A PILOT-SCALE SYSTEM FOR OZONE TREATMENT OF FRUITS AND VEGETABLES

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Abstract

Using existing and newly acquired equipment, a system was constructed for the testing of ozone (0_3) for use as a sanitizing agent in food processing. The intended use of the system is to demonstrate that ozone is an effective and efficient germicide for the treatment of raw agricultural commodities. The system has the capacity to ozonate 200 gallons of water which can then be used to wash produce, reducing the microbial l6ad through direct contact between the ozone in the water and the microbes on the produce. The system is designed to model a flume wash system with a cascading water supply. A one horsepower motor powers the water flow and ozone levels are monitored continuously via in-line ORP probes. 0_3 levels are confirmed using the HACH colorimetric assay. The corona discharge ozone generator is combined with an oxygen generator yielding ca. 15 grams 0_3 per hour. This allows for sufficient variation in test parameters, such as organic loading, incoming microbial load, the decay rate of 0_3, specific surface area of the food, water flow, and temperature. All expenmental samples are tested immediately on-site for Aerobic Plate Count, Yeast and Mold, Coliforms, or Mesophilic Spores. Initial studies indicate that a three log-fold reduction in microbial load is possible with a ten minute contact time (CT: where CT - mg/L 0_3 x minutes). In order for the process to be commercially feasible, the CT must be reduced by at least 50% without sacrificing the germicidal efficacy. From an engineering stand-point, the goal is to develop specific CT values for different commodities based upon the above mentioned variables. These studies are of significance to the government for the approval of 0_3 as a food-contact sanitizing agent; to the industry as a chlorine alternative; and to the consumer, and everyone, from a food safety perspective.

KEY WORDS: Ozone, food processing, contact time

Introduction

A pilot study was conducted to access the capabilities of ozone as a sanitizing agent in food processing, and to study the effectiveness of ozone as a germicide for the treatment of raw agricultural commodities. The major objective was to develop and establish specific CT values (CT; where CT - mg/L 0_3 x minutes) for different commodities based on the concentration of ozone used and time of contact.

The underlining objective of this study will be to model the disinfection processes of ozone on several commodity types. Also, an investigation into how ozone's germicidal properties are influenced by the following factors will be considered: Temperature and pH of the water; specific surface area of the commodity; flow rate of processing water; effects of non-target demand substances; incoming microbial loading; and ozone concentration.

Ozone is a highly effective disinfectant, both in terms of its broad range of germicidal activity and rapid aqueous phase reaction kinetics. It is a 52% stronger oxidant than chlorine and acts more rapidly over a wider spectrum of microorganisms than all other disinfectants.

Ozone can be produced when oxygen is energized by electricity or ultraviolet light (<200 nm). Ozone is more soluble in water than oxygen, but saturation conditions are seldom achieved due to the low partial pressures normally used. In aqueous systems, ozone is unstable and decays to the normal diatomic form quite rapidly. Because of this instability, any time ozone reacts with a substance, such as a metal or an organic carbon molecule, it pulls some electrical energy away from that molecule. This is called oxidation. The oxidation potential of ozone in water is greater than that of the most commonly used disinfectants such as chlorine or bromine (Table I).

Currently, the food processing industry is evaluating the implementation of ozone treatment into current processing systems. This is important because it has been determined that chlorination, the primary means of disinfection within the industry, produces harmful disinfectant by-products. Examples of these include chloramines (toxic to fish), trihalomethanes (THMs; potential carcinogens) and the formation of chloroorganic residues on processed foods.

At this time, the use of ozone as a food contact disinfectant has not been approved by the Food and Drug Administration (FDA) or the United States Department of Agriculture (USDA). However, 0_3 is approved for bottled water, municipal drinking water treatment, swimming pools and spas, as well as other water treatment applications.

Ozone Generation

A model P-2000 corona discharge ozone generator (Clearwater Tech$_1$ San Luis Obispo, CA) was used to generate ozone *(Fig.* I). See Figure 2 for the complete schematic of the pilot-scale ozonation system.

Ozone Measurement

Ozone levels in the processing water were continuously monitored using an oxidation reduction potential (ORP) meter in millivolts. Periodic grab samples of the processing water were drawn and analyzed using a HACH DR-700 meter. A graph comparing millivolt readings and parts per million (ppm) of dissolved ozone was developed (Fig. 3).

Sample Treatment

Approximately 1000 grams of each sample (broccoli, broccoflower and carrots) was weighed and placed into pre-sanitized nylon mesh bags. These samples were treated in ozonated water for one$_1$ five or ten minutes. The control sample was washed for a period of five minutes in non-ozonated water. After treatment, samples were cut into small segments using a sanitized knife. A random 50 gram sample was blended with 450 ml of peptone broth (1:10 dilution) and scheduled microbial tests were performed within 30 minutes of washing.

Microbial Tests

Aerobic Plate Count (APC) and yeast & mold (using DRBC agar; Oxoid) tests were performed using standard microbiological methods (FDA BAM, APHA).

Result:

The following figures depict the results of using ozone in the range of 0.64 to 1.11 ppm on broccoli, carrots and broccoflower.

- Figure 4 - Reduction of microorganisms on broccoli using ozone at a concentration of 1.11 ppm.
- Figure 5 - Reduction of microorganisms on carrots using ozone at a concentration of 0.64 ppm.
- Figure 6 - Reduction of microorganisms on broccoflower using ozone at a concentration of 1.08 ppm.

Under typical experimental conditions, anywhere from 1 to 3 microbial load reductions were seen. Broccoli shows the best reduction.

From the experimental data obtained, CT value equations were derived for broccoli, carrots and broccoflower. The following three figures shows this information.

- Figure 7 - Plot of CT values vs. log reduction for broccoli.
- Figure 8 - Plot of CT values vs. log reduction for carrots.
- Figure 9 - Plot of CT values vs. log reduction for broccoflower.

The broccoli gave the smallest CT value per given log reduction. Each graph shows a high degree of correlation among the plotted CT points.

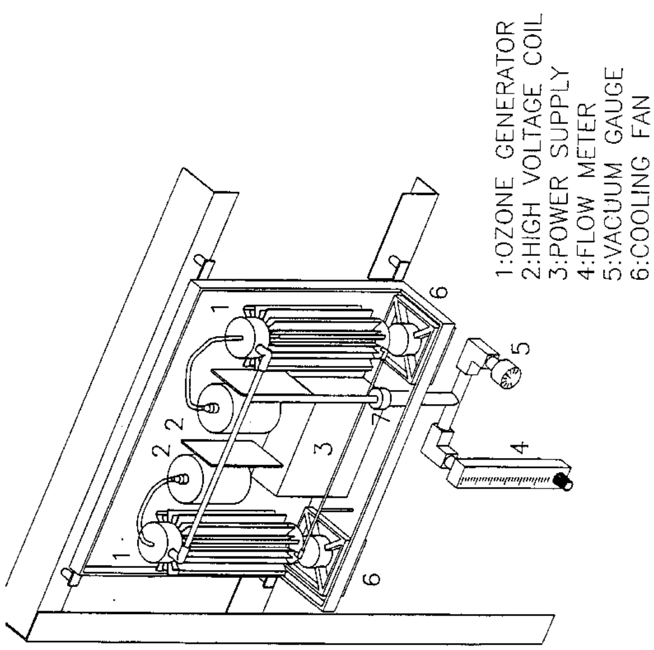

Figure 1: Ozone Generator

Table 1: COMPARATIVE OXIDIZING POTENTIALS, 25 C

	VOLTS
Fluorine (F2)	2.87
Ozone (O3)	2.07
Hydrogen Peroxide (H2O2)	1.78
Potassium Permanganate (KMnO4)	1.70
Hypobromous Acid (HOBr)	1.59
Hypochlorous Acid (HOCl)	1.49
Chlorine (Cl)	1.36
Oxygen (O2)	1.23

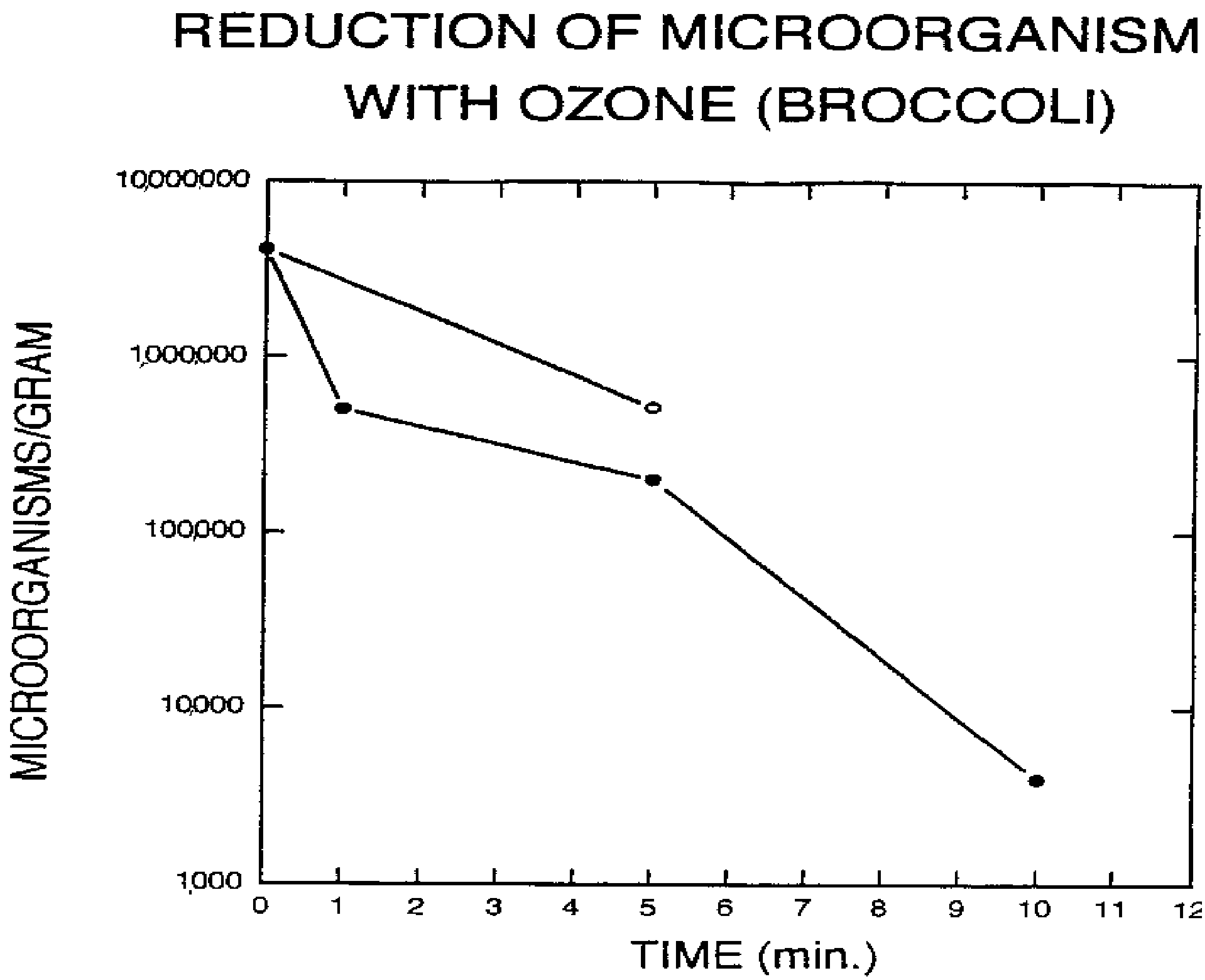

Figure 4: Ozonation of broccoli using 1.11 ppm of ozone.

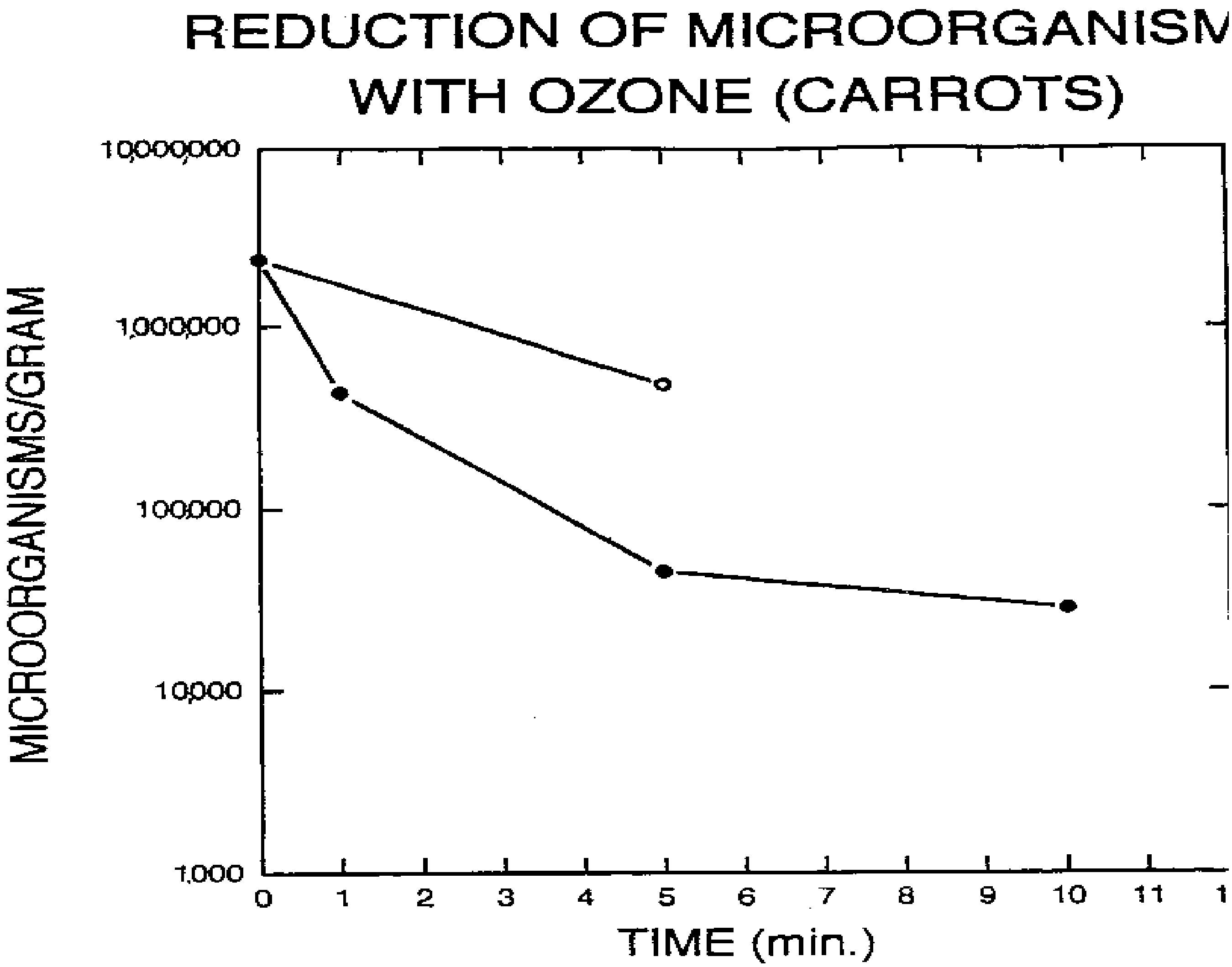

Figure 5: Ozonation of carrots using 0.64 ppm of ozone.

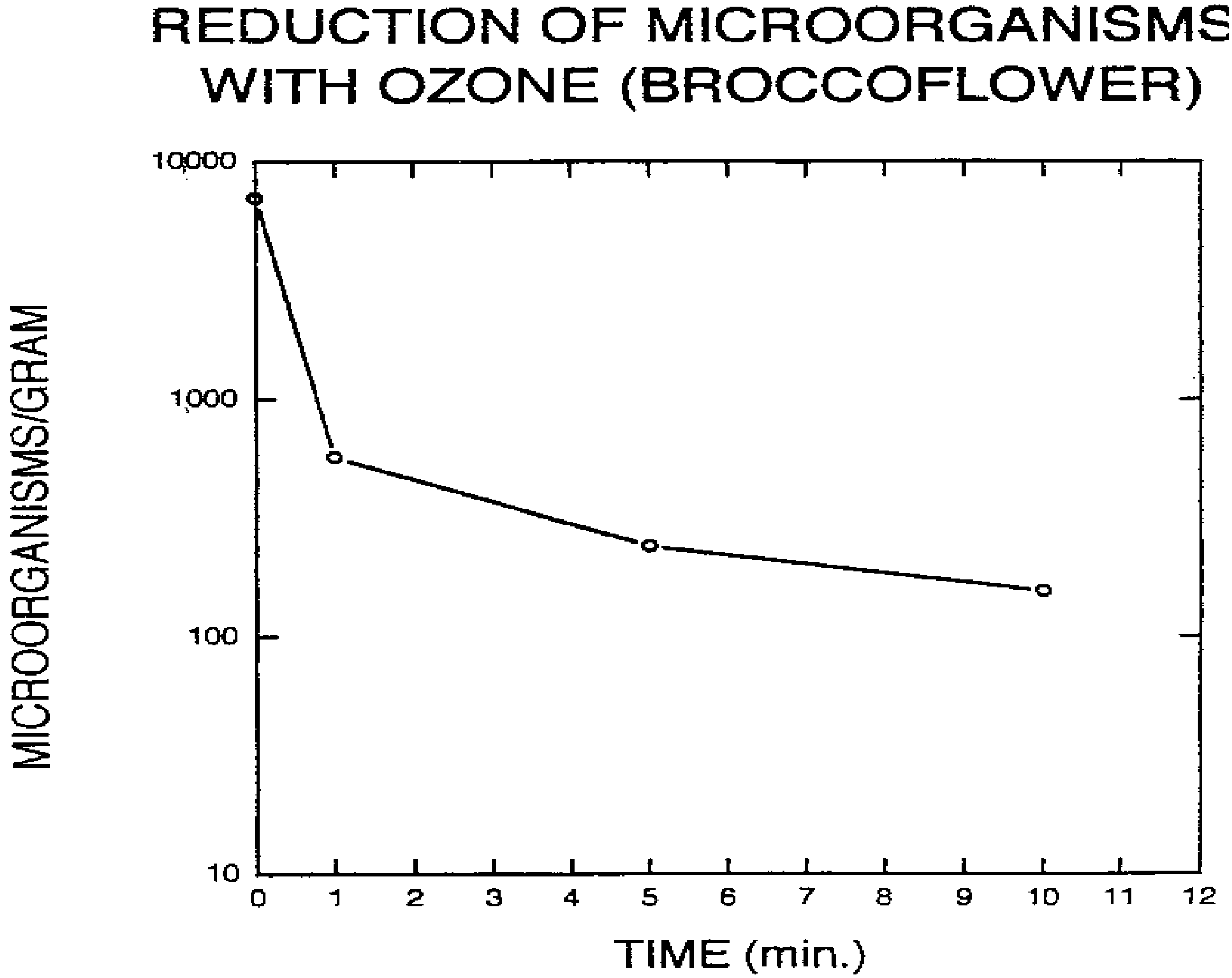

Figure 6: Ozonation of broccoflower using 1.08 ppm of ozone.

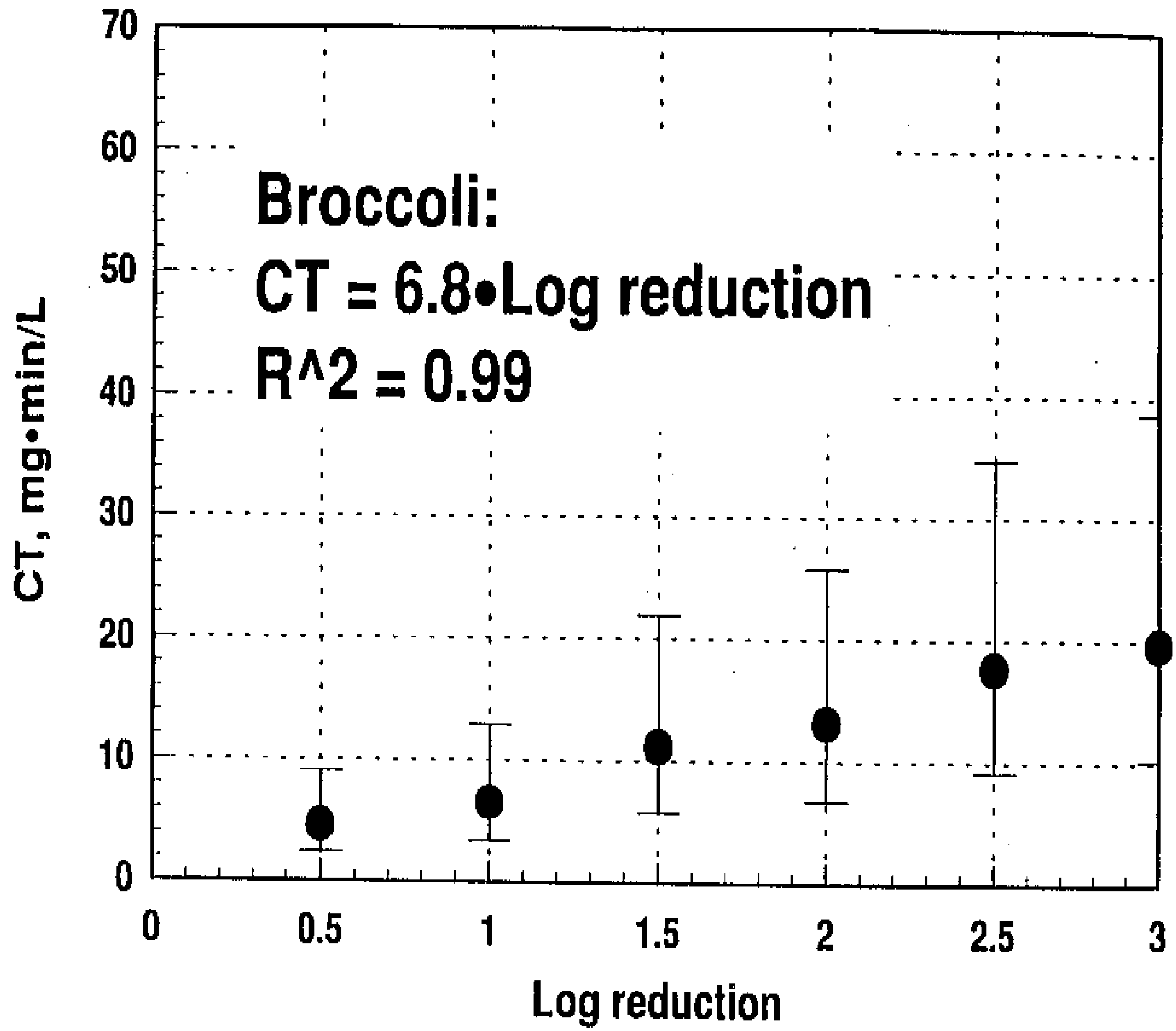

Figure 7: Plot of CT values vs. log reduction for

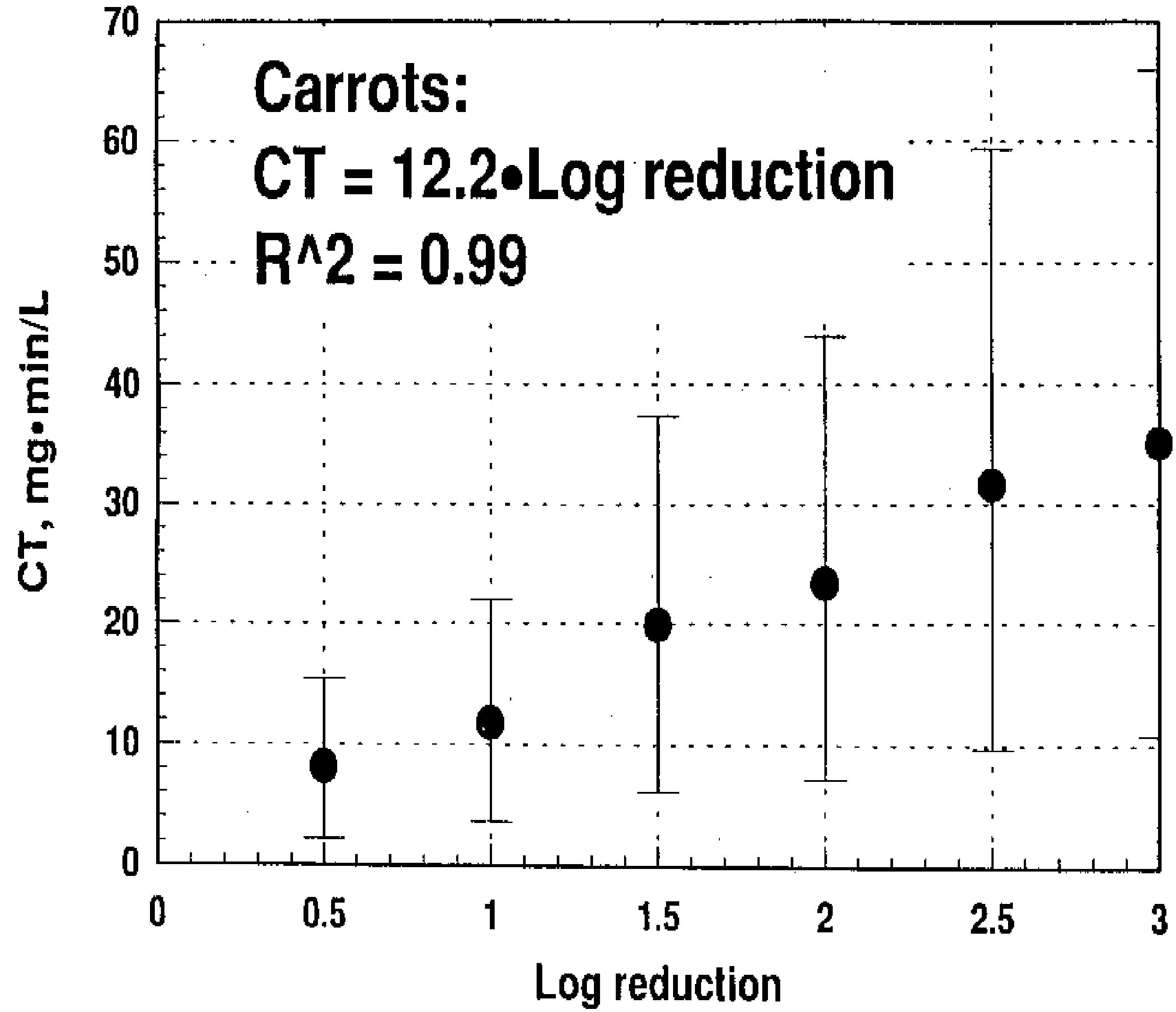

Figure 8: Plot of CT values vs. log reduction for carrots

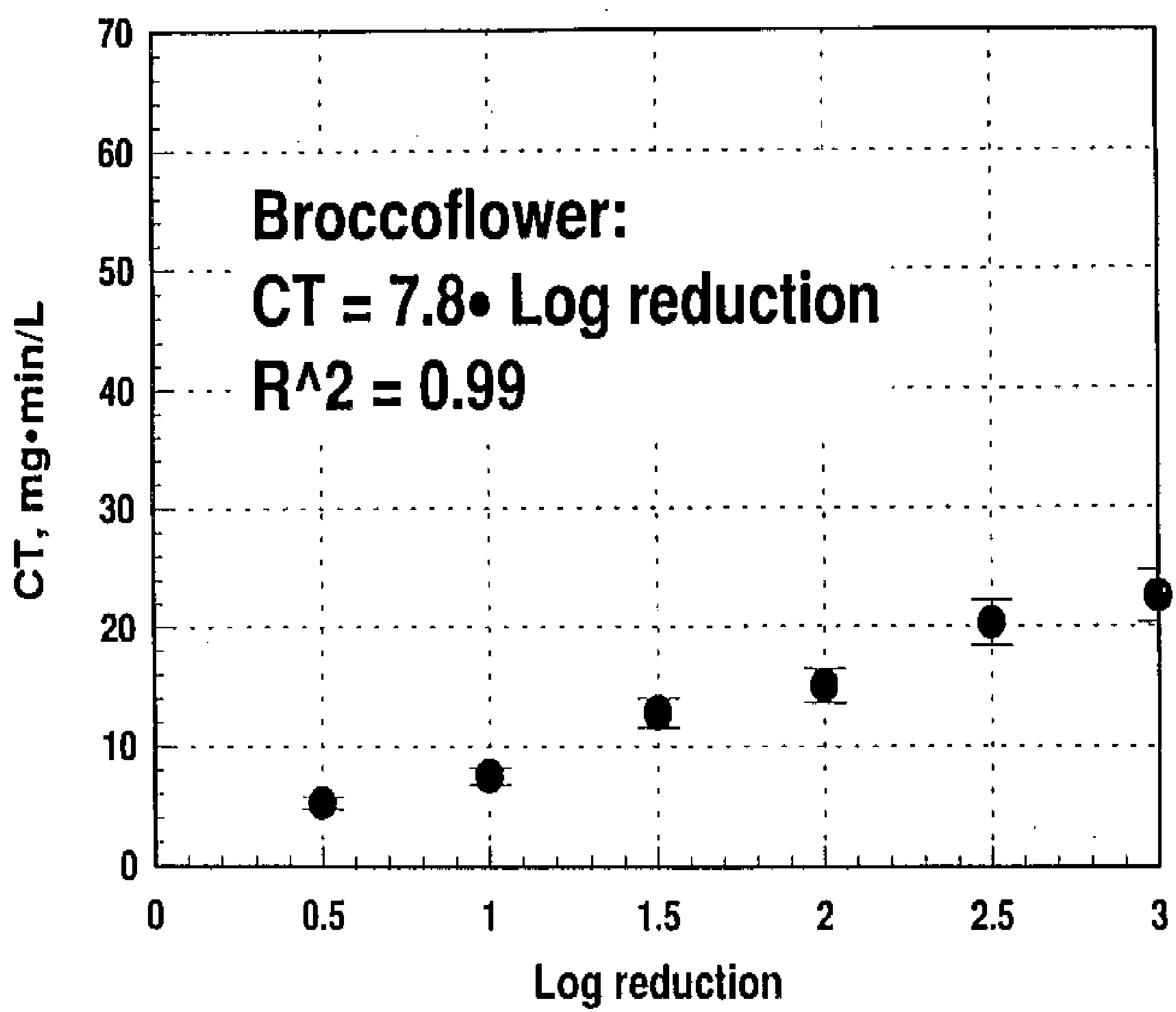

Figure 9: Plot of Ct values vs. log reduction for

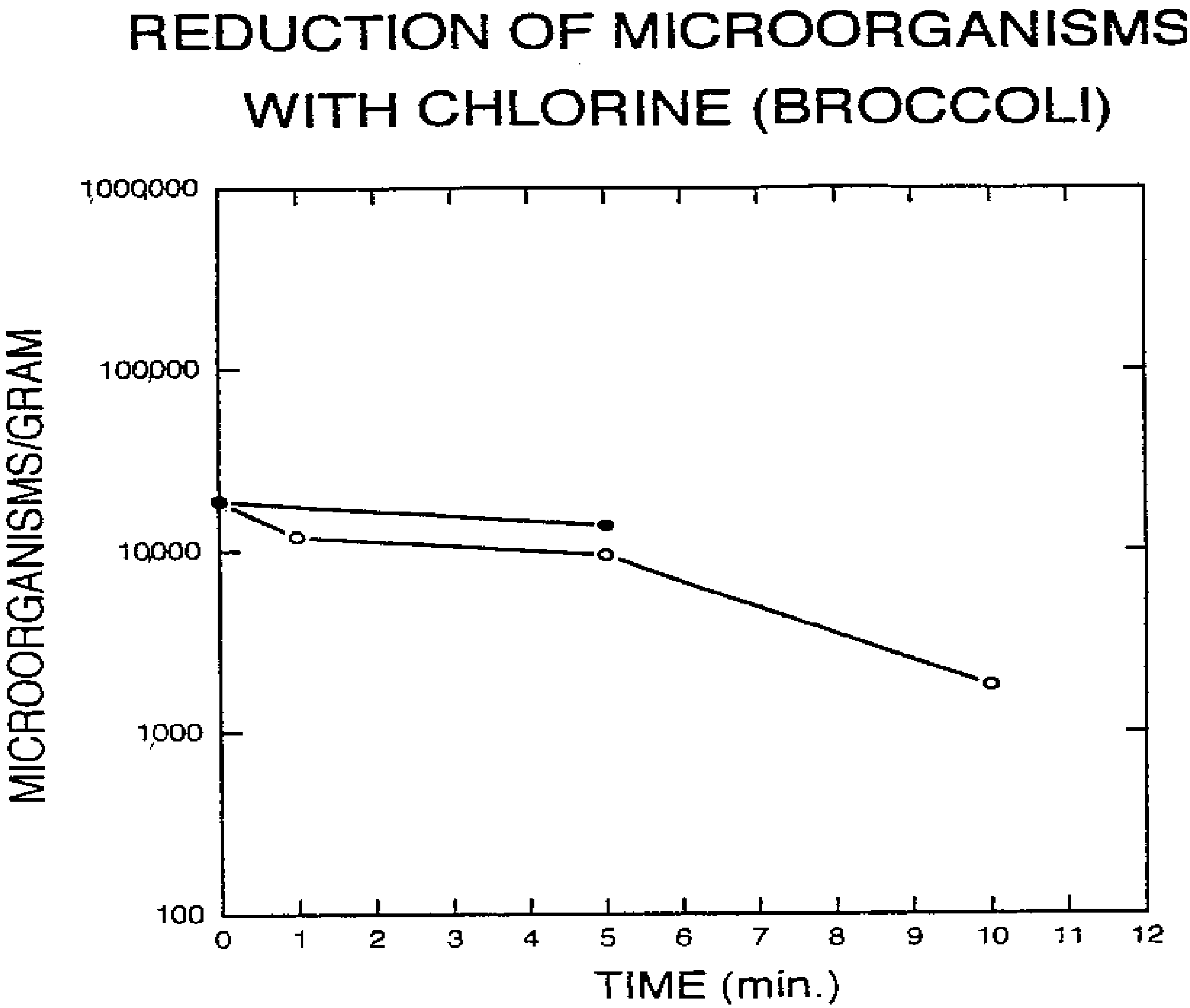

Figure 10: Chlorination of broccoli using 100 ppm of chlorine.

Using the same experimental protocol, chlorine was substituted for ozone as the germicidal agent.

Figure 10 - Chlorination of broccoli using 100 ppm of chlorine.

Comparing chlorination (Fig. 10) to the results obtained using ozone, an additional log reduction was realized for APC when ozone was used as the germicidal agent. This comparative aspect of the study will be investigated further. In addition, ozone combined with chlorine or another germicide to determine if there is a synergistic germicidal effect will be investigated.

Conclusions

The results from this study support the following conclusions:

- Ozonation of raw agricultural commodities is a first order disinfection process.

- The results of this study give positive indications that 0_3 is an effective disinfectant.

- A number of independent factors influence the overall effectiveness of ozone as a disinfectant:
  1. Water temperature
  2. Ozone concentration
  3. Non-target demand substances
  4. Specific surface area

- Broccoli had the lowest CT values to achieve a given log reduction followed by broccoflower, then carrots.

- Preliminary results indicate that ozone proves to be a better disinfectant than Cl_2 under the conditions noted above.