Extended Shelf Life for Produce

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INTRODUCTION

The preservation of food quality and reduction of spoilage organisms are of paramount importance to the food industry. Economic benefits through extended shelf life can be meaningful at every step along the food process. Figures as high as 30% or more have been used to assess the amount of produce lost to microbial activity between the time of harvest and consumption. Losses occur at every step of handling, including transient time, processing, and storage. The USDA says the effective extension of produce requires an understanding that spoilage can be reduced at numerous points along the food chain. Therefore, it is important to apply risk reduction strategies at each step and process.

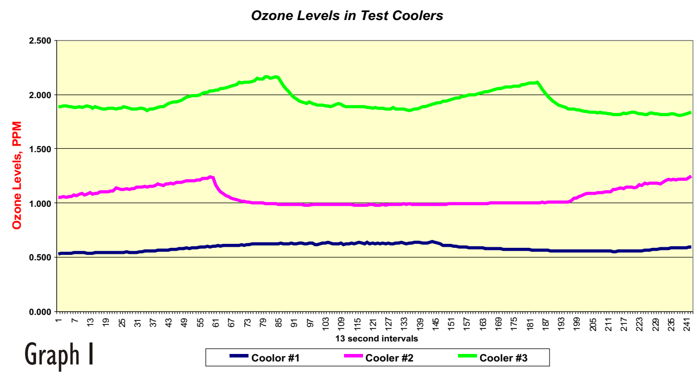
One strategy to reduce various spoilage organisms, such as bacteria and mold, as well as the losses from accelerated ripening is through the introduction of gas phase ozone. Hundreds of scientific papers have been published proving ozone kills spoilage organisms and neutralizes the off-gasses that accelerate ripening and spoilage. The FDA has approved the use of ozone for all food storage and preparation, and the USDA has acknowledged ozone's role for improved food production.

While there has been significant research on the use of ozone for extending the shelf life of a variety of foodstuffs, the purpose of Biozone Scientific's research is to define more closely the parameters necessary to maximize the reduction of spoilage, and to apply them to common, everyday food processing and storage applications. Specifically, laboratory testing was performed to quantify the life extension of produce in cold storage, combining variant ozone levels and ultraviolet light. Testing protocol was written by Dr. B.V. Rajmane and followed Good Laboratory Procedures in Biozone Scientific's Analytical Testing Laboratory.

MATERIALS AND METHODS

Produce products were stored in 4matching coolers. A Biozone Scientific 100FS model UV/ozone unit was placed inside each cooler. The ozone generation rate was adjusted to maintain a relatively constant, predetermined ozone level over the duration of the testing (see graph 1). A recently calibrated INUSA-2000-1 gaseous ozone analyzer measured ozone levels. A monitoring probe was installed in each cooler and connected to the analyzer with ozone levels sampled every 13 seconds. Results were fed directly from the monitor to a Dell computer via serial port download using Windows Hyperterminal and importing the data into Excel. In addition, temperature conditions were monitored in each cooler with professional-grade refrigerator thermometers to ensure proper and homogeneous storage conditions in each cooler of 42F. See Figure 1 below. The ozone levels selected for testing were based on previously published research, as well as previously conducted in-house testing.

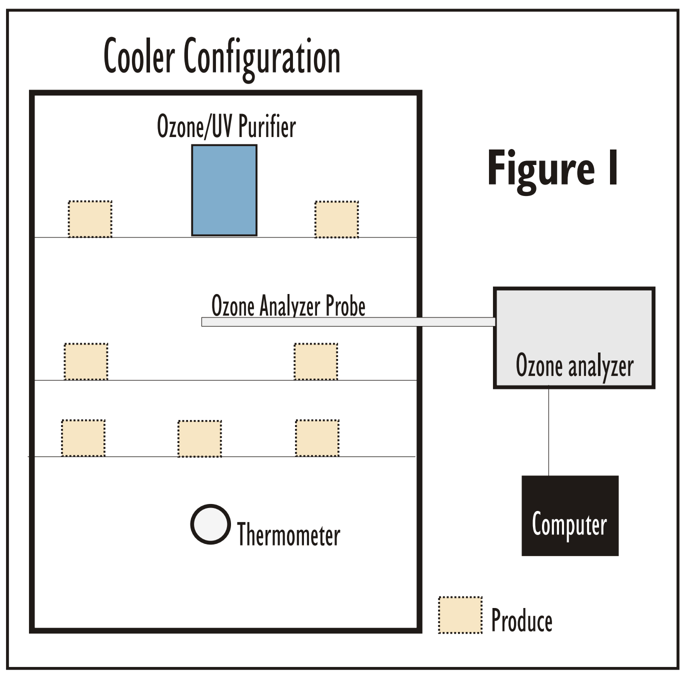
Cooler "C" control, no ozone
Cooler #1 - 0.6 ppm
Cooler #2 1.0 ppm
Cooler #3 2.0 ppm



Graph I

The produce selected for testing was purchased at a local produce stand, and all five of the following produce items were consistent in freshness and appearance.

Strawberries   Raspberries
Blueberries   Asparagus
White grapes



The produce was inspected each day for mold, color, ripeness and firmness. All coolers were opened for the same time intervals each day, and to assume "real world" commercial applications, many days the doors were opened numerous times.

RESULTS

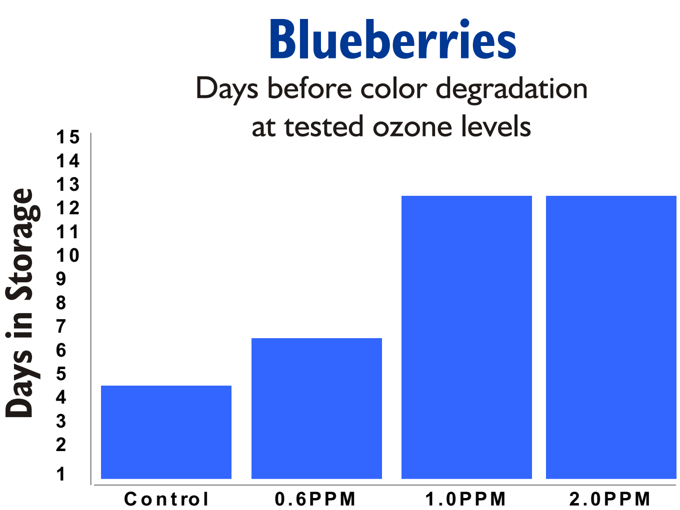
The results of produce exposure to variant ozone levels in a refrigerated environment compare well to results from other investigators and further support ozone's effectiveness in extending produce shelf life. In addition, testing variant levels simultaneously provided indications of optimum ozone levels for maximum effectiveness (see Graph II, III, IV,, and Table I).

Delaying the formation of mold on produce was easily accomplished in an ozone environment. Strawberries in the control cooler began forming mold after 2 days (this was on a bruised section), but no mold ever formed (even on bruised berries) in any of the coolers containing ozone for the duration of the 15-day test (see figures II & III). Highly sensitive raspberries experienced mold growth on the 3rd day in the control cooler but showed no mold growth until the 5th day in the 0.6 ppm cooler with no mold growth for the duration of the test at the higher ozone levels of 1.0 ppm and 2.0 ppm. Blueberries, white grapes and asparagus showed no mold growth in the control or ozonated coolers.

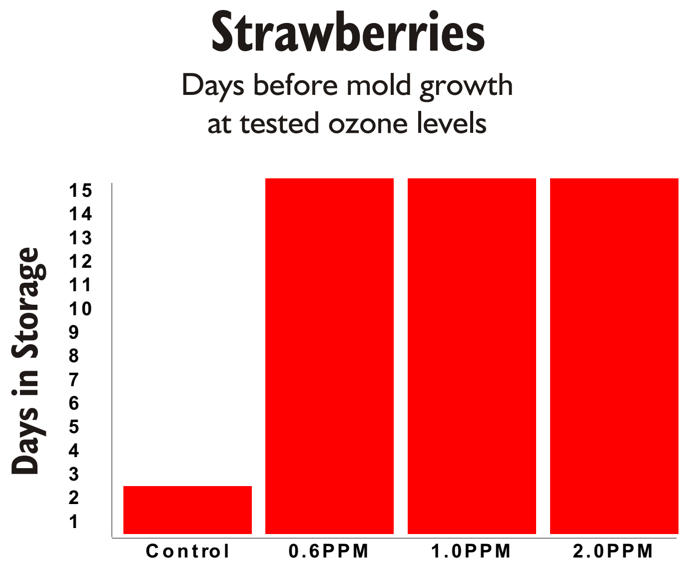
Indications as to produce quality and freshness are displayed in the color and firmness of the product. Dramatic improvements in the color retention of all produce stored in ozone environments were observed. Asparagus color remained good throughout. Strawberries held their color 5 days longer than the control group while raspberry color remained 3 days longer and blueberries 3 to 9 days longer. Asparagus firmness lasted as long as 17 days longer depending on the ozone level. The color and firmness of white grapes lasted 7 days longer at the 2.0ppm level.

CONCLUSIONS

The results presented here demonstrate that a high degree of improved shelf life of produce products can be achieved with airborne ozone. The shelf life improvements in this study compare well with the best results obtained in numerous studies on the effects of ozone in prolonging the life of foodstuffs through inactivation of spoilage organisms and reduction of produce-generated gases that enhance ripening. The use of ozone for inactivation of spoilage organisms to extend the useful life of produce also strongly parallels other studies performed on the reduction of pathogenic and non-pathogenic organisms with ozone. The results would suggest that worthwhile product life extension could easily be accomplished by introducing appropriate amounts of ozone into refrigerated environments.

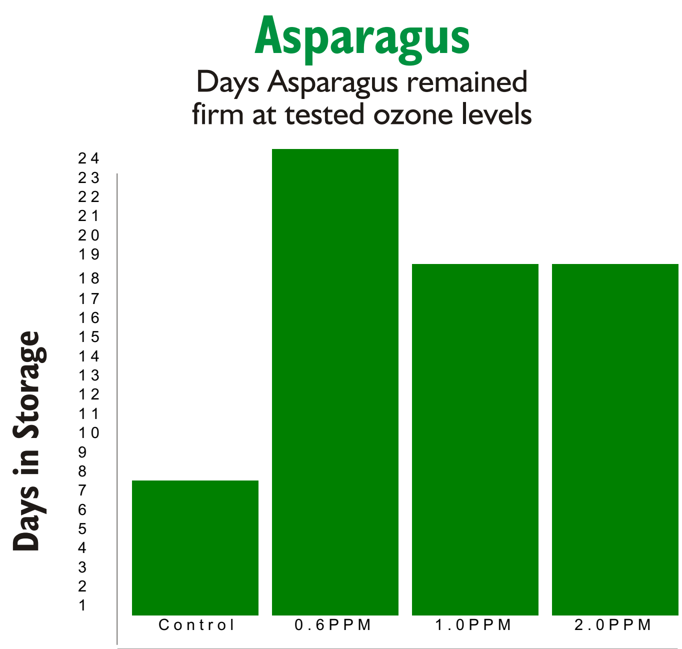


Graph II



* No mold developed on the strawberries for the duration of the test - 15 days

Graph III



Graph IV

While this research examined the results of three levels of ozone, precise ozone levels necessary for optimum results have not been determined. However, if exact levels were established, their practicality would be suspect in actual application due to the nature of produce processing and storage. As a result, an optimum or preferred ozone range could be determined that would achieve desirable results for each produce product or for a "mix" of stored produce. This research indicates the following levels were most effective for achieving overall improved quality (mold, color, firmness):

Strawberries	1.0 ppm
Raspberries	1.0 ppm
Blueberries	1.0 ppm
Asparagus	0.6 ppm
White Grapes	2.0 ppm

A recommendation as to a level for storing a mixture of produce in an environment that would indicate significant improvements in shelf life would be 1 & 2ppm. It should be noted that previous studies have indicated life extension benefits from levels as low as .3 -.5 ppm, and such levels, while perhaps not optimal, should be considered when integrating storage with worker exposure times. In addition, this study did not directly determine the microbial reduction benefits of the

Produce	Ozone Level	Days Before Mold Growth	Days Before Color/ Appearance/Firmness Change
Strawberries	0.0	2	3
	0.6	none	8
	1.0	none	8
	2.0	none	10
Blueberries	0.0	none	2
	0.6	none	5
	1.0	none	7
	2.0	none	11
Raspberries	0.0	3	1
	0.6	5	4
	1.0	none	4
	2.0	none	4
White Grapes	0.0	none	3
	0.6	none	5
	1.0	none	7
	2.0	none	15
Asparagus	0.0	none	7
	0.6	none	none - 24 days
	1.0	none	18
	2.0	none	18

Table I

use of ultraviolet light as the ozone generation source. In spite of this unknown, the results, as well as previous studies on the subject, would indicate that ultraviolet light would encourage the reduction of organic contaminants and further enhance an environment for extended product shelf life.

The results presented here continue to support the

Bruised Strawberries After Just 2 Days

Mold is already forming in untreated cooler

No Mold Ever Formed On Any Strawberry in an Ozone Containing Cooler Throughout the Test Period

Figure II

Results After 15 Day Test Duration

Control | Ozone Environment

Figure III

benefits of ozone in cold storage and the obvious economic benefits to everyday food storage and processing applications. Additionally, the tests confirm the effectiveness of Biozone Scientific's products to substantially extend the shelf life of the tested produce.

ADDITIONAL BENEFITS

While the primary purpose of this research was investigation of shelf life extension, tests were also conducted to ascertain the reduction of odors, and, in particular, odor contamination between products. It is well documented that ozone neutralizes most odors. The application of gas phase ozone into refrigerated containers substantially reduced foodstuff odors. Specifically, it eliminated "cross-odor" contamination, i.e., the absorption of one product's odor by another product. For example, strawberries stored next to onions did not absorb the onion smell (or taste) as they did in the control cooler (no ozone).

CASE STUDY - APPLICATION OF RESEARCH RESULTS

A commercial retailer of produce was selected as a test site to demonstrate the effectiveness of ozone in prolonging shelf life in a real world environment. A Biozone Scientific ozone/UV unit was placed in his 713 cubic ft. Cooler.

During a 30-day test, the owner compared shelf life with previous experiences. His records verified a reduction in product waste of 66%. Examples from his data included:

- Strawberries remain in saleable condition 12 to 14 days longer
- Raspberries that normally last only a few days now last as long as 13 days
- Lettuce life was extended 4 to 5 extra days
- Absolutely no mold growth on any produce product

The reduction in spoilage was significant and resulted in favorable economic benefits and dramatic improvement in product quality.

References:

M.M. Barth, C. Zhou, J. Mercier and F.A. Payne, 1995 "Ozone storage effects on anthocyanin content and fungul growth in blackberries":, J. Food Science, 60(6): 1286-1288

W.J. Blogoslawski and P.O. Monasterio, 1982, "Bacterial depuration of the Mexican scallop, Argopecten circularis", Ozone: Sci & Engrg. 4(3): 121-129

P. Bouregeault, 1989, "Ozone, substitute for chlorine", Chinook Phi Beta Corporation, Ottawa, Canada

W.T. Broadwater, R.C. Hoehn, P.H. King, 1973, "Sensitivity of three selected bacterial species to ozone", Applied Microbiology, Vol 26, Pg 391

H.C. Chen, S.O. Chang and S.T Ing, 1987, "A study on the sterilization effect of ozone and its application for marine food processing", J. Fish. Soc. Taiwan 14(2): 79-89

D.S. Clark, J. Takacs, 1980, "Gases as preservatives In: Microbial ecology of foods", Vol 1: Factors affecting life and death of microorganisms, pp. 170-192

J.W. Colbert, 1952, "Removal of ethylene from storage atmospheres", Food Investigations, National Research Council, Ottawa, Canada. Refrigerating Engineering. Vol 60, pg 265

A. Dondo, C. Nachtman, L. Doglione, A. Rooso and A. Genetti, 1992, "Foods: their preservation by combined use of refrigeration and ozone", Ingegneria Alimentare le Conserve Animali, 8(3): 16, 18-19, 22-23, 25

W.J. Elford, J.V. Eude, 1942, "An investigation of the merits of ozone as an aerial disinfectant", J. Hyg. 42:240-265

EPRI, 1997, Expert Panel Report: Evaluation of the History and Safety of Ozone in Processing Food for Human Consumption, Vol.1: Executive Summary. Electric Power Research Institute, Palo Alto, CA, USA, TR-108026-V1, 4827, May 1997

A.W. Ewell, 1950, "Ozone and its application in food preservation", Refrigerating Engineering Application Data - Section 50, published in Refrigerating Engineering, Section 2 (Sept. 1950)

Y. Fauvel, 1963, "The use of ozone as a sterilizing agent in seawater for the depuration of shellfish", Intl. Comm. Sci. Explor. of the Mediterranean Ocean, Reports and Verbal Proc., 17(3): 701-706

R.H. Fetner, R.S. Ingolis, 1956, "Bacterial activity of ozone and chlorine against Escherichia coli at 1 degree C", J. Gen. Microgrol. 15,381

G.R. Finch, D. Smith, M.E. Stiles, 1988, "Dose-response of Escherichia coli in ozone demand free phosphate buffer", Wat. Res. Tech. 22:1563-1570

P.M. Foegeding, F.F. Busta, 1991, "Chemical food preservatives in: disinfection, sterilization and preservation", 4th ed. S.S. Block Ed. Lea & Febiger

France, 1995, "Decrees of 24 January and 23 January 1995 relative to various technological additives in human foods", J. Officiel de la Republique Francaise, 4 March 1995, p. 3457

M. A. Gabriel'yants, L.N. Teplova, T.I. Karpova, R.A. Kozlova, and G.F. Makarova, 1980, "Storage of hard rennet cheeses in cold stores with ozonization of air", Xholodil'naya Tekhnika 5:35-37

D.M. Graham, M. Pariz, W. H. Glaze, G. W. Newell, J. W. Erdman and J.F. Borzelleca, 1997, "Use of ozone for food preservation", Food Technology 51(6): 72-76

A.K. Greene, B.K. Few and J.C. Serafini, 1993, "A comparison of ozonation and chlorination for the disinfection of stainless steel surfaces", J. Dairy Science 76:3617-3620

C.R. Gross, R.M. Smock, 1945, "Studies on odor elimination in apple storage", Refrigerating Engineering. Vol. 50, pg. 535

T. Haraguchi, U. Simidu and K. Aiso, 1969, "Preserving effect of ozone to fish", Bull. Japanese Soc. Scientific Fisheries 35(9): 915-919

F.E. Hartman, 1924, "The industrial applications of ozone", Am. Soc. Heating & Ventilating Engrs. J. 30:711-727

A. Haufele, 1973, "Ozone for disinfection of water contaminated with vegitative and spore forms of bacteria, fungi, and viruses", Microbiol. Abst., 8B7200

Health and Welfare Canada, Bureau of Chemical Safety, "Letter of No objection to the use of ozone from ozone emitting machines to treat the air in food handling areas in food plants"

J.T. Holah, S.J. Rogers, J. Holder, K.E. Hall, J. Taylor and K.L. Brown, 1995, "The evaluation of air disinfection systems", R&D Report, Campden - Chorleywood Food Research Association, No. 13, 40pp

S. Hoshida, 1995, "Ozone for preservation of poultry eggs", Japan (patent) Kokia Tokkyo Koho; JP 95,236,415 A2; J 07236415; 12 Sept. 1995

D. Imroth, 1985, "The Braunwalder AG large-scale meat processing plant in Wohlen, Switzerland. Ripening under controlled conditions with air sterilization", Fleischerei 36(8): 589-590

G. Kaess and J.F. Wiedemann, 1968, "Ozone treatment of chilled beef. I. effect of low concentration of ozone on microbial spoilage and surface color of beef", J. Food Technology 3(4): 325-334

T. Kasei, A. Iwashita and S. Kiriyama, 1994, "Modified process for preparation of ozonated casein and nutritional evaluation of the product with rats", Biosci. Biotech. Biochem. 58:451-454

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