Eur Food Res Technol (2001) 212:165–169

ORIGINAL PAPER

Habibunnisa · Revathy Baskaran · Rajendra Prasad
Krishnaprakash Mysore Shivaiah

Storage behaviour of minimally processed pumpkin (*Cucurbita maxima*) under modified atmosphere packaging conditions

Received: 24 January 2000 / Revised version: 4 April 2000

Abstract Minimally processed vegetables in fresh, ready-to-cook form are gaining the confidence of both the trader and the consumer. This has led to a need to develop technology for increasing shelf life while maintaining the microbial, nutritional and sensory quality of minimally processed vegetables. This investigation was carried out on pumpkin in minimally processed form, packed in different polymeric film bags of varying permeabilities, creating an active equilibrium modified atmosphere within the package for the extention of storage life. It was observed that minimally processed pumpkin, which has a high respiratory rate at room temperature (155.7 mg CO_2/kg/h) could be stored for a period of 25 days at 5±2 °C under modified atmosphere packaging conditions with a minimum physiological loss in weight of 0.06% and marginally low changes in biochemical constituents, such as vitamin C, total soluble solids, moisture, carotenoids and titrable acidity, enabling the retention of near-fresh quality. The microbial loads of mesophilic aerobes and coliforms, which were log 5.5 and log 4.3 were less than threshold level. There was no growth of yeasts and moulds or mesophilic spore formers at the end of the storage period.

Keywords Pumpkin · Minimal processing · Modified atmosphere packaging · Shelf life

Introduction

Minimally processed refrigerated fruits and vegetables have attracted the interest of many facets of the food industry, including such diverse areas as food manufacturers, retail food stores, restaurants, carry-out establishments and commissary units. Much of the developmental work in this field is being carried out in developed countries in response to strong consumer demand, both individual and institutional, for new types of like-fresh, high-quality convenience foods [1]. Minimally processed vegetables deteriorate rapidly in quality and have a short storage life. The high moisture content and numerous cut surfaces of minimally processed vegetables provide optimal conditions for the growth of microorganisms [2]. Modified atmosphere packaging (MAP) is an efficient means of extending the shelf-life of prepared vegetables and protecting fresh vegetables from sensory quality deterioration [3, 4].

Pumpkin (*Cucurbita maxima*) is a high-yielding cucurbit. A number of varieties are grown in India. Due to their large size and weight, they present a number of problems during harvesting, handling, packaging, transportation, storage and marketing, leading to enormous wastage.

Pumpkin could be preserved in minimally processed form, which would be more convenient to store and use, and thereby reduce wastage. The present investigation was undertaken to standardize the conditions for extending the shelf-life of minimally processed pumpkin using various methods, such as MAP using films of variable permeabilities to match the respiratory requirement and the use of chemical preservatives and antimicrobial agents, and to study their effect on the physiological and pathological behaviour of pumpkin during storage.

Materials and methods

Fully mature whole pumpkins without any damage were procured from the local market. They were pre-cooled for 18 h at 5–6 °C and then peeled and cut into pieces of 1 1/4″ in size. The spongy portion with the seeds was removed.

The preparation of the pieces resulted in 17% wastage, which included peel and the spongy tissue.

Habibunnisa · R. Baskaran (✉) · R. Prasad
K. Mysore Shivaiah
Department of Fruit and Vegetable Technology,
Central Food Technological Research Institute,
Mysore - 570 013, India
e-mail: revbas@yahoo.com

Treatment and experimental design. The cut pieces were dip treated with:

1. soft water (15–20 °C), dipping for 5 min (control)
2. antimicrobial solution containing citric acid (0.2%) and potassium metabisulfite (0.1%) for 3 min
3. a solution of soluble starch (0.2%) extrapure (Sd Fine Chemicals) plus calcium chloride (0.1%) (dihydrate), dipping the cut pumpkin for 3 min
4. mannose (0.1%) solution, then placed inside a vacuum oven and vacuumized (25″ vacuum) for 5 min (the mannose is infiltered by displacing the interstitial gas).

The treated pieces were spread on a wire mesh tray, drained and surface dried in a cross-flow drier for 30 min at 35 °C. They were then packed (250 g quantities) in polypropylene (PP) and low-density polyethylene (LDPE) bags, sealed with and without vacuum and stored at 5 ± 2 °C, 13 ± 2 °C and 23 ± 2 °C.

Instrumental analysis. The texture of the pumpkin pieces (initial and after storage) was measured by the Warner-Bratzler compression test on an Instron Model 430, keeping 80% compression. The peak force was recorded and expressed as kgF, and was taken as the indicator of toughness. The colour of the initial and stored pumpkin pieces (reflectance values) was measured using a UV/visible recording spectrophotometer (Shimadzu UV 100, Japan) at wavelengths ranging from 360 nm to 800 nm and expressed as Hunter colour values *L*, *a* and *b* [5].

Chemical analysis. Total carotenoids were determined at the initial stage and at the end of the storage life by methods of vitamin assay. Ascorbic acid was determined by direct titration method using 2, 6-dichlorophenol indophenol dye as indicator [6]. Total soluble solids were determined as soluble solid in degree Brix using a hand refractometer (0–32°Brix) on expressed juice [7] at the initial stage and at the end of the storage period. Moisture content was determined at the initial stage and at the end of the storage period by an oven-dry method. Total acidity was determined with 0.1 N sodium hydroxide and the pH was recorded using a pH meter.

Rate of respiration. The rate of respiration was determined by the continuous current method [8] and was expressed as mg CO_2/kg/h. Q_{10} values were collected by determining the rate of respiration of the commodity at three different low temperatures with a difference of 10 °C. This study was essential to develop suitable packaging to establish the equilibrium modified atmosphere required to extend the shelf-life.

Physiological losses in weight (PLW). Packaged samples were marked for PLW. The initial weight was taken and periodical observations on the loss in weight were made by weighing the samples every 24 h for those stored at ambient temperature and every alternate day for those stored at 5 ± 2 °C. The PLW was calculated and expressed as a cumulative percentage loss.

Gas analysis. Head-space gas (oxygen and carbon dioxide) composition was measured using a gas analyser (Systech, Model Portamap Oxygen/Carbon Dioxide Analyzer) at 12 h intervals for control samples stored in LDPE bags at three different temperatures.

Statistical analysis. The data were subjected to analysis of variance (ANOVA) using the method of Snedcor and Cochran [9].

Microbiological studies. The initial and final microbial profiles were studied. One gram of sample was stomachered and serially diluted with saline. Serially diluted samples (0.5 ml) were plated on plate count agar, potato dextrose agar, McConkey agar and bromocresol purple agar to determine mesophilic aerobes, yeasts and moulds, coliforms and mesophilic spore formers respectively. The plates were incubated, observations recorded and results expressed as colony forming units (cfu) per gram then converted to log units.

Sensory evaluation. The samples were boiled in 2% salt solution, maintaining constant time and temperature, and then were organoleptically evaluated after the storage period of 25 days for their quality attributes, such as flavour, texture, colour and appearance, by a 10-member panel using a 10-point hedonic scale.

Results and discussion

The PLW and the respiration rate are given in Tables 1 and 2. Dicing was found to enhance respiration over a short period (less than 24 h) and stabilized it afterwards. The carbon dioxide output of diced pumpkin at ambient conditions (28 ± 2 °C) was 155.8 mg CO_2/kg/h and at 5 ± 2 °C the carbon dioxide output was reduced to 24.3 mg CO_2/kg/h. The respiration rate of commodities is halved under MAP conditions, as reported earlier.

The Q_{10} values of most plant tissues range from 2 to 3 and linearly increase with an increase in temperature [10]. However, Q_{10} may slightly exceed 3, as in the case of blueberries [11]. The Q_{10} value of diced pumpkin was 2.5 in the temperature range 0–30 °C. The PLW in diced pumpkin at the end of storage period of 25 days at 5 ± 2 °C was negligible (0.40–0.06) under MAP conditions as against 2.06% in the control, thus enabling preservation of the produce with a fresh appearance.

Gas composition

Accumulation of carbon dioxide and depletion of oxygen were determined as a percentage of total head-space gas to find the effects of various holding conditions on the rates of respiration. Figure 1 shows the head-space oxygen and carbon dioxide gas composition during storage of minimally processed pumpkin (average of triplicate packs, 250 g samples) at three different temperatures (5 ± 2 °C, 13 ± 2 °C, 23 ± 2 °C). At 5 ± 2 °C there was an increase in carbon dioxide accumulation in the first 12 h. from 0.03% to 15% and thereafter it remained constant up to 60 h, while oxygen depletion was from 20.7% to 7% after 12 h and steadily decreased over 60 h to a minimum of 2%. On increasing the temperature, there was an increase in carbon dioxide accumulation and depletion of oxygen in the same pattern as observed at 5 ± 2 °C. The increase in the rate of respiration may be considered as linear, thus proving a close relationship between storage duration and temperature.

It was found that carbon dioxide accumulation continued to increase well beyond 21%, which would be the limit of carbon dioxide production by strictly aseptic respiration. Hence it can be assumed that some aseptic respiration took place in the sample stored at room temperature, as observed earlier [12].

There were slight decreases in moisture, vitamin C and carotenoids at the end of the storage period, and a slight increase in total solids, acidity and total sugars (Table 3).

Table 1 Storage life and physiological loss in weight (*PLW*) of minimally processed pumpkin. *PP* Polypropylene; *MP* microperforations; *LDPE* low-density polyethylene

Control	Storage life (in days)			% Physiological loss in weight		
Treatment	5±2 °C	13±2 °C	23±2 °C	5±2 °C	13±2 °C	23±2 °C
1. PP	12	5	1	0.08	0.09	0.16
2. PP with MP	10	3	1	0.18	0.271	0.29
3. PP with 0.2% vents (control packaging)	7	2	<1	2.46	2.50	2.70
4. PP with vacuum	11	4	1	0.12	0.23	0.35
5. LDPE	20	10	1	0.06	0.18	0.25
6. LDPE with MP	16	7	1	0.15	0.19	0.20
7. LDPE with 0.2% vents (control packaging)	8	3	<1	2.06	2.56	2.62
8. LDPE with vacuum	20	9	1	0.04	0.05	0.08
Treated						
1. PP	18	8	1	0.07	0.09	0.15
2. PP with MP	18	7	1	0.18	0.20	0.27
3. PP with 0.2% vents	10	3	<1	0.44	0.55	0.70
4. PP with vacuum	15	5	1	0.12	0.21	0.34
5. LDPE	25	10	1	0.06	0.09	0.21
6. LDPE with MP	21	8	1	0.13	0.16	0.18
7. LDPE with 0.2% vents	22	5	<1	0.48	0.52	0.62
8.LDPE with vacuum	24	10	1	0.04	0.05	0.06

Table 2 Rate of respiration, Q_{10} values and PLW of minimally processed pumpkin under modified atmosphere packaging (MAP)

Treatment	Rate of respiration ($mg/CO_2/kg/h$)		Q_{10} value	PLW (%) (after 25 days)
	28±2 °C	5±2 °C	0–30 °C	5±2 °C
Control	157.54	25.26	2.40	2.06
LDPE	155.76	24.30	2.50	0.06
LDPE (vacuum)	160.08	28.00	2.60	0.04

Pumpkin pieces under different MAP treatments (LDPE, PP, etc.) stored at 5±2 °C showed a slight decrease in toughness (compression) at the end of the storage period of 25 days. The minimum decrease of 16.9% was observed in treated samples packed in LDPE pouches.

L a and *b* are Hunter colour values, where *L* gives a measure of lightness on a scale ranging from 0 (black) to 100 (white) and *a* denotes redness when values are positive. Hunter colour data calculated as the ratio of *a*:*b* indicate that the higher the ratio, the more reddish is the material. No significant change was observed in the colour of pumpkin pieces stored for a period of 25 days at 5±2 °C (Fig. 2).

Viable counts of mesophilic aerobes, yeasts, coliforms and mesophilic spore-forming bacteria in the minimally processed vegetables initially and at the end of the storage period of 25 days at 5±1 °C are presented in Table 4. All the samples were free from *Escherichia coli*. The viable populations of mesophilic aerobes and coliforms present in the initial stages remained un-

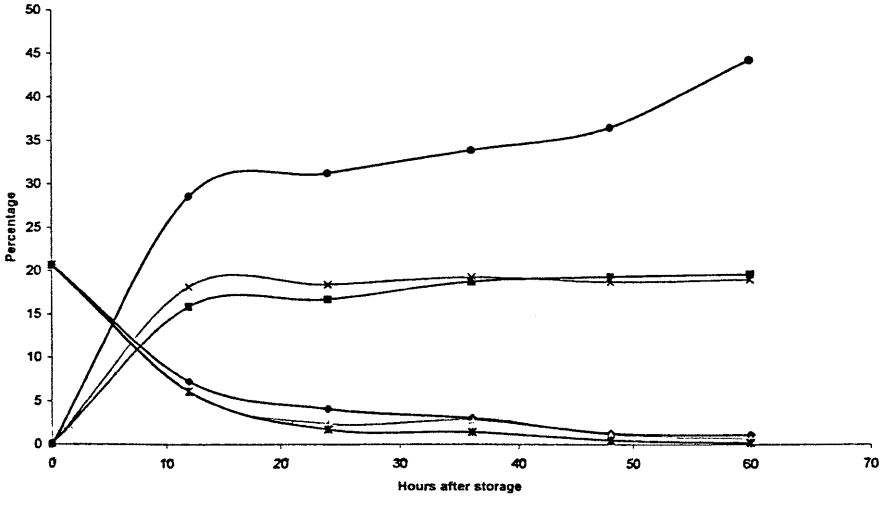

Fig. 1 Head-space gas composition in minimally processed pumpkin. —◆— Oxygen (5 °C); —■— carbon dioxide (5 °C); —▲— oxygen (13 °C); —×— carbon dioxide (13 °C); —*— oxygen (23 °C); —●— carbon dioxide (23 °C)

Table 3 Changes in chemical constituents of minimally processed pumpkin during storage under MAP conditions. Values are the mean of four replicates ± SEM

Parameter (s)	Control		LDPE		LDPE (vacuum)	
	Initial	Final[a]	Initial	Final	Initial	Final
Caroteniod (μg/100 g)	606.95 ± 13.90	590.08 ± 18.07	606.95 ± 13.90	608.48 ± 17.70	606.95 ± 13.90	12.85 ± 16.64
Acidity(%)	0.38 ± 0.05	0.39 ± 0.04	0.38 ± 0.05	0.42 ± 0.06	0.38 ± 0.05	0.46 ± 0.06
VitaminC (mg/100 g)	6.78 ± 0.32	4.70 ± 0.16	6.78 ± 0.32	5.30 ± 0.27	6.78 ± 0.32	5.70 ± 0.30
Moisture (%)	86.65 ± 0.64	82.50 ± 0.63	86.65 ± 0.64	85.03 ± 0.63	86.65 ± 0.64	83.90 ± 0.42
Total sugar (%)	3.86 ± 0.46	3.94 ± 0.03	3.86 ± 0.46	4.21 ± 0.22	3.86 ± 0.46	4.55 ± 0.17
Total soluble solids (°Brix)	7.96 ± 0.11	7.69 ± 0.15	7.96 ± 0.11	7.91 ± 0.13	7.96 ± 0.11	8.52 ± 0.51

[a] At the end of shelf-life (25 days) for LDPE and LDPE (vacuum), and after 8 days for control

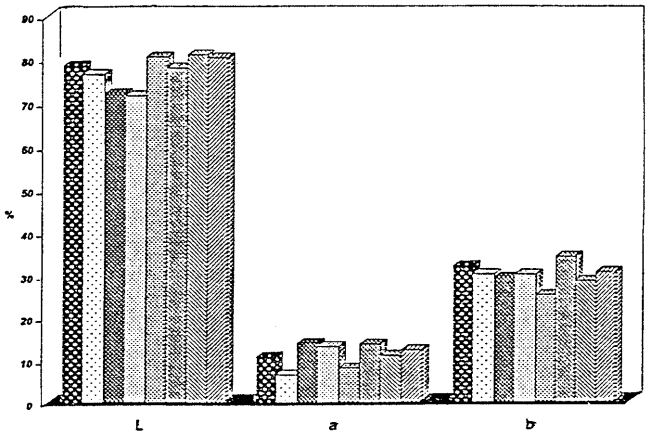

Fig. 2 Variation of *L, a* and *b* colorimetric values during storage. ■ T-1, initial; ⊡ T-2, initial; ▩ T-3, initial; ⬚ T-4, initial; □ T-1, final; ▨ T-2, final; ▧ T-3, final; ▨ -4, final

changed and were within the threshold level of causing any spoilage or hazards. The counts were 32.4×10^4 cfu/g (5.5 log unit) and 2.5×10^4 cfu/g (4.3 log unit), respectively, and the threshold level is 6 log 10 [13].

Sensory evaluation

Diced pumpkin that was treated and packed in LDPE bags and stored at 5 ± 2 °C remained in good condition for a period of 25 days with the retention of fresh appearance, colour, texture, taste and flavour, and was rated the highest for overall quality. Beyond 25 days of storage, softening of tissue, loss of moisture and deterioration started slowly. While pumpkin under other packaging systems retained its sensory quality only up to a period of 10–15 days, on day 25th these samples could not be compared with those treated and packed in LDPE they had deteriorated. Control samples (without treatment and without MAP) could be stored with the retention of good quality parameters for up to 7 days.

Table 4 Microbial profile of minimally processed pumpkin at the end of the storage period

Mesophilic aerobes (cfu/g)	Yeasts and moulds (cfu/g)	Coliforms (cfu/g)	Mesophilic spore formers (cfu/g)
32.4×10^4 (log 5.5)	0	2.5×10^4 (log 4.3)	0

Conclusion

At a temperature of 5 ± 2 °C diced pumpkin treated with antimicrobial solution containing 0.2% citirc acid and 0.1% potassium metabisulfite and stored under MAP conditions (packed in LDPE bags) could be stored in good condition for a period of 25 days with a minimum PLW of 0.06%, minimum loss in nutrient composition and staying microbially safe. Control diced pumpkin could only be stored for a period of 15–20 days in a similar packaging system (MAP). Pumpkin kept at higher temperatures (13 ± 2 °C, 23 ± 2 °C) could be stored for a period of 10 and 1 day, respectively, in similar packaging systems.

Acknowledgements The authors wish to acknowledge the Ministry of Food Processing Industries, New Delhi, for the financial support given to carry out this work.

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