdot s^{-1}$ flow rate. Column temperature was 75℃; injector and detector temperature was 80℃.

The oxygen consumption rate (RO_2) and carbon dioxide production rate (RCO_2) of whole vegetables were measured using the closed system method. Air-tight organic glass jars of 3 L with a lid and rubber septum in the middle were used to and the samples were stored at different temperatures (10, 15 and 20℃). Gas samples of 1 ml were withdrawn from the head space through rubber septum and injected to the GC hourly for 2 hours.

RO_2 and RCO_2 were calculated with the following equations (1) and (2).

$$RO_2 = (KO_2 \times V_f) / m \quad (1)$$

$$RCO_2 = (KCO_2 \times V_f) / m \quad (2)$$

where RO_2 is oxygen consumption rate and RCO_2 is carbon dioxide production rate which can be expressed as $mg \cdot kg^{-1} \cdot h^{-1}$; KO_2 KCO_2 are the slopes of oxygen and carbon dioxide concentration percent versus time curve respectively which can be expressed as $\% \cdot h^{-1}$; V_f is the free volume of container that subtracted the sample's volume from the container volume and expressed as liter; m is the mass of the produce and expressed as kg.

Respiration rate measurements may also be used to calculate the respiratory quotient (RQ), which is the ratio of CO_2 produced to O_2 consumed (RCO_2/ RO_2). Changes in RQ can indicate the nature of the substrates utilized by the tissue, and also whether anaerobic respiration is occurring[5,6].

2.4 Statistical analysis

All the results were expressed as mean values± standard deviation (SD). All data were analyzed by analysis of variance (ANOVA).

III. RESULT AND DISCUSSION

3.1 Comparison of packages of the vegetables and in-package gas concentration

Compared with the peaks of authentic films, the film applied on Shiitake mushroom, Maitake mushroom, Long bean and Green hot pepper could be judged as EVA film, and on Enokitake mushroom, Edamame and Baby leaf could be judged as PP film.

3.2 Effect of temperature on respiration rate and respiratory quotient

Table 1 described the significance of differences of respiration rate and respiratory quotient (RQ) at different temperatures. But among them, Shiitake mushroom, Enokitake mushroom and Green hot pepper showed significant increases of O_2 consumption rate with the temperature increasing. Especially shiitake mushroom had a RO_2 increase from 114.16 $mg \cdot kg^{-1} \cdot h^{-1}$ to 312.40 $mg \cdot kg^{-1} \cdot h^{-1}$ and a RCO_2 increase from 98.22 $mg \cdot kg^{-1} \cdot h^{-1}$ to 359.74 $mg \cdot kg^{-1} \cdot h^{-1}$ when temperature increased from 10 °C to 20 °C, and a significant difference between 10, 15 and 20 °C as well as an extremely significant difference between 10 and 15 °C. The huge increment indicated that respiration rate of shiitake mushroom is susceptible to temperature which called for a proper storage and distribution temperature to prolong the shelf life. But the CO_2 production rates of all the seven kinds of vegetables were significantly influenced by temperature. Normal respiratory quotient (RQ) values limit with 0.7 to 1.3 for aerobic respiration [7]. Shiitake mushroom, Enokitake mushroom, long bean showed the extremely significant increases and green hot pepper showed the significant increase of RQ with the temperature increasing. Therefore, Shiitake mushroom, Enokitake mushroom, long bean are very easy to be induced to anaerobic respiration when the O_2 concentration depletes to low level.

Normal respiratory quotient (RQ) values limit with 0.7 to 1.3 for aerobic respiration [7]. Shiitake mushroom, Enokitake mushroom, Long bean showed the extremely significant increases and Green hot pepper showed the significant increase of RQ with the temperature increasing. Therefore, Shiitake mushroom, Enokitake mushroom, Long bean have greater possibility to induce the anaerobic respiration when the temperature increasing.

Table 1 Changes in O_2 consumption rate (RO_2), CO_2 production rate (RCO_2) and respiratory quotient (RQ) at 10, 15 and 20 °C

	T (°C)	Shiitake mushroom	Maitake mushroom	Enokitake mushroom	Long bean	Green hot pepper	Edamame	Baby leaf
RO_2 ($mg \cdot kg^{-1} \cdot h^{-1}$)	10	114.16 ± 10.26^{cB}	115.57 ± 23.74^{aA}	165.01 ± 18.02^{bB}	30.75 ± 0.65^{cC}	112.10 ± 15.03^{cB}	95.52 ± 7.43^{bB}	60.23 ± 16.18^{bB}
	15	228.87 ± 33.66^{bA}	109.71 ± 6.14^{aA}	173.67 ± 1.42^{bB}	39.08 ± 0.49^{bB}	185.82 ± 57.76^{bB}	103.12 ± 2.52^{bB}	73.87 ± 3.63^{bB}
	20	312.40 ± 39.63^{aA}	137.28 ± 9.08^{aA}	278.21 ± 2.87^{aA}	54.06 ± 3.10^{aA}	296.75 ± 0.78^{aA}	150.89 ± 1.94^{aA}	110.60 ± 11.66^{aA}
RCO_2 ($mg \cdot kg^{-1} \cdot h^{-1}$)	10	98.22 ± 4.54^{cB}	97.16 ± 8.87^{bB}	64.53 ± 13.33^{bB}	37.76 ± 0.41^{bB}	188.27 ± 21.75^{bB}	130.48 ± 23.43^{bB}	64.57 ± 10.74^{bB}
	15	260.91 ± 40.51^{bA}	110.70 ± 3.95^{bB}	78.20 ± 12.73^{bB}	43.08 ± 1.44^{bB}	200.45 ± 15.20^{bB}	108.42 ± 5.07^{bB}	74.15 ± 6.27^{bB}
	20	359.74 ± 47.85^{aA}	146.51 ± 14.64^{aA}	154.78 ± 8.29^{aA}	64.36 ± 4.37^{aA}	310.73 ± 26.27^{aA}	189.70 ± 8.51^{aA}	117.06 ± 14.04^{aA}
RQ	10	0.86 ± 0.04^{bB}	0.87 ± 0.19^{aA}	0.39 ± 0.04^{bB}	1.23 ± 0.02^{aB}	1.70 ± 0.29^{aA}	1.36 ± 0.14^{aA}	1.14 ± 0.39^{aA}
	15	1.14 ± 0.02^{aA}	1.01 ± 0.02^{aA}	0.45 ± 0.07^{bAB}	1.10 ± 0.04^{bAB}	1.13 ± 0.24^{bA}	1.05 ± 0.04^{aA}	1.00 ± 0.04^{aA}
	20	1.15 ± 0.02^{aA}	1.07 ± 0.04^{aA}	0.56 ± 0.02^{aA}	1.19 ± 0.04^{aA}	1.05 ± 0.09^{bA}	1.26 ± 0.04^{aA}	1.06 ± 0.08^{aA}

Mean values± standard deviations with different lowercase letters are significant different ($p \leq 0.05$), different capital letters are extremely significantly different ($p \leq 0.01$);
T: temperature (°C).

3.3 Comparison of the total O_2 transmission rate and total O_2 consumption rate

The O_2 concentration and the comparison of total O_2 transmission rate through the package films and total O_2 consumption rate by respiration of product were shown in Table 2. In this study, the extremely low O_2 concentration was created in packages of Shiitake mushroom, Maitake mushroom and Enokitake mushroom. According to the respiration rates of them, it could be explained that these three kinds of mushrooms had very high respiration rates compared with other vegetables. The oxygen transmission of the package films of these three products were 22.69, 21.90 and 13.57 ml·package^{-1}·d^{-1}, but the oxygen consumption rate of them were 211.43, 205.48 and 517.62 ml·package^{-1}·d^{-1} respectively. Although the package films are permeable, the high respiration induced the oxygen inside the package was soon consumed. The oxygen concentration was high in the packages of Long bean, Green hot pepper, Edamame and Baby leaf. For Long bean and Baby leaf, high oxygen concentration was attributed to their low respiration rate and accordingly low oxygen consumption. Although Green hot pepper had a higher respiration rate, the mass in the package was only 10.05g, which did not induce the much oxygen consumption. For edamame, although the oxygen transmission rate of the PP film applied on it was 11.92 ml·package^{-1}·d^{-1} and the oxygen consumption rate was 421.90 ml·package^{-1}·d^{-1}, still higher oxygen concentration inside the package could be created. The reason is that the package of edamame was perforated. The size of 1 mm in diameter and numbers of 30 of the perforations on each package were observed, which induced a high gas transmission and no MA effect. So the perforations of the packages for edamame should be decreased and the optimal modified atmosphere condition would be created.

	Mass of product (g)	O_2 (v/v %)	Total O_2 transmission rate from film (ml·package^{-1}·d^{-1})	Total O_2 consumption rate by respiration (ml·package^{-1}·d^{-1})
Shiitake mushroom	110.24±3.45	0.87±0.25	22.69±2.56	211.43±20.57
Maitake mushroom	105.83±3.56	0.24±0.15	21.90±2.87	205.48±35.63
Enokitake mushroom	186.72±6.78	0.28±0.13	13.57±3.12	517.62±30.25
Long bean	135.33±6.24	15.79±2.54	25.37±3.58	69.91±2.77
Green hot pepper	10.05±2.12	16.74±5.32	16.90±2.09	18.93±3.54
Edamame	262.91±10.65	13.99±3.66	11.92±3.45	421.90±15.35
Baby leaf	28.85±3.01	15.00±4.85	10.01±1.36	29.19±6.54

Table 2 Comparison of the total O_2 transmission rate and total O_2 consumption rate

IV. CONCLUSION

Temperature greatly influenced the O_2 consumption rate (RO_2) of Shiitake mushroom, Enokitake mushroom and Green hot pepper, and significantly influenced CO_2 production rates (RCO_2) of all these seven kinds of vegetables. It was also found that RQ was dependent on the temperature, and became high when the temperature increased from 10 to 20°C. Temperature also influenced the gas composition of MAP systems for many fruit and vegetables. The respiration rate of the product and the gas transmission rate of package film were also affected by temperature. Therefore, the O_2 and CO_2 levels depend on film permeability and product respiration, and the temperature dependence of these two processes is determined by film type, commodity physiology, respectively [8].

In this study, for the Long bean, Edamame, Green hot pepper and Baby leaf, the oxygen concentration was higher than 10 % which could not create the MA condition to prolong the shelf life. For the vegetables with high respiration rate (Shiitake, Maitake and Enokitake mushroom), the packages are not suitable either for the reason of the extremely low oxygen concentration in the packages and anaerobic respiration would be induced soon. It was suggested that the appropriate package types should be considered to modify the in-package atmosphere and to avoid the anaerobic fermentation and prolong the shelf life of them.

Therefore, for Shiitake, Maitake and Enokitake mushrooms, in-package oxygen concentrations were extremely low for the reason of high oxygen consumption by respiration and low oxygen transmission from film. So the suggestive solution is to improve the film gas transmission rate or increase the initial oxygen concentration. Decreasing the mass of produce is not suggested because of the waste of package materials and the high cost. For Long bean, Green hot pepper and Baby leaf, the MA atmosphere was not created for the too high oxygen concentration inside the packages, and the respiration won't be inhibited, and the suggestions for these three vegetables are to select the package film with lower gas permeability or increase the mass of being packaged produce. For Edamame, perforation-mediated method was suggested, but the number of perforations should be decreased.

In the further study, we will select the shiitake mushroom as the experimental samples and research for the optimal packaging condition for fresh shiitake mushrooms.

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