EXPERIMENTAL DEVICE TO STUDY TEMPERATURE EFFECTS ON FOOD QUALITY

Adriano Saquet[1], Josef Streif[2], Luis Cristóvão[3], Pedro Carreira[3], Domingos Almeida[4*]

1: Federal Institute of Science and Education Farroupilha – Campus Panambi, Rua Erechim, 860, 98280-000 Panambi, RS, Brazil
2: Competence Center of Fruit Growing Bavendorf, University of Hohenheim, Schuhmacherhof 6, 882313 Ravensburg, Germany
3: Frincor - Frio Industrial e Comercial, Lda, Rua Casal da Ligeira, 20 Armazém 14, Ral, 2710-446 Sintra, Portugal.
4: Instituto Superior de Agronomia, Universidade de Lisboa, Tapada da Ajuda, 1349-017 Lisboa, Portugal. e-mail: dalmeida@isa.ulisboa.pt, web: http://www.isa.ulisboa.pt/freshness

Abstract: *Food quality is highly dependent on temperature management. A laboratory experimental device was designed to study the temperature effects on food quality and its performance characterized herein. The equipment is composed of: a) a refrigeration unit; b) an insulated container with total volume of 500 L of a streaming glycol solution; and c) a set of 12 sealed glass jars with 2.15 L volume each, placed inside the container. Cooling of 450 L of glycol solution at 10% from 22.8 °C to 0 °C required 5.5 h, corresponding a cooling rate of 4.14 °C h^{-1}. The continuous circulation of the glycol solution at a flow rate of 1.8 m^3 h^{-1} allowed 100% uniformity in temperature distribution in the 12 sampling points, where the glass jars are located. No temperature differences were observed between a depth of 5 and 20 cm. Measurements during 24 h showed a fluctuation of the temperature around the set point of the refrigeration unit (0 ºC) from 0 to 0.6 °C and down to 0 ºC in 54-min cycles. In conclusion, the device provides fast cooling of a 10% glycol solution with temperature uniformity within the container of 100%. It proves to be effective for precise short-term experiments on the effects of temperature or cooling rate on food quality characteristics.*

Keywords: Cooling Rate, Fruit Quality, Refrigeration, Temperature Management, Vegetables

1. INTRODUCTION

Food quality is multidimensional and depends on a range of physical, chemical, biochemical, physiological, and microbial processes. The individual processes of different nature also interact in complex ways to determine food quality. The laws of thermodynamics determine the direction of changes in food systems but the knowledge of their rate requires kinetics [1]. Temperature is a key factor determining the kinetics of food quality changes. Arrhenius' law and Arrhenius-like models, empirical rules such as the van't Hoff rule of the parameter Q_{10} are used to describe the effect of temperature on the rate of quality changes [1]. Knowing the temperature dependence of kinetic rate is essential to understand food quality, shelf life, food safety, and to develop and correctly apply many food processing or preservation technologies. Perishable fruit and vegetables require prompt and fast cooling after harvest to reduce their metabolic rate, water loss, and decay [1, 2]. Cooling rates and keeping temperatures are, therefore, key independent variables that affect food quality characteristics, with particular relevance in perishable fruits and vegetables. However, addressing some research objectives related to temperature effects on perishable produce in standard cold rooms or cooling systems can be cumbersome, due to limitations regarding the: i) optimization of temperature conditions; ii) optimization of cooling rates; iii) use of extreme test conditions. Therefore, experimental devices that provide fast cooling rates, high temperature uniformity, and thermal inertia can be very useful in the study of temperature effects on fresh produce. Here we describe a laboratory-scale device engineered to study temperature effects on fruits and vegetables quality maintenance.

2. DESCRIPTION OF THE DEVICE

The device described herein was engineered by the authors, built by Frincor, and is currently in use at the Freshness Lab of Instituto Superior de Agronomia, University of Lisbon.

A stainless steel (1.5 mm thick) container with internal dimensions of 1960 × 800 × 330 mm (L × W × H) and an internal free volume of 500 L was insulated with polyurethane (80 mm; density of 70 kg m-3) covered by an external aluminum sheet of 0.6 mm thick. Liquid (water or a glycol solution) within the container is circulated through a chiller for heat removal. The use of a glycol solution at 10% allows operation at temperature below 0 °C without freezing.

The top lid of the container is a 55 mm-thick polyurethane panel covered with aluminum sheet (0.6 mm thick) and 12 openings (140 × 140 mm), where glass jars are inserted. The openings for the glass jars are sealed and thermally isolated to avoid external room temperature interference.

The system is equipped with a Universal Transfer Switch (UPS) water pump (25-120 Grundfos Pumps Corporation, Downers Grove, USA) with a maximal pressure of 10 bar, operating temperature ranging from -25 °C to + 95 °C, and energy class F. The pump circulates water or a glycol solution though a closed circuit of perforated copper pipes, operating with a flow rate of 1.8 m^3 h^{-1}. The glycol solution is taken up from one end of the container, forced into the chiller, and injected into the container at the opposite end, creating a continuous flow.

The refrigeration system is composed by a condensation unit using air as the cooling fluid (UNT 6222 6K, Embarco) with a refrigeration capacity of 1.42 kW, operating with aspiration at -10 ºC and 32 ºC ambient, 0.75 kW of electrical power, and a service tension of 230/1/50 Hz. A static evaporator of copper tubing (external diameter of 1.2 cm). The system uses the refrigeration fluid R 404a.

Additional equipments in the mechanical refrigeration system include a drying filter, a pressure switch, a digital thermometer sensor, an electric valve, and circulation valves. The aspiration pipe is insulated with Armaflex® foam. An electric board controls the functioning of the equipment.

Glass jars (12) with volume of 2.15 L each are placed on two equidistant rows inside the container. The jars have a glass lid sealed with a rubber O-ring and contain gas tight valves in the Teflon tubes to control internal atmospheres if necessary. Figure 1 shows an overview of the top lid with glass openings and their dimensions.

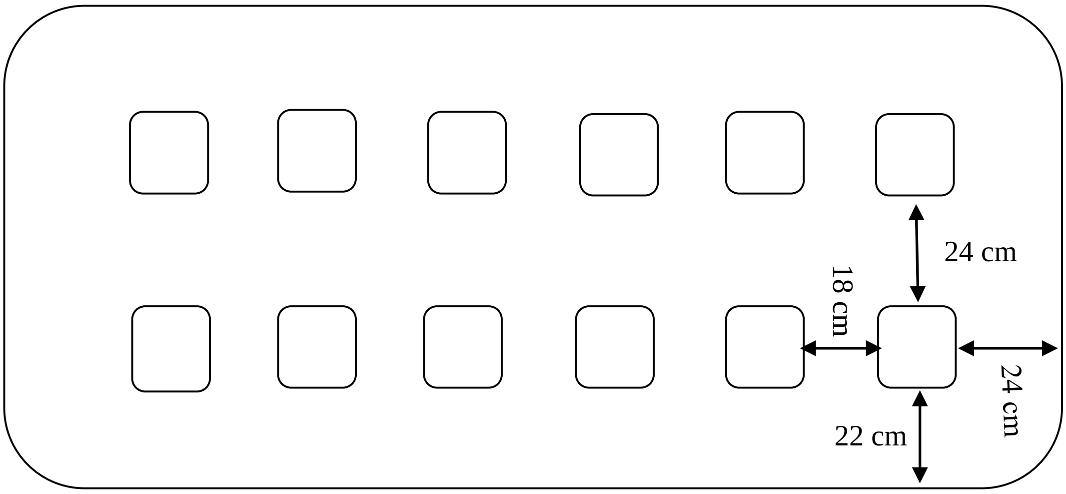

Figure 1: Overview of the top lid of the device with the location of the openings for 12 glass jars containing produce.

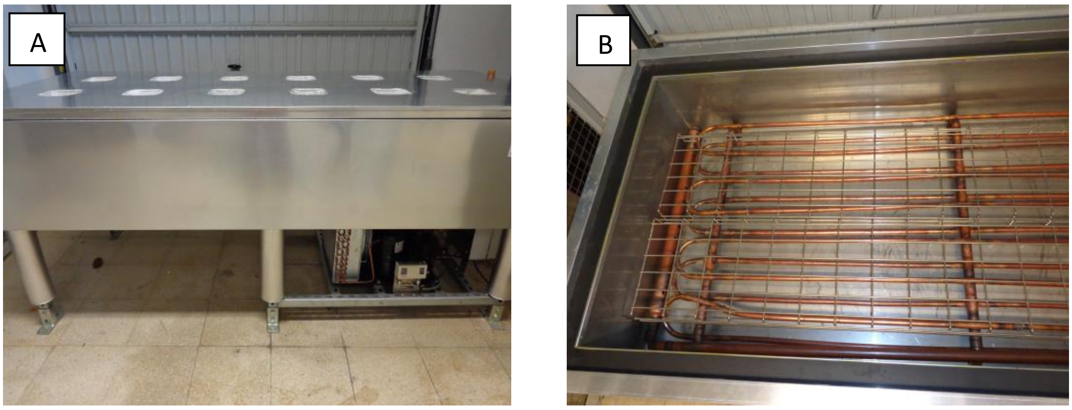

Figure 2: Overview of the device (A), and internal view of the gas expansion tubes immersed in the glycol solution (B).

3. DEVICE TESTING

The device was tested for cooling rate of a glycol solution (10%), temperature uniformity, and temperature fluctuation around the set point of the refrigeration unit.

3.1. Cooling rate of the glycol solution

The container was filled with 450 L of glycol solution at 10%. The temperature of the glycol solution was measured at 30 min intervals at 5 and 20 cm depth in the 12 sampling points (see Figure 1) with a digital thermometer probe (model Checktemp 1, Hanna Instruments), with maximal deviation of 0.3 °C.

A glycol solution with an initial temperature of 22.8 °C cooled to 0 °C in 5.5 h, corresponding to a cooling rate of 4.14 ºC h^{-1} (Figure 3).

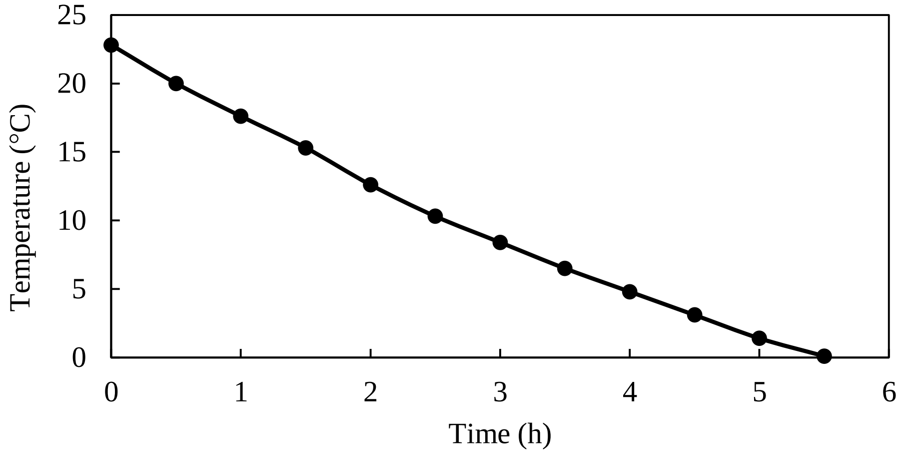

Figure 3: Cooling rate of the glycol solution and uniformity of temperature inside the container.

3.2. Temperature uniformity in the container

Temperature was measured in 12 sampling points located as described in Figure 1. Temperature values were equal in all locations and during the cooling period, i.e. temperature uniformity with the container was 100%. Therefore, the cooling curves of all sampling points are overlapped in Figure 3.

3.3. Temperature fluctuation around the set point

After cooling of the glycol solution to 0 °C, temperature was measured in the 12 sampling locations. All openings for glass jars were properly isolated to eliminate the interference of the environmental heat. The time required for each temperature change of 0.1 °C was registered. The temperature of the glycol solution increased from 0 °C to 0.6 °C in 41 min, after which time the pressostat was automatically activated and the solution cooled from 0.6 °C to 0 °C in 13 min. This 54 min cycle was measured for a 24 h-period.

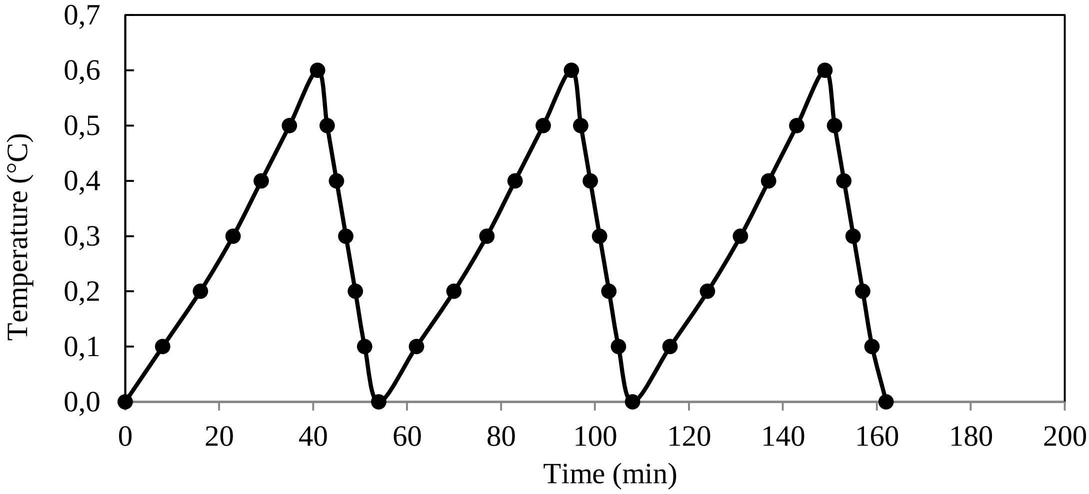

Figure 4: Fluctuation of the temperature of the glycol solution around the set point of the refrigeration unit.

CONCLUSIONS

A custom-made prototype designed to study the effects of temperature on fresh food quality provided fast cooling of a glycol solution and a temperature uniformity within the container of 100 %. When the glycol solution is at 0 °C, a maximum fluctuation of 0.6 °C was registered in 55 min cycles. Steady state temperature conditions can be reached relatively quickly. The device is being used for experiments related with thermal properties and temperature effects on fresh food products.

REFERENCES

[1] van Boeke, MAJS. Kinetic modeling of food quality: A critical review. Comprehensive Reviews in Food Science and Food Safety, 2008, 7: 144-158.
[2] Paull, RE. Effect of temperature and relative humidity on fresh commodity quality. Postharvest Biology and Technology, 1999, 15: 263-277.