Department of Biosystems
and Agricultural Engineering
MICHIGAN STATE UNIVERSITY

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Biosystems Design Projects

Ensuring Ice Cream Quality Through Palletization Management (Under NDA)

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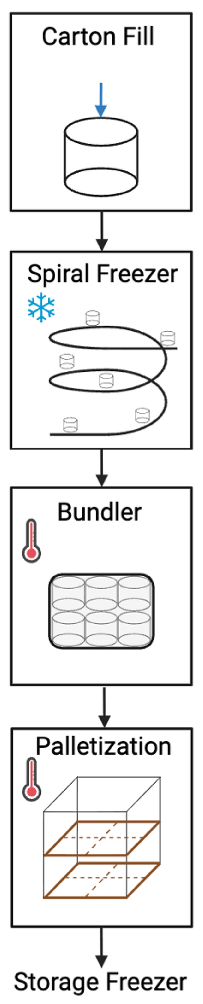
Background

Tillamook opened a new ice cream facility in Decatur, IL. This facility is experiencing ice cream melting during the palletization stage of the manufacturing process, seen in Figure 1.

Palletization Overview



1. Individual cartons are filled with inclusions, variegate, and ice cream
2. Each carton enters the spiral freezer at ambient temp of -30°F for 2 hours
3. Ice cream is exposed to an ambient temp of 350°F for approx. 30 secs (6 cartons= 1 case)
4. Individual cases are stacked on a larger pallet. The ice cream is exposed to ambient temp of the plant

Figure 1: Packaging Process

- The pallet stacking area is not temperature controlled and can reach up to 70 °F in the summer
- Minimal stabilizers increases the ice cream's susceptibility to melting
- Temperature abuse causes ice crystal formation and shrinkage of their ice cream displayed in figure 2 and figure 3.

Figure 2: Ice crystal formation

Figure 3: Shrinkage

Tillamook produces four subcategories of ice cream displayed in figure 4.

Figure 4: Ice cream subcategories

Ice cream quality is monitored throughout production using periodic ice cream cuttings shown in figure 5. The ice cream is evaluated on a pass, fail, warn system.

- Pass: No defects, continue production
- Warn: Minor defects, investigate cause
- Fail: Major defects, product not released

Improved palletization management increases the # of "pass" cartons

Figure 4: Ice cream cutting to identify inclusions, variegate, and sensory attributes

Problem Statement

Evaluate the deterioration of ice cream quality due to the melting and refreezing throughout the current palletization process. Identify points of failure at Decatur plant. Provide recommendations for maximizing ice cream quality while minimizing economic impact.

Constraints

The selected design solution must:

- Total implementation cost of < $20,000
- Adhere to Tillamook's Good Manufacturing Practices
- Proposed changes must not reduce operational efficiency of 65 cartons per min

Objectives

The objectives list serve a key milestones of the project laying out essential steps to achieve all deliverables for project completion:

- Identify a time point at which sensory attributes lead to a 'Fail' within 10 mins of accuracy
- Evaluate the max time to stack a pallet before quality does not meet 'Pass' baseline
- Assess operation factors in the case packing rooms
- Propose recommendation on mitigating melt issues for each ice cream type to reduce the # of bad cartons by 4%
- Calculate the annual loss due to bad cartons

Site Testing

To produce a Heat Transfer Model (HT) of the ice cream carton, temperature probes were used to measure internal temperature of the carton, at three distinct locations listed in Figure 5, during the processes outlined in Figure 1.

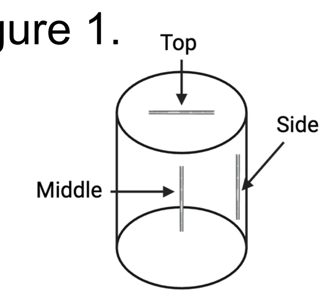


Figure 5: Temperature study probe locations

The results of the data collection are seen in Figure 6, which provide insight for how the ice cream behaves when exposed to the temperature changes

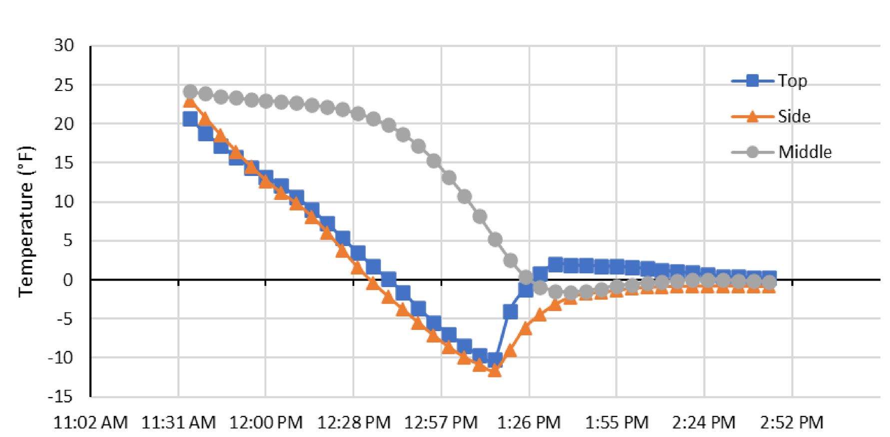


Figure 6: Temperature study results

Modeling

Experimental data helped verify the HT model, which maps the temperature profile of the ice cream and enables testing under different conditions

- On site sensory testing revealed vanilla ice cream reached failure after **45 mins** in the palletization area
- Figure 7 shows that the internal temperature is **16° F** at failure

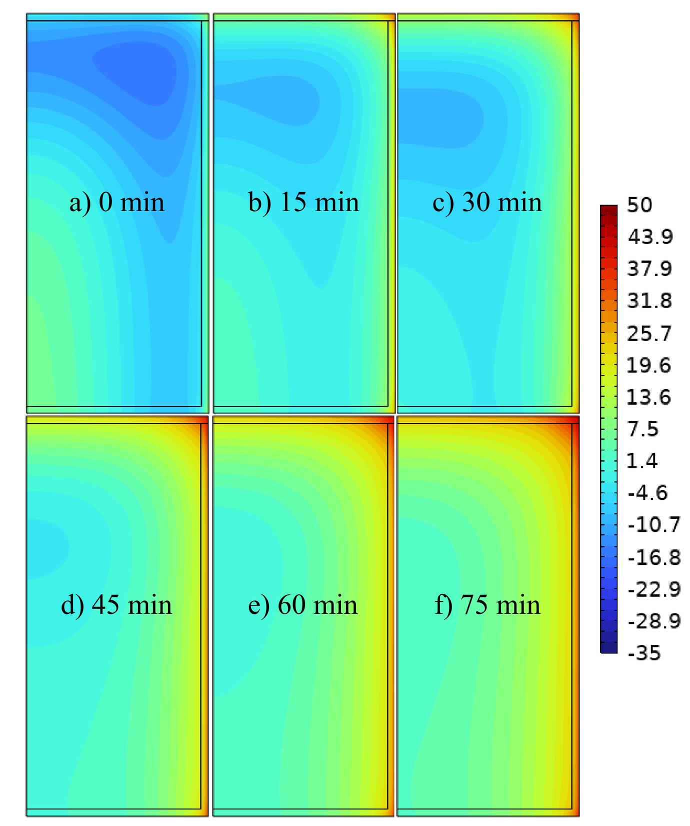


Figure 7: COMSOL model for vanilla ice cream

The same testing was done for 3 different subcategories of ice cream:

- Vanilla – no inclusions or variegate
- Chocolate Peanut Butter – variegate
- Mudslide – inclusions and variegate

There is a statistically significant difference in the variance of temperature. Tillamook can use this model to determine failure points for all ice cream subtypes.

Design Alternatives

Four design solutions were considered: Insulative Cover, Handheld Thermometer, Countdown Timer, and Thermal Camera

The final design selected was the thermal camera, for strong performance in:

- Safety: Meets food safety standards and minimal human intervention
- Accuracy: Camera's is +/- 2 °F from exact temp
- Maintenance: Low risk and easy updates

Figure 8 shows the camera mounted 8-10 ft high on the wall beside the pallet, angled downward to monitor the side.

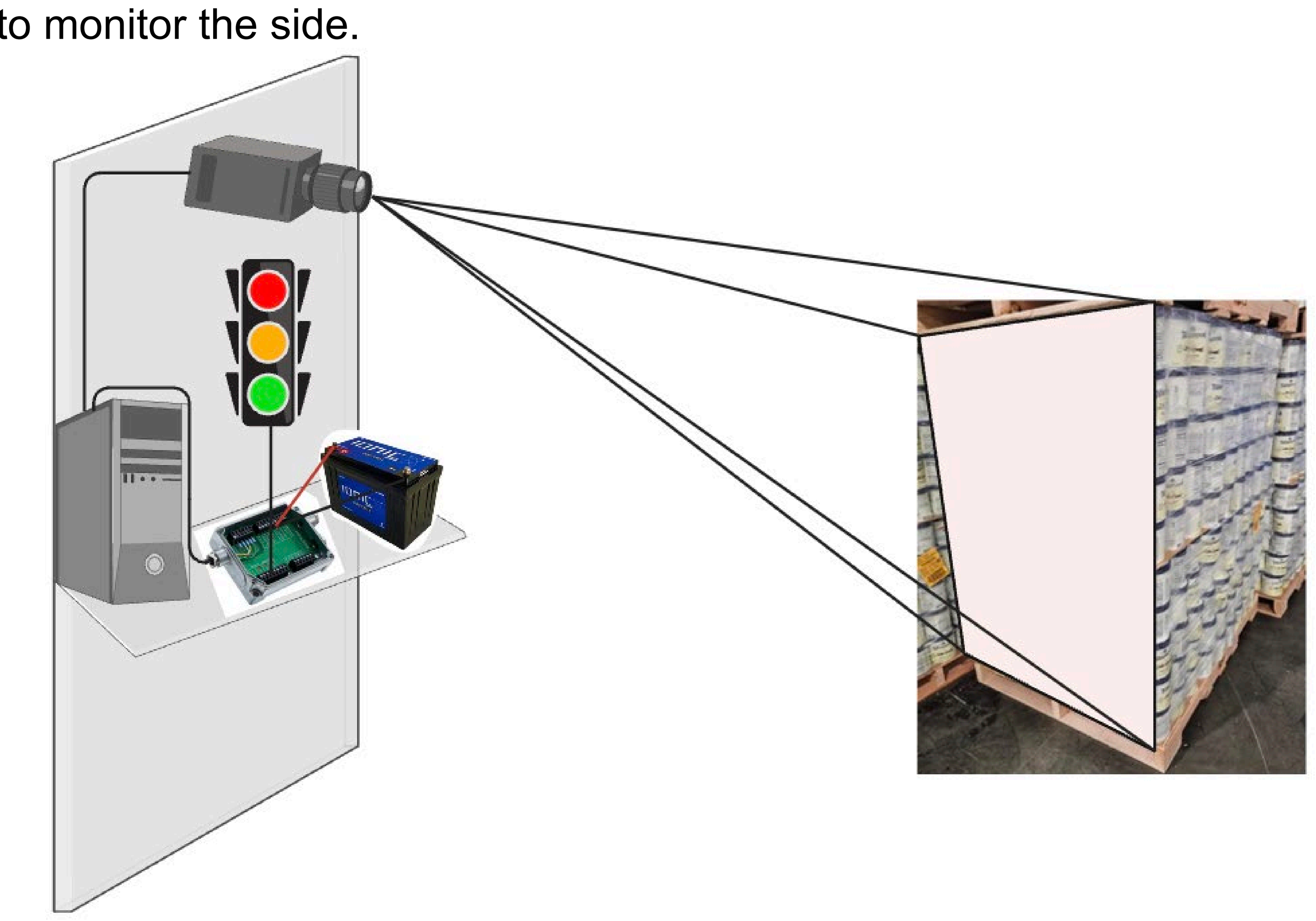


Figure 8: Conceptual drawing of thermal camera system

Final Design

The team recommends using the **Optris 400i LT thermal camera** with a **stack light** to monitor pallet surface temperature. The **COMSOL model** correlates this surface reading to the internal carton temperature at failure. For **vanilla ice cream**, the failure temperature is **26°F**. **Table 1** outlines how this method will be applied in the plant.

Table 1: Stack Light Temperature Threshold

Temp (°F)	Color	Meaning
<20	Green	Safe Temperature
20-25	Yellow	Approaching Threshold
26-30	Red	Critical Temperature

Two thermal cameras will be implemented for each stacking area in the Decatur facility, as shown in Figure 9.

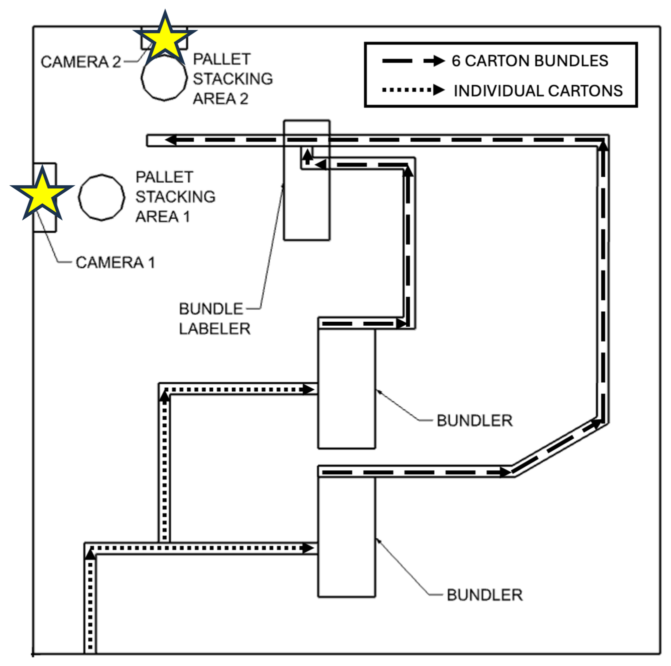


Figure 9: CAD drawing layout of plant floor.

Temperature is continuously monitored through a PC using **PIX Connect**. A **Process Interface (PIF) module** and external power supply connect to the stack light via a digital output pin, which controls the light's displayed color. **Figure 10** shows the key design components.

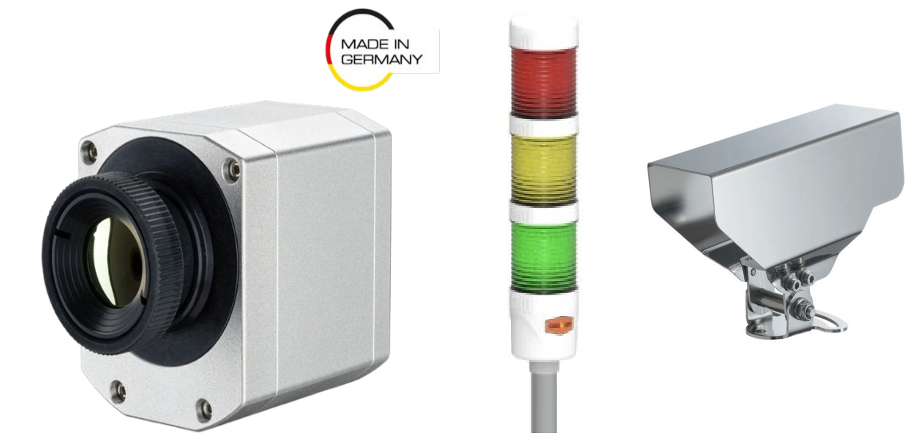


Figure 10: Select hardware for plant application of the system (Optris, n.d., Stack-light.com, n.d)

Safety

- Low-voltage, properly grounded (OSHA, NFPA 79, NEMA compliant)
- Stack light provides clear visual alerts at critical temperatures
- Filtering non product temperatures reduces false alarms and operator fatigue

Maintenance

- **Routine:** Calibration, lens cleaning, power/connection checks
- **Monthly:** Mount inspection, software updates, FOV check
- **Semiannual:** Calibration + environmental checks.

Economics

Table 2: Economic Analysis

Failure %	6%	4%	2%
ROI		10.89	32.97
Payback		1.01	0.35
NPV	$35,799,634	$36,425,605	$37,617,536
COPQ	$538,027	$349,718	$174,859

The economic analysis evaluated three failure-rate scenarios for the thermal camera system: the current 6%, an improved 4%, and the target 2%. The project shows strong feasibility, supported by a high ROI and a short payback period, which both indicate profitable investment. NPV increases by 1.75% at a 4% failure rate and by 5.08% at 2%, demonstrating improved profitability. The Cost of Poor Quality also drops significantly, decreasing 35% at 4% failure and 67.5% at 2%, which leads to substantial profit gains.

Final Considerations

After confirming system effectiveness, additional thermal cameras are recommended.

- Provides backup units to prevent downtime and monitoring gaps
- Expands coverage
- Enables faster replacement and reduces vendor lead time dependence
- Strengthens overall quality control and reliability

Select References

Cogné, C., Andrieu, J., Laurent, P., Besson, A., & Nocquet, J. (2003) Experimental data and modelling of thermal properties of ice creams. *Journal of Food Engineering*, *58*(4), 331– 341. https://doi.org/10.1016/S0260-8774(02)00396-5

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