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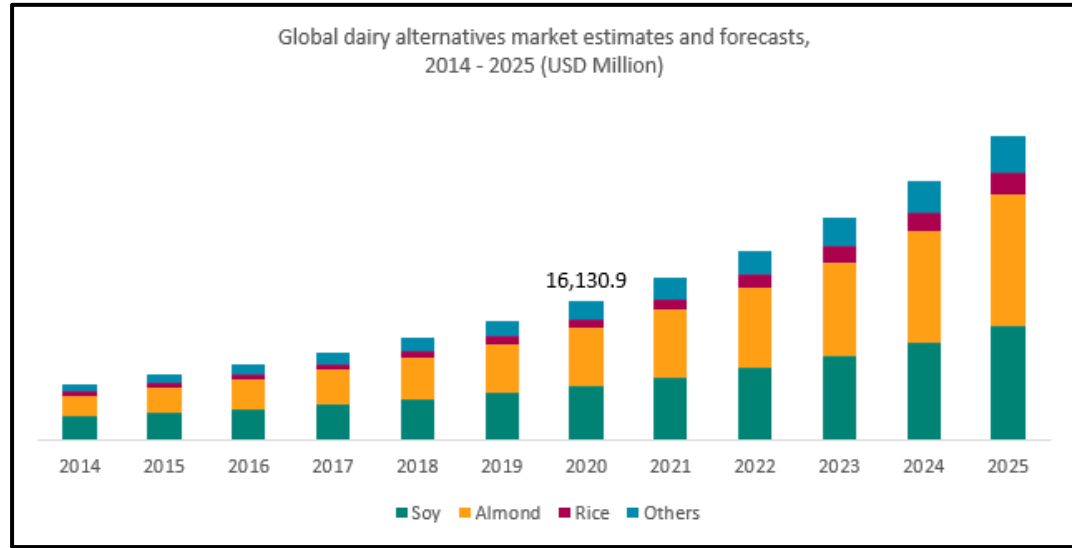
Ollscoil Teicneolaíochta na Mumhan
Munster Technological University

Growth of *Listeria* in plant-based milk beverages

Klaudia Bartula and Michael Callanan

25th May 2023

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Plant-based sector deep dive: France

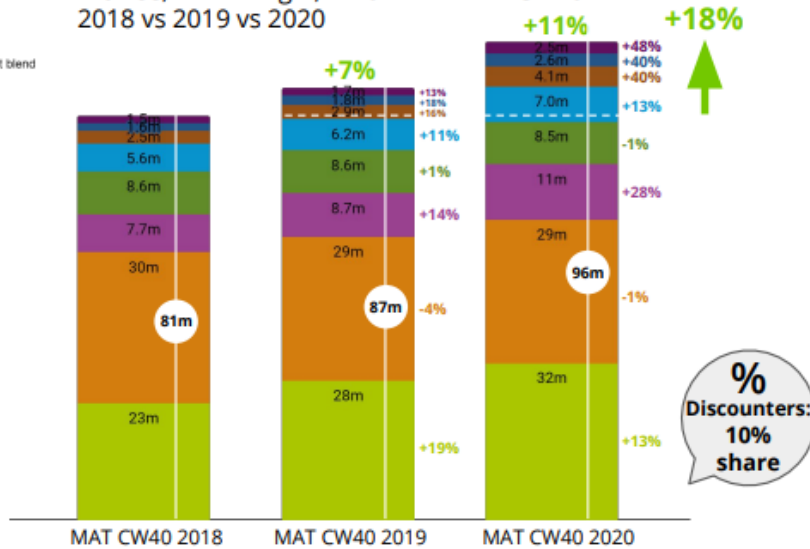
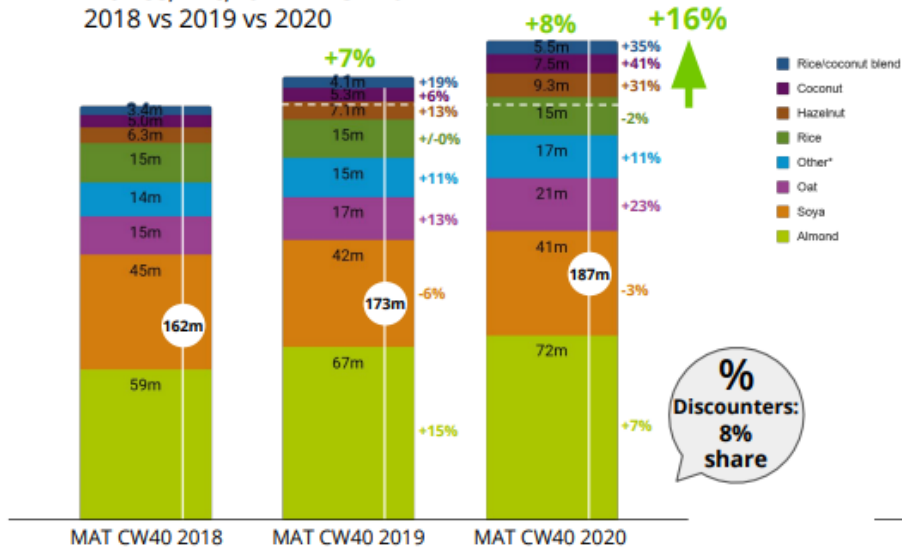
Total plant-based milk sales



Almond milk has the highest sales value and volume, followed by soya and oat.

Sales value of plant-based milk in France, in €, for MAT CW40 2018 vs 2019 vs 2020

Sales volume of plant-based milk in France, in Kg/L, for MAT CW40 2018 vs 2019 vs 2020



*Other includes more than 20 subsegments, with the most dominant being rice/coconut and spelt/hazelnut. Total includes hypermarkets, supermarkets, Proximité, eDrive, & discounters

Source: Nielsen MarketTrack

MAT=Moving Annual Total

(<https://smartproteinproject.eu/>)



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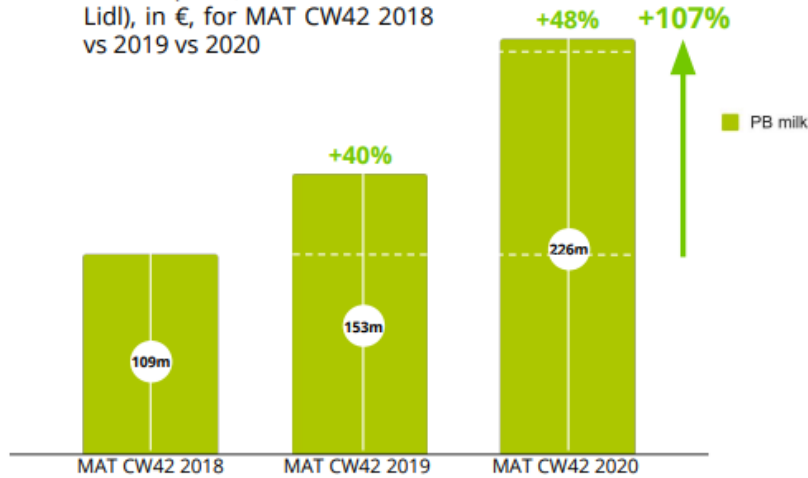
Plant-based sector deep dive: UK

Total plant-based-milk sales

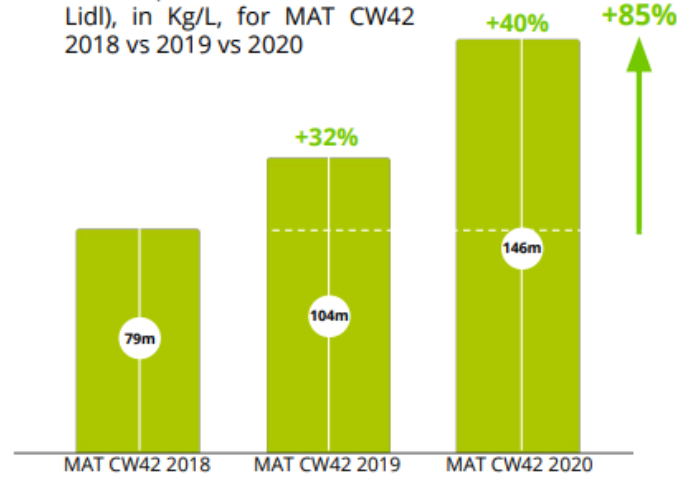


Sales value of plant-based milk grew 107% over the past two periods, while sales volume increased by 85%.

Sales value of plant-based milk in UK (total incl. grocery and impulse, excl. Aldi and Lidl), in €, for MAT CW42 2018 vs 2019 vs 2020



Sales volume of plant-based milk in UK (total incl. grocery and impulse, excl. Aldi and Lidl), in Kg/L, for MAT CW42 2018 vs 2019 vs 2020



Source: Nielsen MarketTrack

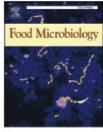
MAT=Moving Annual Total

PB=Plant-Based

(<https://smartproteinproject.eu/>)

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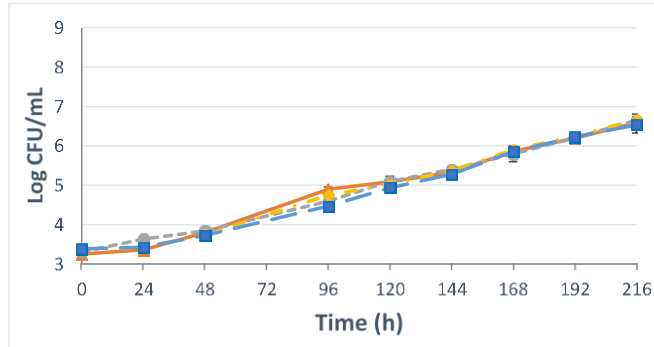
Growth of food-borne pathogens *Listeria* and *Salmonella* and spore-forming *Paenibacillus* and *Bacillus* in commercial plant-based milk alternatives

Klaudia Bartula, Máire Begley, Noémie Latour, Michael Callanan*

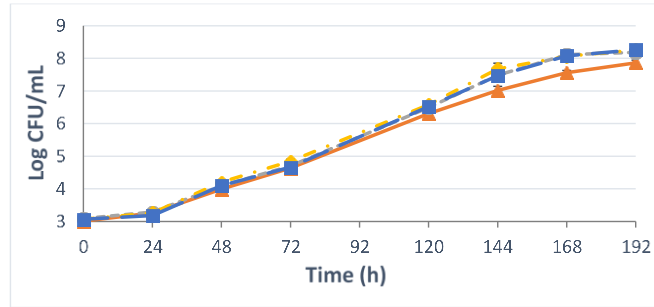
Department of Biological Sciences, Munster Technological University, Bishopscourt, Cork, Ireland

- *Listeria* cocktail in bovine, almond, coconut and cashew milk
- Growth at 4, 8 and 20°C
- Growth equivalent in all milks
- No significant variation amongst strains

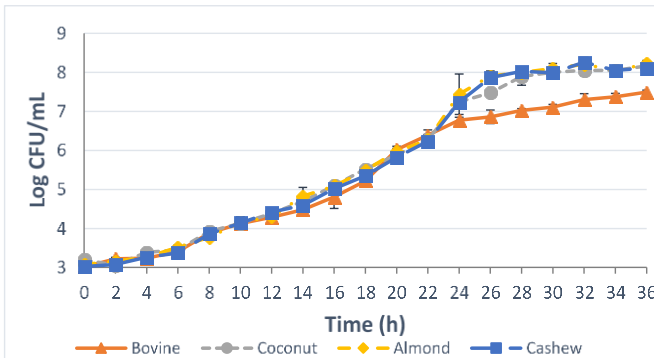
A - 4°C



B - 8°C



C - 20°C



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Department of
**Agriculture,
Food and the Marine**
An Roinn
**Talmhaíochta,
Bia agus Mara**



Growth of food-borne pathogens *Listeria* and *Salmonella* and spore-forming *Paenibacillus* and *Bacillus* in commercial plant-based milk alternatives

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	Whole Bovine Milk 1	Coconut beverage 1	Coconut beverage 2	Coconut beverage 3	Almond beverage 1	Almond beverage 2	Almond beverage 3	Cashew beverage 1
Energy	66 kcl	20 kcl	18 kcl	15 kcl	22 kcl	27 kcl	16 kcl	23 kcl
Fat content	3.8 g	0.9 g	0.9 g	1.4 g	1.1 g	1.3 g	1.3 g	1.1 g
of which saturates:	2.3 g	0.9 g	0.8 g	1.2 g	0.1 g	0.1 g	0.2 g	0.2 g
Carbohydrates	4.7 g	2.7 g	1.9 g	0.5 g	2.4 g	2.9 g	0.9 g	2.6 g
of which sugars:	4.7 g	1.9 g	1.9 g	0.5 g	2.4 g	2.8 g	<0.5 g	2.0 g
Protein	3.2 g	0.1 g	0.4 g	0.2 g	0.4 g	0.6 g	0.3 g	0.5 g
Fibre	-	0.1 g	0.5 g	0.5 g	0.4 g	0.5 g	<0.5 g	0.2 g
Salt	0.1 g	0.13 g	0.1 g	0.1 g	0.14 g	0.1 g	0.1 g	0.13 g
pH	6.5	6.8	7.8	8.3	7.5	7.8	8.1	6.7

- One third of energy content of cow's milk
- One third the fat content
- Less than half the sugar
- Ten times less protein

TABLE 4. Carbon sources supporting growth of *L. monocytogenes* in minimal medium

Energy source ^a	Growth (A_{600}) after 24 h
Glucose	1.18
Fructose	1.09
Mannose	1.10
N-Acetylglucosamine	0.99
N-Acetylmuramic acid	0.88
Glucosamine	1.00
Cellobiose	1.10
Trehalose	0.96
Maltose	0.10 ^b
Glycerol	0.11 ^b

Premaratne et al AEM 1991

Beverages sweetened and/or supplemented with protein

	Whole Bovine Milk 1	Coconut beverage 1	Coconut beverage 2	Coconut beverage 3
Energy	66 kcl	20 kcl	18 kcl	15 kcl
Fat content	3.8 g	0.9 g	0.9 g	1.4 g
of which saturates:	2.3 g	0.9 g	0.8 g	1.2 g
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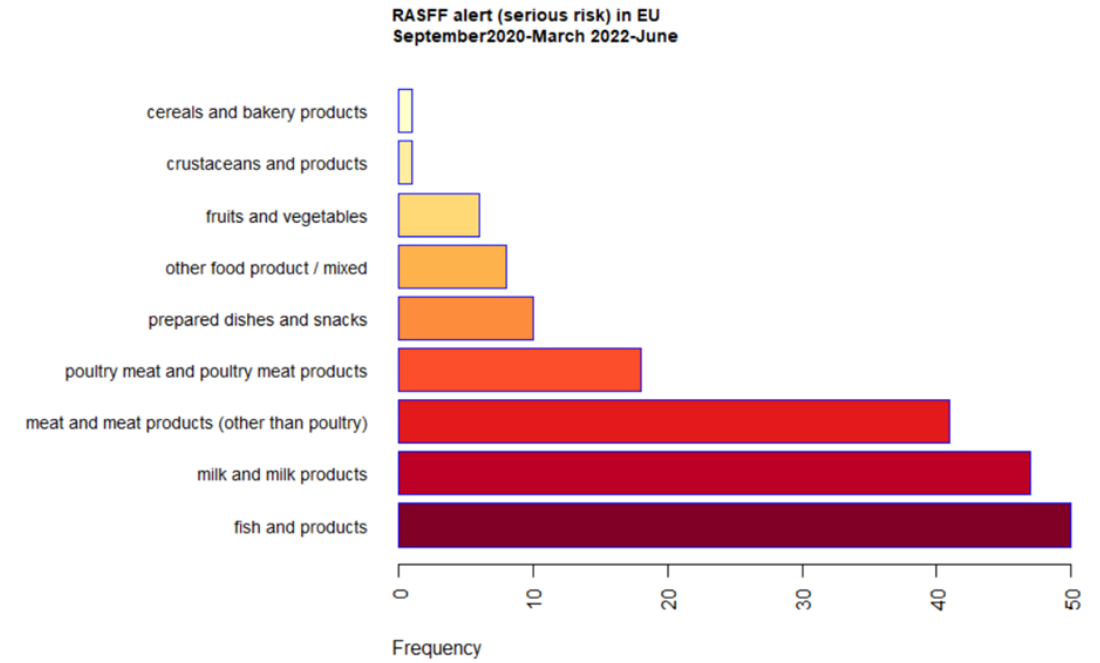
Table 2. Maximum growth rates of a cocktail of *Listeria* strains (log₁₀ CFU/mL/h, ± standard errors) at 4°C in different brands of almond and coconut beverages.

Test matrices:	Maximum Growth Rate:	<i>p</i> -Value
Almond 1	0.0180 ± 0.0012 ^{a, b}	0.0290
Almond 2	0.0198 ± 0.0008 ^a	
Almond 3	0.0174 ± 0.0015 ^b	
Coconut 1	0.0166 ± 0.0004	0.1150
Coconut 2	0.0181 ± 0.0013	
Coconut 3	0.0166 ± 0.0003	



Multi-strain cocktail of <i>Salmonella</i>	8 °C	0.0060 ± 0.0006	0.0060 ± 0.0032	0.0014 ± 0.0002	0.0027 ± 0.0010	0.1910
Multi-strain cocktail of <i>Salmonella</i>	20 °C	0.1790 ± 0.0021 ⁱ	0.2820 ± 0.0103 ^j	0.2930 ± 0.0061 ^j	0.2730 ± 0.0096 ^j	<0.0010
<i>Paenibacillus chitinolyticus</i>	20 °C	0.0511 ± 0.0156 ^k	0.0415 ± 0.0121 ^k	0.1680 ± 0.0204 ^l	0.1060 ± 0.0083 ^m	<0.0010
<i>Bacillus subtilis</i>	20 °C	0.1600 ± 0.0075 ⁿ	0.1040 ± 0.0091 ^p	0.1500 ± 0.0120 ^{n, o}	0.1270 ± 0.0094 ^o	<0.0010

- *Salmonella* cocktail grew more rapidly in plant milks
- *Paenibacillus* (industrial UHT spoilage isolate) also grows more rapidly
- *Bacillus subtilis* grew more slowly in plant based milks



Conclusions

- Growth of *Listeria* in plant-based milks equivalent to bovine milk
- Products UHT treated so sporeformers primary concern
- Post processing contamination or home processing a concern



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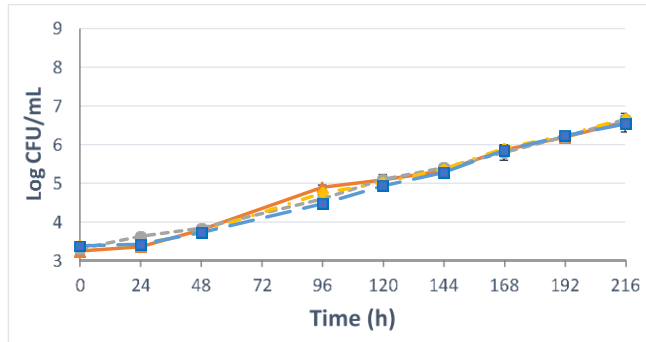
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Fig. 1 Growth of a cocktail of *Listeria* strains in bovine (▲) and plant-based beverages (coconut (●),

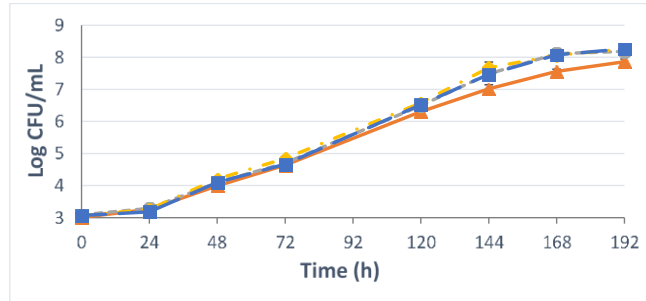
almond (◆) and cashew (■)). Growth curve at 4°C (A), 8°C (B) and 20°C (C). Each time point

represents a mean of triplicate results with ± standard errors.

A - 4°C



B - 8°C



C - 20°C

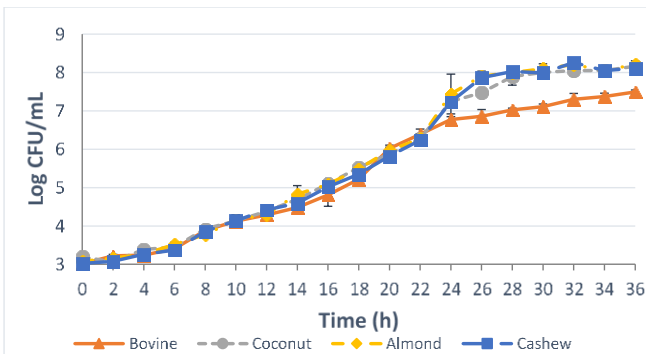


Table 1

Maximum growth rates of *Listeria*, *Salmonella*, *Paenibacillus* and *Bacillus* (log₁₀ CFU/mL/h, ± standard errors) at the specified temperature in each tested matrix.

Organism	Maximum growth rate					p-Value
	Temperature	Bovine milk	Coconut beverage Brand 1	Almond beverage Brand 1	Cashew beverage	
Multi-strain cocktail of <i>Listeria</i>	4 °C	0.0170 ± 0.0001	0.0180 ± 0.0010	0.0180 ± 0.0009	0.0190 ± 0.0004	0.0570
Multi-strain cocktail of <i>Listeria</i>	8 °C	0.0340 ± 0.0008 ^a	0.0390 ± 0.0007 ^b	0.0390 ± 0.0012 ^b	0.0390 ± 0.0004 ^b	0.0010
Multi-strain cocktail of <i>Listeria</i>	20 °C	0.1990 ± 0.0028 ^c	0.2300 ± 0.0099 ^d	0.2500 ± 0.0126 ^d	0.2450 ± 0.0031 ^d	0.0010
Multi-strain cocktail of <i>Listeria</i> (test matrix O/N)	8 °C	0.0370 ± 0.0025	ND	0.0416 ± 0.0016	ND	0.0140
Multi-strain cocktail of <i>Listeria</i> (test matrix O/N)	20 °C	0.1620 ± 0.0063	ND	0.2040 ± 0.0055	ND	0.0040
<i>L. innocua</i>	8 °C	0.0293 ± 0.0013 ^c	ND	0.0430 ± 0.0010 ^c	ND	<0.0010
<i>L. monocytogenes</i> (pathogenic strains cocktail)		0.0409 ± 0.0046 ^c	ND	0.0617 ± 0.0038 ^f	ND	
<i>L. innocua</i>	20 °C	0.1640 ± 0.0064 ^g	ND	0.2160 ± 0.0057 ^h	ND	<0.0010
<i>L. monocytogenes</i> (pathogenic strains cocktail)		0.1800 ± 0.0087 ^g	ND	0.2240 ± 0.0170 ^h	ND	
Multi-strain cocktail of <i>Salmonella</i>	8 °C	0.0060 ± 0.0006	0.0060 ± 0.0032	0.0014 ± 0.0002	0.0027 ± 0.0010	0.1910
Multi-strain cocktail of <i>Salmonella</i>	20 °C	0.1790 ± 0.0021 ⁱ	0.2820 ± 0.0103 ^j	0.2930 ± 0.0061 ^j	0.2730 ± 0.0096 ^j	<0.0010
<i>Paenibacillus chitinolyticus</i>	20 °C	0.0511 ± 0.0156 ^k	0.0415 ± 0.0121 ^k	0.1680 ± 0.0204 ^l	0.1060 ± 0.0083 ^m	<0.0010
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