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

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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 ft²
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


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

- 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.
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
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 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

<table>
<thead>
<tr>
<th>Beer Sales Statistics</th>
<th>Open Display Case Line-Up</th>
<th>Doored Display Case Line-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Weekly Quantity Sold, Pre-Installation</td>
<td>104.4</td>
<td>55.4</td>
</tr>
<tr>
<td>Standard Deviation of Weekly Quantity Sold, Pre-Installation</td>
<td>9.26</td>
<td>10.6</td>
</tr>
<tr>
<td>Mean Weekly Quantity Sold, Post-Installation</td>
<td>134.6</td>
<td>70.5</td>
</tr>
<tr>
<td>Standard Deviation of Weekly Quantity Sold, Post-Installation</td>
<td>26.7</td>
<td>11.1</td>
</tr>
<tr>
<td>Percentage Increase</td>
<td>29%</td>
<td>27%</td>
</tr>
</tbody>
</table>

- 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 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

<table>
<thead>
<tr>
<th>Dairy Sales Statistics</th>
<th>Open Display Case Line-Up</th>
<th>Doored Display Case Line-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Weekly Quantity Sold, Pre-Installation</td>
<td>3864</td>
<td>639.4</td>
</tr>
<tr>
<td>Standard Deviation of Weekly Quantity Sold, Pre-Installation</td>
<td>403.6</td>
<td>41.3</td>
</tr>
<tr>
<td>Mean Weekly Quantity Sold, Post-Installation</td>
<td>3846</td>
<td>621.5</td>
</tr>
<tr>
<td>Standard Deviation of Weekly Quantity Sold, Post-Installation</td>
<td>464.5</td>
<td>152.2</td>
</tr>
<tr>
<td>Percentage Increase</td>
<td>-0.47%</td>
<td>-2.8%</td>
</tr>
</tbody>
</table>

- **Two-sample, unequal-variance t-test:**  
  - No significant difference (at the 0.05 level) in dairy 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 dairy 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?