Number 1

FOCUSING on predictive modelling for shelf-life

by Linda Everis, Principal Research Office, Campden BRI. www.campdenbri.co.uk

How do we define shelf-life? It is typically the time after production during which a food or drink product remains acceptable for consumption. A straightforward definition, right? But the food and drink industry faces many hurdles when setting a shelf-life protocol. It is a complex task. From manufacture to consumer storage, products can encounter a range of fluctuating temperatures as they are passed from one stage of the cold chain to the next. Determining what these temperatures are and the time spent at them is a challenge. But it must be done to deliver a relevant shelf-life protocol.

Retailers have often developed their own company-specific shelf-life protocols for manufacturers to follow. When developing them, they ask questions such as, "How long will the product be out of chill when purchased?" and "What temperatures will the product be stored at during purchase and in the customer's fridge?"

Often, protocols can differ between retailers, meaning a manufacturer may end up supplying similar products to different customers while following different test protocols.

This leaves us to question whether these differences in shelf-life protocol significantly impact a product's assigned shelf-life. Will spoilage organisms behave in the same way? How much faster may they grow and spoil the product? How much of a potential safety risk is there? Predictive modelling helps us to answer these questions.

What is predictive modelling?

Predictive modelling is a tool used to assess the survival and/or growth of a micro-organism under a range of temperatures, pH and water activities (a_w). The models are generated using computer-based software packages and can be used to quickly assess the effect of different storage regimes on the microbiological levels in products.

It is also extremely useful at the product development stage, allowing a quick evaluation of the impact of recipe changes – for example, the effect of salt reduction on listeria.

Overall, it can be used to help determine the likely shelf-life of products from both a quality and a safety viewpoint.

Modelling can be used alongside testing real-life samples. Challenge testing involves deliberately inoculating a product with relevant micro-organisms and assessing their growth over time. This approach considers all factors that may influence growth.

Predictive modelling, however, will usually only consider three factors: pH, a_w and temperature.

The unaccounted factors include:

- Natural antimicrobials that may be present (for example allicin in garlic).
- Differences in structure across a food sample.
- Change of a_w and pH over time.
- Competing organisms.

How does predictive modelling work?

Laboratory generated microbial growth curves are used to produce the models. Microbiological growth media (broths) with different intrinsic parameters (for example varying pH and salt levels) are inoculated with the relevant organism or cocktail of organisms and incubated at a range of temperatures.

Mathematical equations are then applied to the data and used to construct models that allow us to predict how the organisms are likely to grow in conditions similar to that of a particular product. As a result, we can then use this data to predict what kind of shelf-life this product will have.

Table 1. Potentially achievable shelf-life in standard cooked ham – the number of days taken for each organism to reach its specified cut-off value (pH: 6.29 a_w: 0.980. Assumed initial level: 10cfu/g).

Protocol	C. botulinum	Listeria	Enterobacteriaceae
1d 4°C, 18d 6°C, 2d 10°C	21	6	10
14d 6°C, 7d 8°C	21	5	10
24h 4°C, 2h 22°C, 20d 8°C	14	4	6
19d 4°C, 2d 8°C	28	8	–
16d 5°C, 2h 22°C, 5d 8°C	23	7	14
14d 7°C, 7d 12°C	15	5	7
7d 8°C, 14d 12°C	9	4	6

*10^6 cfu/g level not reached by enterobacteriaceae for protocol '19d 4°C, 2d 8°C'.

Table 2. Potentially achievable shelf-life in raw meat – the number of days taken for each organism to reach its specified cut-off value (pH: 5.66 a_w: 0.986. Assumed initial level: 10cfu/g).

Protocol	C. botulinum	Listeria	Enterobacteriaceae
1d 4°C, 15d 6°C, 2d 10°C	19	7	9
12d 6°C, 6d 8°C	19	7	8
24h 4°C, 2h 22°C, 16d 8°C	14	5	5
16d 4°C, 2d 8°C	25	10	*
14d 5°C, 2h 22°C, 4d 8°C	19	8	12
12d 7°C, 6d 12°C	13	5	6
6d 8°C, 12d 12°C	8	5	5

*10^6 cfu/g level not reached by enterobacteriaceae for protocol '16d 4°C, 2d 8°C'.

What predictive modelling can tell us about shelf-life protocols

We used this technique to investigate how seven different protocols, that can be used to set a shelf-life, showed variations in the growth of different micro-organisms. Cooked ham and raw meat were chosen for the study. The goal was to understand how slight differences in protocols impacted shelf-life.

To do this, two approaches were taken. One to assess the product's safety (by measuring the growth of two pathogenic species: listeria and C. botulinum) and the other which assessed the product's quality (by measuring the level of the spoilage organism enterobacteriaceae).

For each organism, the 'end of shelf-life' was taken to be the time at which there was an increase of 0.5 log cfu/g for C. botulinum, an increase from 10 to 100cfu/g for listeria or the time taken for enterobacteriaceae to reach 10^6 cfu/g. At this point, the product was then taken to be unsafe or spoilt.

What did we find?

The results highlighted considerable differences in the growth potential of micro-organisms depending on the storage protocol used. This would affect the setting of shelf-life for those products. This is significant, especially where safety is concerned.

Neurotoxin-producing C. botulinum showed this variation most clearly in the duration of the shelf-life that was predicted to be with the consumer, and therefore at the highest temperature of the cold chain.

The protocols that predicted the product to be with the consumer for most of its shelf-life showed significant growth of this organism. In fact, the shelf-life was shortened by 14 days in the most extreme case compared to the protocol that had not factored in as much time with the consumer.

As these results have shown, following one protocol can lead to unsafe food two weeks earlier than another (when both are applied to the same product), so it does make you question which protocol is more appropriate and which is most realistic.

The food and drink industry should be aware of these differences and think about how realistic their testing protocols are when all factors are taken into consideration. ■

Number 2

FOCUSING on food safety culture excellence

by Bertrand Emond, Principal Research Office, Campden BRI. www.campdenbri.co.uk

The importance of food safety culture has become increasingly recognised in the past few years, as has the role of psychology and the importance of behaviour-based approaches to food safety management. Within the food industry, food safety culture can be described as the 'prevailing attitudes, values and practices related to food safety that are taught, directly and indirectly, to new employees'. Some of these are easy to observe, such as the facilities and equipment, posters and paperwork, and the visible behaviours of staff. However, some are harder to see, such as underlying values and priorities, unspoken rules, and the way things are done when no-one is looking. This makes the clear identification and evaluation of food safety culture very challenging.

Analysing food safety culture first requires a clear model of what an effective food safety culture actually is, including its technical, managerial and psychological aspects.

The Culture Excellence Model provides a theoretical framework for understanding the multi-layered and multi-dimensional elements involved. Evaluating food safety culture then requires an in-depth, unbiased mechanism of understanding where a company stands in relation to the model.

The benefits of such an assessment include:

- Pinpointing strengths and weaknesses in food safety culture.
- Providing insight into staff experiences, attitudes and values.
- Identifying the most important targets for resource allocation.
- Evaluating the return on investment of budget and effort.
- Measuring the impact of training, systems and other initiatives.

Cultural assessment methods

An assessment of culture must look beneath the surface of an organisation and draw out the attitudes and values of a wide range of people working in different departments and at different levels.

For the early research, in-depth psychological interviews were developed and used with great success. However, in response to industry feedback during the testing phase of the Culture Excellence Model, an online data-gathering tool was developed for faster and more easily quantifiable data.

It was necessary to create a set of survey questions that would be clear yet subtly probing, simple yet meaningful and could achieve a similar level of depth to the interview approach in a shorter time, with higher sample sizes, and at a distance. The online tool allows a large number of employees within a company to be surveyed, anonymously and confidentially, and cross-referenced quickly and easily in a wide variety of ways.

Questions were carefully designed to facilitate objectivity and openness, and probe in-depth issues across the spectrum of 16 cultural dimensions.

Where did the Culture Excellence Model come from?

The Culture Excellence Model is built on over 15 years of research from across a range of academic disciplines and industry sectors.

It started in 1999 at the University of Central Lancashire, when Dr Joanne Taylor began an investigation into psychological barriers to the implementation of food safety management systems in food manufacturing businesses.

From 2002 this was broadened to include an in-depth study of catering businesses during her work on a large research project for the UK Government Food Standards Agency at the University of Salford.

These research studies showed that regardless of business sector or size, there were a large number of knowledge, attitudinal and behavioural dimensions that could prevent or facilitate the establishment and maintenance of a safe food operation. From 2006 onwards, during her time teaching organisational culture and HACCP on two separate Masters programmes at the University of Salford, Dr Taylor investigated the parallels between the two subjects. Building on the original barriers model with input from organisational culture theory, she finalised the 'Food Safety Culture Excellence Model', structured around four categories (People, Process, Purpose and Proactivity) and incorporating 16 psychological and management dimensions.

The Model and its assessment tool have been widely reviewed and piloted, and extended to include modules on quality and assess a broader range of organisations.

Working in partnership, in 2014 Taylor Shannon International SI and Campden BRI launched the Culture Excellence Program, which includes assessment, analysis, reporting and on-going support to food businesses of all types and sizes.

The Programme has been implemented with great success in small, medium and large food businesses in manufacturing, farming, catering and food service.

In 2015, a new set of quality questions were developed and piloted, allowing measurement of both food safety and quality culture.

Common areas requiring improvement

Based on the research studies that have been conducted, and data from the Culture Excellence Programme so far, the following three examples show common areas for improvement.

- **Reinforcement:**

While most companies have established reward and incentive schemes, not all are specifically linked to food safety or sufficiently transparent to be perceived as attainable by all employees.

Reinforcement of positive food safety attitudes and behaviours must be consistent, clear, timely, fair and well communicated in order to be most effective.

- **Training:**

While most companies provide food safety training for their employees, not all has a direct impact on behaviour or is perceived as enjoyable and worthwhile.

It is important that training programmes are carefully designed to incorporate clear and measurable objectives, and that training methods are sufficiently dynamic, varied and practical to make a lasting impact on food safety knowledge, attitude and behaviour.

- **Risk foresight:**

Over the past 15 years the general level of risk awareness has been seen to increase in the food industry, but the challenge of understanding how to prioritise and focus based on the significance of particular hazards still remains. In some companies, there is also a gap between the priorities of the individual and those of the company. It is important for companies to both develop and also communicate risk-based approaches in order to reduce the likelihood of mistakes with serious consequences.

It is also beneficial to assess individual and organisational risk perception to identify potential gaps and inconsistencies.

New developments

The most recent development in the Culture Excellence journey has been the expert review and adoption of the Culture Excellence Audit by BRC Global Standards, one of the world's leading safety and quality certification programmes, used by over 23,000 certificated suppliers in 123 countries.

BRC Global Standards has incorporated the Culture Excellence Audit into a Voluntary Module that is offered alongside its BRCGS Food Safety Standard, providing companies with the opportunity to have their food safety culture assessed alongside their on-site food safety audit.

Alongside this development is the start of a new research project to compare data gathered from on-site audits with data gathered online, in order to provide further insights into both types of food safety audit.

Additional research will investigate the links between organisational culture and traditional business Key Performance Indicators (KPIs). ■

"Culture matters . . . Failure to understand culture and take it seriously can have disastrous consequences for an organisation"

Edgar H. Schine, 1999

Number 3

FOCUSING
on ensuring factory hygiene

by Annette Sansom, Senior research officer, and Nigel Blitz, Food safety management systems specialist, Campden BRI. www.campdenbri.co.uk

Whether it is for prevention or dealing with a Covid-19 outbreak, ensuring that your factory and premises are clean and hygienic requires a comprehensive approach. It begins with ensuring you are doing all you can to create a factory environment that both prevents Covid-19 and reduces the likelihood of its spread in the event of SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2, that causes Covid-19) entering your factory. To help you with this, we have developed new methods at Campden BRI to help ensure your cleaning is killing the virus that causes Covid-19. Our food safety management systems specialists have also compiled a useful checklist on what to consider for effective factory hygiene.

Checklist – have you implemented the following?

The actions you should consider to guard against SARS-CoV-2 include:

- Reviewing HACCP plans – if they have not already been reviewed, they should be!
- Seeking advice from engineers regarding ventilation systems and air conditioning.
- Deep cleaning – what should you do?
  - Avoid creating splashes and spray when cleaning.
  - Plan your deep clean carefully – it should be for an entire area not just the equipment, and needs to be carried out thoroughly.
  - Staffing – ensure the correct level of trained staff are available; extra untrained labour is a hindrance not a help.
  - Change detergent? Normally you do not need to change your detergent or disinfectant for a deep clean, but with SARS-CoV-2, it is advisable to consult your chemical supply company.
  - Work top down – systematically clean from high levels down to floor level.
  - Equipment cleaning – this needs to be carried out to standards above and beyond a normal daily clean and will involve, for example, fully stripping down equipment to thoroughly clean components and bodies.
  - Drains - drains, drain covers and floors need to be cleaned thoroughly and disinfected post washing.
  - Walls, ceilings and wall fittings need to be cleaned.
- Reinforcing hand hygiene policy – circulate Campden BRI's popular hand washing video to your teams.
- Reviewing PPE policies if necessary.
- Enhancing cleaning of touch points and equipment from door handles to forklift and pallet trucks.
- Possibly increasing frequency of waste collections.
- Reviewing locker room policy, including cleaning frequency.

Does your cleaning kill the Covid-19 virus?

Of course, companies want to be sure their cleaning regimes inactivate or remove SARS-CoV-2. However, as you might imagine, ensuring this is a challenge – not least because working with a human pathogen like this is fraught with problems. One way around this is to use a 'surrogate' that is structurally similar to the SARS-CoV-2 but which is much safer to use.

New test for virus 'kill'

This is the approach we took to develop and validate a test in our microbiology laboratories. The test can be used by companies who want to compare the efficacy of different methods of cleaning and disinfection or assess the effectiveness of a surface cleaning regime. And because the surrogate is safe, it can be used to test control measures in the real environment (for example, on a factory or retail surface) and even on hands.

The interesting feature is that the test does not look for the surrogate directly – it looks for activity of the surrogate. So, it will not detect inactivated virus even if it is there – it will only detect active virus.

The surrogate story

Compared to other types of organisms – for example, bacteria and plants – viruses are structurally quite simple. This opens the gateway to the surrogate approach as viruses with a very similar structure to SARS-CoV-2 will 'behave' in a similar way in many circumstances.

The virus Phi6 is the one we are using as a surrogate for SARS-CoV-2. Structurally the Phi6 (or Φ6) virus particle is very similar to SARS-CoV-2: they are about 100nm, they have a lipid (fatty) envelope, and their genes are made of RNA.

Recent publications have suggested that Phi6 is an appropriate surrogate for infectious enveloped viruses like coronavirus and influenza virus.

Better yet, as a bacteriophage (a virus that infects bacteria), Phi6 does not infect plants or animals, including humans – and so is much safer to work with than SARS-CoV-2.

Plaques on your lawn

So, how does it work? The key is looking at the damage caused by any active Phi6 in a 'lawn' of Pseudomonas syringae (the bacteria it infects). You can grow a 'lawn' of bacteria by pouring a small amount of liquid bacterial culture over the surface of a gel in a petri dish and allowing the bacteria to grow.

But if you add phage to the liquid culture, the lawn will have holes (plaques), where the phage has killed some of the bacteria. The more plaques you get, the more phage is in your sample.

If a cleaning chemical or disinfectant has inactivated the phage there will be fewer or no plaques in the lawn – so you can compare different cleaning systems based on how much they can prevent plaques compared to control samples.

Ultimately, we can use this test to help you get your approach to sanitising and cleaning right by checking the efficacy of your virus inactivation.

Determining the presence of SARS-CoV-2 in your factory

Perhaps you would like to test high-risk areas which come into direct contact with many people – such as door handles, control panels etc – or simply want to reassure your workforce that the virus is not present in specific areas of your factory.

We have also developed a swab method to help determine the presence of SARS-CoV-2 on a surface. The environmental surface swab testing, now offered as a service by Campden BRI, will identify the presence of SARS-CoV-2 even if it has been there for a few days.

What does a positive result mean?

If the swab test yields a positive result, this will indicate that either the virus or the RNA from the virus was present on the surface where the swab was taken. This means that there was potentially someone with Covid-19 in that area within the last few days.

What should you do if you find Covid-19?

A result like this suggests that enhanced cleaning regimes should be put in place and disinfectants, suitable for use against enveloped viruses, should be used, as well as a reminder that strict hygiene rules should be followed.

Campden BRI can provide advice and guidance on your factory hygiene concerns. ■

Number 4

FOCUSING on reducing food waste

by Linda Everis, principal research officer at Campden BRI. www.campdenbri.co.uk

The Food and Agriculture Organisation (FAO) of the United Nations estimates that if food waste was a country, it would be the third-highest emitter of greenhouse gases after the US and China. Alarmed? With tonnes of food wasted in the UK each year, you are right to be. Food manufacturers tolerate roughly 5% waste within their food processes under normal production, but often look for ways to reduce it. Making a product using ingredients that are a day or two old (instead of discarding them) is one way that manufacturers can attempt to reduce their overall food waste. This is common practice, assuming that the ingredients are used within their shelf-life and it is considered in the life of the product in which they are incorporated.

Being open to using older ingredients effectively extends their life, which provides greater flexibility and scope to make use of them before they are discarded.

On paper, this sounds like a win-win scenario: food waste is reduced while manufacturers have more time to use their ingredients before they are deemed unacceptable.

As food manufacturers consider incorporating one- or two-day-old ingredients into their products to reduce food waste, food safety must, of course, remain a priority.

This was recently highlighted by the Foods Standards Agency when, upon announcing its research priorities, it was made clear that reducing the impact of foodborne pathogens was one of its focuses.

So, for a product made with several ingredients, what impact does the ingredient age have on the final product's shelf-life? Our microbiologists at Campden BRI used coleslaw to find out.

Coleslaw: the model product

For products like coleslaw, it is easy to think of them as their own entity, one that is not dependent on the sum of its counterparts – but, of course, it is. A number of ingredients are brought together to create the final product, which then has a single shelf-life attributed to it.

Each of these ingredients may be at a different stage of its own life. You would assume ingredients at the start of their life would create a final product with a longer shelf-life (due to a lower microbial loading than ingredients later in their life), but is this the case in practice?

We selected coleslaw because it contains three ingredients – raw onion, carrot and cabbage – with potentially high levels of microflora that could increase over time during storage.

Ingredient age and coleslaw shelf-life

Three batches of coleslaw were made with ingredients of varying age (including fresh, one day old or two days old). They were then stored in a chilled environment and assessed over a 16-day period.

These were sampled at specific intervals to determine whether the microbial count had exceeded an unacceptable amount.

Guidance produced by the Health Protection Agency (HPA) – now part of Public Health England – stated that, for coleslaw, a total aerobic count and level of $>10^7$ cfu/g is unacceptable. In this context, 'unacceptable' means the product might appear spoiled, so it may not be suitable for consumption or sale. So, once exceeded, this was the level that would deem the end of the coleslaws' shelf-life.

What did we find?

Our results show just how much the shelf-life of coleslaw will vary depending on the age of the ingredients used to prepare it; a difference of days. As you will see from Fig. 1, coleslaw made with two-day-old ingredients reached an unacceptable level of micro-organisms (and therefore the end of its shelf-life) in just nine days. The coleslaw made with one-day-old ingredients reached the same level after 10 days, while the coleslaw containing fresh ingredients lasted an extra two days – its shelf-life ending after a total of 12 days.

Also worth noting was the initial microbial load of the two-day-old coleslaw at day zero: at least one log higher than the other two recipes. This will have influenced the shorter time to reach unacceptable microbial levels.

Although it cannot be confirmed without a study like this, similar results may arise in other products. In fact, the impact of using older ingredients could be even greater.

What does this mean for the industry?

Food manufacturers assign their final product's shelf-life with the individual ingredients in mind, so the final product should never contain ingredients that spoil during that product's life. Increasing the life of ingredients is one way in which food waste could be reduced – but it does have drawbacks, which need to be carefully considered. Trials would need to be carried out to show that a product remains acceptable with the same shelf-life, or indeed if the use of older ingredients would require a shorter shelf-life for a final product.

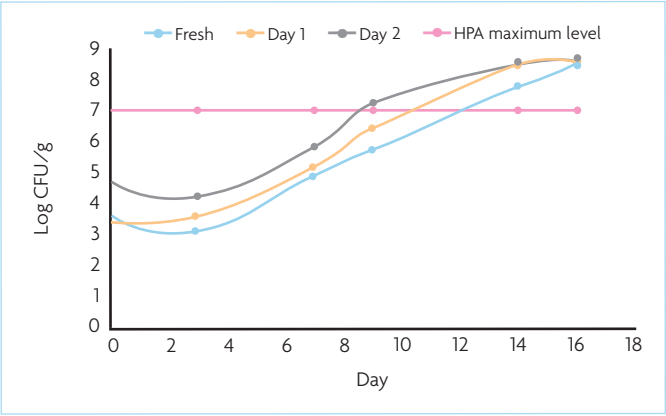
Overall, the results of this research have shown that ingredient age can have a significant effect on the achievable shelf-life of a final product and, therefore, should be considered in shelf-life trials. As this research has provided some light on just how quickly a product can reach an unacceptable level of micro-organisms when made with ingredients of different age, we hope that this insight will provide scope for food manufacturers to further reduce food waste in the future.

Of course, each product behaves differently, so if you are looking to test what your final product's shelf-life would be when made with ingredients of varying ages, then this is something that the team at Campden BRI can help you with.

We have conducted similar shelf-life research on other products which has allowed us to better predict the microbial levels of these products as they age, right up until the point of consumption. This, in turn, allows us to put together appropriate shelf-life protocols.

Campden BRI's recently updated shelf-life determination guidance, that is backed by expert advice and practical shelf-life assessment, has been aligned with new EU regulation and recommendations for setting a shelf-life. The new guidance, which has been extended beyond chilled foods to include ambient stored foods, is now available. ■

Fig. 1. The increase in microbial load of three batches of coleslaw containing ingredients of varying ages, including the point that they breach the HPA maximum level of 10^7 cfu/g.



Number 5

FOCUSING on food delivery safety

by Linda Everis, senior microbiologist at Campden BRI. www.campdenbri.co.uk

Covid-19 has obviously been devastating for almost every aspect of the food industry, but perhaps a calling for food delivery. Even at the earlier stages of the pandemic, the total number of food delivery users in the UK rose to 22.5 million – a 9.8% increase compared to the same period in 2019, according to Statista. There is no doubt that we have seen an explosion in food delivery this year. You may have even found yourself mixing up the flavours of your week with a meal-kit company.

Supermarkets have been jumping on the bandwagon too and expanded their delivery offering by partnering with takeaway courier groups to meet the surge in demand. This expansion is essential, especially for vulnerable customers who are most at risk if they contract Covid-19. However, with this rapid expansion come concerns over food safety.

Food delivery: a key 'takeaway' from Covid-19

It does not take a scientist to realise that when a country locks down and restaurants close, more people may seek food that can be brought to them. What does require a scientist, however, is a study to determine whether chilled food that is being delivered remains chilled.

To be precise, 8°C is the maximum temperature at which chilled products sold in the UK can legally be stored. Exceeding this temperature could make foods unsafe and susceptible to spoilage impairing the quality of the delivered foods. External environmental factors also need to be considered. For example, the UK summer saw temperatures soar above 30°C, meaning this legal maximum leaves little room for error for non-chilled food delivery.

Chilled courier is technically the safest way to deliver foods that need to be kept chilled but transporting products in this way can get expensive – hence why non-chilled courier or delivery via the postal service is more popular. However, foods delivered with these services are potentially vulnerable to fluctuations in temperature that occur throughout the day and night. This prompts the question: can these forms of non-chilled delivery prevent food and drink products from exceeding 8°C? To find out, our team of microbiologists promptly conducted a comprehensive study.

Research into temperature abuse during postal delivery

The method was simple. Chilled and frozen ready meals were packed into a cardboard box with ice packs and bubble wrap and then stored at various temperatures, mimicking those encountered during non-chilled delivery.

From braised steak to vegetable bake, each box of ready meals was subjected to one of three different temperature regimes that replicated worse-case food delivery processes:

- Regime one: 53.5 hours at 20°C or above.
- Regime two: 15 hours at 5°C with a further 24 hours at 20°C or above.
- Regime three: 10 hours at 5-8°C followed by 59.5 hours above 20°C.

What did we find? In short, if products are delivered by non-chilled courier and are subjected to prolonged temperature abuse (meaning they are stored above 8°C) then they may not remain chilled. This may seem like a no brainer, but the data allowed us to visualise how foods behave when exposed to these conditions. Why is this important? Because it can provide us with the insights we need to understand how, for example, to pack foods to increase their chance of staying chilled for longer.

What the research revealed

We learnt that the rate at which a product reaches 8°C can depend heavily on the type of product it is and (sometimes) its placement within a box.

A perfect example of this can be seen in Fig. 1, which represents data from a box stored under the conditions of regime two. Some variation is seen between the three products (the green, purple and orange line) despite all of them being stored at the bottom of the cardboard box. As a result of this variation, two of the products exceeded the UK legal maximum storage temperature, indicated by a red line in the figure.

Surprisingly, ready meals kept at different levels within the same box sometimes behaved quite differently.

For the box mentioned in the example above, a ready meal at the top of the box also remained below 8°C throughout, but several of the meals in the centre exceeded this maximum legal temperature (data not shown).

As expected, the external temperature played a pivotal role in increasing the temperature of the ready meals. What we have seen for the first time, however, is just how rapidly they warmed up. Looking at the worst-case example in Fig. 1, the salt and pepper chicken (the one represented as a green line) climbed 8°C from 0°C during nine hours at a 20°C external temperature, putting it directly on the cusp of exceeding the UK legal maximum storage temperature.

When it comes to transit time, how long should food and drink be out for delivery? Our data has shown that if these worst-case scenarios are expected then these products should be delivered within 24 hours to ensure they stay chilled, even when ice packs are included.

What can the food industry learn from this?

The research highlights the three main questions that food businesses must ask themselves before sending their products out for delivery: how long will they take to reach the consumer? What time of day will it be? And are they packaged sufficiently to remain chilled?

Careful consideration should be given to the amount of insulation, packaging material, ice packs used and even the placement of products. This is particularly important when it comes to mixing products of different temperatures as we found that some chilled ready meals began to freeze if placed between two frozen ones.

With this in mind, a manufacturer may be tempted to pack products tactically to increase the likelihood of them maintaining temperature, especially if a long delivery time is expected.

However, there is no guarantee they would remain under 8°C during non-chilled transport. Providing product quality would not be affected, another approach could be to send chilled products out frozen, potentially helping maintain temperature control.

Overall, as mentioned earlier, the rate at which a product reaches 8°C can depend heavily on the product and its placement in a box, and it is for this reason that we suggest food businesses undertake studies like this one before embarking on this type of delivery service.

This is a service that our team of highly experienced microbiologists at Campden BRI can perform. We can monitor the temperature of products prepared for delivery and use the data to predict the potential for growth of both pathogens and spoilage organisms. ■

Fig. 1. Data from a box stored under the conditions of Regime 2.