PLANT-BASED ALTERNATIVE PRODUCTS SURVEY

NSW GOVERNMENT Food Authority

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Contents

Executive summary

In Australia, the market for plant-based products as alternatives to animal products (e.g. meat and milk) has increased over recent years for a number of reasons. For example, the increasing concern around the sustainability of meat and livestock production due to the growing world population, allergies or intolerances, and an increase in popularity of vegetarian and vegan diets. One solution to increasing protein demand is to use protein rich-plants in innovative processed products such as soy-based or wheat-based foods that have a 'mouth-feel' and taste that mimic meat, to increase consumers' acceptance.

Information on the microflora of plant-based alternative products is not widely available in the scientific literature. Reports available mainly focus on the nutritional aspects or consumers' acceptance. Therefore, this survey was carried out to gather information on the microbiological safety of these products and their labelling compliance with the Australia New Zealand Food Standards Code (the Code).

In total, 85 plant-based alternative products available in NSW supermarkets, green grocers and through online shops were tested for a range of microorganisms, pH and water activity. Testing results show that there was no microbiological safety concern with the products included in this survey. In addition, approximately three quarters of the products had compliant labels according to the Code. The common non-compliances observed were the use of unsubstantiated nutritional claims and nutritional information panel not complying with the Standard. Follow-up work on the labelling assessment was conducted in November 2020. Products with non-compliant labels identified in the survey were purchased and the labels were assessed again. When a product continued to have a non-compliant label, the manufacturer or importer was sent an advisory letter asking the business to rectify the issue (for businesses based in NSW). For businesses based in other jurisdictions, the issue was referred to the appropriate regulatory body in that jurisdiction.

Four of the most important control measures for ensuring the safe production of these products involve:

- Using high quality raw ingredients with low microbial load,
- Effective heat treatment,
- Strict hygiene and sanitation regime to prevent post-processing contamination, and
- For the 'raw' products, appropriate cooking instructions to kill any pathogenic organisms.

Introduction

In Australia, the market for plant-based products as alternatives to animal products (e.g. meat and milk) has increased over recent years for a number of reasons. For example, the increasing concern around the sustainability of meat and livestock production due to the growing world population, allergies or intolerances, and an increase in popularity of vegetarian and vegan diets. One possible meat alternative solution is the use of protein-rich plants in the unprocessed forms to substitute meat in meals (e.g. lentils or other legumes) or through more innovative processed products such as soy-based or wheat-based products that have a 'mouth-feel' and taste that mimic meat to increase consumers' acceptance (Admassu et al. 2020; Food Frontier, 2019; World Economic Forum, 2019). The products included in this project were those from the latter category and they are called 'plant-based alternative products'[1] throughout the report.

Plant-based alternative products are a fast-growing market segment with products stocked in increasing numbers in retail outlets in NSW. A NSW supermarket survey with a nutrition focus was conducted in 2019 and reported a 5-fold increase in product numbers in this category in the past four years (Curtin & Grafenauer, 2019). A publication by Food Frontier (2019) identified 100 plant-based meat substitute products from 25 brands in Australian supermarkets. Further products have been introduced since the publication of that report. A report by CSIRO Futures provided an economic valuation for alternative protein (plant proteins, insect-based proteins and meat products produced in-vitro) to be worth about 4.5 billion dollars by 2030 (CSIRO, 2019).

These products are sold as ready to eat (RTE) food or as components of ready to reheat and eat meals or sold to be cooked by consumers. Most of them are sold refrigerated or frozen, with some canned products also available. These foods are sold in a range of forms, including:

- Mince,
- Patties (such as burgers or rissoles),
- Pieces (such as nuggets, schnitzels), or
- Sausages.

These foods are moist protein foods and the hazard of microbial growth would be expected to be the same as in traditional meat products although the initial contamination levels and the range of organisms present may be different from those found in traditional animal protein foods. Some of the products are made by extrusion and undergo a heat process reported to be in the range of 130 to 170°C, so they would be fully cooked. Extrusion cooking is a high temperature short time (HTST) thermal process that cooks, dries and restructures product in one integrated operation. The process lowers microbial contamination and inactivates enzymes, but spore forming organisms may be of interest in these products (Choton et al., 2020; Deora & Dwivedi, 2018; Leutgeb, 2015).

A review of literature and regulatory web pages indicated that there have been no local or international reports of outbreaks of foodborne illnesses attributed to these food products. A European Food Safety Authority (EFSA) Opinion paper on the risk posed by pathogens in foods of non-animal origin, published in two parts in 2013 and 2014 did not include this category of foods (EFSA, 2013; EFSA 2014).

Recall and withdrawal records in United States and Europe show occasional recalls and withdrawals for meat substitutes or other vegan foods, due to undeclared allergens and errors with date labelling, but these types of foods have not, to date been represented in Australian food recalls and withdrawals.

[1] The Australian Government Department of Health defined plant-based alternative as a product derived from plants (including nuts, seeds, legumes, algae, fungi), which can be used as a substitute to dairy or meat products. Often designed to mimic the taste, look, texture and smell of an animal or dairy product.

Aim

This survey aimed to:

- Identify plant-based alternative product manufacturers in NSW,
- Assess the safety of these products by analysing the microbiological organisms of concern, and
- Assess the labelling compliance against the Food Standards Code requirements.

Materials and Methods

The survey was conducted from February to July 2020.

Product testing

In total, 85 samples were tested. Products tested included mince, patties, pieces, sausages and slices. Products were all pre-packaged and purchased from supermarkets and green grocers in Sydney as well as through online stores. The labels of these products were photographed.

All refrigerated products were stored according to the manufacturer's instruction and tested at the end of their shelf life. However, to complete the project within the timeframe, a number of frozen products were tested at the end of June 2020 even though their best before dates were not until 2021.

All samples were tested for a range of microorganisms, pH and water activity (Table 1).

Sample information and its corresponding testing results were recorded in an Excel spreadsheet specifically developed for this project.

Table 1. Tests and method

Tests	Method Reference	Limit of Reporting
Standard Plate Count	AS 5013.5:2016	<10 cfu/g
Salmonella – presence/absence	Vidas (NF VALIDATION (BIO 12/10-09/02)); AOAC 996.08	p/a per 25g
Escherichia coli – enumeration	ISO 16649-2: 2001 (E)	<10 cfu/g
Coagulase positive staphylococcus – enumeration	AS 5013.12.1:2004	<100 cfu/g
Listeria monocytogenes – presence/absence	VIDAS; AOAC 2004.06	p/a per 25g
Bacillus cereus – enumeration	AS 5013.2:2007	<100 cfu/g
Clostridium perfringens – enumeration	AS 5013.16:2004	<10 cfu/g
Yeasts & Moulds – enumeration	AS1766.2.2:1997	<100 cfu/g
pH	AOAC 981.12 3.2; 970.21	0.1 pH unit
Water Activity	Aqua Lab Manual	0.01 Aw

Results analysis

For the purpose of this survey, the microbiological results for RTE products and products requiring heating were assessed against the NSW Food Authority's '*Microbiological quality guide for ready-to-eat foods*' (Table 2). There is no guideline for the products requiring cooking ('raw' products).

Table 2. Guideline levels for determining the microbiological quality of ready-to-eat foods (NSW Food Authority, 2009)

Test	Microbiological result (CFU/g)			
	Good	Acceptable	Unsatisfactory	Potentially hazardous
Standard Plate Count[2]				
Category B	$<10^6$	$<10^7$	$\geq 10^7$	N/A
Indicators				
E. coli	<3	3 to $<10^2$	$\geq 10^2$	N/A
Pathogens				
B. cereus	$<10^2$	10^2 to $<10^3$	10^3 to $<10^4$	$\geq 10^4$
C. perfringens	$<10^2$	10^2 to $<10^3$	10^3 to $<10^4$	$\geq 10^4$
Coagulase positive staphylococci (CPS)	$<10^2$	10^2 to $<10^3$	10^3 to $<10^4$	$\geq 10^4$
Listeria monocytogenes – Food Group 1[3]	Not detected in 25g	-	-	Detected in 25g
Salmonella	Not detected in 25g	-	-	Detected in 25g

In addition, the sample label was assessed against Standard 1.2 – Labelling and other information requirements.

[2] Standard Plate Count Category B – applies to RTE foods that are fully cooked with further handling or processing before consumption

[3] *L. monocytogenes* Food Group 1 applies to RTE food that will support the growth of *L. monocytogenes* and has been stored prepared for greater than one day

Results

Type of products

Types of plant-based alternative products included in the survey can be found in Table 3.

Table 3. Types of plant-based alternative products

Type of products	Number of products tested
Mince	5
Patties (e.g. burger or rissoles)	32
Pieces (e.g. nuggets, strips, schnitzels)	24
Sausages	15
Slices (RTE thinly sliced plant-based food e.g. 'ham', 'turkey')	9
Total	**85**

Storage conditions and shelf life

About three quarters (73%) of the products surveyed required refrigeration storage and the rest must be kept frozen. The number of products and their storage conditions for each product type are shown in Table 4.

Table 4. Number of products and their storage condition

Type of products	Storage conditions	
	Refrigerated	Frozen
Mince	5	-
Patties	25	7
Pieces	12	12
Sausages	12	3
Slices	8	1
Total	**62**	**23**

At sampling, the use-by-date or best-before date was recorded. For refrigerated products, 60 of 62 products had either use-by date or best before date on their labels and about a fifth of products had more than ten weeks remaining shelf life, with the longest being 37 weeks (Figure 1). For frozen products, all had more than seven weeks remaining shelf life with the longest being 85 weeks (Figure 2).

Figure 1. Remaining shelf life for refrigerated products surveyed

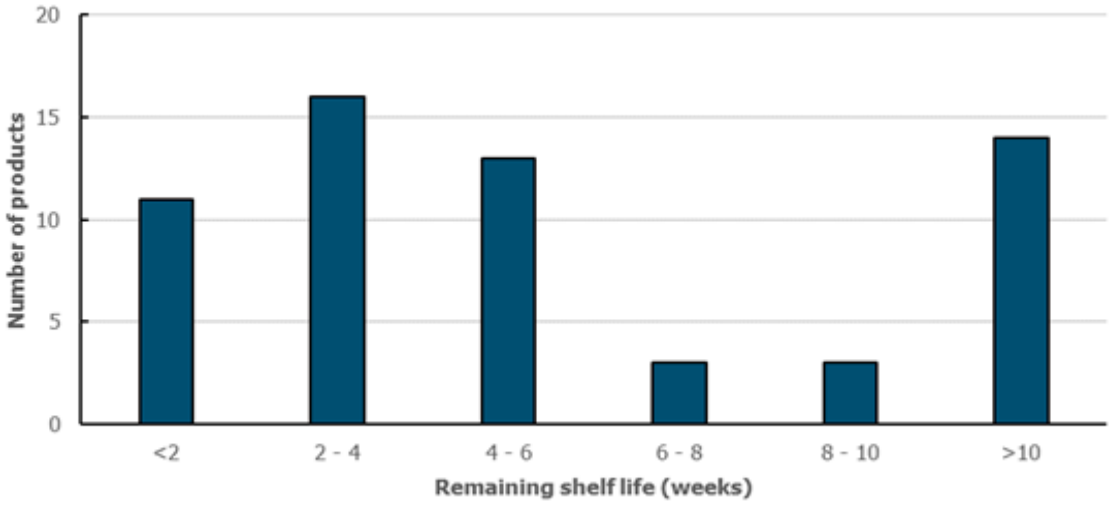
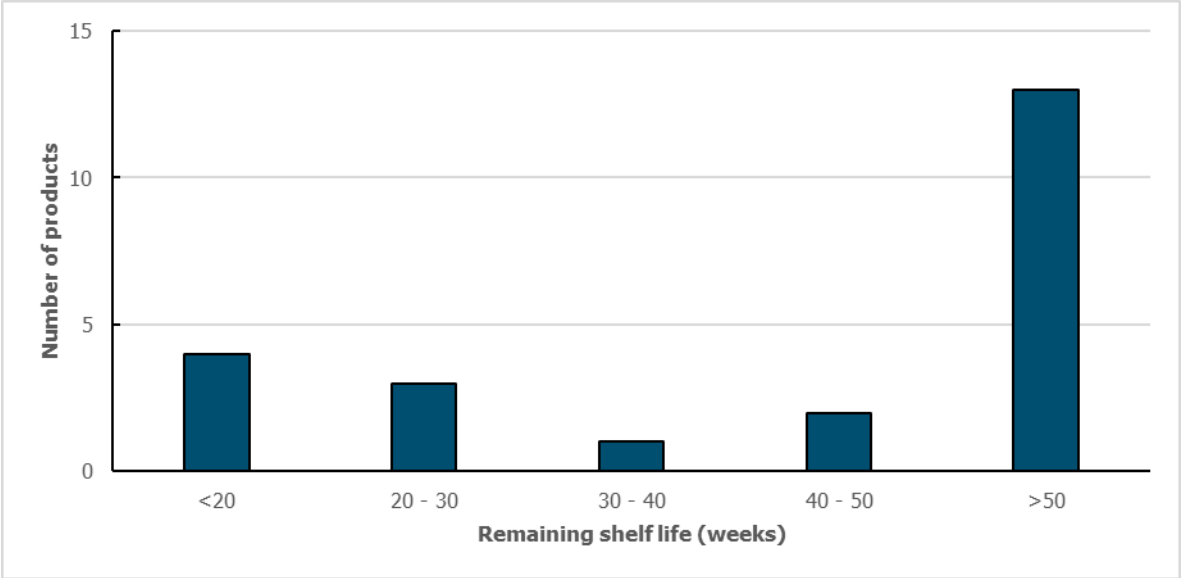


Figure 2. Remaining shelf life for frozen products surveyed



Country of Origin

Approximately 40% of products surveyed were made in Australia, with fourteen of them manufactured in NSW by six manufacturers (Table 5).

Table 5. Country of origins for products surveyed

Country of Origin	Number of samples
Australia	
– NSW	14
– Queensland	1
– Victoria	20
– Western Australia	1
Canada	1
Czech Republic	1
Denmark	3
Germany	3
Italy	1
Malaysia	3
New Zealand	3
South Africa	2
Switzerland	2
Taiwan	6
The Netherland	2
United Kingdom	15
United States of America	6
Unknown	1

Microbiological results

Ready-to-eat and products requiring heating

A total of 27 products were ready-to-eat or only required heating before consumption. The NSW Food Authority's *Microbiological quality guide for ready-to-eat foods* was used to analyse the microbiological testing results for these products. These products fall into category B for Standard Plate Count – ready-to-eat foods that are fully cooked with further handling or processing before consumption [i.e. products are categorised as good when SPC is less than 10^6 cfu/g, acceptable when less than 10^7 cfu/g and unsatisfactory when greater than 10^7 cfu/g].

The results are shown in Table 6. Twenty of the products (74%) were categorised as good or acceptable. For the other seven samples, the SPC level was not available (they were reported as greater than $3x10^5$ cfu/g), which means that they couldn't be categorised. However, no pathogens were detected in these products, so they were not potentially hazardous.

Table 6. Assessment of results for products using the microbiological criteria for ready-to-eat foods

Type of product		No of samples	Microbiological quality				
			Good	Acceptable	Unsatisfactory	Potentially hazardous	Can't be categorised
RTE	Sausage	1	1 (100%)	-	-	-	-
	Slices	8	5 (63%)	-	-	-	3 (37%)
Products required heating	Patties	12	8 (67%)	1 (8%)	-	-	3 (25%)
	Pieces	4	3 (75%)	-	-	-	1 (25%)
	Sausage	2	2 (100%)	-	-	-	-
Total		**27**	**19 (70%)**	**1 (4%)**	**-**	**-**	**7 (26%)**

Products requiring cooking ('raw' products)

No CPS, *Salmonella* or *Cl. perfringens* were detected in any of the 54 products that required cooking.

Six products had SPC less than 10 cfu/g. For 38 products with SPC detected, a range from 10 to 2,200,000 cfu/g was reported with an average of 93,000 cfu/g. Ten products had SPC greater than $3x10^5$ cfu/g.

E. coli was detected in one product at the level of 10 cfu/g and *Listeria* spp was also detected in this product. *B. cereus* was detected in nine other products – six products were at the level of 100 cfu/g, two products at the level of 200 cfu/g and one product at the level of 1,300 cfu/g.

Listeria species was detected in six products and two of the six isolates were *L. monocytogenes* at the level of less than 100 cfu/g. These two products were manufactured by the same manufacturer based in NSW.

Yeast was detected at the level of less than 100 cfu/g in 38 products and at the level of greater than 30,000 cfu/g in four products. For the rest of the twelve products, yeast was detected at the level of 100 to 21,000 cfu/g.

The majority of products (50/54) had mould at the level of less than 100 cfu/g. The other four products had mould at the level of 100, 200, 500 and 2,400 cfu/g

Products with no cooking instructions

A total of four products had no cooking instructions.

One of the products contained SPC at the level of greater than $3x10^5$ cfu/g and 18,000 cfu/g yeast. Another product had SPC at the level of 13,000 cfu/g.

No microorganisms were detected in the two other products.

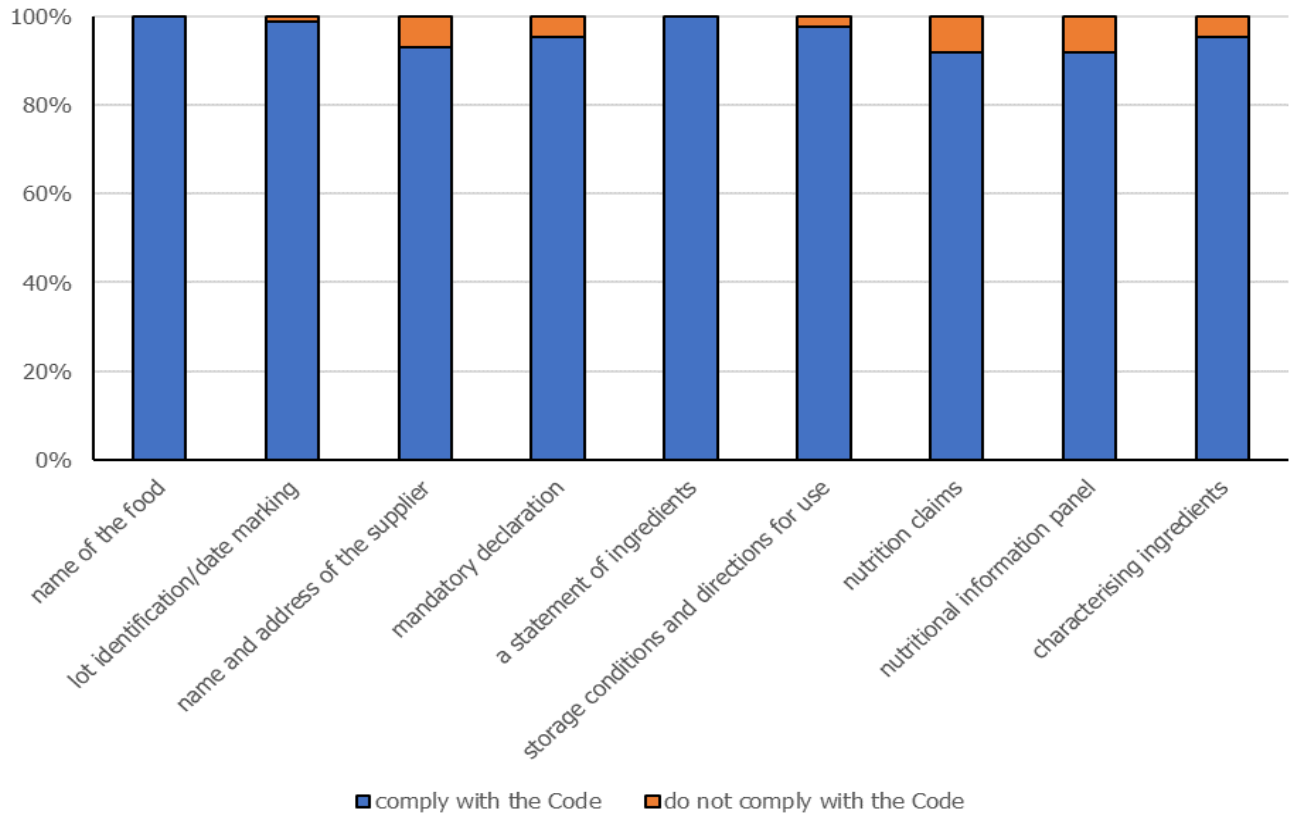
pH and water activity profile

The products' pH ranged from 4.59 to 7.21 and water activity ranged from 0.9 to 0.99. Based on the combination of pH and water activity, all of the products are categorised as potentially hazardous and require temperature control. All products were purchased either refrigerated or frozen.

Labelling

All 85 labels were analysed for the general labelling requirements as outlined in Standard 1.2 (Figure 3).

Figure 3. Labelling assessment of plant-based food surveyed



When assessed against Standard 1.2 of the Code, 63 labels were found to be compliant. For the rest of the labels (22/85), non-compliance was found in one to three areas of the Standard. No products had health claims on their labels.

The top four non-compliant issues with the labels:

1. Seven labels had unsubstantiated nutritional claims.
2. All labels had a nutrition information panel (NIP), however seven of them did not comply with the requirements in the Code. Those NIPs were in the American or European style. For imported products, it is the responsibility of the importers to ensure that all labelling components, including NIPs, comply with the Code.
3. Name and address of supplier. Six imported products did not have the name of importer and address in Australia.
4. Mandatory declaration. Four imported products did not have an allergen statement even though they contained soy or wheat.

Discussion

Almost half of the products tested were soy-based (45%) and about a quarter of them were wheat-based (24%). The rest of the products used other vegetables, pea protein, lentil, chickpeas or mycoprotein as the main ingredient. Soy protein and wheat gluten have been the most common raw materials used in meat substitute products for a long time because of their low price, high nutritional quality, versatility, and abundant production throughout the world. In addition, soy protein was also reported to have a Protein Digestibility Corrected Amino Acid Score (PDCAAS), a true faecal digestibility of protein, equivalent to animal protein (Hoffman & Falvo, 2004; Joshi & Kumar, 2015; Wild et al., 2014).

Information on the microflora of plant-based alternative products is not widely available in the scientific literature. A number of reports are available but mainly focusing on the nutritional aspects or consumers' acceptance (Curtain & Grafenauer, 2019; Froggatt & Wellesley, 2019; Hoffman & Falvo, 2004; Joshi & Kumar, 2015; Kyriakopoulou et al, 2019; Wild et al., 2014). Therefore, this project was carried out to gather information on the microbiological safety of these products and their labelling compliance with the Food Standards Code.

Testing results show that there was no microbiological safety concern with the plant-based alternative products included in this survey. For the ready-to-eat (RTE) products and products requiring heating, about three quarters of them were categorised as good or acceptable. *B. cereus* was detected at the level of 100 cfu/g in one product, which led to it being categorised as acceptable. Seven of the samples could not be categorised because the Standard Plate Count (SPC) was not quantified, but no pathogenic microorganisms were detected. A high SPC did not mean that the food was considered unsafe because SPC represents all microorganisms present in a food including yeasts, moulds and other spoilage organisms which are not harmful to humans (FSAI, 2016; McLean, Dunn & Palombo, 2010; NSW Food Authority, 2009).

The microbial load of the raw materials plays an important role in the safety of these products. Filho et al. (2005) conducted a study that involved testing of 288 lots of canned meat analogue product over a period of two years. The study found that it was important to have a raw material with low microbial load and control at all processing stages. The use of soy protein and the hydration process required during processing caused a considerable increase in the microbial load. Thus, an adequate cooking process was needed to ensure safety of the RTE product.

Currently, production processes for most of the plant-based alternative products include a heating step, for example during extrusion or frying. During an extrusion process, the temperature and pressure conditions (e.g. 130 - 180°C, 20 - 50 bar for seconds to minutes) inactivates vegetative microbial cells as well as bacterial endospores to a very high extent. This may contribute to the high microbiological quality of the products tested in this project. However, if the products were contaminated after heat processing, harmful microorganisms could grow especially since these products contain high level of nutrients, with a neutral pH, high water activity and moderate salt level. Post-processing treatments such sterilisation, pasteurisation or freezing should be considered, on top of strict hygienic practices. In addition, some studies also reported risks with resistant spores of *Bacillus* and *Clostridium* spp in plant ingredients that may survive the extrusion process, and can be reactivated in the post-process treatment (Filho et al., 2005; Leutgeb, 2015; Mwangi, 2008; Wild et al., 2014).

Bacillus cereus and *Listeria* were detected in fourteen 'raw' products (products required to be cooked before consumption). Since *B. cereus* is found in soil, raw plant foods are a common source of *B. cereus*. *Listeria* spp is commonly found in the environment and because it is tolerant to low temperature, can grow in food even if it is stored under refrigeration. Cooking at recommended temperatures will kill vegetative cells of *B. cereus* and *L. monocytogenes*. Heat resistant spores of *B. cereus* are more likely to survive cooking processes and start growing again if the food is cooled gradually over an extended period of time. Therefore, it is important for consumers to follow the manufacturer's cooking instructions and reduce the time between cooking and eating.

Approximately three quarters of the products had compliant labels according to the Code. The common non-compliances observed were the use of unsubstantiated nutritional claims and nutritional information panel not complying with the Standard. Issues with the use of the animal product descriptors such as 'plant-based roast pork', 'smoked turkey style' slice or 'chick'n schnitzel' and the position of these products at retail shelves (next to the meat products) were raised as concerns. The use of animal product related descriptors does not make labelling or advertising misleading, however, it may be confusing to the consumers (Australian Government Department of Health, 2019). Froggatt & Wellesley (2019) also found that decisions on labelling requirements for meat analogues in Europe will be particularly important in determining consumer acceptance of these products.

Follow-up actions

Follow-up work on the labelling assessment was conducted in November 2020. Of 22 products with non-compliant labels, 16 were able to be purchased, photographed and analysed against the labelling requirements in the Code. The other six products were not available in the market any more.

One product had changed their labels and the new label complied with the requirements in the Code. A further three products had very minor issues i.e. NIP was missing the word ‘average’ only, so no follow-up action was required.

For 12 products, the label remained non-compliant. For NSW businesses, an advisory letter was sent asking the manufacturer or importer to rectify the issue. For businesses based in other jurisdictions, the issue was referred to their regulatory bodies.

Conclusion

Product testing revealed no major safety issue with plant-based alternative products available in the NSW market. Four of the most important control measures for ensuring the safe production of these products involve:

- Using high quality raw ingredients with low microbial load,
- Effective heat treatment,
- Strict hygiene and sanitation regime to prevent post-processing contamination, and
- For the ‘raw’ products, appropriate cooking instructions to kill any pathogenic organisms.

References

Admassu, S. Fox, T., Health, R. & McRobert, K. (2020). *The changing landscape of protein production. Opportunities and challenges for Australian agriculture*. Retrieved on 7 September 2020 from https://www.agrifutures.com.au/wp-content/uploads/2020/02/20-001.pdf

Australian Government Department of Health. (2019). Misleading descriptions for food. Options Paper. Retrieved 24 September 2020 from https://www.health.gov.au/sites/default/files/documents/2020/04/foi-request-1456-food-labelling-misleading-descriptions-for-food-options-paper.pdf

Choton, S., Gupta, N., Bandral, J.D., Anjum, N. & Choudary, A. (2020). Extrusion technology and its application in food processing: A review. *The Pharma Innovation Journal, 9*(2), 162 – 168. https://doi.org/10.22271/tpi.2020.v9.i2d.4367

Commonwealth Scientific and Industrial Research Organisation (CSIRO). (2019). Growth opportunities for Australian food and agribusiness. Retrieved on 7 September 2020 from https://www.csiro.au/en/Do-business/Futures/Reports/Ag-and-Food/Opportunities-for-Food-and-Agribusiness

Curtain, F. & Grafenauer, S. (2019). Plant-based meat substitutes in the flexitarian age: an audit of products in supermarket shelves. *Nutrients, 11*, 2603.

Deora, N.S. & Dwivedi, M. (2019). Structuring meat analogues using extrusion: an insight. *EC Gastroenterology and Digestive System 6*(1): 29 – 31.

Filho, G.C.S., Vessoni Penna, T.C., & Schaffner, D.W. (2005). Microbiological quality of vegetable proteins during the preparation of a meat analog. *Italian Journal of Food Science, 3*(17), 269 – 283.

Food Frontier. (2019). *Meat the alternative. Australia's $3 billion opportunity*. Retrieved on 7 September 2020 from https://www.foodfrontier.org/wp-content/uploads/2019/09/Meat-the-Alternative-Food-Frontier.pdf

Food Safety Authority of Ireland (FSAI). (2016). *Guidelines for the interpretation of results of microbiological testing of ready-to-eat foods placed on the market* (revision 2). Retrieved 9 September 2020 from https://www.fsai.ie/food_businesses/micro_criteria/guideline_micro_criteria.html

Froggatt, A. & Wellesley, L. (2019). Meat analogues. Consideration for the EU. Retrieved 9 September 2020 from https://www.chathamhouse.org/sites/default/files/2019-02-18MeatAnalogues3.pdf

Hoffman, J.R. & Falvo, M.J. (2004). Review article: Protein – which is best? *Journal of Sports Science and Medicine, 3*, 118 – 130.

Joshi, V.K. & Kumar, S. (2015). Meat analogues: plant-based alternatives to meat. A review. *International Journal of Food Fermentation Technology, 5*(2), 107 – 119.

Kyriakopoulou, K., Dekkers, B., van der Goot, A.J. (2019). Plant based meat analogues. In C.M Galanakis (Eds). Sustainable Meat Production and Processing (Chapter 6, pp. 103 – 126). Academic Press. https://doi.org/10.1016/C2017-0-02230-9

Leutgeb, K. (2015). *Microbial examination of raw and extruded products for the production of a vegetarian meat analogue* (Master Thesis, University of Natural Resources and Life Sciences, Vienna) Retrieved 22 September 2020 from https://epub.boku.ac.at/obvbokhs/download/pdf/1935843?originalFilename=true

McLean, S.K., Dunn, L.A. & Palombo, E.A. (2010). A pilot study of the microbiological quality of culturally diverse, ready-to-eat foods from selected retail establishments in Melbourne, Australia. *Foodborne Pathogens and Disease, 7*(5), 585 – 588.

Mwangi, R. (2008). *Inactivation of wild-type Bacillus spores in a soy meat analog model by extrusion cooking* (Master Thesis, University of Missouri). Retrieved 22 September 2020 from https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/5763/research.pdf?sequence=3&isAllowed=y

NSW Food Authority. (2009). *Microbiological quality guide for ready-to-eat foods*. Retrieved 7 September 2020 from https://www.foodauthority.nsw.gov.au/sites/default/files/_Documents/scienceandtechnical/microbiological_quality_guide_for_RTE_food.pdf

Wild, F., Czerny, M., Janssen, A.M., Kole, A.P.W., Zunabovic, M. & Domig, K.J. (2014). The evolution of a plant-based alternative to meat. *Agro Food Industry Hi Tech, 25*(1), 45 – 49.

World Economic Forum. (2019). *White Paper – Meat: the future series, Alternative Proteins*. Retrieved 7 September 2020 from http://www3.weforum.org/docs/WEF_White_Paper_Alternative_Proteins.pdf

6 Avenue of the Americas, Newington NSW 2127
PO Box 6682, Silverwater NSW 1811
T 1300 552 406
E food.contact@dpi.nsw.gov.au