An overview of the refrigeration facilities in Portuguese agro-food industries: energy consumption and refrigerants

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PARTICIPATING ENTITIES:

FINANCED BY:
COMPETE/SIAC-AAC1/SIAC/2011 - Project nº 18642
OBJECTIVES:

• Characterize
• Quantify
• Publicize

Energy Efficiency Measures
6 sectors of the national agro-food industry
for cooling systems in

INDUSTRIAL REFRIGERATION

(60-70%)
energy consumption

Sectors:

• Meat
• Fish
• Milk & Dairy
• Fruit & Vegetables
• Wine
• Food Distribution
LEGAL FRAMEWORK:

- **SGCIE:**
  - A management system for the Intensive Energy Consumers (IEC).
PRESENT DATA:

- Dimensional Characteristics (Cold Stores);
- Used refrigerants;
- Annual production and energy consumption;
- Correlations of energy requirements with:
  - Total refrigerated areas (refrigeration and freezing);
  - Total volume of refrigeration and freezing chambers.
OBTENTION OF:

• **Key Performance Indicators (KPI’s):**
  
  • Energy intensity (\(\text{kWh/tonne of product}\));
  
  • Cold stores’ specific energy consumption (\(\text{kWh/m}^3\text{.year}\));
  
  • Average **number** and **capacity** (\(\text{m}^3\)) of cold stores per sector;
  
  • Rated **refrigeration plant capacity** (\(\text{kW}\))
    
    or
    
    **Relation** **Contracted Electric Power/ Total cold storage capacity**.

• **Benchmarking (useful tool for management):**
  
  • Energy consumption ranking - companies position in their sector
    
    (developed by UBI – Covilhã).
RESULTS AND ANALYSIS

AVERAGE NUMBER AND VOLUME OF COLD STORES

- **Meat:**
  - High number of cold stores, but with lower volume per store.
FACILITY AREA AND PERCENTAGE OCCUPIED BY COLD STORES

• Meat:
  • More steps in the Process;
  • Lower percentage, as they have more processing/transformation area.

• Food Distribution and Fish:
  • Larger occupied area.
CONTRACTED ELECTRIC POWER, RATED COMPRESSOR CAPACITY AND DEPLOYMENT AREA

RESULTS AND ANALYSIS

Meat:
- Lower deployment area;
- Higher installed capacity, thus higher energy consumption.

Fruit & Vegetables:
- Larger areas, when compared to the other sectors.
AVERAGE VOLUME AND SPECIFIC ANNUAL ENERGY CONSUMPTION

RESULTS AND ANALYSIS

- unexpected inverse correlation: volume and consumption/volume
• Highest % freezing storage ($T<0^\circ C$) $\Rightarrow$ Smaller annual specific energy consumption.
• Temperature lift ($\Delta T_{\text{evaporation/condensation}}$) does not have the expected impact.
RELATION BETWEEN SPECIFIC ENERGY CONSUMPTION AND VOLUME OF COLD STORES

- Higher specific energy consumption in smaller cold stores.

RESULTS AND ANALYSIS
• Most-used:
  • R-404A (P+S: 33%, P: 40%);
  • R-22 (P+S: 21%, P: 25%);
  • Water + Glycol (P+S: 17%)
    In Wine sector (44%)
    and in the Fruit & Vegetables (12%) sectors;
  • R-407C (P+S: 7%, P: 8%);
  • R-410C (P+S: 6%, P: 7%);
  • R-717 (P+S: 6%, P: 7%).
RESULTS AND ANALYSIS

TOP MOST-USED REFRIGERANTS

Meat
- R-404A: 43%
- Others: 29%
- R-422A: 8%

Milk & Dairy
- R-404A: 44%
- R-410A: 13%
- Others: 13%
- R-22: 26%

Fruit & Vegetables
- R-404A: 38%
- Others: 10%
- R-717: 21%
- R-22: 31%

Fish
- R-404A: 58%
- R-507C: 8%
- R-410A: 8%
- Others: 17%

Wines
- R-404A: 43%
- R-410A: 25%
- Others: 29%
- R-407C: 18%

Food Distribution
- R-404A: 52%
- R-507C: 5%
- R-717: 5%
- R-22: 38%

- Most-used:
  - R-404A (except Wine)
ENVIRONMENTAL IMPACTS

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<th>Global Warming Potential GWP</th>
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<td>R-407C</td>
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<td>R-410A</td>
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<th>Global Warming Potential GWP</th>
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<td>R-417B</td>
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<tr>
<td>R-422A</td>
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<td>R-422D</td>
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<td>R-717</td>
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- **HCFC’s (hydrochlorofluorocarbon)**
  - R22 (transition);

- **Organic:**
  - R-717;

- **HFC’s (hydrofluorocarbon):**
  - R-404A;
  - R-407C.
RESULTS AND ANALYSIS

COEFFICIENT OF PERFORMANCE (COP)

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<tr>
<th>N.º</th>
<th>Name</th>
<th>COP</th>
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<tbody>
<tr>
<td>R-717</td>
<td>Ammonia</td>
<td>4.84</td>
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<tr>
<td>R-290</td>
<td>Propane</td>
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<td>R-600</td>
<td>Butane</td>
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<td>Tetrafluorethane</td>
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<td>R-407C</td>
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<td>R-404A</td>
<td>R-125/R-143a/R-134a (44/52/4)</td>
<td>4.21</td>
</tr>
<tr>
<td>R-744</td>
<td>Carbon Dioxide</td>
<td>2.96</td>
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• Opportunities:
  • Replacement for more favourable refrigerants (not only for thermodynamic properties, but also for environmental impact);
  • Refrigeration system’s update (lack of maintenance).
SUMMARY:

- **Meat sector:**
  - Largest areas for food transformation/processing;
  - More manpower requirements;
  - Low % of freezing chambers (negative cold).

- **Distribution sector:**
  - Larger areas (long-term) storage;
  - Highest % of freezing chambers, contrary to Meat and Fruit & Vegetables’ sectors.

- **Refrigerants:**
  - **R-404A** is the most-used (complying with Kyoto Protocol);
  - **R-22 widely used** (2nd place, an HCFC).
CONCLUSIONS

• Inverse correlation between dimension and specific consumption:
  • Smaller volume stores ⇒ Higher specific consumption;
  • Air change rate (moister and heat) enhanced by:
    1) Lower volume (for the same opening area);
    2) Higher number of accesses/hour.

• Specific consumption:
  • Major % positive cold stores ⇒ Higher specific consumption;
  • More accesses/hour ⇒ Higher infiltration rate (air change rate);
  • Temperature lift ⇒ 2nd plan.

• Refrigerants (replacement and retrofitting):
  • Opportunity for energy efficiency improvement;
  • Lower environmental impact (GWP ↓, ODP ↓).

• Visited companies:
  • Lack of maintenance; pipe’s insulation (poor); heat exchangers dirtiness (condensers) and bad location (exposure and ventilation).
THANK YOU FOR YOUR ATTENTION