# IMPROVING THE KEEPING QUALITY OF CUT HEAD LETTUCE

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ABSTRACT

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By

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Keeping quality of cut (salad prepared) head lettuce was affected by temperature, modified atmospheres and chemical treatments.

Temperature control was the most effective means of improving keeping quality with a 0°C temperature being preferable; a range 0° to 2.2°C was acceptable, however, storage life decreased proportionally as temperature increased. Chemical treatments tested, including sodium bisulfite, calcium chloride, calcium oxalate and calcium nitrate, were of little or no value in extending storage life. Modified atmospheres with 2 to 3% $O_2$ provided substantial benefit at normal atmospheric pressure, however, when these conditions were created by hypobaric methods, keeping quality of cut head lettuce was substantially reduced.

Storage in a dry untreated condition, in an impermeable heat sealed film, resulted in the most desirable product after two weeks storage, especially if a cold water rinse was used before product consumption.

Sliced radishes provided a worthwhile indicator of browning or dehydration, when evaluating a handling system. Chemical treatments provided a degree of benefit in improving keeping quality of sliced radishes, while modified atmospheres were not as important as for cut head lettuce.

# IMPROVING THE KEEPING QUALITY OF CUT HEAD LETTUCE

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TO THE EXAMINING COMMITTEE

The body of this thesis has been prepared in a publication format and will be submitted for publication to the Journal of the American Society for Horticultural Science.

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Abstract. Keeping quality of cut head lettuce (salad prepared) was affected by temperature, modified atmospheres and chemical treatments.

Temperature control was the most effective means of improving keeping quality with a 0°C temperature being preferable; a range 0° to 2.2°C was acceptable, however, storage life decreased proportionally as temperature increased. Chemical treatments tested, including sodium bisulfite, calcium chloride, calcium oxalate and calcium nitrate were of little or no value in extending storage life. Modified atmospheres with 2 to 3% $O_2$ provided substantial benefit at normal atmospheric pressure, however, when these conditions were created by hypobaric methods, keeping quality of cut head lettuce was substantially reduced.

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The use of fresh cut head lettuce (lettuce prepared in a manner suitable for use in tossed salads), and other prepared foods is a rapidly expanding segment of today's food industry, benefiting from the ever increasing consumption of food outside the home. Restaurants and other serving institutions are facing a problem of how to efficiently prepare these various food items; therefore, centralized preparation, storage, transportation and handling of cut head lettuce may take on additional significance. Long distance transportation of fresh cut head lettuce offers advantages in shipping

no waste, and reducing labor requirements at the serving destination. However, quality maintenance over an extended period presents new and varied problems for produce handlers.

The limited research conducted on the handling of prepared and cut vegetable products for salads and relishes has mostly concerned coleslaw and root vegetables, with relatively little attention given to the handling and storage of cut lettuce.

The shelf life of coleslaw was extended by proper handling, with the main benefit accruing from low temperatures (6,11,12,15,24). The limiting factor in the storage of pre-peeled turnips and rutabagas was discoloration and shriveling (2,3); chemical dips being of little benefit. Peeled, sliced and packaged parsnips stored best at low temperatures and the prevention of discoloration was aided by dipping in chemicals, such as sodium acid sulfite and sorbic acid (13). Shelf life of pre-peeled French fry potatoes was extended by treatment with the antibiotics oxytetracycline and chlorotetracycline (5,7). Antibiotics also improved the keeping quality of cut fresh vegetables including cucumbers, chicory, escarole, lettuce, radish and red cabbage (4). Discoloration of cut cabbage was reduced by rinsing with cold water, followed by spin drying (8). Fresh packaged kale stored best at 0°C and 90 to 95% relative humidity (11). The shelf life of prepackaged and shelled lima beans was extended mainly by hydrocooling while chemical treatments, including antibiotics, were of little

or no value (14). Apple slices stored at 1.1°C benefited from sulfite treatments which were needed to preserve the light color of apple slices stored for several weeks (19, 20).

Head lettuce responds favorably to controlled atmosphere conditions for transit and storage, provided $CO_2$ levels are not above 1 to 2% (25) and $O_2$ levels do not reach zero (16).

Reduced pressure storage has received wide attention in recent research, and has been found to be of benefit for various fruit, vegetable and flower crops (26,27).

An investigation was conducted to determine the effect of various treatments on the keeping quality of cut head lettuce. Our studies included the evaluation of temperature effects on metabolic activity, the influence of modified atmospheres, both controlled atmospheres and hypobaric methods, and the modification of handling techniques to more adequately meet the needs of cut head lettuce users and handlers.

## Materials and Methods

Freshly cut (salad prepared) head lettuce was obtained from the Michigan State University food processing center, or hand cut as required. All experiments were conducted during 1972, at temperatures of 0° and 5°C (unless otherwise indicated). Evaluations generally were made following two weeks of storage.

All evaluations were made on a subjective basis and ratings established on a scale of 1 to 9. Ratings were based on the degree of browning or discoloration, texture, flavor and general appearance. The following descriptions should be used when interpreting our data.

| Rating | Description |
|---|---|
| 9 | fresh condition, the ideal |
| 8 | no browning or discoloration, excellent general condition |
| 7 | slight browning, good overall condition |
| 6[z] | slight-some browning, good general appearance |
| 5 | some-moderate browning, fair general appearance |
| 4 | moderate-severe browning, poor general appearance |
| 3 | severe browning, poor general condition |
| 2 | very poor general condition, some evidence of decay |
| 1 | complete loss of texture, totally unacceptable |

[z]Minimum rating at which quality is acceptable for use in food operations.

Temperature effects on respiration. Five chambers containing various quantities of cut head lettuce ranging from 280 to 410 grams were connected to an air supply with a flow rate of approximately 1 ml/min flowing through the chambers. $CO_2$ evolution was monitored by daily extraction of a 1 ml sample of air, and analyzing it by gas chromatography.

Modified atmospheres. a) Controlled atmospheres. A wide range of concentrations and combinations of $CO_2$ and $O_2$

were investigated and related to their suitability for preserving freshness of cut head lettuce. These were: 100% nitrogen (0% $CO_2$-0% $O_2$), 20% $CO_2$-2% $O_2$, 10% $CO_2$-2% $O_2$, 5% $CO_2$-2% $O_2$, 10% $CO_2$-5% $O_2$, 5% $CO_2$-5% $O_2$, 5% $CO_2$-10% $O_2$, and air (0% $CO_2$-21% $O_2$). After placing two replicates of cut head lettuce in each chamber, approximately 6 cubic feet in volume, the atmosphere conditions were established by flushing each chamber with pure nitrogen ($N_2$) until the desired level of $O_2$ was reached; then pure $CO_2$ was added to establish the desired level of $CO_2$. Daily monitoring of atmosphere composition was conducted by removing a representative 1 ml air sample and analyzing it by gas chromatography for $CO_2$ and $O_2$. Atmosphere modifications were made as required by flushing the chambers with $CO_2$ or $N_2$.

b) Reduced pressure storage. Samples of cut head lettuce were placed in mesh bags or in perforated plastic bags before placing in vacuum chambers (8 liter desiccators), at 8.8° and 0°C; chambers were evacuated to 1/10 and 1/5 atmosphere with a vacuum pump. Each chamber was continuously supplied with fresh humidified air. A control was established by using a sealed non-perforated polyethylene bag and maintained in atmospheric pressure and 0°C. Evaluations were made after one week.

c) Plastic films. Cut head lettuce is normally transported and stored in a plastic film, therefore, we investigated the effect of varying the type of film on the keeping quality of lettuce. Four films, 2 mil polypropylene, 2 mil

polyvinylchloride (PVC), 2 mil experimental polyethylene and a commercially manufactured 2 mil polyethylene bag were evaluated. In all cases the bags were made by heat sealing a continuous sheet of the film on three sides, except the commercial polyethylene bag which was only heat sealed to close it. Two experiments were conducted.

Cut head lettuce was stored in heat sealed bags made of each film. An analysis of the internal atmosphere of each bag was made before opening by removing two representative 1 ml air samples. One air sample was analyzed for $CO_2$ and $O_2$ and the other for ethylene by gas chromatography. The levels present suggested the inclusion of an ethylene absorbent in the second experiment.

The same films as used in the first experiment were used; 2 replicates of each film were placed at each temperature, one containing approximately 180 grams of Purafil (an $C_2H_4$ absorber available from H. E. Burroughs and Assoc. Inc., Chamblee, Georgia). Each was monitored daily to determine the rate of modification of $CO_2$, $O_2$ and $C_2H_4$ levels inside the package. A small patch of rubberized self sealing contact cement was applied to each package, through which syringes were inserted for atmosphere sampling.

Handling methods. Several experiments were conducted to determine the effect of handling methods, such as chemical treatments, method of chemical application and temperature, on keeping quality.

a) Chemicals. Following preliminary investigations, a trial replicated 4 times was conducted comparing the following treatments: 1) 0.2% sodium bisulfite ($NaHSO_3$) solution dip, 2) cold water dip and 3) dry, untreated. Produce was stored in heat sealed 2 mil polyethylene bags; final $CO_2$ and $O_2$ levels were checked and related to quality ratings.

We investigated the feasibility of using various calcium salt solutions including a saturated solution of calcium oxalate, a 1% solution of calcium chloride, and a 1% solution of calcium nitrate, as a replacement for sodium bisulfite. Lettuce was stored in 2 mil polyethylene heat sealed bags and quality ratings related to final $CO_2$ and $O_2$ levels.

b) Generating sulfur dioxide. Several different procedures for generating sulfur dioxide ($SO_2$) within commercial polyethylene bags, were evaluated, with the objective of replacing the standard solution dip. Quantities of dry sodium bisulfite ranging from 0.1 to 0.6% of total weight, were placed in paper envelopes or plastic vials and inserted in each package.

c) Temperature. The effect of temperature in relation to length of storage and keeping quality was determined by the evaluation of 3 treatments; 1) dry, untreated, 2) cold $H_2O$, and 3) 0.2% $NaHSO_3$; at 0° and 5°C, every 2 days over a two week period. A similar experiment was conducted at 0°, 2.2° and 3.3°C.

## Results

Temperature effects on respiration. Carbon dioxide production was calculated as milligrams of $CO_2$ per kilogram hour (Table 1); data is the average of 5 replicates, and reflects the influence of temperature on cut head lettuce respiration. Respiration rates at 5°C were approximately 40% higher than at 0°C.

Modified atmospheres. a) Controlled atmospheres. Modification of normal atmospheres, by changing $CO_2$ and/or $O_2$ levels had a definite effect on the keeping quality of cut head lettuce. Browning and discoloration was substantially reduced in comparison with storage in regular atmosphere conditions. Texture and flavor were also maintained at a high level. Controlled atmospheres in combination with low temperature resulted in the best quality after two weeks of storage (Table 2).

b) Reduced pressure storage. Table 3, summarizes the results of our experiments with cut head lettuce using reduced pressure storage. The quality ratings indicate that reduced pressure storage was not suited to the storage of cut head lettuce. The reduction in quality was due to severe browning, and texture loss.

c) Plastic films. The type of plastic film used in handling cut head lettuce may well have an effect on the length of time such lettuce can be kept. Our results also indicate that keeping quality is related to the levels of $CO_2$ and $O_2$. These levels are related to the permeability of the film and

Table 1. Effect of temperature on the respiration rate of cut head lettuce.

| Time of determination Days | $CO_2$ production (mg/Kg. hr.) 0°C | 5°C |
|---|---|---|
| 1 | 4.6 | 8.2 |
| 2 | 7.2 | 7.9 |
| 3 | 5.8 | 7.9 |
| 4 | 5.7 | 7.6 |
| 5 | 5.6 | 7.8 |
| 6 | 5.4 | 7.2 |
| 7 | 5.2 | 7.0 |

Table 2. Effect of selected controlled atmospheres and temperature on keeping quality of cut head lettuce after 2 weeks storage.

| Temperature | Atmosphere % $CO_2$ | Atmosphere % $O_2$ | Rating | % wt. loss |
|---|---|---|---|---|
| 5°C | 0 | 0 (100% $N_2$) | 7 ± .3 | 1.9 |
| | 20 | 2 | 7 ± .4 | .7 |
| | 10 | 2 | 5 ± .7 | 1.0 |
| | 5 | 2 | 6 ± .9 | 1.0 |
| | 10 | 5 | 3.5 ± .4 | .3 |
| | 5 | 5 | 4 ± .6 | .4 |
| | 5 | 10 | 5 ± .4 | .5 |
| | 0 | 21 (Air) | 4 ± .4 | .5 |
| 0°C | 0 | 0 (100% $N_2$) | 7 ± .0 | .3 |
| | 20 | 2 | 6 ± .6 | .2 |
| | 10 | 2 | 7 ± .4 | .4 |
| | 5 | 2 | 6 ± .3 | .3 |
| | 10 | 5 | 7 ± .3 | .3 |
| | 5 | 5 | 5.5 ± .2 | .3 |
| | 5 | 10 | 4 ± .4 | .2 |
| | 0 | 21 (Air) | 5 ± .4 | .3 |

Table 3. Effect of reduced pressure storage on keeping quality of cut head lettuce after 1 week of storage.

| Temperature | Atmosphere pressure | Treatment | Rating | % wt. change |
|---|---|---|---|---|
| 8.8°C | 76 mm Hg. | mesh bag | 1 | --[1] |
| | 76 mm Hg. | plastic bag | 1 | -- |
| 0°C | 76 mm Hg. | mesh bag | 2 | -4.0 |
| | 152 mm Hg. | mesh bag | 6 | +.8 |
| | 152 mm Hg. | plastic bag | 5 | -.6 |
| | 760 mm Hg. | control | 8 | +.3 |

[1]Lettuce under these conditions was completely broken down and not weighed.

the degree of efficiency in sealing the film (10,21). We again point out the importance of low $O_2$ levels and the effect of temperature (Table 4). Highest quality was attained at 0°C and where the $O_2$ was lowest and $CO_2$ was highest.

Ethylene concentrations of .02 to .6 ppm were found in the internal atmospheres of various packages. The use of an ethylene absorber reduced the ethylene levels to .006 to .01 ppm, however, there was no apparent correlation between the concentrations of ethylene found and the keeping quality of cut head lettuce during storage over a 2 week period.

The rate at which $O_2$ levels approach 2 to 3%, the desired level, is dependent on the film's permeability. The most rapid decline in $O_2$ concentration occurred during the first 2 days of storage and generally leveled off after 4 or 5 days (Fig. 1). When produce was stored at higher temperatures, such as 5°C, considerable benefits in improved quality occurred from proper sealing of films and consequent increase in the modification of atmospheres. We attributed the difference in keeping quality between the two types of polyethylene used, to the fact that the commercially manufactured bag was only heat sealed on one side, while the experimental polyethylene was heat sealed on all sides. A correlation existed with quality ratings and internal atmosphere (Table 4).

Handling methods. The standard procedure in commercial handling of cut head lettuce, has been to dip the product in

Table 4. The influence of plastic films on keeping quality of cut head lettuce after 2 weeks storage.

| Temperature | Plastic film | Rating | Final % $CO_2$ | $O_2$ |
|---|---|---|---|---|
| 5°C | comm. polyethylene | 2 ± .7 | 1.0 | 17.0 |
| | exp. polyethylene | 3 ± .9 | 6.0 | 8.6 |
| | polyvinylchloride | 5 ± .4 | 9.0 | 8.4 |
| | polypropylene | 6 ± .4 | 10.0 | 4.8 |
| 0°C | comm. polyethylene | 5 ± .3 | 2.0 | 18.8 |
| | exp. polyethylene | 5 ± .4 | 3.0 | 13.2 |
| | polyvinylchloride | 6 ± .6 | 7.0 | 10.8 |
| | polypropylene | 7 ± .4 | 9.0 | 11.2 |

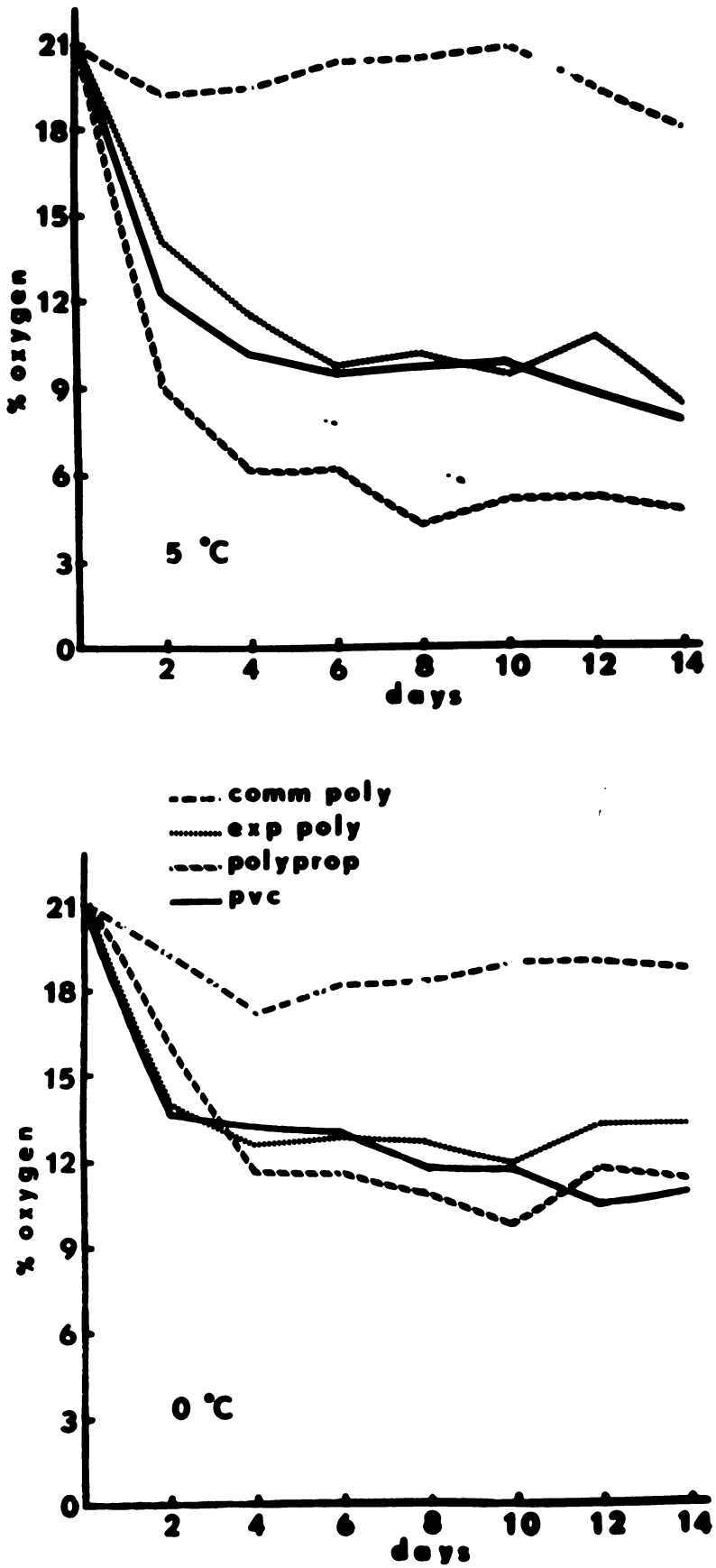


Fig. 1. The effect of plastic film and temperature on the modification of $O_2$ levels in packages of cut head lettuce, stored for two weeks.

a 0.2% solution of sodium bisulfite before bagging. This procedure generally delays the browning of the cut product, but results in considerable water soaking especially after several days of storage. Flavor and texture may be affected, and a rather objectionable odor is often detected.

a) Chemicals. Table 5, compares the standard treatment, with a cold $H_2O$ treatment and a dry cut control at temperatures of 0° and 5°C. Our results indicate that the present method may not be the most practical or beneficial. Severe water soaking occurred in the cold $H_2O$ and sodium bisulfite treatments partially because sufficient water could not be removed. As shown in Table 5 and Fig. 2 the best results were obtained at 0° and 5°C when cut head lettuce was held in a dry untreated condition.

Table 6 shows the effect of several other chemicals which have received some use in other areas of freshness preservation. Our results indicate an excessive degree of browning and general discoloration with these chemicals.

b) Generating sulfur dioxide. An attempt was made to generate $SO_2$ inside packages by the insertion of various quantities of dry sodium bisulfite. When this chemical was placed in paper envelopes, lettuce immediately surrounding the envelopes became 'slimy'; as structure was completely destroyed. In cases when considerable quantities (4 and 8 grams) were used, the entire bag of lettuce became slimy and when similar quantities were placed in plastic vials with perforated tops, no benefit beyond the dry control was

Table 5. Treatment effects on keeping quality of cut head lettuce after 2 weeks storage in commercial polyethylene bags.

| Temperature | Treatment | Rating | Final % $CO_2$ | Final % $O_2$ |
|---|---|---|---|---|
| 5°C | 0.2% $NaHSO_3$ | 5.0 ± .3 | 11.9 | 3.0 |
| | cold $H_2O$ | 2.7 ± .8 | 8.2 | 4.9 |
| | dry untreated | 5.3 ± .5 | 5.3 | 8.8 |
| 0°C | 0.2% $NaHSO_3$ | 5.5 ± .2 | 7.0 | 6.2 |
| | cold $H_2O$ | 4.9 ± .9 | 5.1 | 8.2 |
| | dry untreated | 6.3 ± .3 | 4.0 | 12.0 |

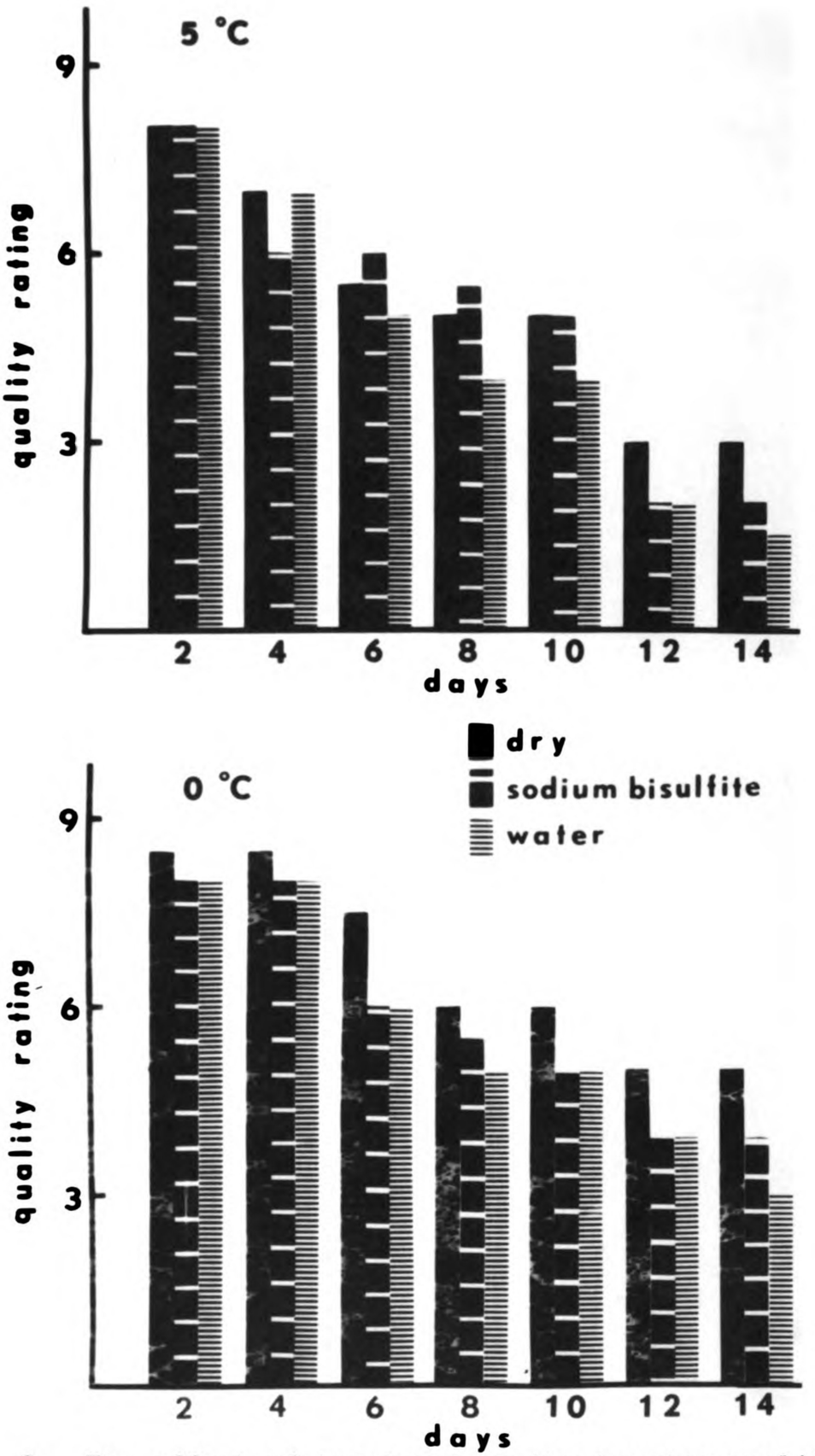


Fig. 2. The effect of treatment on the keeping quality of cut head lettuce stored in commercial polyethylene bags for 2 weeks at 0° and 5°C.

Table 6. The effect of chemicals on keeping quality of cut head lettuce after 2 weeks storage in commercial polyethylene bags.

| Temperature | Chemical | Rating | Final % $CO_2$ | $O_2$ |
|---|---|---|---|---|
| 5°C | sat. calcium oxalate | 3 | 4.9 | 13.8 |
| | 1% calcium chloride | 3 | 5.3 | 10.6 |
| | 1% calcium nitrate | 3 | 4.5 | 5.3 |
| | 0.2% sodium bisulfite | 5 | 11.9 | 3.0 |
| 0°C | sat. calcium oxalate | 3 | 3.2 | 14.2 |
| | 1% calcium chloride | 3 | 2.0 | 18.0 |
| | 1% calcium nitrate | 4 | 3.3 | 9.9 |
| | 0.2% sodium bisulfite | 5 | 7.0 | 6.2 |

achieved. In most cases when sliminess was detected, color of the product was normal but texture was not.

c) Temperature. The most important factor in holding cut head lettuce appears to be proper temperature control as shown in Tables 4 and 5. A range of 0° to 2.2°C was acceptable, however, as storage temperature increased storage life was decreased proportionally.

## Discussion

The respiration rate of cut head lettuce is an important factor in determining the proper handling techniques for such products. We demonstrated a clear correlation between temperature and respiration rate and this in part explains the beneficial effect of temperatures near 0°C in all of our experiments (Table 1). The value of low temperatures for horticultural crop storage in reducing respiration rates is well documented (17,23). The respiration rates of injured produce is normally higher than for regular produce; an increase of 20 to 25% in respiration rate for cut kale leaves was noted when comparing to whole kale leaves (11). Temperature control is thus of greater significance for cut products.

The use of modified atmospheres for the storage and transportation of head lettuce has been established (6,22, 25), as well as for cabbage (1) and other horticultural products (12,18). We also found this technique to be of use for the storage of cut head lettuce; higher levels of $CO_2$ and lower levels of $O_2$ than those recommended for head

lettuce provided the best results (Table 2). We did not experience problems with $CO_2$ injury, except some slight damage occurring at 20%. This is contrary to evidence reported for $CO_2$ injury to head lettuce at concentrations as low as 1% (16,25). This difference is attributed to the less compact nature of cut head lettuce as compared to heads of lettuce. It should be emphasized that the maximum benefit of controlled atmosphere results when it is combined with temperatures of 0°C. These ideal conditions may be achieved in transit, as has been the case for other produce items (16), however, at the point of destination, the serving institution, it may not be practical to expect modified atmosphere capabilities. At this point we would suggest that adequate refrigeration facilities are the most critical.

For this reason we spent considerable time evaluating various types of plastic films, films that when properly sealed have the capability of creating their own modified atmosphere condition (10,21). The permeability of films will affect the rate of $O_2$ depletion and $CO_2$ build up (9). Respiration rate is also influenced by temperature (11,12) and internal atmosphere (10). Our evidence indicates that the film polypropylene is considerably more effective in creating these conditions, than the other films tested (Table 4, Fig. 1). We would again emphasize the value of proper sealing. The difference between the two polyethylene films must be attributed to the method of bag manufacture. Handlers of cut head lettuce probably could

improve their operations by purchasing only top quality plastic bags.

Atmosphere modification by reduced pressures, generally created unfavorable conditions for cut head lettuce storage (Table 3). Storage life was less than one week, and quality was considerably below that of the controls. The technique appears to be of no value for this type of storage.

Ethylene was found not to be a factor in the browning of cut head lettuce, although measurable quantities were produced by the injured tissue over two weeks of storage.

Antibiotics and chemical dips have provided considerable benefit in improving storage and shelf life of coleslaw, pre-peeled French fry potatoes and other vegetable products (3, 4,7,24). We evaluated several chemicals for effectiveness in improving keeping quality of cut head lettuce. Because of the present concern over food additives and food purity we did not test any antibiotics, but instead concentrated our efforts in developing a handling method superior to the current practice of using a 0.2% $NaHSO_3$ dip. As previously mentioned, the inability to remove excess water from dipped lettuce before bagging results in excessive water soaking of the product, and a resultant effect on texture and general appearance. We also found this to be the case with other chemical or water dips. Tables 5 and 6 reflect the level of quality achieved after two weeks of storage. Sodium bi-sulfite does prevent the majority of browning while the other chemicals, calcium oxalate, calcium chloride, calcium

nitrate and water do not; in fact these latter treatments seem to enhance the process.

Our evidence thus suggests that the best method of handling cut head lettuce is to simply cut and bag the product without additional processing. There is some evidence of dehydration after 10 to 14 days of storage when this method is used, however, this can be corrected by a cold water rinse immediately before use. The rinse also serves to restore freshness of the product.

The effect of temperature control cannot be replaced by any other technique; this supports data published on the storage of commodities such as Brussel sprouts (18), head lettuce (10), cabbage (1) and products like coleslaw (12) and sliced kale (11). Temperature maintenance in the range of 0°-2.2°C is critical, with temperatures at the bottom of that range preferred. Storage life will be cut sharply as temperatures range above 2.2°C and this decline cannot be significantly affected by chemical treatment or modified atmosphere.

We have further evidence that cut head lettuce should not be stored above 2.2°C if it is to be kept for more than 4 days, the range of 0°-2.2°C will give satisfactory results up to 8 days (Table 7) and as shown by Fig. 2, at 0°C storage life may be as long as 10 days.

The best handling practice therefore is very temperature dependent. Our evidence strongly suggests that a combination of the following factors, listed in their order

Table 7. Effect of temperature and treatment on the keeping quality of cut head lettuce stored in commercial polyethylene bags for 2 weeks.

| Treatment | Days stored | Temperature | Rating |
|---|---|---|---|
| Dry | 4 | 3.3°C | 6 |
| | | 2.2° | 7 |
| | | 0° | 7 |
| Sodium bisulfite | 4 | 3.3° | 6 |
| | | 2.2° | 7 |
| | | 0° | 7 |
| Dry | 8 | 3.3° | 4 |
| | | 2.2° | 5 |
| | | 0° | 6 |
| Sodium bisulfite | 8 | 3.3° | 4 |
| | | 2.2° | 4 |
| | | 0° | 5 |
| Dry | 12 | 3.3° | 3 |
| | | 2.2° | 4 |
| | | 0° | 5 |
| Sodium bisulfite | 12 | 3.3° | 3 |
| | | 2.2° | 3 |
| | | 0° | 3 |

of importance will achieve the most favorable results when handling cut head lettuce:

1) a 0°C temperature
2) a dry cut product
3) a properly sealed permeable package such as the plastic polypropylene
4) the use of a 5 minute cold water rinse before consumption to restore freshness.

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# APPENDIX

## REDUCED PRESSURE STORAGE

In addition to testing reduced pressure storage on cut head lettuce, its effect on endive, cabbage (coleslaw), carrot sticks, celery sticks, and sliced radishes was evaluated.

### Materials and Methods

Cut products as listed were obtained from the Michigan State University food processing center and placed in vacuum chambers at two temperatures, 8.8° and 0°C. Samples were contained in mesh bags and in perforated plastic bags; chambers were evacuated to 1/10 and 1/5 atmosphere. A control was established by placing each vegetable in a sealed non-perforated plastic bag and holding at 0°C. Products were stored for 1 week before evaluating. Each evacuated chamber was humidified by bubbling air through flasks of water (Fig. 3).

### Results and Discussion

Results of our experiments are summarized in Table 8. These data indicate that no benefit was achieved by the use of reduced pressure at either temperature. In all cases of

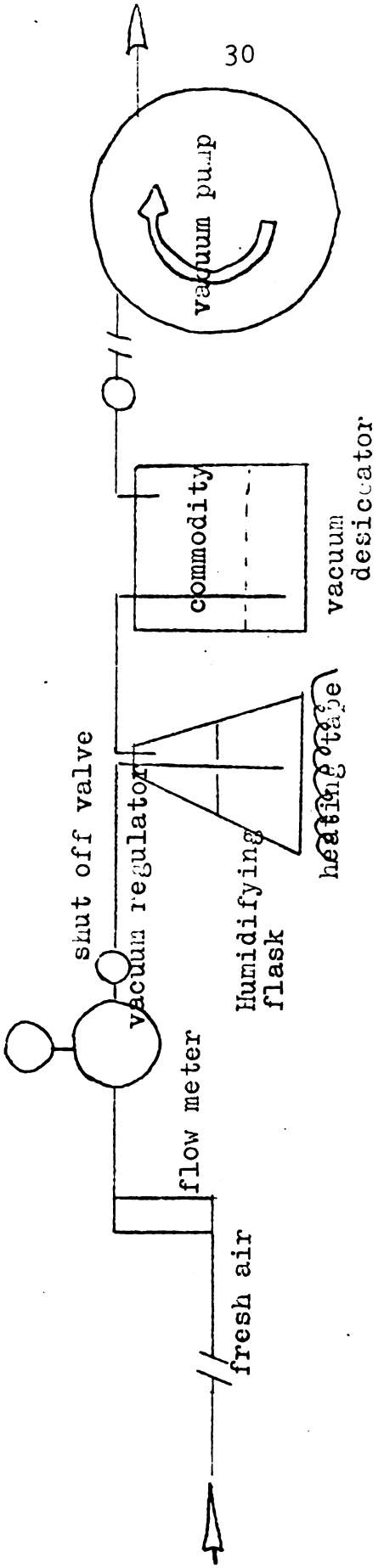


Fig. 3. Reduced pressure storage test equipment.

Table 8. Effect of reduced pressure storage on the keeping quality of cut vegetables after 1 week storage at 2 temperatures.

| Product | Temperature | Pressure (mm Hg.) | Treatment | Rating | % wt. change |
|---|---|---|---|---|---|
| Celery | 8.8°C | 76 | mesh bag | 6 | -.7 |
| | | | plastic bag | 5 | +.6 |
| | | 142 | mesh bag | 7 | -3.4 |
| | 0°C | 76 | mesh bag | 6 | -2.4 |
| | | 142 | plastic bag | 6 | +.7 |
| | | 760 | control | 7 | -.5 |
| Carrots | 8.8°C | 76 | mesh bag | 5 | -8.0 |
| | | 76 | plastic bag | 5 | -.5 |
| | | 142 | mesh bag | 5 | -6.8 |
| | 0°C | 76 | mesh bag | 5 | -.5 |
| | | 142 | plastic bag | 7 | +.5 |
| | | 760 | control | 6 | -1.0 |
| Radishes | 8.8°C | 76 | mesh bag | 3 | -1.5 |
| | | 76 | plastic bag | 1 | -.4 |
| | | 142 | mesh bag | 2 | -5.2 |
| | 0°C | 76 | mesh bag | 4 | -6.0 |
| | | 142 | plastic bag | 4 | +.8 |
| | | 760 | control | 7 | -1.3 |
| Cabbage | 8.8°C | 76 | mesh bag | 2 | -.7 |
| | | 76 | plastic bag | 3 | +.2 |
| | 0°C | 142 | mesh bag | 6 | 1.4 |
| | | 142 | plastic bag | 3 | +.1 |
| | | 760 | control | 8 | +.5 |
| Endive | 8.8°C | 76 | mesh bag | 3 | -.7 |
| | | 76 | plastic bag | 6 | -8.7 |
| | 0°C | 142 | mesh bag | 6 | -5.8 |
| | | 142 | plastic bag | 6 | -1.3 |
| | | 760 | control | 8 | -3.5 |

higher temperature, the leafy vegetables showed damage; almost complete discoloration of the coleslaw, severe dehydration and discoloration of endive. Radishes generally showed a considerable degree of discoloration, while carrots and celery tended to become dehydrated and in some cases texture was affected.

Keeping quality was not improved by increasing humidification in each chamber; this was done by using an additional water flask through which the air was passed before entering the chamber.

The technique of reduced pressure storage appears to be of no benefit for the storage of fresh cut vegetables.

## SLICED RADISHES AS AN INDICATOR

From our reduced pressure storage data, we concluded that sliced radishes would be a good indicator of the degree of browning of produce, for a particular handling system. Therefore, in combination with our cut head lettuce experiments described previously, sliced radishes were used in specific instances.

### Materials and Methods

Modified atmospheres. a) Controlled atmospheres. Sliced radishes were stored in controlled atmosphere chambers, established at 5% $CO_2$-2% $O_2$, 10% $CO_2$-2% $O_2$, 5% $CO_2$-5% $O_2$, 5% $CO_2$-10% $O_2$, 5% $CO_2$-15% $O_2$ and 0% $CO_2$-21% $O_2$ (Air).

Chambers were located at temperatures of 5° and 0°C and radishes were evaluated after two weeks of storage. Atmospheres were established and chambers monitored in the same manner previously indicated.

Chemicals. An investigation of the effect of various chemical dips on the keeping quality of sliced radishes was conducted. Chemicals used were sodium bisulfite, calcium oxalate, calcium chloride, calcium nitrate and water. After treatment radishes were placed in heat sealed commercial polyethylene bags and stored for two weeks at 5° and 0°C.

## Results and Discussion

Modified atmospheres. a) Controlled atmospheres. Controlled atmosphere conditions which were of value in promoting the keeping quality of cut head lettuce (high $CO_2$, low $O_2$ levels), do not appear to have the same effect for sliced radishes (Table 9).

As is indicated by the rating column, a certain amount of variability exists. The ratings are generally an indication of darkening of the radish slices, however, they should be interpreted in the same manner as those described for the cut head lettuce evaluation. The weight loss column also indicates a moderate amount of dehydration, and this contributes to a lowering of quality.

Chemicals. From our data (Table 10), we can see that sliced radishes respond to chemical treatment somewhat better than cut head lettuce does, and further suggests that

Table 9. The effect of selected controlled atmospheres on the keeping quality of sliced radishes after 2 weeks storage.

| Temperature | Atmosphere % $CO_2$ | % $O_2$ | Rating | % wt. loss |
|---|---|---|---|---|
| 5°C | 5 | 2 | 2 | 2.1 |
| | 10 | 2 | 4 | 1.9 |
| | 5 | 5 | 4 | 2.2 |
| | 5 | 10 | 7 | 1.7 |
| | 5 | 15 | 6 | 2.3 |
| | 0 | 21 (Air) | 6 | 2.7 |
| 0°C | 5 | 2 | 4 | 2.2 |
| | 10 | 2 | 5 | 2.7 |
| | 5 | 5 | 5 | 2.8 |
| | 5 | 10 | 5 | 2.8 |
| | 5 | 15 | 5 | 3.1 |
| | 0 | 21 (Air) | 3 | 3.1 |

Table 10. Effect of chemical treatments on the keeping quality of sliced radishes stored for 2 weeks in commercial polyethylene bags.

| Temperature | Treatment | Rating | Final % $CO_2$ | Final % $O_2$ |
|---|---|---|---|---|
| 5°C | 0.2% sodium bisulfite | 5 | 11.3 | 4.0 |
| | sat. sol. calcium oxalate | 6 | 4.9 | 13.8 |
| | 1% sodium chloride | 6 | 5.3 | 10.6 |
| | 1% sodium nitrate | 6 | 4.5 | 5.3 |
| | water | 5 | 4.9 | 2.3 |
| 0°C | 0.2% sodium bisulfite | 6 | 6.4 | 9.1 |
| | sat. sol. calcium oxalate | 6 | 3.2 | 14.2 |
| | 1% sodium chloride | 5 | 2.0 | 18.0 |
| | 1% sodium nitrate | 6 | 3.3 | 9.7 |
| | water | 5 | 1.6 | 12.1 |

controlled atmospheres are of little value, since the best ratings reflect much higher $O_2$ levels than we found best for cut head lettuce. Dehydration does not seem to be a problem when storing in plastic bags, and radishes drain easier than cut head lettuce, therefore, water soaking does not become a problem and may account for the increased benefit of chemical dips for sliced radishes over their effect on cut head lettuce.