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Effect of display case cooling technologies on shelf-life of beef and chicken

Keith Vorst[a,b,*], Niraja Shivalingaiah[a], Ana Lorena Monge Brenes[a,b], Shannon Coleman[a], Aubrey Mendonça[a], J. Wyatt Brown[b,c], Angela Shaw[a]

[a] Department of Food Science and Human Nutrition, Iowa State University, 536 Farmhouse Lane Ames, 50010 IA, USA
[b] Polymer and Food Protection Consortium, 536 Farmhouse Lane, Ames, IA 50010, USA
[c] Horticulture and Crop Science Department, Building 11, California Polytechnic State University, San Luis Obispo, 93407 California, USA

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ABSTRACT

Shelf-life is defined as the time a food product retains its desired sensory, chemical, and physical characteristics while also remaining safe for consumption. Bacteria associated with meat spoilage produce off-odors and flavors, tissue discoloration, gas, and slime. The objectives of this study were, 1) to determine the effect of refrigerated-display-case type on the shelf-life and microbial load of the natural flora found on beef steak and chicken breasts and, 2) to evaluate the effect of gravity coil conductive cooling vs. complete conductive cooling on the growth of *Escherichia coli* K12 artificially inoculated onto beef steak under abusive conditions. In Study 1, beef steak and chicken breasts were placed for 8 or 5 days, respectively, in a conduction cooling gravity assist service case, gravity coil service case with partial conduction coil base deck, gravity coil service case with serpentine assist, or blower coil service case with an additional fogging system. Mesophilic bacteria, *Pseudomonas* spp. and psychrotrophic bacterial counts on meat surfaces, and meat color, internal meat temperature, case temperature and case relative humidity were determined daily. In Study 2, two of the four types of display case– the complete conductive cooling and gravity-coil conduction cooling systems– were chosen to evaluate microbial growth on beef steak due to novel conductive cooling technologies. Temperature and weight loss, aerobic plate counts and viable *E. coli* colony-forming-units on the beef steaks were determined daily. In study 1, the warmest display ambient air temperature was found in the gravity coil service case with partial conduction coil base deck (PCC). The coldest tissue temperatures were observed for steaks and chicken breasts placed in the conduction cooling gravity assist service display case. The lowest RH also tended to occur in the PCC case. Overall, the type of retail display case had no effect on the growth of mesophilic and psychrotrophic bacteria or *Pseudomonas* on both steaks and chicken breasts. In study 2, the initial numbers of viable *E. coli* K12 on inoculated steaks were low and remained low through 7 days storage, regardless of display case. The novel conduction cooling gravity assist service display case used in this study has the greatest potential for extending shelf-life due to lower overall tissue temperatures and reduced water loss from meat products held in this case during high traffic and abusive retail conditions.

1. Introduction

Shelf-life is defined as the length of time that it takes for the quality of food to deteriorate to the point where it becomes undesirable for sale or consumption (Sun & Holley, 2012). Delmore (2009) describes shelf-life, with respect to meat, as the amount of time that passes before it becomes unfit for human consumption due to the growth of spoilage organisms. The spoilage microorganisms most frequently found on fresh meats include *Pseudomonas*, *Acinetobacter*, *Moraxella*, *Psychrobacter*, *Aeromonas* and *Enterococcus* (Jay, Loessner, & Golden, 2005).

Spoilage of fresh meats is often indicated by slimy microbial masses on the cut surfaces, or loss of texture (softening) via degradation of the meat structure by microbial enzymes (Dave & Ghaly, 2011). Meat spoilage is also commonly evident through the formation of off-odors and gas production from microbial metabolism (Dave & Ghaly, 2011; Jay et al., 2005). Off-odors from aerobically-stored fresh meats are usually detected when the aerobic plate count (APC) reaches $\sim 10^7$ colony-forming units (CFU)/g. As the APC reaches a level of $10^{7.5}$–10^8 CFU/g, slime on the meat surface also becomes apparent (Ayres, 1960).

The quality of meats is influenced by factors such as packaging, storage condition, gas composition (O_2, CO_2, inert gases) around the tissues, relative humidity (RH), light and temperature (Singh & Cadwallader, 2004). Temperature and RH appear to have the greatest

* Corresponding author. Department of Food Science and Human Nutrition, Iowa State University, 536 Farmhouse Lane, Ames, IA, 50010, USA.
E-mail address: kvorst@iastate.edu (K. Vorst).

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effect on the microbial quality characteristics of fresh meats held in retail display cases (Leclercq-Perlat, Sicard, Trelea, Picque, & Corrieu, 2012).

Microorganisms grow over a wide range of temperatures. Therefore, it is important to consider the optimum growth temperature for food-borne spoilage organisms when selecting the proper temperature for storage of meats. Refrigeration temperatures slow down microbial growth, so meats are typically refrigerated at 1–7 °C. The organisms that grow at or below 7 °C are mainly psychrotrophs (Jay et al., 2005); however, certain non-psychrotrophic bacterial pathogens including *Escherichia* coli O157:H7 can grow when refrigeration temperatures exceed 7.2 °C.

The RH of the storage environment is important in altering the water activity (a_w) in foods and reducing the growth of microorganisms on the surfaces of meat products (Jay et al., 2005). At low RH, the meat surfaces become dry and bacterial growth slows down. However, many molds and yeasts grow at a lower water activity and are mainly responsible for surface spoilage at low RH (Jay et al., 2005). Improperly-wrapped meats such as poultry and beef cuts exhibit surface spoilage during refrigeration due to high surface moisture exacerbated by high RH.

1.1. Cooling technologies in retail environments

Refrigerated cases with various configurations and cooling technologies are widely used at retail markets to display fresh and processed meats. Recirculated cold air maintains the case contents at a preset temperature (Navaz, Faramarzi, Gharib, Dabiri, & Modarress, 2002) while allowing customers easy access to the products. Four full-service display cases utilizing 4 separate cooling technologies were used in this study: conduction cooling gravity assist service case (CCGA), gravity coil service case with partial conduction coil base deck (PCC), gravity coil service case with serpentine assist (GSA) and blower coil service case with an additional fogging system (BCF).

A conduction cooling display case (CCGA) removes heat by direct transfer, or conduction, of heat from one substance to another. Conduction heat transfer in a CCGA display case occurs through a single heat-transfer-surface via glycol-filled channels located in the aluminum deck pans where the product is displayed. This process allows for even cooling. The glycol flow in deck pans utilizes pulse-flow control, freezing and thawing moisture on the deck pans as they cycle between set points of −1.7 °C and 0.6 °C. A small gravity coil at the top of the case assists in tempering the air, maintaining natural circulation and humidity within the display case. The gravity coil also utilizes a pulse-flow control. With conduction cooling, the air above the product is simply tempered since the majority of cooling is being accomplished through direct contact of product with the deck pans.

A gravity coil service case with partial conduction coil base deck removes heat through a combination of convection and conduction cooling. A gravity coil in the top of the display case is designed to keep product cold through natural convection heat transfer. Refrigerant runs through the gravity coil and absorbs heat from the air. The cooled air falls from the top coil and cascades around the product, removing heat in the process. This type of display/service case also utilizes partial conduction cooling through means of a covered, serpentine deck coil. Refrigerant flows through a spiral copper coil which cools the metal deck. The majority of refrigeration occurs through the action of the top gravity coil.

A gravity coil case with serpentine base deck assist cools through convection utilizing a top gravity coil and lower serpentine coil. A gravity coil located in the top of the display case is designed to keep the product cold through convection heat transfer. Most gravity convection cooling is designed for HFC/HFO refrigerants to run through the gravity coil where they absorb heat from the air. The cooled air falls from the top coil and cascades around the product, removing heat. This type of display/service case also utilizes a serpentine base deck coil. Chilled refrigerant flows through copper piping under the deck pans to enhance refrigeration and to assist keeping the underside of the product cool.

A blower coil case with fogging system consists of a forced air blower coil underneath the deck area of the display case. It is designed to keep product cold by forcing air through a coil for heat transfer. A fogging system is utilized to reduce the moisture loss that often results from air flowing over product.

The effectiveness of display cases in maintaining a desired temperature depends on their engineering and design. Currently, manufacturers design units which are intended to extend the shelf-life of fresh meats (Glavan et al., 2016). The objectives of this study were, 1) to determine the effect of refrigerated-display-case type on the shelf-life and microbial load of beef steak and chicken breasts and, 2) to evaluate the effect of gravity coil conductive cooling vs. complete conductive cooling on the growth of *Escherichia coli* K12 artificially inoculated onto beef steak under abusive conditions.

2. Materials and methods

An initial study was conducted to determine the effect of retail display case type on the shelf-life and microbial load of fresh beef and chicken.

2.1. Study 1: refrigerated display case conditions

The blower coil case with fogging system (BCF) used in this study was equipped with the traditional gravity coil blower coil assist with additional fogging system, while the gravity coil case with serpentine base deck assist (GSA) was equipped with a traditional gravity coil with serpentine-assist refrigeration system. Both systems are commonly used in retail groceries and convenience stores. The fogging system used in the BCF case was installed at the top of the case, had a fogging rate of 2.4 l/h and mist size of 5 μm continuously cycled to maintain 90–95% RH. The conduction cooling display case (CCGA) was equipped with the novel complete conductive cooling refrigeration with coolant recirculating system (Hillphoenix, Conyers, GA) while the gravity cooled case with a partial conduction coil base deck (PCC) was equipped with gravity coil conduction cooling (Hussman, Bridgeton, MO). All cases utilized 3500° Kelvin C3+ lighting. The dimensional height of the product storage area of each case was as follows: CCGA: 32.38 cm; PCC: 38.10 cm; BCF: 49.69 cm; GSA: 46.36 cm.

Five stainless steel sterile trays (72.3 × 41 cm) were lined with butcher paper and placed in each of the four sanitized display cases. Trays were evenly distributed and each touched the front of the display case. The CCGA, GSA and BCF refrigerated display cases used in this study were each 1.22 m in length while the PCC case was 2.44 m long. Each case was filled with samples; however, due to the size difference of the PCC display case, only ½ the case was filled. High-density polyethylene bags containing 50% propylene ethylene glycol were used to fill the other half of the case to compensate for heat load to simulate a fully merchandised display case.

All four display cases were equipped with a rear service door compliant with current American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) standards (ANSI/ASHRAE, 2005). Each service door was fitted with a pneumatic door opener programmed to open 6 times per hour for 6 s over the course of an 8-h day, to simulate retail display case openings by a butcher or service counter representative.

2.2. Study 1: beefsteak preparation and display

Fresh, vacuum-packed beef rounds from the same lot were received from an USDA inspected processing plant in Iowa one day after packing. Rounds were immediately stored at 7 °C. During the preparation process, stainless steel contact surfaces were sanitized with Alconox Powdered Precision Cleaner (Alconox, Inc., White Plains, NY) followed

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