UK Health Security Agency

Assessing the Microbiological Safety of Plant-Based Alternatives to Meat and Dairy Products

UKHSA annual programme of food and environmental studies

- National studies
  - All Local Authorities requested to participate
  - Questionnaires used to gather details relating to samples
  - Pre-planned topics of interest and reactive studies
  - Aim to publish results wherever possible

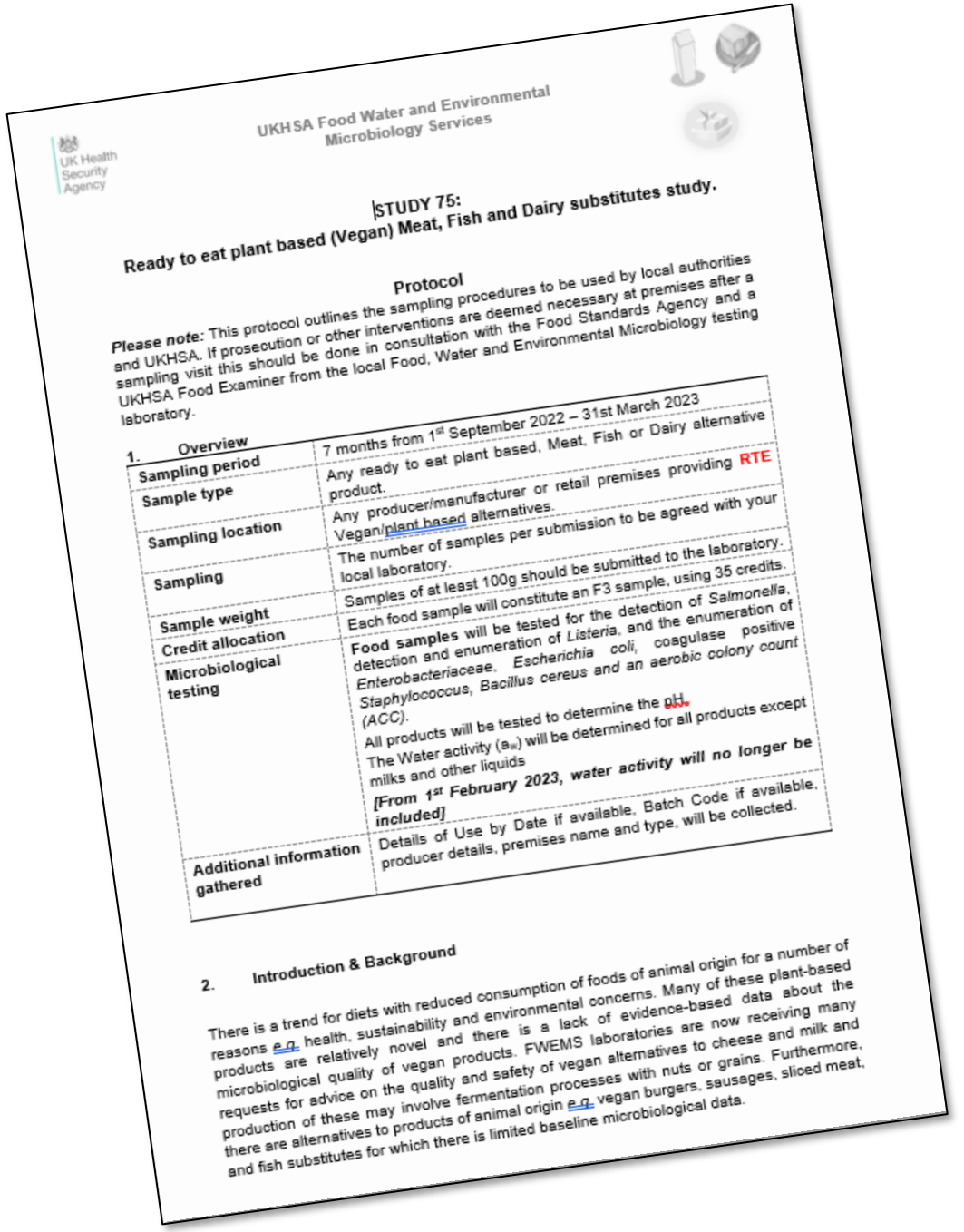
- Consultation on short-list of suggestions – circulated to stakeholders in November / December each year
- Top two options selected, plus a reactive study dependent on current issues

- Regional studies may be organised by each lab based on local concerns – may be useful for local understanding or as pilot studies for future national focus

Protocol shared

- Specifies time period, types of premises
- Sample types included and excluded
- Tests to be performed
- Interpretation of results

- Does not prescribe numbers of samples of each type (i.e. not based on market share etc)
- We accept that our surveys will tend to focus more on higher risk products



UK Health Security Agency

UKHSA Food Water and Environmental Microbiology Services

STUDY 75:
Ready to eat plant based (Vegan) Meat, Fish and Dairy substitutes study.

Protocol

Please note: This protocol outlines the sampling procedures to be used by local authorities and UKHSA. If prosecution or other interventions are deemed necessary at premises after a sampling visit this should be done in consultation with the Food Standards Agency and a UKHSA Food Examiner from the local Food, Water and Environmental Microbiology testing laboratory.

1. Overview	
Sampling period	7 months from 1st September 2022 – 31st March 2023
Sample type	Any ready to eat plant based, Meat, Fish or Dairy alternative product.
Sampling location	Any producer/manufacturer or retail premises providing RTE Vegan/plant based alternatives.
Sampling	The number of samples per submission to be agreed with your local laboratory.
Sample weight	Samples of at least 100g should be submitted to the laboratory.
Credit allocation	Each food sample will constitute an F3 sample, using 35 credits.
Microbiological testing	**Food samples** will be tested for the detection of *Salmonella*, detection and enumeration of *Listeria*, and the enumeration of *Enterobacteriaceae*, *Escherichia coli*, coagulase positive *Staphylococcus*, *Bacillus cereus* and an aerobic colony count (ACC). All products will be tested to determine the ~~ph.~~ The Water activity (a_w) will be determined for all products except milks and other liquids ***[From 1st February 2023, water activity will no longer be included]***
Additional information gathered	Details of Use by Date if available, Batch Code if available, producer details, premises name and type, will be collected.

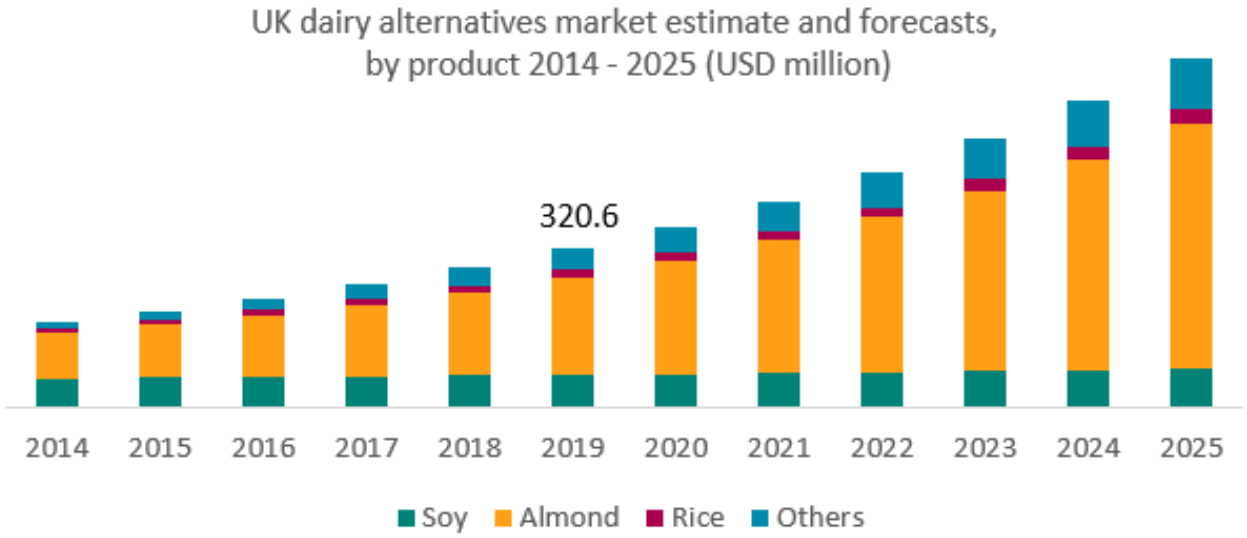
2. Introduction & Background

There is a trend for diets with reduced consumption of foods of animal origin for a number of reasons *e.g.* health, sustainability and environmental concerns. Many of these plant-based products are relatively novel and there is a lack of evidence-based data about the microbiological quality of vegan products. FWEMS laboratories are now receiving many requests for advice on the quality and safety of vegan alternatives to cheese and milk and production of these may involve fermentation processes with nuts or grains. Furthermore, there are alternatives to products of animal origin *e.g.* vegan burgers, sausages, sliced meat, and fish substitutes for which there is limited baseline microbiological data.

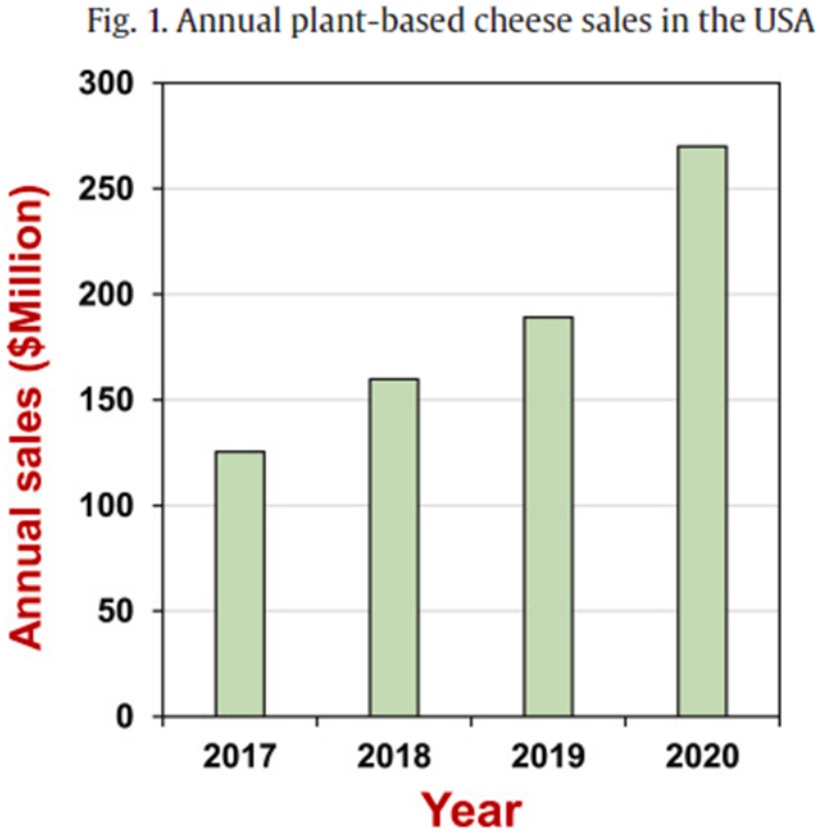
Plant-based diets

- Plant-based diets increasingly popular
- Shown to be healthier –
  - significantly reduced risk of negative health outcomes (high blood pressure, heart disease, diabetes)
- Climate considerations
- Increasing availability of meat-free and dairy-free plant-based options

Plant-based milk and cheese sales



By 2019, plant-based milks accounted for 8% of all milk sales in UK



How are they made? Plant-based milks

Variations in the manufacturing depending on starting plant material

For soy milk, process involves:

- cleaning, soaking and dehulling the beans
- grinding beans to a slurry
- heating to denature lipoxidase enzymes to reduce effects flavour
- removing solids by filtration
- adding water, sugar and other ingredients to improve flavo and micronutrient content; oils / thickening or stabilising agents
- pasteurizing the pre-final liquid

Storage at refrigeration or ambient temperature, depending heating stage

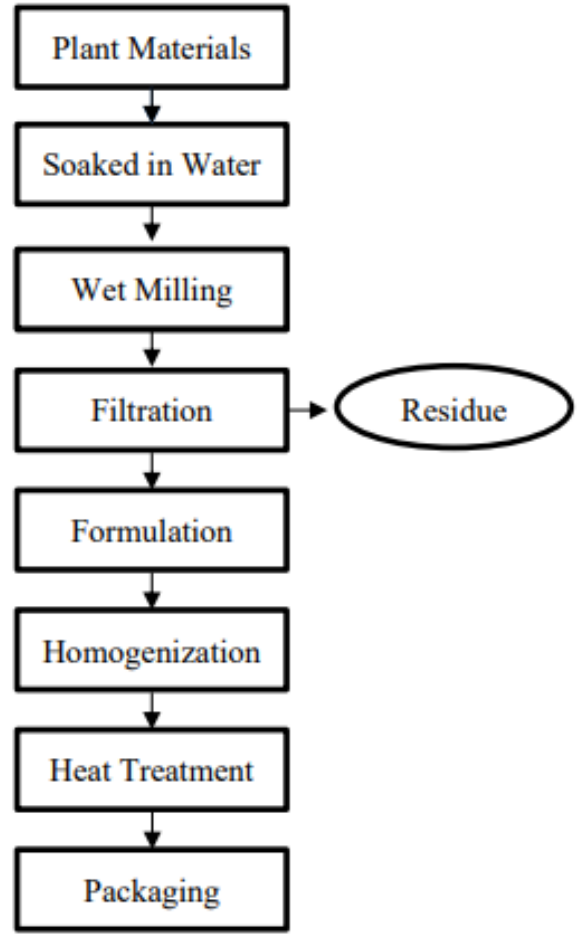


Figure 1. Procedure of plant-based milk production

How are they made? Vegan cheeses

- Soaking of nuts (eg cashews or almonds) for at least 4 hours
- Blending (with eg nutritional yeast, lemon juice, vinegar, flavourings)
- Addition of tapioca starch or agar agar powder for more stretchy / melting consistency
- Cook to achieve consistency
- Transfer to mold and let it set

OR

- Fermentation of eg soy milk using starter culture
- Curd cut, pressed and salted

Common plant-based cheese components

Study carried out on commercial plant-based cheeses in UK identified 109 products on the market

74% coconut-oil based

10% nut-based

6% palm-oil based

5% rice-based

3% soy-based

2% sunflower oil-based

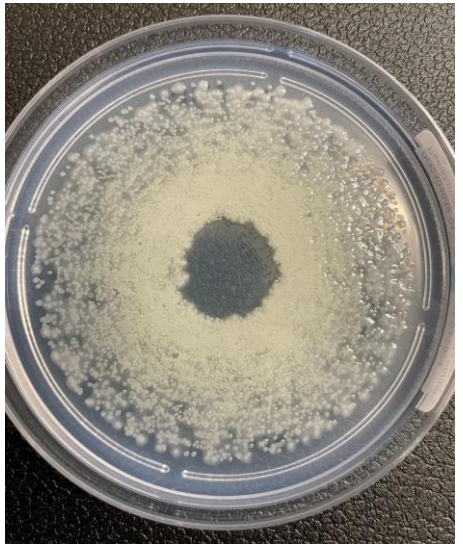
(Nicolás Saraco & Blaxland, 2020)

How are they made? Vegan meat substitutes

- Protein source selected (legumes; wheat gluten; soy; algae)
- Texturisation – mix protein source with water / other liquid to produce dough-like consistency – subjected to mechanical processing to achieve fibrous texture
- Binders (starches / gums) may be added
- Fats and flavourings added
- Colourings added
- Formed into shapes by extrusion into sausage shape / moulding into burgers etc
- Cooked to develop flavour / texture

Potential risks

- Contamination of plant-based ingredients
  - dried pulses / nuts / grains likely to contain spores – *Bacillus cereus*
  - *Salmonella* previously associated with nuts
  - Yeasts and moulds likely on dried ingredients
- Soaking process may allow growth of bacteria
- Soaking of kidney beans overnight – *Bacillus* shown to grow at ambient temperature but not if soaked in fridge
- Relatively few controls in final products to minimise microbial growth during shelf-life



Salmonella and vegan cheese

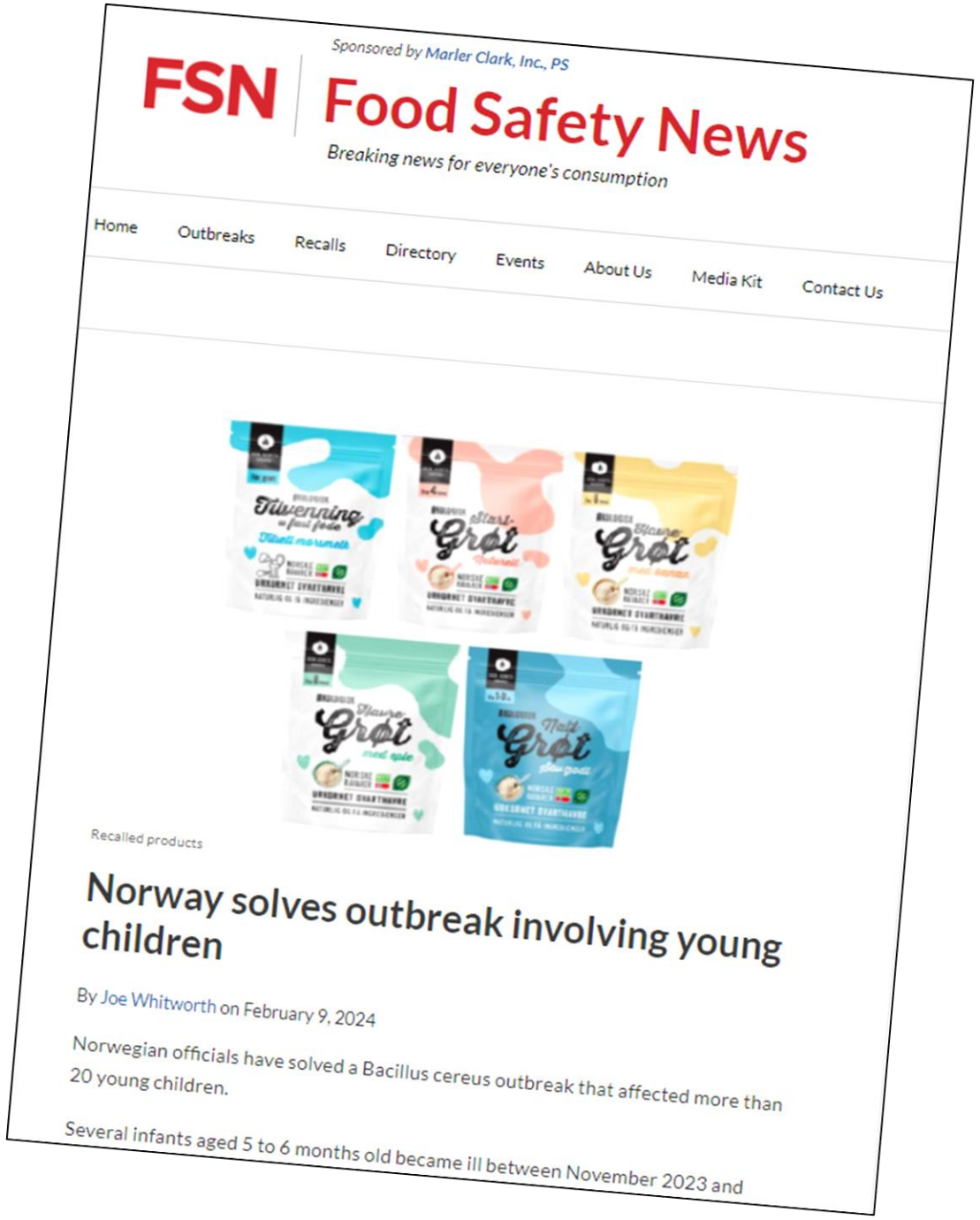
2020 / 2021:

- Salmonella outbreak linked to vegan cheese in US
- 20 cases – S. Chester, S. Urbana, S. Duisburg and S. Typhimurium!
- Outbreak strains (S. Chester and S. Urbana) found in production environment and in raw cashew nuts used in cheese production
- No pasteurisation step included in processing

2013 / 2014:

- 17 cases of salmonellosis (S. Stanley) linked to cashew cheese in California
- S. Weltevreden also isolated from fermenting cashew nuts at production premises

Bacillus in oats



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FSN Food Safety News

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Recalled products

Norway solves outbreak involving young children

By Joe Whitworth on February 9, 2024

Norwegian officials have solved a Bacillus cereus outbreak that affected more than 20 young children.

Several infants aged 5 to 6 months old became ill between November 2023 and

Bacillus levels in plant-based ingredients

- Study carried out in Netherlands
- Tested 88 samples of pulses, cereals and drupes (coconut / almond / cashew)
- *B. cereus* detected at >10 cfu/g in
  - 30% of pulses
  - 13% of cereals (oat ingredients)

- 9% of *B. cereus* strains contained emetic toxin (*ces* gene)
- 42% /28% / 69% contained different enterotoxins (*cyt*K, *hbl, nhe*)
- 9% contained both emetic and enterotoxin
- 4% contained no toxin genes

Kyrylenko et al (2023) Int J Food Microbiol

Study 75: Ready to eat plant based meat, fish and dairy substitutes - September 2022 to March 2023

- Meat alternatives *e.g.* salami style, chicken style, vegan sausage rolls, pepperoni style, tofu based, *etc*
- Fish alternatives *e.g.* vegan salmon, vegan shrimp, etc
- Dairy alternatives *e.g.* Plant based cheese, milk, cream, yoghurt *etc*

- From any retail or catering premises

- NOT: products needing further cooking or processing (*e.g.* soya or Quorn mince) or products with multiple ingredients *e.g.* meals.

Test for:

- *Salmonella*
- *Listeria* - detection and enumeration
- *Enterobacteriaceae*
- *Escherichia coli*
- coagulase positive *Staphylococcus*
- *Bacillus cereus*
- Aerobic colony count (ACC)
- pH
- Water activity (a_w) for all products except milks and other liquids

Samples collected

- 937 samples:
  - 44% meat substitutes
  - 26% vegan cheeses
  - 15% plant-based milks
  - 12% other dairy alternatives
  - 1% fish alternatives
  - 2% other (eg egg alternatives / vegan desserts)

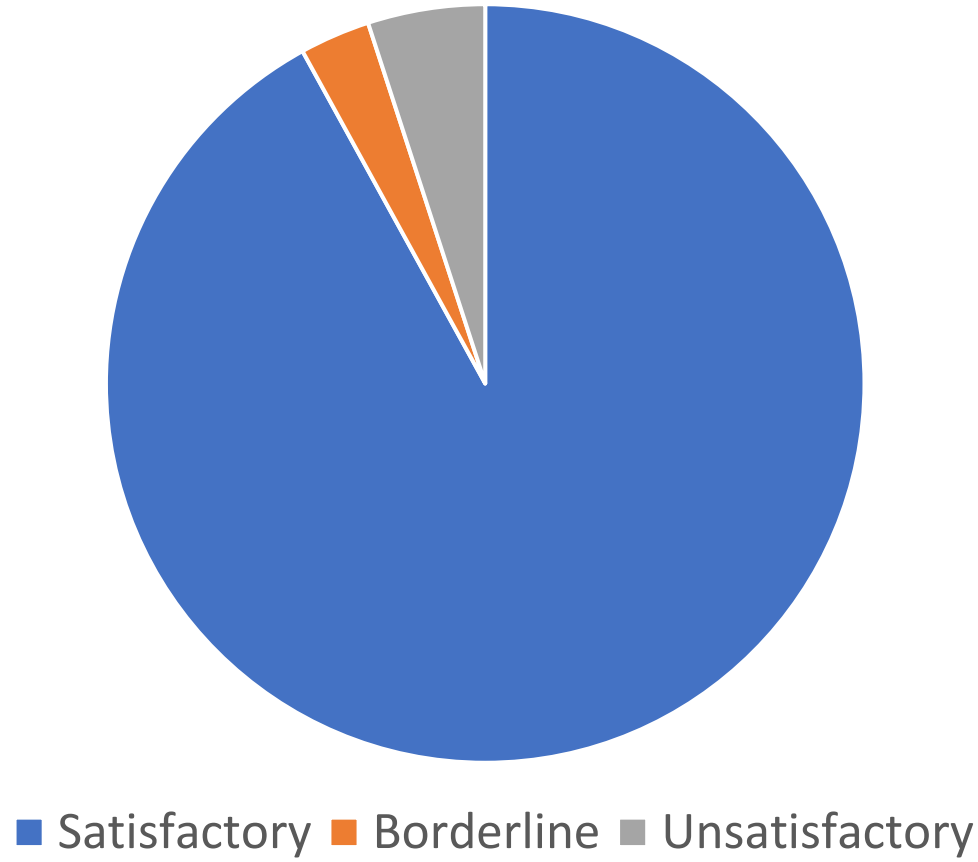
- Packaging:
  - 80% pre-packed, unopened
  - 3% pre-packed but opened
  - 10% loose / not pre-packed

Sampling point:
- 90% retail
- 9% producers
- 1% catering

Results

- 92% satisfactory
- 3% borderline
- 5% unsatisfactory
  - due to Enterobacteriaceae and *E. coli*

- No Salmonella detected
- *Bacillus cereus* borderline in 2 samples
- *L. monocytogenes* in 5 samples
- Other *Listeria* species in 4 samples



Interpretation of Enterobacteriacae

- Are high Enterobacteriaceae levels expected in plant-based foods?
- Many products include a pasteurisation or cooking stage

- Borderline / unsatisfactory Enterobacteriaceae levels in:
  - 17% of unpackaged or open packs
  - 5% of unopened packs

- Considered that it is reasonable to interpret Entero levels according to HPA / UKHSA Ready-To-Eat Guidelines

  <100 cfu/g = satisfactory

  100 – 10,000 cfu/g = borderline

  >10,000 cfu/g = unsatisfactory

Listeria in vegan products

- *L. monocytogenes* detected in 5 tofu samples from same producer:

Sampling date	No. samples	Product	L. mono Result	Type
Jan 23	1	Organic natural tofu	Detected 20 cfu/g	Serotype 1/2a (ST37)
Feb 23 (early)	5	Organic natural tofu	3 x detected: 20, <20, <20 cfu/g	Serotype 1/2a (ST37) Serotype 4 (ST145)
Feb 23 (late)	5	Various tofu products	All negative	
Mar 23	5	Various tofu products	1 x detected 20 cfu/g	Serotype 1/2a (ST37)
Mar 23	1	Swab from producer	Detected	Serotype 1/2a (ST37)
May 23	1	Environmental sample – commercial lab		Serotype 4 (ST145)

- L. species in 4 meat substitutes (2 burgers / 2 ‘chicken’)

Interpretation of Listeria results – EC 2073/2005

Chapter 1. Food safety criteria

Food category	Micro-organisms/their toxins, metabolites	Sampling plan (1)		Limits (2)		Analytical reference method (3)	Stage where the criterion applies
		n	c	m	M		
1.1 Ready-to-eat foods intended for infants and ready-to-eat foods for special medical purposes (4)	*Listeria monocytogenes*	10	0	Absence in 25 g		EN/ISO 11290-1	Products placed on the market during their shelf-life
1.2 Ready-to-eat foods able to support the growth of *L. monocytogenes*, other than those intended for infants and for special medical purposes	*Listeria monocytogenes*	5	0	100 cfu/g (5)		EN/ISO 11290-2 (6)	Products placed on the market during their shelf-life
		5	0	Absence in 25 g (7)		EN/ISO 11290-1	Before the food has left the immediate control of the food business operator, who has produced it
1.3 Ready-to-eat foods unable to support the growth of *L. monocytogenes*, other than those intended for infants and for special medical purposes (4) (8)	*Listeria monocytogenes*	5	0	100 cfu/g		EN/ISO 11290-2 (6)	Products placed on the market during their shelf-life

‘Unable to support growth’

Products with

- pH ≤ 4.4
- aw ≤ 0.92
- pH ≤ 5.0 AND aw ≤ 0.94
- shelf-life of less than five days

shall be automatically considered to belong to this category.

Other categories of products can also belong to this category, subject to scientific justification.

Impact of pH and water activity

- pH and Aw determined (Aw stopped from Feb 2023)
  - 38% had pH <5.0
  - 18% had Aw < 0.94
  - Mainly not protective against bacterial growth

- Tofu with *L. monocytogenes*:
  pH 5.3 – 6.3; Aw 0.97 – not protective

- Camembert-style cheese with 2800 cfu/g *B. cereus*:
  pH 5.2; Aw 0.95 – not protective

- Garlic and herb soft cheese with 8800 cfu/g *B. cereus*:
  pH 4.4 (Aw not determined) – control of *B. cereus* growth likely

Conclusions

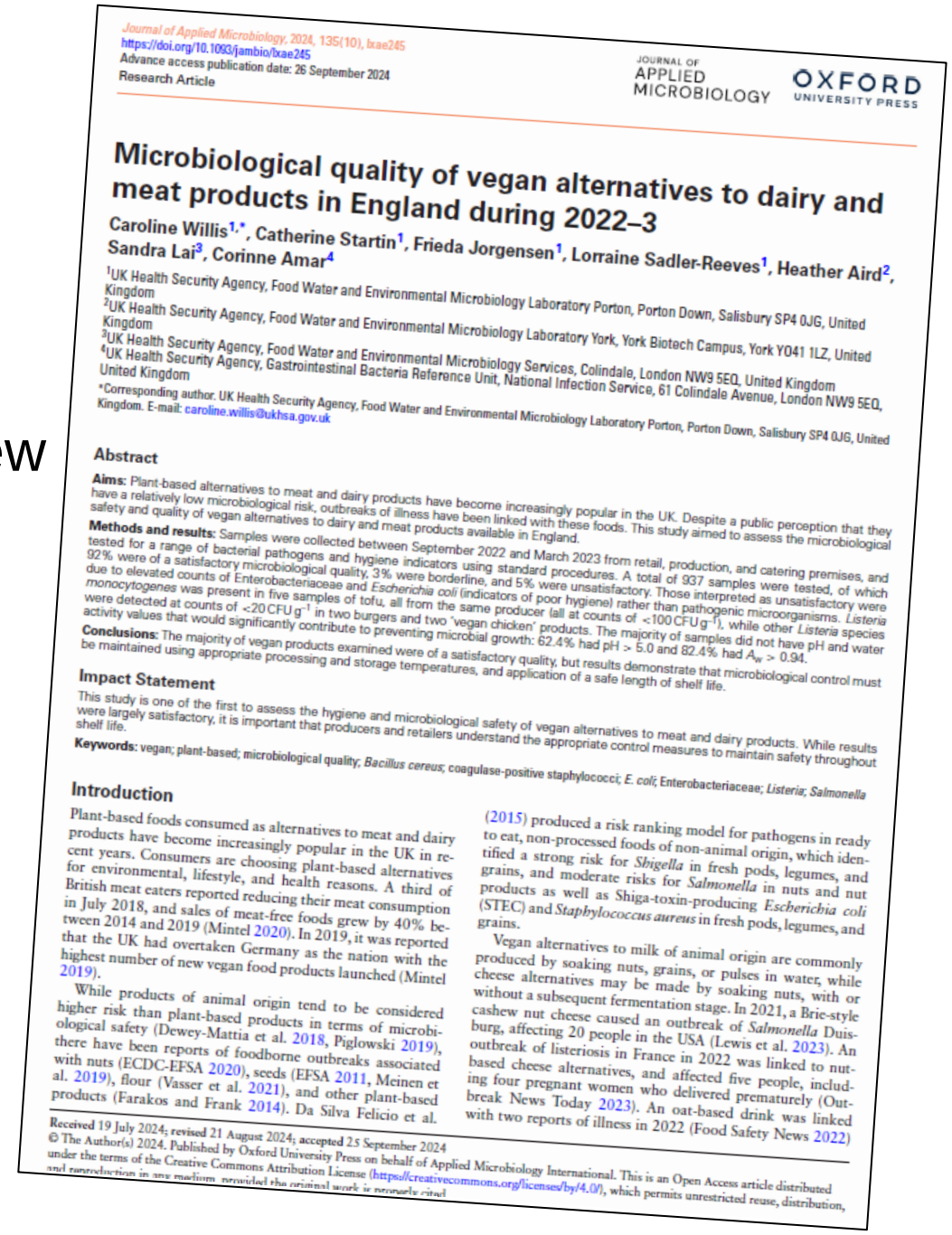
- Plant-based meat/dairy alternatives are largely of a satisfactory microbiological quality
- Conditions allow *Listeria* survival and growth – particularly in meat substitutes?
- *Bacillus cereus* not observed frequently – but pH / Aw may not be sufficient to control growth when present
- Storage temperature and shelf-life must be carefully considered for these products to ensure safety
- Important that the public – and Food Businesses - don’t assume these products are risk-free, just because they are plant-based

Acknowledgements

- FW&E teams at London, Porton and York
- Lorraine Sadler-Reeves – study coordination
- Cat Startin – data analysis and literature review

Publication:

Willis et al (2024)
Journal of Applied Microbiology 135: lxae245



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Research Article

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Microbiological quality of vegan alternatives to dairy and meat products in England during 2022–3

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Abstract

Aims: Plant-based alternatives to meat and dairy products have become increasingly popular in the UK. Despite a public perception that they have a relatively low microbiological risk, outbreaks of illness have been linked with these foods. This study aimed to assess the microbiological safety and quality of vegan alternatives to dairy and meat products available in England.

Methods and results: Samples were collected between September 2022 and March 2023 from retail, production, and catering premises, and tested for a range of bacterial pathogens and hygiene indicators using standard procedures. A total of 937 samples were tested, of which 92% were of a satisfactory microbiological quality, 3% were borderline, and 5% were unsatisfactory. Those interpreted as unsatisfactory were due to elevated counts of Enterobacteriaceae and *Escherichia coli* (indicators of poor hygiene) rather than pathogenic microorganisms. *Listeria monocytogenes* was present in five samples of tofu, all from the same producer (all at counts of <100 CFU g^{-1}), while other *Listeria* species were detected at counts of <20 CFU g^{-1} in two burgers and two 'vegan chicken' products. The majority of samples did not have pH and water activity values that would significantly contribute to preventing microbial growth: 62.4% had pH > 5.0 and 82.4% had A_w > 0.94.

Conclusions: The majority of vegan products examined were of a satisfactory quality, but results demonstrate that microbiological control must be maintained using appropriate processing and storage temperatures, and application of a safe length of shelf life.

Impact Statement

This study is one of the first to assess the hygiene and microbiological safety of vegan alternatives to meat and dairy products. While results were largely satisfactory, it is important that producers and retailers understand the appropriate control measures to maintain safety throughout shelf life.

Keywords: vegan; plant-based; microbiological quality; *Bacillus cereus*; coagulase-positive staphylococci; *E. coli*; Enterobacteriaceae; *Listeria*; *Salmonella*

Introduction

Plant-based foods consumed as alternatives to meat and dairy products have become increasingly popular in the UK in recent years. Consumers are choosing plant-based alternatives for environmental, lifestyle, and health reasons. A third of British meat eaters reported reducing their meat consumption in July 2018, and sales of meat-free foods grew by 40% between 2014 and 2019 (Mintel 2020). In 2019, it was reported that the UK had overtaken Germany as the nation with the highest number of new vegan food products launched (Mintel 2019).

While products of animal origin tend to be considered higher risk than plant-based products in terms of microbiological safety (Dewey-Mattia et al. 2018, Piglowski 2019), there have been reports of foodborne outbreaks associated with nuts (ECDC-EFSA 2020), seeds (EFSA 2011, Meinen et al. 2019), flour (Vasser et al. 2021), and other plant-based products (Farakos and Frank 2014). Da Silva Felicio et al. (2015) produced a risk ranking model for pathogens in ready to eat, non-processed foods of non-animal origin, which identified a strong risk for *Shigella* in fresh pods, legumes, and grains, and moderate risks for *Salmonella* in nuts and nut products as well as Shiga-toxin-producing *Escherichia coli* (STEC) and *Staphylococcus aureus* in fresh pods, legumes, and grains.

Vegan alternatives to milk of animal origin are commonly produced by soaking nuts, grains, or pulses in water, while cheese alternatives may be made by soaking nuts, with or without a subsequent fermentation stage. In 2021, a Brie-style cashew nut cheese caused an outbreak of *Salmonella* Duisburg, affecting 20 people in the USA (Lewis et al. 2023). An outbreak of listeriosis in France in 2022 was linked to nut-based cheese alternatives, and affected five people, including four pregnant women who delivered prematurely (Outbreak News Today 2023). An oat-based drink was linked with two reports of illness in 2022 (Food Safety News 2022)

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