J. Trop. Agric. and Fd. Sc. 34(1)(2006): 67–76

Effect of different packagings and storage temperatures on the quality of fresh-cut red chilli

(Kesan pembungkusan dan suhu penyimpanan yang berbeza terhadap kualiti hirisan segar cili merah)

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Key words: minimally processed, packaging methods, storage temperature, quality changes, red chillies

Abstract

The effect of three different types of packaging namely, 250 ml polypropylene (PP) semi-rigid container, airtight PVC (aPVC) and non-airtight PVC (nPVC) containers was evaluated for storage of minimally processed (MP) chilli. The samples were stored at 2 °C for 4 weeks and 25 °C for 3 days. There was significant ($p < 0.05$) changes in carbon dioxide (CO_2) and ethylene (C_2H_4) production, and slight changes in total titratable acidity (TTA) and ascorbic acid (AA) content during storage at 25 °C. At 2 °C, the changes of TTA and AA content, CO_2 and C_2H_4 production rates of MP chilli were reduced significantly ($p < 0.05$).

The percentage of weight loss of MP chilli packed in nPVC was significantly ($p < 0.05$) increased during storage at 2 °C and at 25 °C. It caused faster dehydration. This occurrence can be prevented by using PP and aPVC packages. MP chilli in aPVC softened and became soggy quickly which might be due to condensation of water vapour from respiration and low O_2 content in packages resulted in alcoholic fermentation. Microbiological analysis of MP chilli indicated a reduction in coliform contamination and increment in yeast and mould for all samples during storage at 2 °C. The storage life of MP chilli packed in PP can be maintained up to 4 weeks at 2 °C. However, at 25 °C the product can be stored for only 2 days. Therefore, PP container can be used for commercial packing of MP chillies at 2 °C compared to aPVC and nPVC.

Introduction

Fresh pungent chilli has greatly increased in demand and well recognized as a very important ingredient in food preparation (Lownds et al. 1994) as a spice or vegetable (Poulos 1992). Chilli is high in carotenes (8,974 mg/100 g), ascorbic acid (175 mg/100 g), potassium (419 mg/100 g), and phosphorus (80 mg/100 g) (Tee et al. 1997). The hotness or pungency in chilli is due to capsaicin compound (Adinan 1981). Fresh chilli in domestic market are red chilli, green chilli and chilli padi, however, per capita consumption of red chilli is much higher (3–6 times) than others (Adnan 1992).

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Minimal processing for fresh produce involves washing, trimming, peeling, shredding, slicing, grating, coring, dicing, sticking etc. The operations greatly depend on the type of produce and how it is normally consumed. Minimal processing usually increases the degree of perishability due to disruption of cell tissues and breakdown of cell membranes, increases the respiratory rate (Wong et al. 1994), ethylene production (Gordon 1992), surface dehydration and water loss (Barry-Ryan and O'Beirne 1998). All these activities will limit the shelf life (Lownds et al. 1994).

Suitable storage temperature and types of packaging are important factors in maintaining the quality and extending the shelf life of MP vegetables (Osornio and Chaves 1998). Packaging can prevent the produce from drying by creating an atmosphere with a high relative humidity. It can also modify the headspace of the atmosphere yielding high levels of CO_2 and low levels of O_2. Packaging slows maturation and delays changes in acidity, soluble solids, texture, colour and polygalacturonase (Nakhasi et al. 1991) and reduces water loss (Wall and Berghage 1996). Packaging can also be used to create brand names associated with freshness of a produce, besides convenient to handle and maintain an attractive appearance of the product (Bussel and Kenigsberger 1975). This study was conducted with the aim to determine the suitable type of packaging for MP chilli during storage.

Materials and methods

Red chillies *(Capsicum annuum)* at commercial maturity were bought from a local market at Sungai Besi, Kuala Lumpur. Samples were brought to the MARDI Serdang laboratory for selection. Only chillies with full red colour were chosen. Samples with green/dark colour, blemish and physiological defects were removed. Selected samples were washed with chlorinated water to remove dirt, fungicide residue and microbes. Samples were cut into rings with an average thickness of 2 mm. Cut chillies were then immersed in chilled water containing 1% calcium chloride ($CaCl_2$) for about 1 min.

Samples were drip-dried to remove excess water prior to packing with three different types of packaging; 250 ml polypropylene (PP) semi-rigid container, airtight PVC (aPVC) and non-airtight PVC (nPVC) containers. Samples were stored at 2 °C for 4 weeks. Temperature of 25 °C was regarded as control temperature. Physical and chemical changes were noted and microbiological test was carried out daily for samples kept at room temperature (25 °C) and every 3 days for samples stored at 2 °C. Three containers from every packing treatment at the different storage temperatures were used as replication.

Physical measurement

Physical measurement was conducted visually for quality changes (colour, texture, odour and taste, development of chilling injury and blemishes symptoms) (not published). The weight loss of chilli sample was measured by the difference in weight before and after storage.

Chemical measurement

Chemical measurement (pH, TTA and AA) was carried out on the same day, immediately after determining the weight loss by following the method of Ranggana (1977). Samples were blended using a kitchen blender and the pH value was determined using an Orion digital pH meter (model SA520). The total titratable acidity was analysed by titrating 0.1 N NaOH to an end point of pH 8.1. The ascorbic acid content was determined by titrating with 2,6 dichloro-phenolindophenol.

Gas measurement

Gases in the package (CO_2 and C_2H_4) were measured using the gas chromatograph (GC). A sample of 1,000 µl C_2H_4 gas was injected into a Perkin Elmer Auto System

XL gas chromatograph fitted with flame ionization detector (FID) and a stainless steel column packed with Porapak T of 100/120-mesh size. CO_2 was detected using thermal conductivity detector (TCD) with a stainless steel column packed with Porapak R of 80/100-mesh size. The flow rate of the purified helium gas was 30 ml/min and the column oven was operated at 50 °C and 100 °C for CO_2 and C_2H_4 gases, respectively. Helium was used as a carrier gas at the same flow rate and the injector temperature was 35 °C. Three replications were used for each measurement.

Microbiological analysis

Standard microbiological procedures were used for the analysis of the samples (ICMSF 1978). A 10 g sample of randomly selected chilli from each type of packaging was homogenized with 90 ml Ringers solution using a Seward Stomacher Lab Blender 400 for 1 min. The suspension was held for 30 min to allow the larger particles to settle down. Appropriate serial dilutions were made and 1 ml volume of appropriate decimal dilutions was poured on plate using total plate count agar (TPCA) and potato dextrose agar (PDA) to determine the total viable count, yeast and mould count respectively. Microbial colonies were counted after 48 h of incubation at 37 °C. For detection of coliform and *Escherichia coli*, the Multiple Tube Dilution Method was used. Most Probable Number (MPN) table was used to examine the positive tube for the various dilutions. All media were from Difco (Difco Laboratories, Detroit MI).

Statistical analysis

Statistical analyses of the treatment responses were conducted using Analysis of Variance (ANOVA) and Duncan Multiple Range Test to determine whether the comparison between different treatments and different storage durations show significant differences (p <0.05). The main effect means are presented in tables and figures. Experimental data are presented as means ± standard error of the determinations for each sample. For comparison of more than two means, the mean separation was done by Duncan Multiple Range Test (SAS Inst. 1985).

Results and discussion

Weight loss

Air tight packaging significantly (p <0.05) reduced weight loss of MP chilli from 5.66% in non-airtight container (nPVC) to 0.07% (PP) and 0.16% (aPVC) after 24 days of storage at 2 °C; and from 1.27% (nPVC) to 0.37% (PP) and 0.27% (aPVC) during 3 days of storage at 25 °C. The reduction of weight loss by using PP and aPVC was more than 97% than nPVC at storage temperature 2 °C (for 24 days) and, more than 20% at storage temperature 25 °C (for 3 days) *(Figure 1* and *Table 1)*. According to Lownds et al. (1994), packaging can reduce rate of water loss 20 times or more at each storage temperature. Sample in nPVC had highest weight loss that may be due to high permeability to water vapour.

Weight loss causes desiccation of cut surface samples to more than 5% (after 6 days, 2 °C) as reported by Bussel and Kenigsberger (1975) and the maximum acceptable moisture loss (%) of chilli was about 12.2% (Kays 1991). Similar observation was noted in this study. The sample became dry and wilted especially at the sealing point which had higher gas exchange than other parts. Tightness of containers affected permeability and water loss of sample as indicated in the study. The occurrence of water condensation in nPVC caused faster deterioration of MP chilli (wilted, shriveled, browning, inedible) compared to other packages.

Ethylene production rate

At room temperature, the production of ethylene was very high (7.31 µl/kg/h) in sample packed in PP container, but significantly lower in both aPVC (0.98 µl/kg/h) and nPVC (0.12 µl/kg/h)

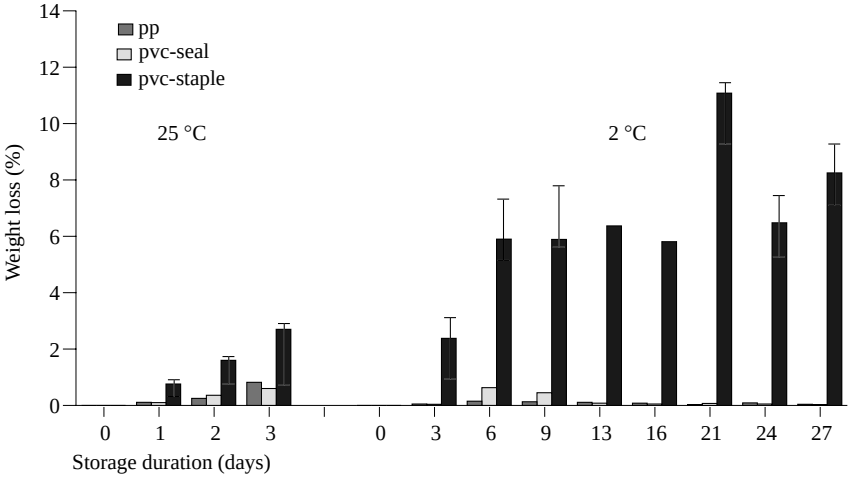

Figure 1. Effect of packaging on weight loss of MP chilli

Table 1. Changes in percentage of weight loss, pH, total titratable acidity, ascorbic acid and CO_2 and ethylene production of minimally processed chilli from different packagings at 2 °C and 25 °C storage temperatures

Types of packaging	Storage temp. (°C)	Weight loss (%)	pH	Total titratable acidity (mg/100 g)	Ascorbic acid (mg/100 g)	CO_2 production (ml/kg/h)	Ethylene production (µl/kg/h)
PP	25	0.30b	4.65a	1.36a	97.86a	14.47b	7.31a
aPVC		0.27b	4.45a	1.65a	90.69a	27.31a	0.98b
nPVC		1.27a	4.63a	1.26a	99.22a	0.18c	0.12b
PP	2	0.07b	4.36a	1.30ab	89.26a	0.62a	0.12a
aPVC		0.16b	4.37a	1.23b	89.61a	0.36b	0.05ab
nPVC		5.66a	4.33a	1.37a	94.32a	0.06c	0.00b

Each value was the mean of three replicates. Means with the same letter are not significantly different at 5% level (p <0.05) according to Duncan Multiple Range Test (DMRT)
PP = polypropylene; aPVC = airtight polyvinyl chloride; nPVC = non-airtight polyvinyl chloride

containers *(Figure 2* and *Table 1)*. However, ethylene production of PP packed samples was significantly reduced with prolonged storage period. Ethylene production significantly (p <0.05) reduced by the reduction of storage temperature from 25 °C to 2 °C in all packagings tested. The increase rate of ethylene production in chilli as a response to mechanical damage has been reported on other produce, which also has an effect on their physiology and quality (Baldwin 1994). Ethylene is always associated with senescence of tissues (Wills et al. 1981). Ethylene can accumulate in sealed packaging and causes undesirable changes to the quality of the products (Abe and Watada 1991). This was also observed in MP chilli during storage at room temperature. The accumulation of ethylene probably contributed greatly to faster deterioration of the MP chilli stored at ambient temperature. The shortcoming of air-tightness of PP and aPVC was the trap of ethylene in packaging higher than nPVC.

Respiration rate

Production of CO_2 was low in all minimally processed chilli packed in different packing systems during storage at 2 °C *(Figure 3* and *Table 1)*. However, at room temperature,

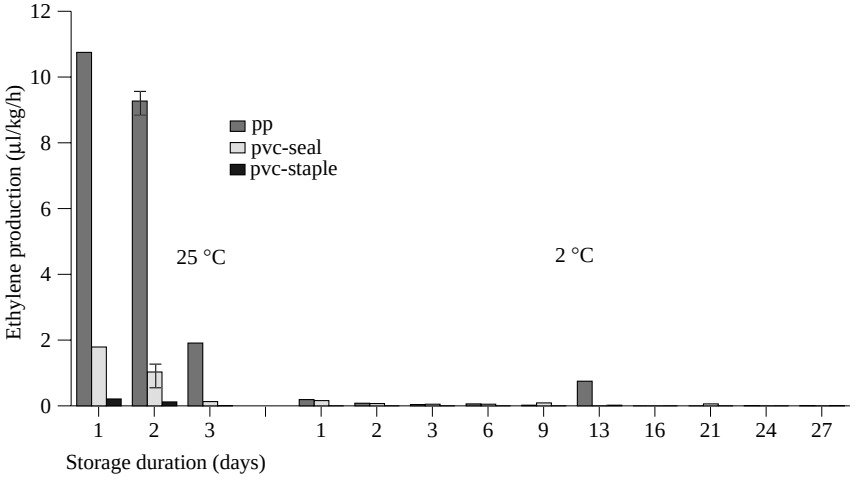

Figure 2. Effect of packaging on ethylene production of MP chilli

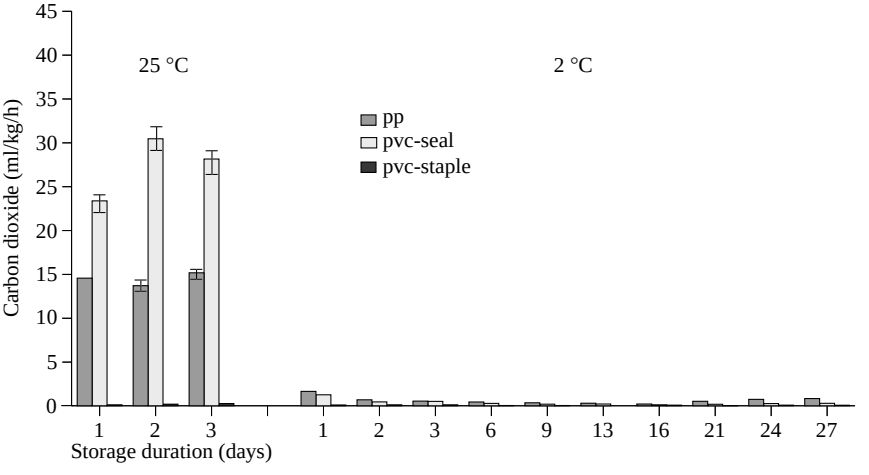

Figure 3. Effect of packaging on CO_2 production of MP chilli

CO_2 production was highest in aPVC container followed by PP and nPVC containers. Higher CO_2 accumulated in PP and aPVC containers compared to those in nPVC was probably due to the C_2H_4 which stimulated the respiration process of MP chilli (Yokotani et al. 2004). This is because mechanical damage, mostly by surface cutting during processing, induces ethylene biosynthesis. The activity of several decay organisms can be reduced by high CO_2 (>10%) (Wills et al. 1981). Carbon dioxide production in all containers was not affected by storage duration. The CO_2 level above 10% noted in PP and aPVC container were able to cause injury of MP chilli as reported by Kader 1986).

CO_2 has an inhibitory effect on ethylene-induced softening (Rosen and Kader 1989), and anaerobic conditions may create off-flavour of the product. Increased CO_2 level in aPVC MP chilli at 25 °C resulted in internal browning and spoilage as reported on bell pepper (Bussel and Kenigsberger 1975; Kays 1991). If a produce can tolerate a high CO_2 atmosphere, the breakdown of pectic substance was inhibited, hence, firmness can be retained for a longer period. Flavour retention may also improve (Salunkhe and Desai 1984) and

chilling injury can be reduced (Weichmann 1987). Furthermore aPVC and PP packages trap more CO_2 and ethylene gases but nPVC package allow the release of CO_2 to outside atmosphere.

pH and TTA

Acidity of MP chilli increased in all types of packaging during storage at room temperature (*Figures 4–5* and *Table 1*). It was observed with prolonged storage period at 25 °C. The increment was gradual in PP and nPVC but rapid in aPVC package. Visually, this increment is parallel with production of fermented aroma and softening of the MP chilli. In most cases, the concentrations of TTA tend to decline during postharvest storage (Wills et al. 1981; Kays 1991). The increase in TTA of MP chilli during storage was probably due to the increase in CO_2 inside the packages. In dark storage with high CO_2, at least two mechanisms can increase the TTA i.e.
(1) pyruvic acid can be converted to malic acid by malic enzyme, and
(2) phosphoenolpyruvate carboxylase is capable to catalyse phosphoenolpyruvate to oxalicacetic acid (Kays 1991). Acidity of the MP chilli was not significantly ($p > 0.05$) different during storage at 2 °C for all package types.

Ascorbic acid

Ascorbic acid content of the MP chilli was not affected by packaging material as observed at both storage temperatures *(Figure 6* and *Table 1)*. Ascorbic acid content was not significantly different during storage at 2 °C, but slightly reduced during storage at room temperature. The loss of ascorbic acid depends on storage temperature rather than on the length of storage period (Adisa 1986). Microbial growth can also cause a decrease in ascorbic acid content. Normally, commodities stored in controlled atmosphere (CA) and modified atmosphere packaging (MAP) have better retention of ascorbic acid than storage in air. The limited air in packages was expected to restrict the oxidation of ascorbic acid by oxidase enzyme or by other degenerating oxidases produced during pathogenesis (Adisa 1986). The role of ascorbic acid as an antioxidant in many fruits is well documented. Ascorbic acid is known to be an enzymatic browning inhibitor caused by polyphenol oxidase and has the ability to convert quinones back to phenols (Miller and Heilman 1952; Lambrecht 1995). Reduction in ascorbic acid content is always associated with the increase of surface browning (Wong et al. 1994).

Microbial count

Bacteria, yeast and mould count were detected in all packed samples regardless of the storage temperature *(Table 2)*. The polypropylene (PP) packages showed a decrease of total viable count (TVC) from 7.80×10^4 colony forming units per gramme of sample (cfu/g) on the third day of storage to 2.3×10^3 (cfu/g) for 28 days *(Table 2)*. However, after 3 days of storage, the TVC count increased to 7.2×10^4 cfu/g. Not much difference was shown in the TVC for the sample packed using aPVC and nPVC. After 28 days of storage at 2 °C, the count was 7.1×10^3 and 8.2×10^3 cfu/g, respectively *(Table 2)*. The counts of yeast and mould in aPVC and nPVC packs after 28 days storage were 6.7×10^5 and 4.6×10^6 cfu/g, respectively *(Table 2)*.

Minimally processed chilli packed with PP can be stored for 4 weeks with good storage condition. However, samples packed with aPVC and nPVC can only be stored for 16 and 13 days of storage, respectively. The analysis also indicated that coliform was present in all the samples but there was no growth of *Escherichia coli* during the storage period.

The presence of *E. coli* must be thoroughly checked as it causes food poisoning. According to Grattridge (1993) the main postharvest problem in chilli during storage is soft rot caused by *Erwinia caratovora*. Packaged products influenced the microbiology of the product.

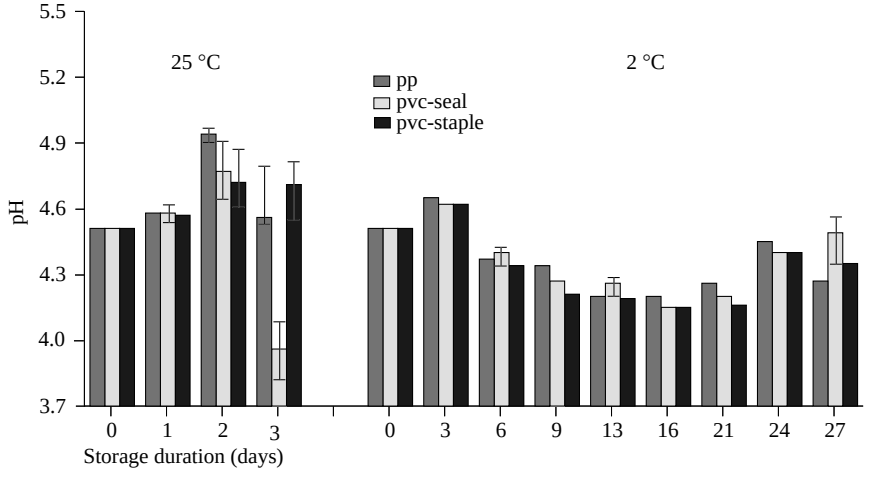

Figure 4. Effect of packaging on pH of MP chilli

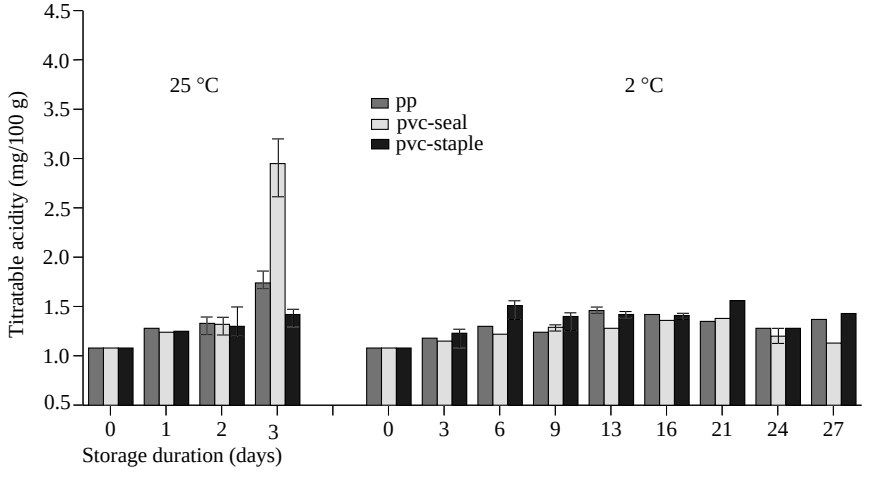

Figure 5. Effect of packaging on titratable acidity of MP chilli

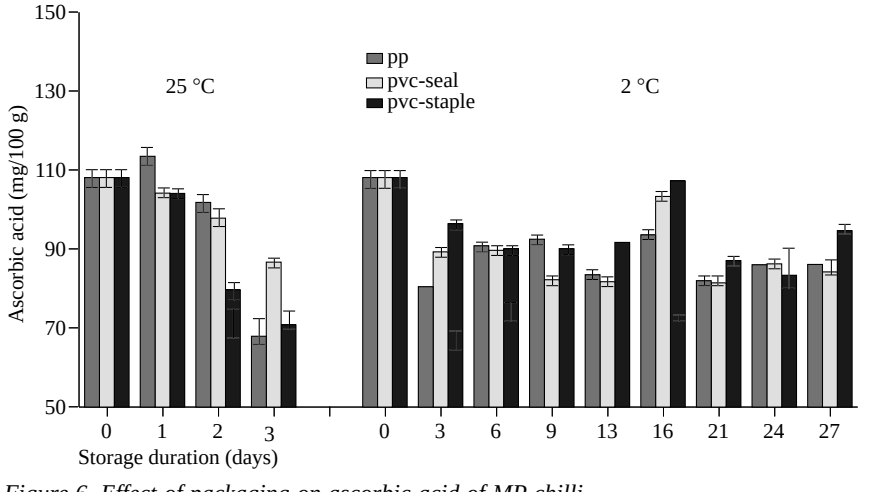

Figure 6. Effect of packaging on ascorbic acid of MP chilli

Table 2. Microbiological changes of minimally processed chilli with different types of packaging stored at 2 °C

Storage period (days)	Types of packaging	Total viable count (cfu/g)	Yeast and mould (cfu/g)	Coliform (MPN/g)	*Escherichia coli* (MPN/g)
0	PP	$1.03x10^6$	$1.76x10^3$	>240	-ve
	aPVC	$1.03x10^6$	$1.76x10^3$	>240	-ve
	nPVC	$1.03x10^6$	$1.76x10^3$	>240	-ve
3	PP	$7.80x10^4$	$1.67x10^3$	>240	-ve
	aPVC	$4.40x10^5$	$1.87x10^3$	>240	-ve
	nPVC	$1.23x10^5$	$1.31x10^3$	>240	-ve
6	PP	$1.98x10^5$	$1.47x10^3$	35	-ve
	aPVC	$3.40x10^4$	$4.10x10^2$	54	-ve
	nPVC	$1.48x10^6$	$1.51x10^3$	>240	-ve
9	PP	$1.44x10^5$	$1.32x10^3$	24	-ve
	aPVC	$1.52x10^5$	$1.29x10^3$	35	-ve
	nPVC	$1.87x10^6$	$1.80x10^3$	>240	-ve
13	PP	$2.60x10^4$	$2.72x10^3$	24	-ve
	aPVC	$2.80x10^4$	$1.78x10^3$	24	-ve
	nPVC	$4.60x10^4$	$1.81x10^3$	92	-ve
16	PP	$1.23x10^4$	$2.73x10^4$	24	-ve
	aPVC	$1.55x10^4$	$1.82x10^3$	13	-ve
	nPVC	$4.40x10^4$	$3.50x10^4$	35	-ve
21	PP	$7.20x10^3$	$4.60x10^4$	24	-ve
	aPVC	$1.14x10^4$	$2.16x10^4$	4.9	-ve
	nPVC	$1.23x10^4$	$6.0x10^4$	13	-ve
24	PP	$6.50x10^3$	$6.50x10^4$	1.3	-ve
	aPVC	$8.50x10^3$	$1.56x10^5$	1.9	-ve
	nPVC	$1.10x10^4$	$2.50x10^5$	7.9	-ve
28	PP	$2.30x10^3$	$7.20x10^4$	0.45	-ve
	aPVC	$7.10x10^3$	$6.70x10^5$	1.4	-ve
	nPVC	$8.20x10^3$	$4.60x10^6$	0.94	-ve

PP = polypropylene; aPVC = airtight polyvinyl chloride; nPVC = non-airtight polyvinyl chloride
-ve = negative

Atmospheric conditions during storage and overall resistance of the package to the passage of moisture, atmospheric gases and odours, may contribute to the increase of the total viable count (Paine 1969).

For longer shelf life, PP packaging can be used to store the minimally processed chilli until 4 weeks of storage. At 4 weeks of storage, MP chilli was still safe to be eaten as the microbial count was still at accepted level (not more than 10^{-6} per gramme). The use of aPVC and nPVC packagings were not encouraged to store minimally processed chilli for long periods because of the poor packaging material and the sample was exposed to contamination during packing process. Once the package is opened, the remaining pieces will require another container for storage until further consumption.

Conclusion

Temperature was the most significant factor influencing the shelf life of MP chilli. MP chilli stored at room temperature had short shelf life (1–2 days) as compared to 28 days stored at 2 °C using PP semi-rigid container. It was due to rapid change in the chemical, physical, gases and microbial properties. Ethylene and CO_2 production, and changes in acidity and ascorbic acid of MP chilli can be minimized during storage at 2 °C. Permeability of gases in packaging container was important in maintaining quality and

shelf life of product. Non-airtight packaging (nPVC) with high permeability caused rapid desiccation because of high transpiration rate and allowed outside O_2 to enter the package and inside CO_2 to go out from the package. These will increase the respiration rate and shorten the shelf life of MP chilli. Low permeability by using airtight packaging (aPVC) caused condensation and high concentration of CO_2 to be trapped inside the package, which resulted in serious softening and off-flavour of MP chilli. PP container provided the best condition to extend storage life (4 weeks, 2 °C) of minimally processed chilli.

Acknowledgement

The authors wish to acknowledge the valuable assistance of Ms Zaipun and Ms Norhayati Maning in carrying out the research. This project was jointly funded by the MARDI and IRPA (Research Grant No. HR-06-03-04).

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Abstrak

Tiga jenis pembungkusan yang berbeza iaitu bekas polipropilena separa tegar 250 ml (PP), PVC kedap udara (aPVC) dan PVC tidak kedap udara (nPVC) diuji keberkesanannya untuk penyimpanan cili yang diproses secara minimum (MP). Sampel-sampel tersebut disimpan pada suhu 2 °C selama 4 minggu dan 25 °C selama 3 hari. Penyimpanan pada 25 °C menghasilkan perubahan yang ketara (p <0.05) bagi gas karbon dioksida dan etilena, dan sedikit perubahan keasidan tertitrat dan kandungan asid askorbik. Pada suhu 2 °C, perubahan terhadap keasidan tertitrat, kandungan asid askorbik dan penghasilan gas karbon dioksida dan etilena dapat dikurangkan dengan ketara (p <0.05) apabila hasilan ini disimpan.

Peratus kehilangan air cili MP yang dibungkus menggunakan nPVC meningkat dengan ketara (p <0.05) semasa penyimpanan pada 2 °C and 25 °C. Ini menyebabkan hasilan mudah kering. Walau bagaimanapun, peratus kehilangan air hasilan dapat dikurangkan dengan menggunakan pembungkus PP dan aPVC. Hasilan yang dibungkus dengan aPVC menjadi cepat lembut dan berair yang mungkin disebabkan oleh kondensasi wap semasa pernafasan dan kekurangan kandungan oksigen yang menyebabkan fermentasi beralkohol berlaku. Analisis mikrobiologi terhadap hasilan menunjukkan pengurangan jumlah kolifom dan peningkatan yis dan kulat bagi semua sampel MP cili semasa penyimpanan pada suhu 2 °C. Jangka hayat simpan cili MP yang dibungkus di dalam bekas PP ini boleh dilanjutkan hingga 4 minggu pada suhu 2 °C. Bagaimanapun, pada suhu 25 °C tempoh penyimpanan hanya 2 hari sahaja. Oleh itu, bekas PP sesuai digunakan di peringkat komersial bagi penyimpanan cili MP pada suhu 2 °C berbanding dengan aPVC dan nPVC.

Accepted for publication on 23 April 2005