Energy Use and Sales Productivity of Doored and Open Vertical Refrigerated Display Cases

Brian A. Fricke, Ph.D.

Bryan R. Becker, Ph.D., P.E.

University of Missouri – Kansas City

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Objective

- Compare a typical new open refrigerated display case line-up to a typical new glass-doored refrigerated display case line-up

- Quantify and compare the following:
  - The overall energy consumption for each case type
  - The impact on food product sales for each case type

Synopsis

- Test Plan
- Supermarket Descriptions and Display Cases Studied
- Display Case Electrical Energy Consumption
- Product Sales
- Conclusions

General Test Plan

- Identify two similar supermarkets to participate in study
- “Before and after” comparison of selected product sales
  - Identify existing display case line-up in each store

    → collect sales data of the products for two months
  - Replace existing display case line-ups with new display case line-ups

    → collect sales data of the products for two months
  - Compare sales data “before and after” installation of the new display case line-ups to determine the effect that new case line-ups had on product sales

General Test Plan

- The products studied in the two supermarkets were different
  - Sales data for the test products were collected from both supermarkets
  - Sales data from one supermarket was used as a control to adjust the sales data of products studied in the other supermarket (and vice versa)

General Test Plan

- The energy usage of each new display case line-up was monitored
  - Compare energy usage of a new open display case line-up versus that of a new doored display case line-up

- Energy consumption of the HVAC systems were not monitored and no modifications were made to the HVAC systems

Test Plan Outline

- For Store #1:
  - Old open case was replaced with new glass-doored case
  - New case was in the same location as old case
  - New case was stocked with the same product as old case
  - Sales of the product were studied before and after the case was replaced
  - Energy usage of new glass-doored display case line-up was monitored

Test Plan Outline

- For Store #2:
  - Old open case was replaced with new open case
  - New case was in the same location as old case
  - New case was stocked with the same product as old case
  - Sales of the product were studied before and after the case was replaced
  - Energy usage of new open display case line-up was monitored

Instrumentation

- Refrigerant mass flow through display case measured with coriolis mass flow meter
- Refrigerant temperature and pressure entering display case measured
- Refrigerant temperature and pressure exiting display case measured
- One minute sampling rate

Instrumentation

- Electrical energy consumption of display case auxiliaries individually measured
  - Fans
  - Lights
  - Anti-sweat heaters
- Indoor ambient temperature and relative humidity at each store measured
- Outdoor ambient temperature and relative humidity at each store measured
- One minute sampling rate

Store #1 Info

- Located in Osawatomie, KS, a community of 4,600 people
  - Approximately 50 miles south west of Kansas City, MO
- Average retail sales of $80,000 per week
- Store size is 23,000 ft^2

Store #1

- Dairy products, including yogurt, prepackaged cheese, butter, and sour cream, were studied in this store
- Dairy products initially resided in a 44 foot open, multi-deck case line-up
- This case was replaced with a new, medium temperature, 20-doored case line-up, nominally 48 feet in length
  - Fluorescent lighting
  - Anti-sweat heaters with no controls (always on)
  - Standard efficiency evaporator fan motors
- Energy consumption of only 10 door portion of case (24 feet) measured

Store #1: Old Open Case Line-Up

Store #1: New Doored Case Line-Up

Store #2 Info

- Located in Wamego, KS, a community of approximately 4000 people
  - Approximately 100 miles west of Kansas City, MO
- Average retail sales of $140,000 per week
- Store size is 30,200 ft^2

Store #2

- Beer and various alcoholic beverages (wine coolers, hard lemonade, etc.) were studied in this store
- Products initially resided in an open, multi-deck case line-up, 24 feet in length
- This open case line-up was then replaced with a new, medium temperature, open, multi-deck case line-up, 24 feet in length
  - Fluorescent lighting
  - Standard efficiency evaporator fan motors

Store #2: Old Open Case Line-Up

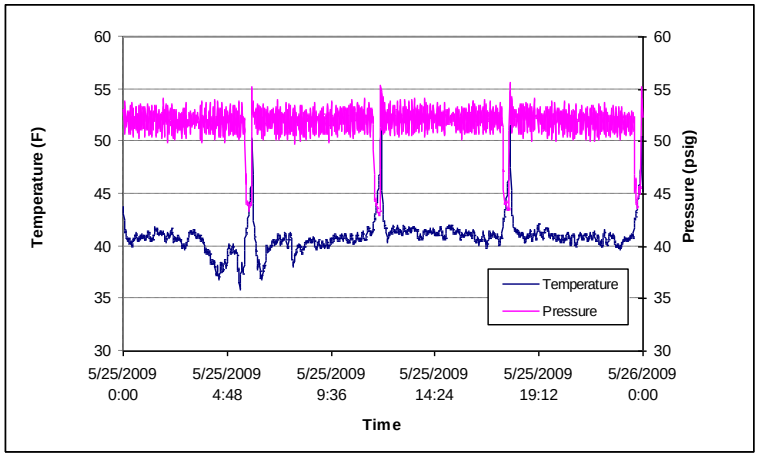
Store #2: New Open Case Line-Up

Serendipity

- Owner of Store #1 (new doored diary case) also replaced 12 feet of open beer case with a 6-doored case, nominally 12 feet in length
- Allowed comparison of:
  - New doored case beer sales to old open case beer sales in Store #1
  - New open case beer sales to old open case beer sales in Store #2
  - New doored case beer sales (Store #1) to new open case beer sales (Store #2)

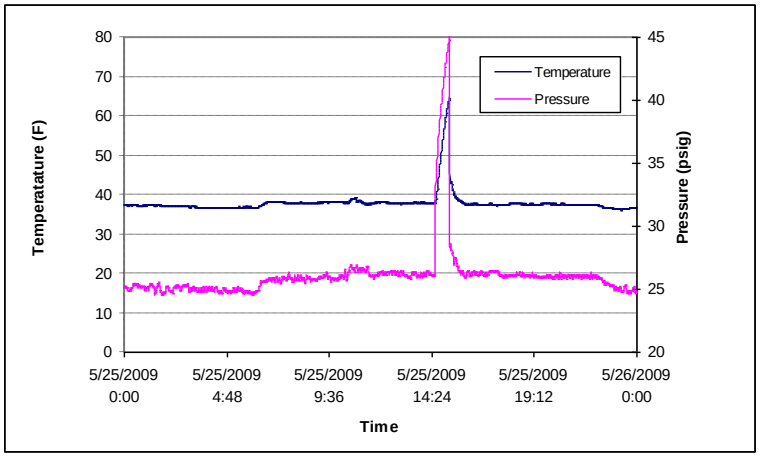
Sample Energy Related Data

– New Open Case Line-Up –

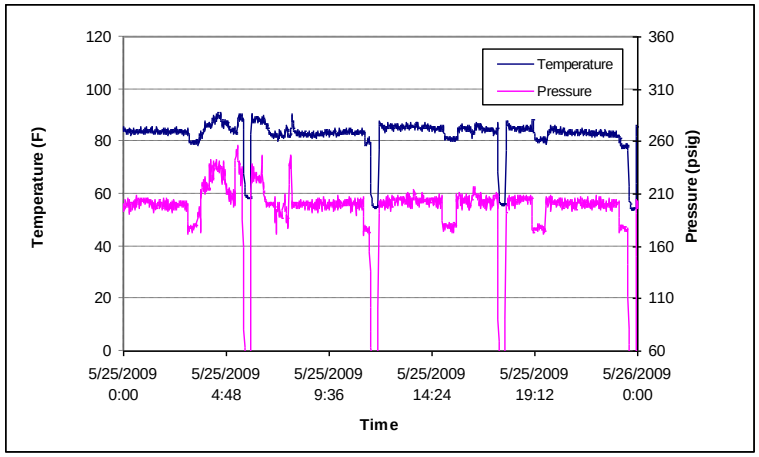


Suction Temperature and Pressure

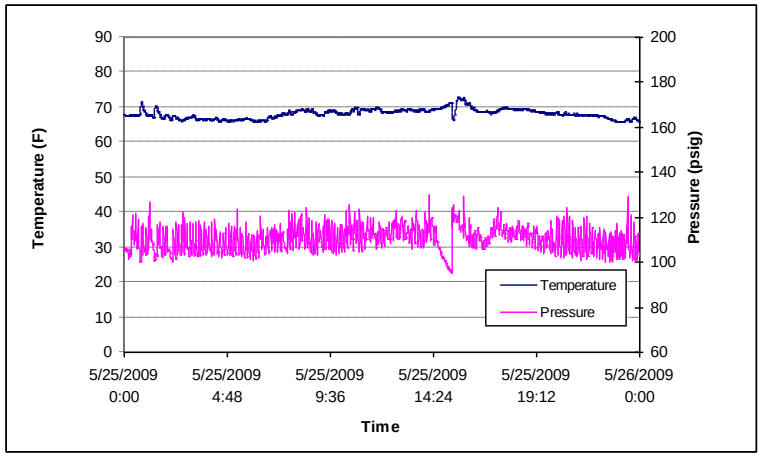
– New Doored Case Line-Up –



Suction Temperature and Pressure



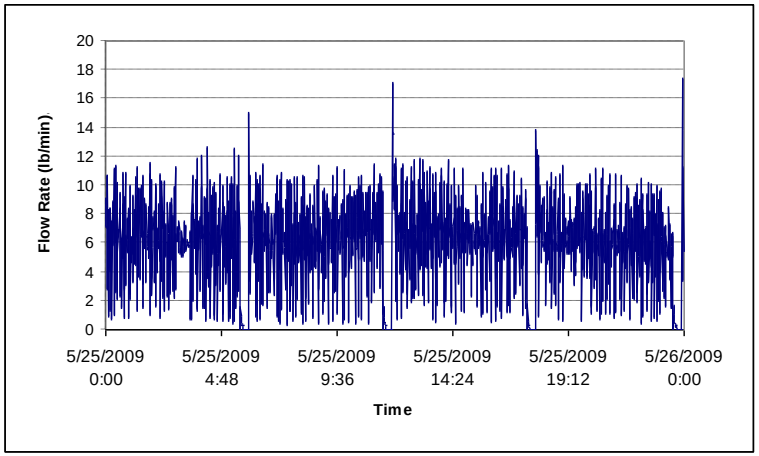
Liquid Temperature and Pressure



Liquid Temperature and Pressure

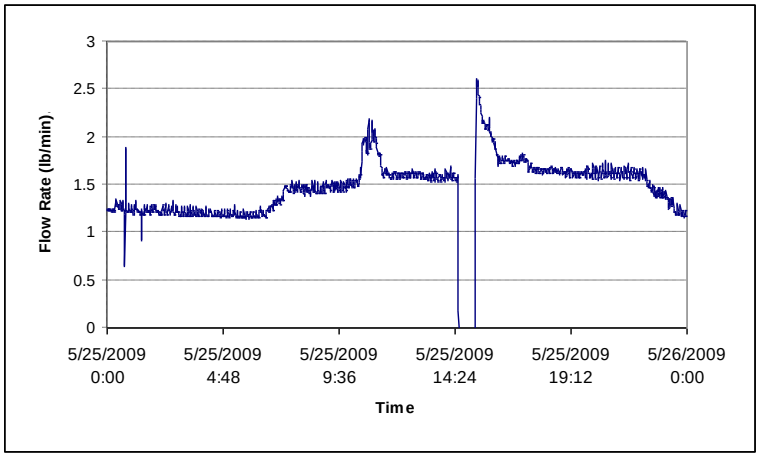
Sample Energy Related Data

– New Open Case Line-Up –

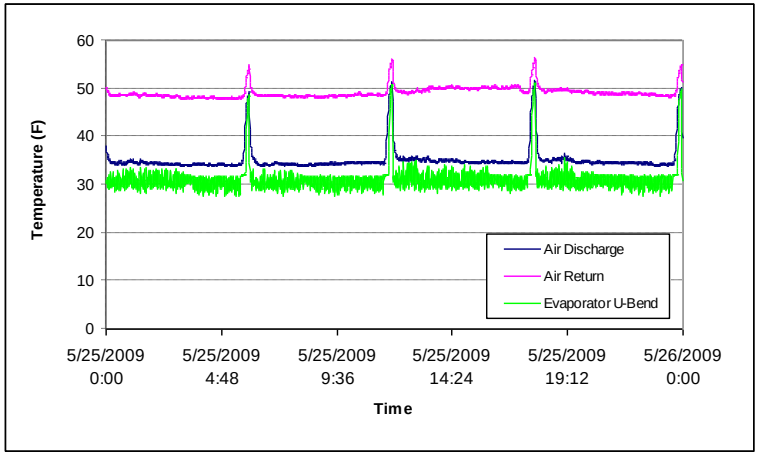


Refrigerant Flow Rate

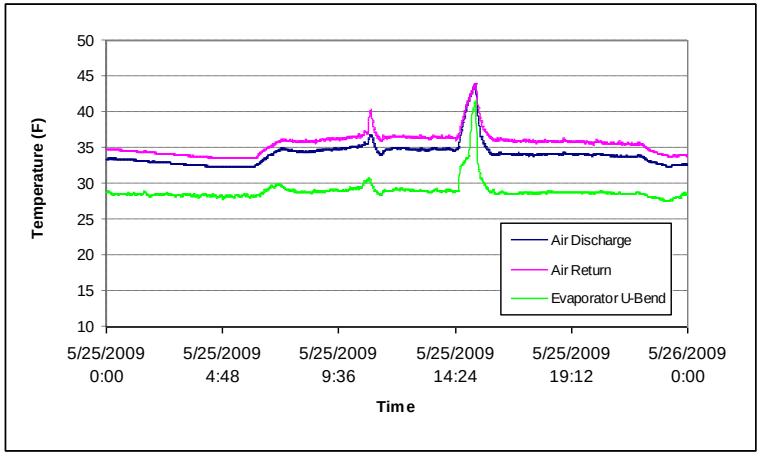
– New Doored Case Line-Up –



Refrigerant Flow Rate



Display Case Temperatures



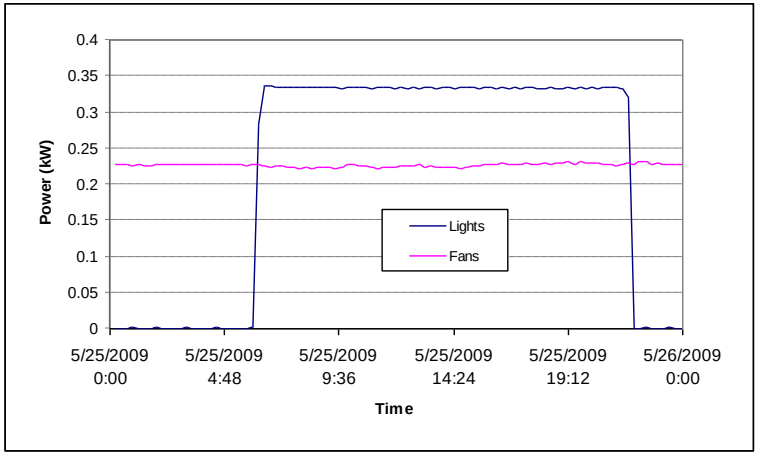
Display Case Temperatures

Air Temperature within Cases

- Smaller temperature difference between discharge and return air temperatures in doored case vs. open case
- Advantage of doored case:
  - Less product temperature variation due to variation in location within case
  - Less product temperature variation due to variation in store ambient conditions
  - Increased food safety

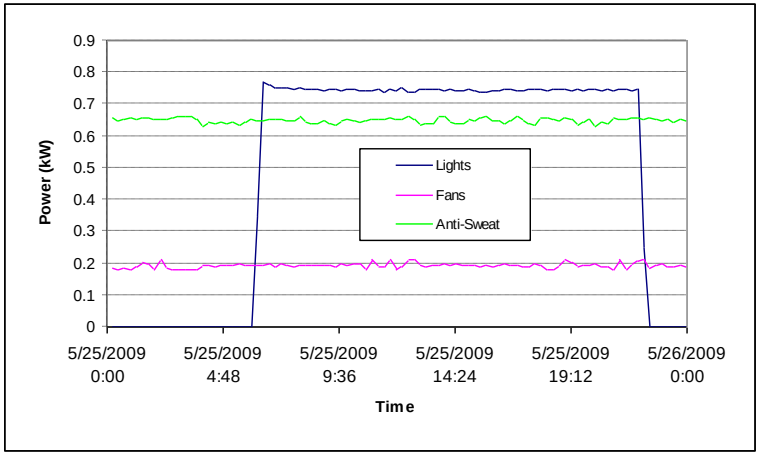
Sample Energy Related Data

– New Open Case Line-Up –



Auxiliary Electrical Power

– New Doored Case Line-Up –



Auxiliary Electrical Power

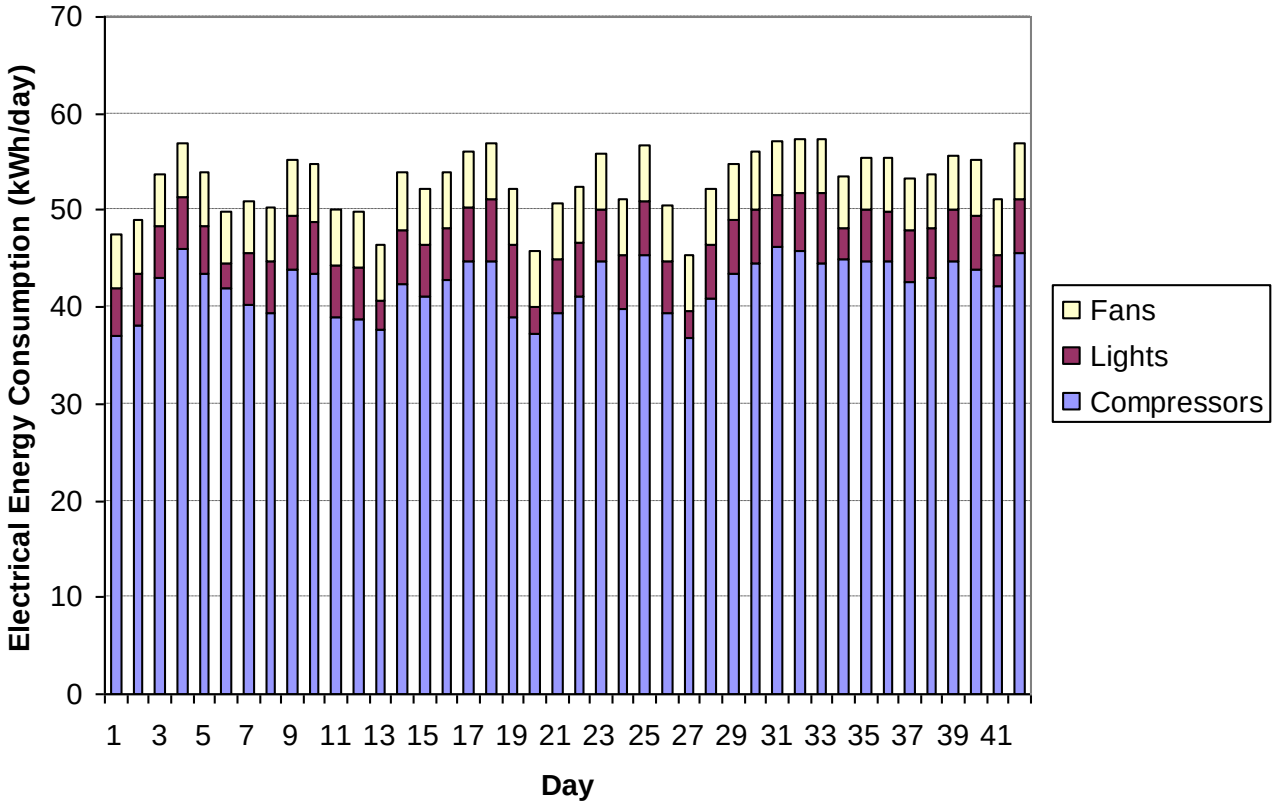
Electrical Energy Consumption

Mean Electrical Energy Consumption of the Open and Doored Display Case Line-Ups Calculated using ARI/ANSI Standard 1200-2006.

Electrical Energy Consumption	Open Display Case Line-Up	Doored Display Case Line-Up
Compressors (kWh/day)	42.20	11.70
Lights (kWh/day)	5.18	11.93
Fans (kWh/day)	5.69	4.58
Anti-Sweat Heaters (kWh/day)	--	15.50
Total (kWh/day)	53.07	43.72
Total (kWh/day per ft)	2.21	1.71

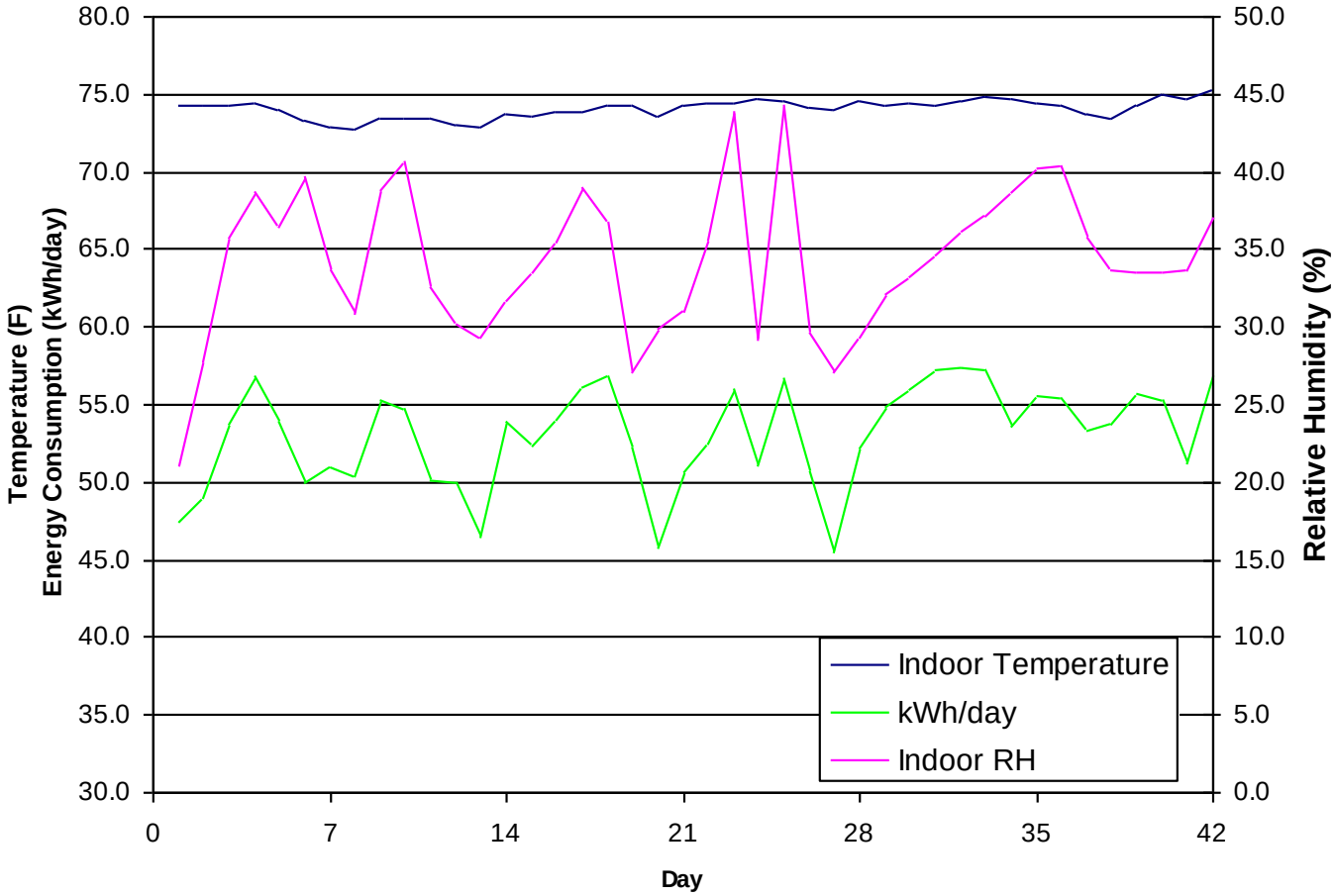
- Per unit length of case, the open display case line-up consumed approximately 1.3 times more energy than the doored display case line-up

Open Case Line-Up Electrical Energy Consumption



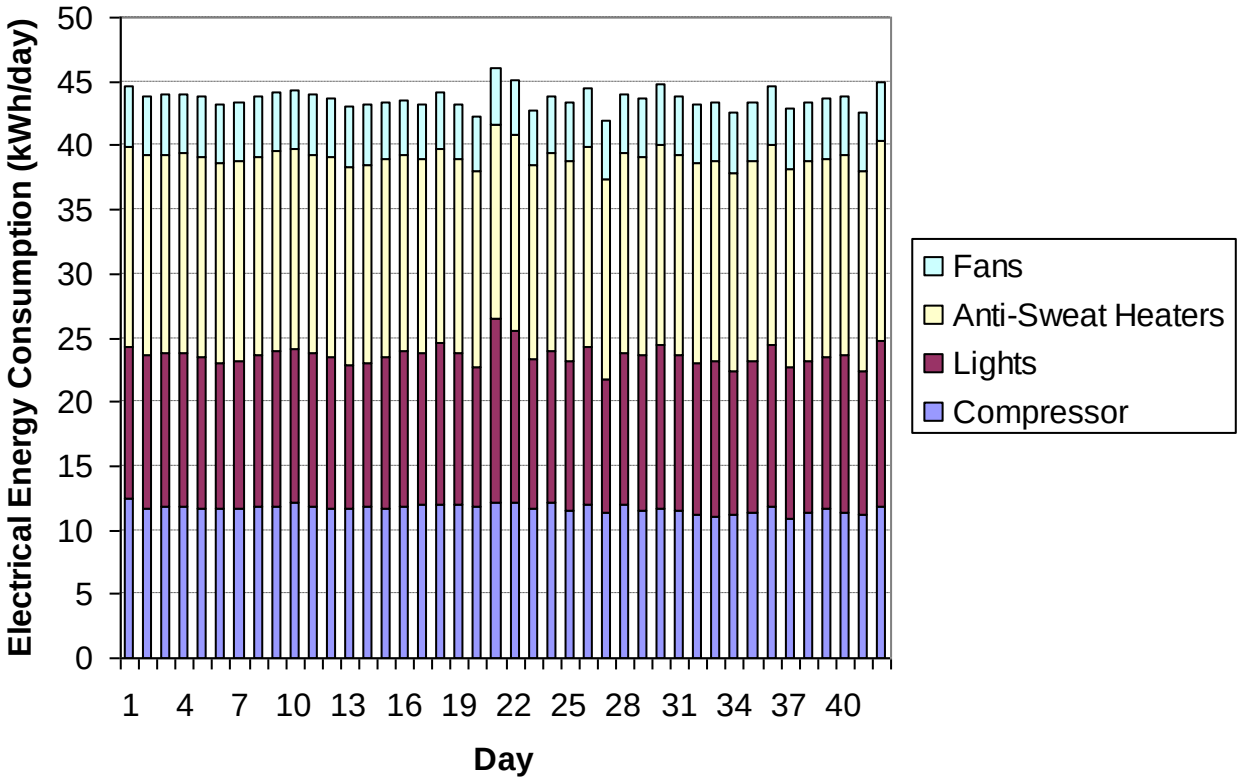
Compressors: 79% of the total daily electrical energy consumption
Fans: 11% of the total
Lighting: 10% of the total

Open Case: Energy Consumption vs Indoor Ambient Conditions



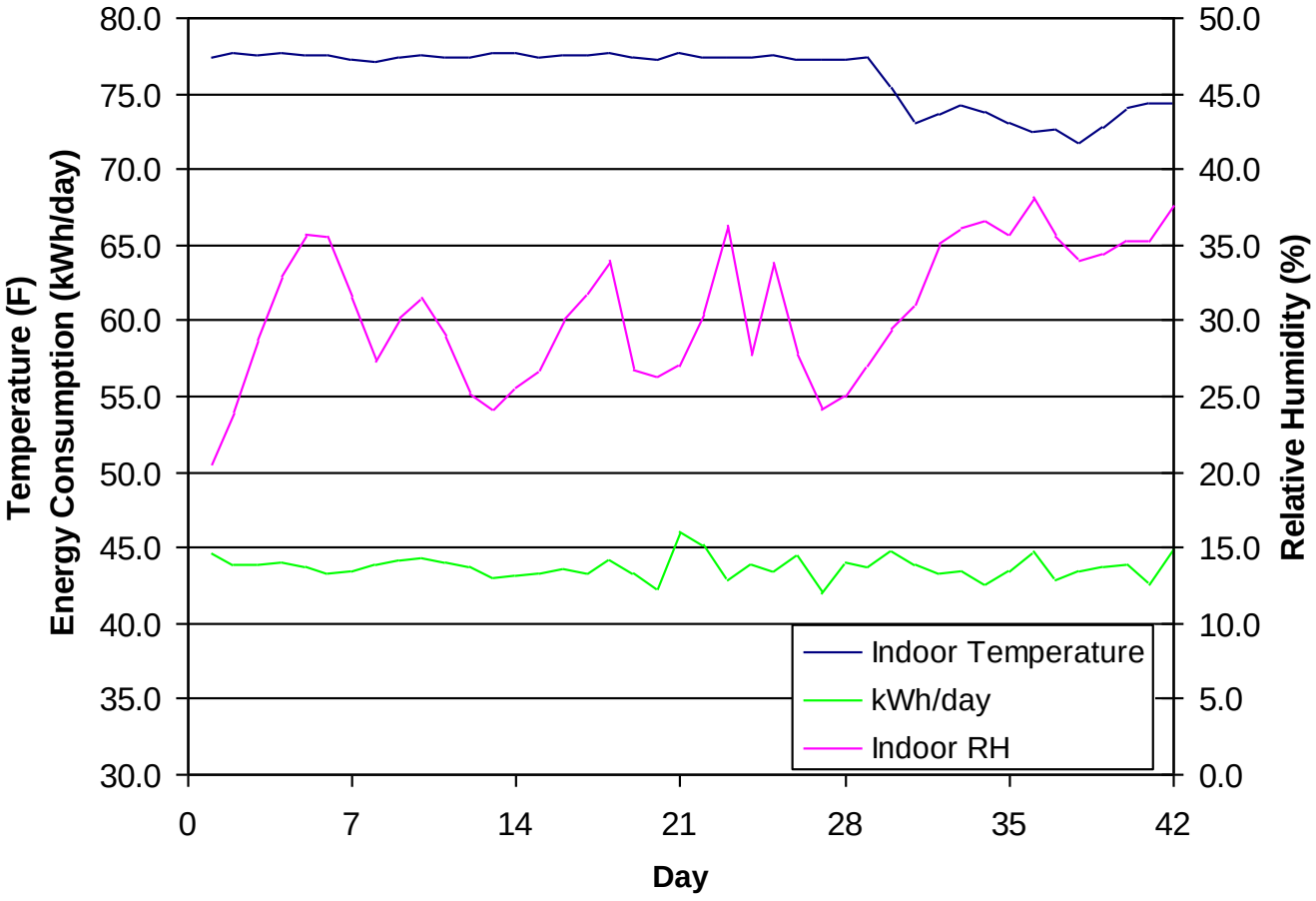
- Energy consumption closely follows indoor ambient humidity

Doored Case Line-Up Electrical Energy Consumption



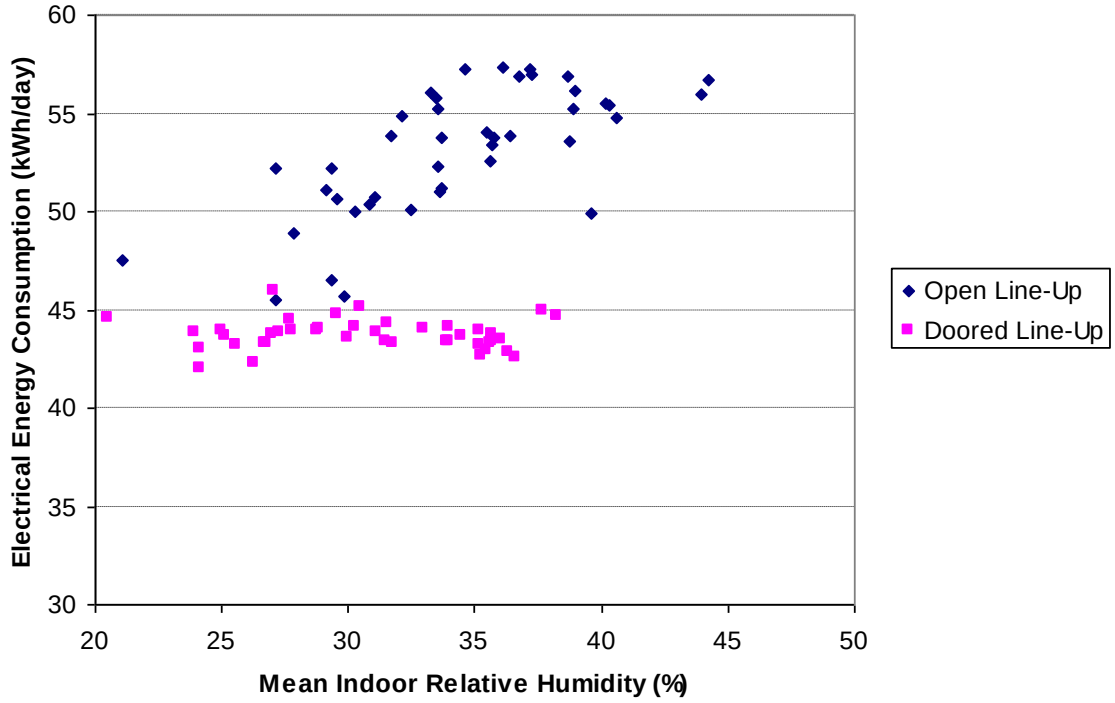
Anti-sweat heaters:	36% of the total daily electrical energy use
Compressors:	27% of the total
Lights:	27% of the total
Fans:	10% of the total

Doored Case: Energy Consumption vs Indoor Ambient Conditions



- Energy consumption independent of indoor ambient conditions

Electrical Energy Consumption vs. Indoor Relative Humidity



- Open case line-up: Consumed 1.25 times as much energy when the indoor relative humidity was 45% as compared to when the mean indoor relative humidity was 20%
- Doored display case line-up: Electrical energy consumption remained relatively constant with increasing mean indoor relative humidity

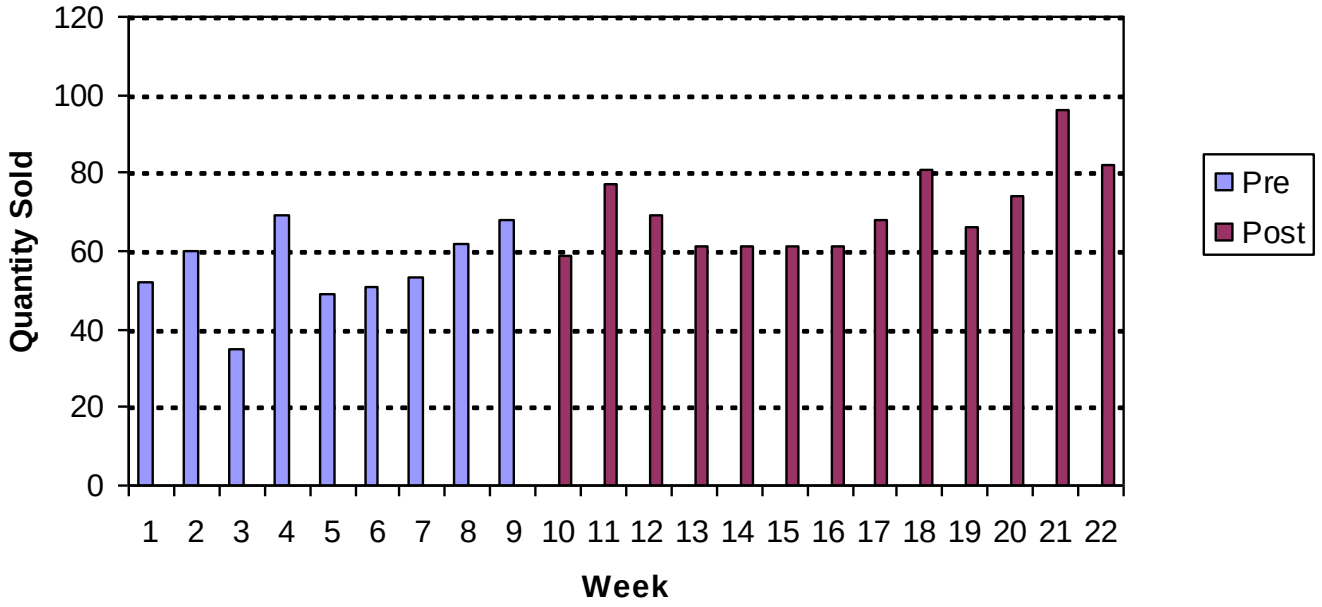
Energy Efficiency Improvements for Doored Display Case

- Significant anti-sweat heater energy usage with doored case
  - Anti-sweat heaters were on continuously
- Energy use could be drastically reduced by using:
  - Anti-sweat heater controls or “no heat” doors
  - LED lighting

Energy Efficiency Improvements for Doored Display Case

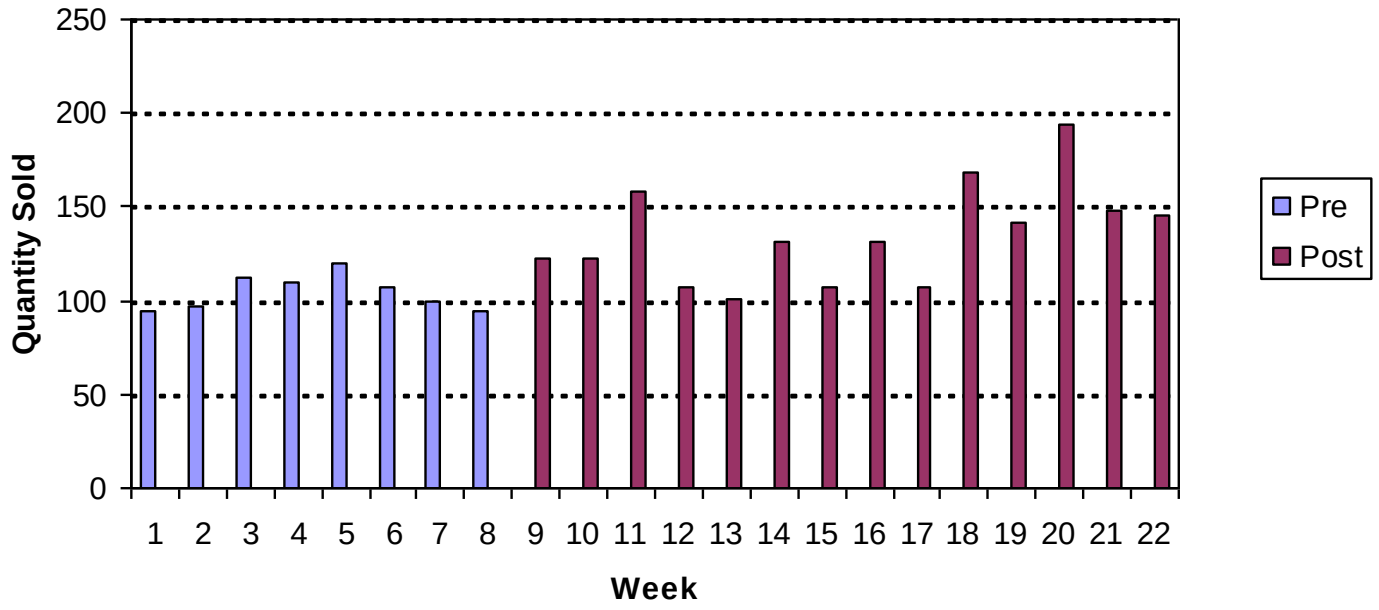
- For 10 doored case line-up, assume:
  - Zero energy consumption for “no heat” doors
  - 265 watts energy consumption for LED lighting
- Estimated energy consumption:
  - 20.5 kWh/day
  - 0.802 kWh/day per foot
    - 53% energy savings compared to new doored display case line-up tested in this study
    - 64% energy savings compared to new open display case line-up tested in this study

Weekly Beer Sales: Store #1 (Control and Serendipity)



Weekly Beer Sales Data from the Old Open and New Doored Display Case Line-Ups for the Period 4 January 2009 through 6 June 2009

Weekly Beer Sales: Store #2



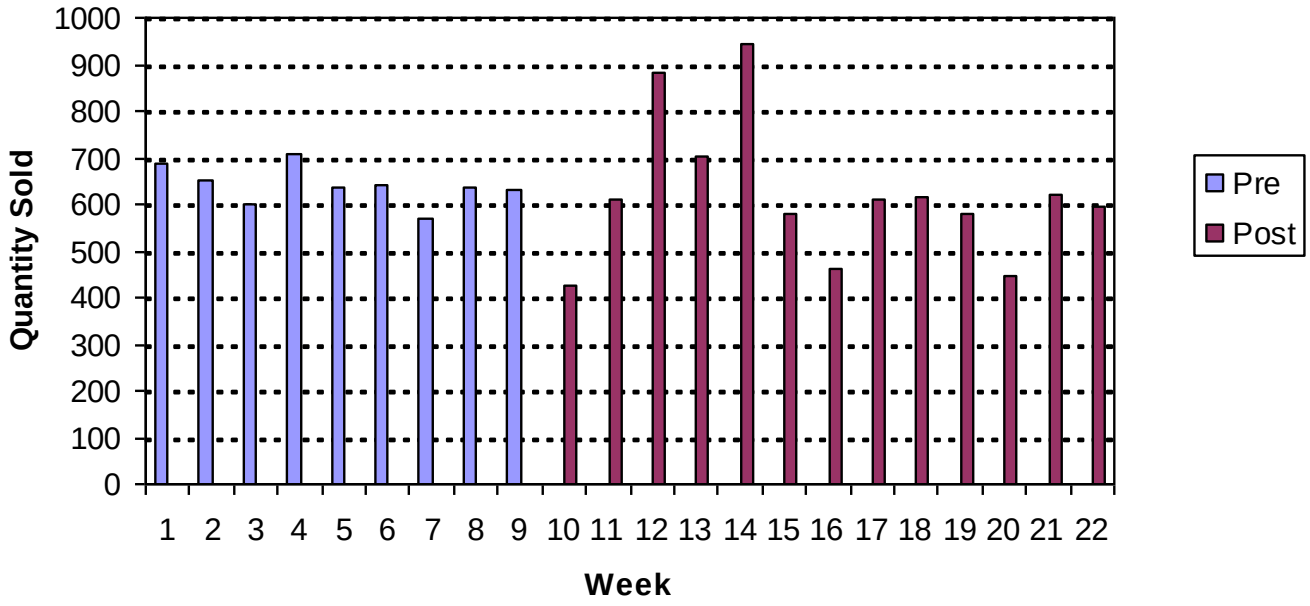
Weekly Beer Sales from the Old Open and New Open Display Case Line-Ups for the Period 4 January 2009 through 6 June 2009

Summary of Weekly Beer Sales

Beer Sales Statistics	Open Display Case Line-Up	Doored Display Case Line-Up
Mean Weekly Quantity Sold, Pre-Installation	104.4	55.4
Standard Deviation of Weekly Quantity Sold, Pre-Installation	9.26	10.6
Mean Weekly Quantity Sold, Post-Installation	134.6	70.5
Standard Deviation of Weekly Quantity Sold, Post-Installation	26.7	11.1
Percentage Increase	29%	27%

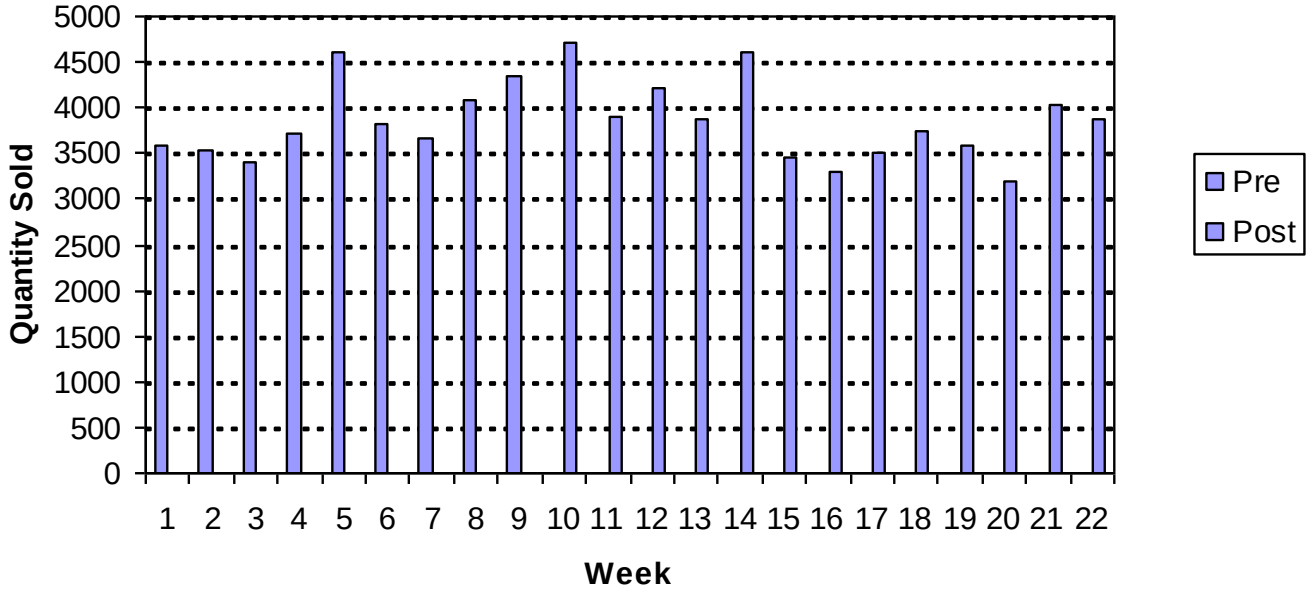
- Two-sample, unequal-variance t-test:
  - Increases in sales were significant at the 0.05 level
- Rate of increase in beer sales was essentially the same for both the new open and new doored display case line-ups:
  - ‘Doored versus open’ had no effect on product sales

Weekly Dairy Sales: Store #1



Weekly Dairy Sales Data from the Old Open and New Doored Display Case Line-Up for the Period 4 January 2009 through 6 June 2009

Weekly Dairy Sales: Store #2 (Control)



Weekly Dairy Sales Data from the Open Display Case Line-Up for the Period 4 January 2009 through 6 June 2009

Summary of Weekly Dairy Sales

Dairy Sales Statistics	Open Display Case Line-Up	Doored Display Case Line-Up
Mean Weekly Quantity Sold, Pre-Installation	3864	639.4
Standard Deviation of Weekly Quantity Sold, Pre-Installation	403.6	41.3
Mean Weekly Quantity Sold, Post-Installation	3846	621.5
Standard Deviation of Weekly Quantity Sold, Post-Installation	464.5	152.2
Percentage Increase	-0.47%	-2.8%

- Two-sample, unequal-variance t-test:
  - No significant difference (at the 0.05 level) in diary product sales before and after installation of the new doored display case line-up
- Rate of dairy sales remained the essentially the same before and after the installation of the new doored display case line-up:
  - ‘Doored versus open’ had no effect on product sales

Conclusions

- Two stores studied:
  - Store #1
    - Replaced old open case with new doored case
    - Measured sales of diary products from old open and new doored cases
    - Measured energy consumption of new doored case
  - Store #2
    - Replaced old open case with new open case
    - Measured sales of beer and alcoholic beverages from old open and new open cases
    - Measured energy consumption of new open case
  - Serendipity
    - Replaced old open case with new doored case
    - Measured sales of beer and alcoholic beverages from old open and new doored cases

Conclusions

- Total electrical energy consumption
  - Per unit length of case, open display case line-up consumed approximately 1.3 times more energy than the doored display case line-up
- Electrical energy consumption of the open display case line-up exhibited significant variation from day-to-day
  - Mainly attributed to daily variation in compressor energy consumption
- Electrical energy consumption of the doored display case line-up was relatively consistent from day-to-day
  - All of the components of the electrical load remained fairly constant
- Increasing mean indoor relative humidity:
  - Electrical energy consumption of the open display case line-up increased
  - Electrical energy consumption of the doored display case line-up remained relatively constant

Conclusions

- Smaller temperature difference between discharge and return air temperatures in doored case vs. open case
- Advantage of doored case:
  - Less product temperature variation due to variation in location within case
  - Less product temperature variation due to variation in store ambient conditions
  - Increased food safety

Conclusions

- Beer sales increased:
  - 29% in the new open display case line-up
  - 27% in the new doored display case line-up
- These increases in sales were significant at the 0.05 level (two-sample, unequal-variance t-test)
- Rate of increase in beer sales was essentially the same for both the new open and new doored display case line-ups:
  - ‘Doored versus open’ had no effect on product sales

Conclusions

- Dairy products:
  - There was no significant difference (at the 0.05 level) in diary product sales before and after installation of the new doored display case line-up (two-sample, unequal-variance t-test)
- Rate of dairy sales remained essentially the same before and after the installation of the new doored display case line-up
  - ‘Doored versus open’ had no effect on product sales

Acknowledgments

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  - American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
  - Air-Conditioning and Refrigeration Technology Institute (ARTI)

- The authors would also like to thank Affiliated Foods Midwest for facilitating our interaction with the supermarket owners that participated in this study

Thank You!

- Questions?