PACKAGING DESIGN: CHILLED/FROZEN SEAFOOD IN AN AMBIENT CHAIN

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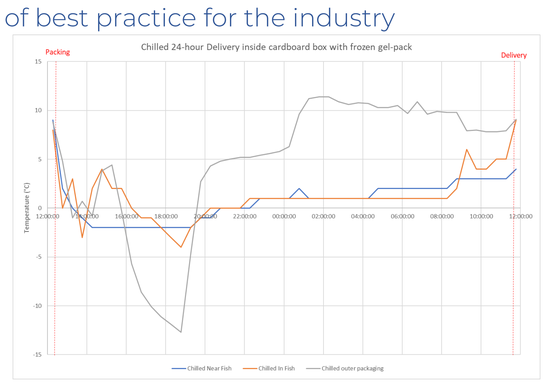
Introduction

The Covid-19 pandemic changed seafood supply chains throughout the UK with substantial numbers of catering supply businesses and new SMEs pivoting towards home delivery direct to consumer. Typically, businesses placed refrigerated products in insulated boxes of various types, with and without extra cooling, which were then delivered through the standard, non-refrigerated delivery chain. Many of the businesses operating in this space became concerned about the ability of the packaging to maintain required temperatures, particularly in the increasingly warm UK summers. Selection of packaging for chilled/frozen delivery in an ambient chain is impacted by many factors: cost, environmental impact, storage space, availability, and increased variability in ambient temperatures.

We have worked with local seafood businesses in Grimsby to identify best packaging options, including required cold packs ("coolth") and insulation, which all interact, given their specific supply chains and products to maintain seafood safety and quality. Then, real, in-the-chain temperature measurements were made to assess choices, to look for weaknesses with the packaging, and identify improvements that could be made. We then setup an environmental chamber to mimic temperatures measured through the delivery chains to simulate packaging performance in a controlled environment indicative of true real-world conditions. Modelling of specific product, packaging, insulation, and cold-pack combinations within this environmental chamber is the next step to build up a code of best practice for the industry



An example of good practice: Temperatures hold chilled (<+5°C) for the full delivery cycle.

Materials and Methods

Throughout many trials, across many different projects, with several Grimsby-based businesses, we have analysed numerous: box materials (e.g., cardboard of many qualities, polystyrene, polypropylene), insulations (e.g., shredded cardboard, WoolCool, bubble wrap, foiled wrap), and "coolth" delivery mechanisms (e.g., Ice, various designs of ice/gel packs, dry ice, frozen water-soaked cellulose sheets).

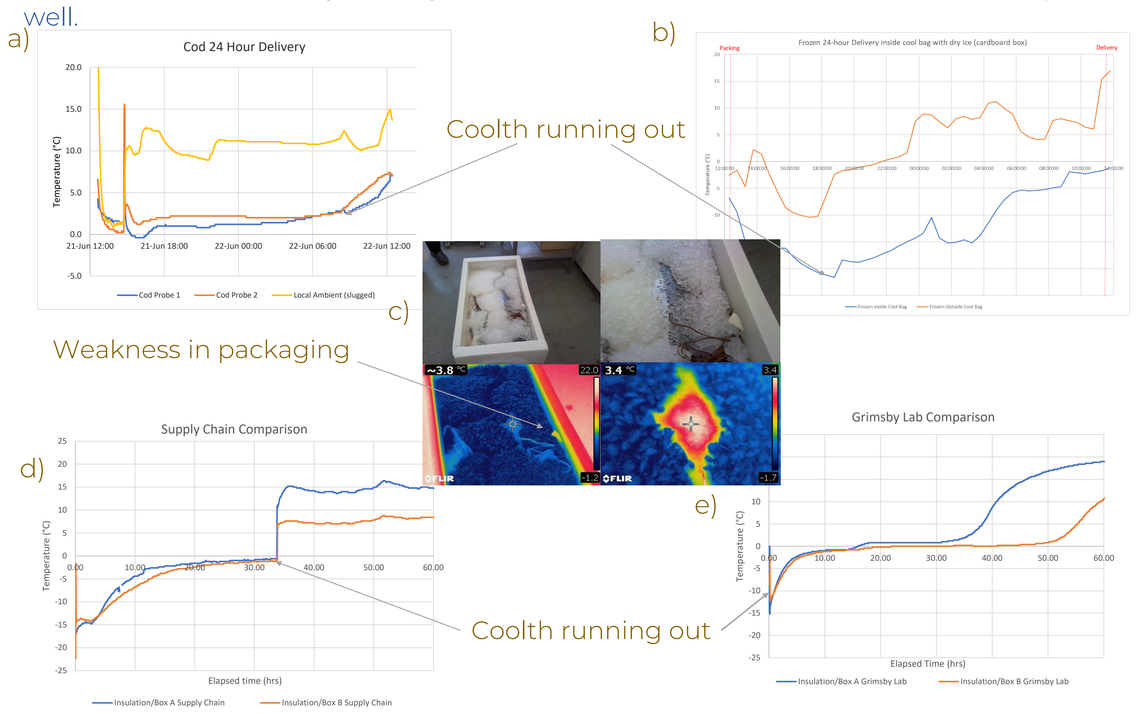
1. Several businesses with different needs and products specified their supply chains, current packaging, insulation, and cold pack choices to be compared with others found within their price range.
2. Threshold temperatures for food safety and quality were identified based on products within.
3. Experiments were undertaken to stress test these designs in chambers that ranged between 20 and 30°C dependent upon the chain being used.
4. The best performing designs were then sent through live supply chains with temperatures being measured again to ensure that packs remained within specification.
5. Across the businesses, similarities between well performing packaging, insulation and cold pack combinations were noted to inform best practice.
6. Where packaging did not perform as well as expected or necessary, improvements were suggested – e.g., more cold packs, better performing cold packs, more insulation, complete filling of box with no air gaps – until specifications were met. Infrared imagery was often used to identify weak points within the packaging at this point.
7. Using Arduino control, an environmental chamber with separate heating and cooling operations was set up to mimic temperatures throughout the delivery chains that businesses were using.

Examples of box packaging materials tested: corrugated cardboard, polypropylene, and a secondary polypropylene multilayered box.

Examples of insulative materials and cold packs tested: Foil-coated bubble wrap, paper wrap, frozen gel pack.

Results and Discussion

Results varied substantially between trials with some packaging designs performing very well and some not holding temperature at all. Chilled deliveries were naturally much easier to hold at temperature than frozen ones due to the temperature difference between aimed holding temperature and ambient. Most businesses used dry ice in their aim to hold frozen temperatures which initially works well but once the dry ice is spent (which happens very quickly on warm days), temperatures increase incredibly quickly. Natural, environmentally-friendly alternatives such as WoolCool were seen to perform well.



a) Good chilled holding, rise in temperature as coolth runs out; b) Poor frozen holding, dry ice runs out very quickly; c) Infrared imagery showing weaknesses in packaging/ice distribution; d) frozen 24hr delivery, product arrived frozen but only just; e) Dry ice providing almost no coolth, samples warm up immediately. Insulation in box B substantially better than box A.

Conclusions

- Changes in shopping patterns have led to substantially more seafood products being delivered to the consumer in ambient temperature supply chains. Although products are supplied into this chain in insulated boxes with a supply of 'coolth', our studies show seafood often arrives at the consumer well above ideal temperatures for safety and quality. This is a recurring issue and potentially highly detrimental to the seafood sector.
- Whilst on the surface, this may seem like a simple problem, the dynamic shifting of product quantities within pack and the interaction of cost, quantity, and quality of packaging makes the solutions bespoke for each business.
- With this being, in most cases, an ambient delivery chain, recommendations were often made to re-run live supply chain trials in the summer months to ensure packaging recommendations could provide a quality, safe product all year round (and in cases where this didn't hold up, improvements to the packaging would be required).
- Many of the businesses supplying seafood in this way are very small, and do not properly understand the thermal characteristics of supplying chilled and frozen products in ambient chain, and neglect sufficient testing to cover all possible delivery scenarios. Many select packaging on cost and availability rather than thermal performance. Likewise, time-Temperature indicators to identify temperature abuse are commercially available but are often not used due to cost.
- There is the need for a simple tool to aid (small) seafood businesses in selection of packaging for supplying chilled and/or frozen seafood in an ambient chain.
- A 'best practice' guide given individual businesses circumstances needs to be outlined and adopted.

Recommendations for Future Work

- Further work is needed to test individual packaging materials, insulations, and cold-packs with different products placed within to assess ability to withstand heat ingress (including specific combinations of the above).
- These trials can be done within an environmental chamber and can compare like-for-like box, product, coolth pack scenarios.
- As all trials up until this point have been business oriented and small in scale, limits have been placed on the ability to compare like with like. Once this is done, and insulative properties of materials are categorised, a model will be created to simulate different combinations: with different amounts of "coolth" and product inside.
- This will alleviate the need for practical assessments and provide businesses with quick and easy answers to their questions regarding the temperature capabilities of different designs.
- In addition to this, if businesses are looking at a change of delivery route or distance without any changes to packaging, this could also be easily modelled.