Vitenskapskomiteen for mat og miljø
Norwegian Scientific Committee for Food and Environment

VKM Report 2023: 25

Mapping of nutrients, food additives and contaminants in plant-based and gluten-free food products and their meat-, dairy- and gluten-containing counterparts

Tove Gulbrandsen Devold, Monica Andreassen, Monica Hauger Carlsen, Eva Denison, Gro Haarklou Mathisen, Josef Daniel Rasinger, Camilla Svendsen, Ellen Bruzell, Berit Granum, Trine Husøy

Report of the Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food, and Cosmetics of the Norwegian Scientific Committee for Food and Environment

Data on nutrients, food additives, natural toxins, environmental and process-induced contaminants in a selection of plant-based and gluten-free food products and their meat and dairy and gluten-containing counterpart products have been mapped. The level of the different substances has been compared.

VKM Report 2023: 25
Mapping of nutrients, food additives and contaminants in plant-based and gluten-free food products and their meat, dairy and gluten-containing counterparts

Scientific Report of the Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food, and Cosmetics of the Norwegian Scientific Committee for Food and Environment
29.11.2023

ISBN: 978-82-8259-436-3
ISSN: 2535-4019
Norwegian Scientific Committee for Food and Environment (VKM)
Postboks 222 Skøyen
0213 Oslo
Norway

Phone: +47 21 62 28 00
Email: vkm@vkm.no

vkm.no

Cover photo: Colourbox

Suggested citation: VKM, Tove Gulbrandsen Devold, Monica Andreassen, Monica Hauger Carlsen, Eva Denison, Gro Haarklou Mathisen, Josef Daniel Rasinger, Camilla Svendsen, Ellen Bruzell, Berit Granum, Trine Husøy (2023). Mapping of nutrients, food additives and contaminants in plant-based and gluten-free food products and their meat-, dairy- and gluten-containing counterparts. The Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food, and Cosmetics of the Norwegian Scientific Committee for Food and Environment. VKM Report 2023:25, ISBN: 978-82-8259-436-3, ISSN: 2535-4019. Norwegian Scientific Committee for Food and Environment (VKM), Oslo, Norway.

Mapping of nutrients, food additives and contaminants in plant-based and gluten-free food products and their meat-, dairy- and gluten-containing counterparts

Preparation of the report

The Norwegian Scientific Committee for Food and Environment (Vitenskapskomiteen for mat og miljø, VKM) appointed a project group to draft the report. The project group consisted of VKM members and VKM staff. The Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food, and Cosmetics assessed and approved the final report.

Authors of the report

The authors have contributed to the report in a way that fulfils the authorship principles of VKM (VKM, 2019). The principles reflect the collaborative nature of the work, and the authors have contributed as members of the project group and/or the VKM Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food and Cosmetics.

Members of the project group (in alphabetical order after chair of the project group):

Tove Gulbrandsen Devold – Chair of the project group and member of the Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food, and Cosmetics.

Monica Andreassen – Member of the Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food, and Cosmetics.

Monica Hauger Carlsen – Member of the Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food, and Cosmetics.

Eva Denison – Member of the Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food, and Cosmetics.

Gro Haarklou Mathisen – Project leader, the VKM secretariat.

Josef Daniel Rasinger – Member of the Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food, and Cosmetics (until October 31 2023).

Camilla Svendsen – Member of the Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food and Cosmetics.

Members of the VKM Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food and Cosmetics that contributed to the assessment and approval of the report (in alphabetical order before chair of the Panel)**:**

Monica Andreassen. Affiliation: 1) VKM; 2) Norwegian Institute of Public Health.

Ellen Bruzell. Affiliation: 1) VKM; 2) Nordic Institute of Dental Materials.

Monica Hauger Carlsen. Affiliation: 1) VKM; 2) University of Oslo.

Eva Denison. Affiliation: 1) VKM; 2) Retired, former Norwegian Institute of Public Health.

Tove Gulbrandsen Devold. Affiliation: 1) VKM; 2) Norwegian University of Life Sciences.

Berit Granum. Affiliation: 1) VKM; 2) Norwegian Institute of Public Health.

Josef Daniel Rasinger (until October 31, 2023). Affiliation: 1) VKM; 2) Institute of Marine Research.

Camilla Svendsen. Affiliation: 1) VKM; 2) Norwegian Institute of Public Health.

Trine Husøy. Chair of the Panel. Affiliation: 1) VKM; 2) Norwegian Institute of Public Health.

Acknowledgement

VKM would like to thank Sagnik Sengupta (Norwegian Scientific Committee for Food and Environment) for data processing, visualisation, interpretation and sharing for the chapter on food additives, including preparation of the UpSet plots and tables showing data, and setting up of the GitHub page linked to this report.

VKM would like to thank the referees Marie Paulsson (Lund University, Sweden) and Laurence Castle (retired, former UK Scientific Civil Service) for their valuable comments through critical review of the draft report. VKM emphasises that the referees are not responsible for the content of the final report. In accordance with VKM's routines for approval of a risk assessment (VKM, 2018), VKM received their comments before evaluation and approval by VKM Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food, and Cosmetics, and before the report was finalised for publication.

Competence of VKM experts

Persons working for VKM, either as appointed members of the Committee or as external experts, do this by virtue of their scientific expertise, not as representatives

for their employers or third-party interests. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

Table of Contents

Summary

In recent years, plant-based meat and dairy analogue products, plant-based snacks alternatives to potato chips and nuts, and various types of "free-from" products including gluten-free products, have appeared on the food market. The content of nutrients, food additives and contaminants in these products differs from their animal-derived, potato-based, and gluten-containing counterparts. This is primarily due to differences in the nutritional and contaminant content of the raw materials used, different needs for food additives in the products, and the use of different production methods.

In this report, the Norwegian Scientific Committee for Food and Environment (VKM) has mapped and compared data on the content of nutrients, food additives, natural toxins, environmental and process-induced contaminants, as well as processing methods in a selection of products (Figure 1). In addition, processing methods used in the production of the selected products have been mapped and compared. This mapping report should not be used to conclude on the nutritional quality or safety of different diets but is intended to be a starting point for identifying important factors considered to be important for safe and healthy food when food products and dietary patterns change.

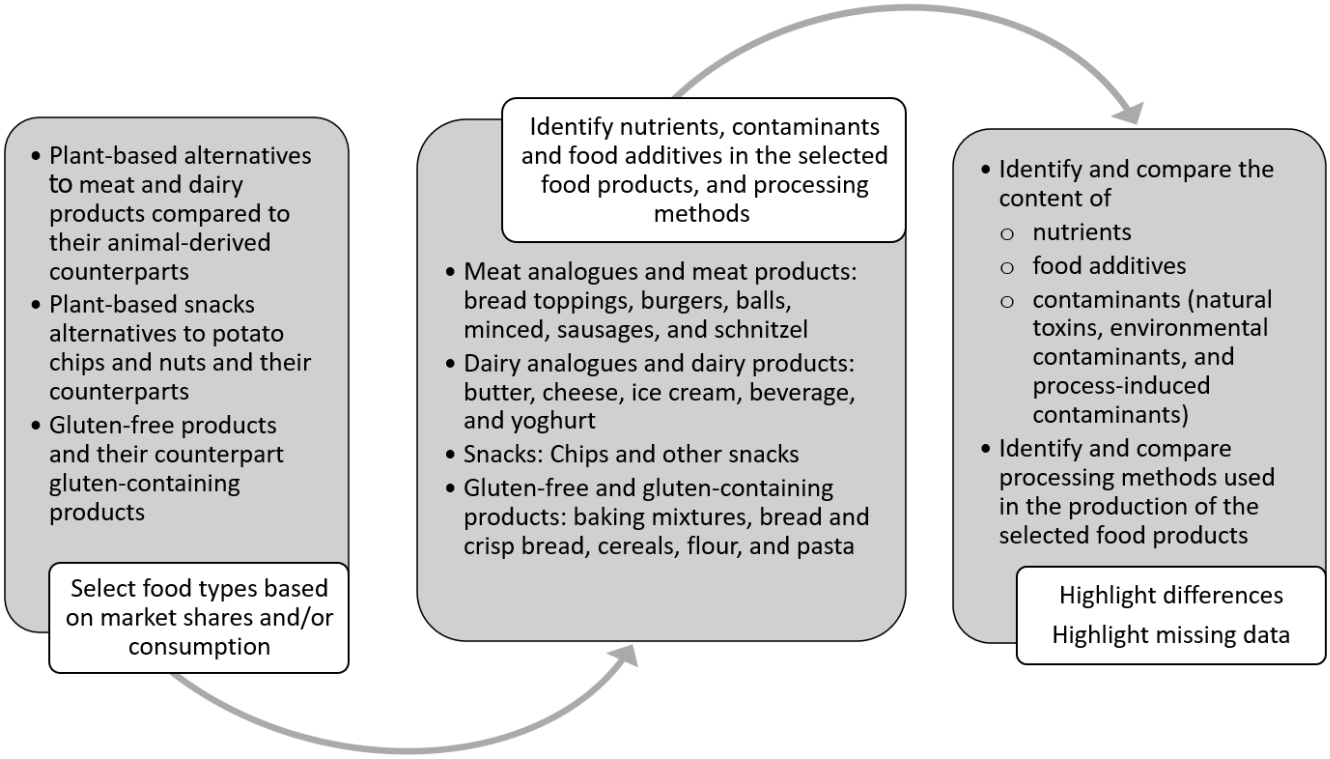


Figure 1. Overview of the workflow. Butter, cheese, ice cream and yoghurt are dairy products, whereas the plant-based analogues are imitations of these.

Food products were selected based on sales and intake data. Using this approach, VKM aimed to avoid inclusion of products that were only transiently available on the market.

Nutrients

Nutrient content information was retrieved from the food composition table of the Norwegian Food Safety Authority (Matvaretabellen.no) and the in-house research food composition database and calculation system of the University of Oslo. For some of the food groups, particularly plant-based yoghurt and ice cream analogues and new plant-based snack alternatives, data on micronutrient content were scarce. Comparisons of the nutrient content were made for all selected food product types. Some main differences were identified:

- The non-fortified plant-based beverages had lower levels of most of the micronutrients for which milk is an important source. The fortified plant-beverages had, to varying degrees, the same or lower levels of micronutrients than milk.
- The plant-based cheese analogues contained carbohydrates in the form of starch, had almost no protein and lower levels of micronutrients compared to the cheese counterparts.
- In general, the meat dinner products and the plant-based dinner analogue products contained approximately the same average levels of protein, with some variation in the plant-based analogue product group. Also, animal protein contains high enough concentrations of all the essential amino acids for the products to be good dietary sources of protein. The plant-based products have in general more varying amino acid profiles, with lower levels of some essential amino acids, depending on the raw material.
- Regarding fat, the animal-based products are sources of saturated fat, while some of the plant-based products are sources of unsaturated fatty acids.
- The animal-based products are sources of vitamin A, of which the plant-based meat analogues have less, while the plant-based products may contain varying levels of vitamin E and minerals, based on the main ingredients.
- The level of calcium was slightly higher in the plant-based meat analogue products compared to the meat products.
- The gluten-free cereal products had a lower protein content than the gluten-containing cereal products.
- The plant-based snacks alternatives contained a lower level of fat and a higher level of protein compared to the potato chips and nuts.

Contaminants

The selected food products were identified to be an important source of 28 contaminants. Comparisons of the contaminant level in food products were based on i) knowledge on which food items are known or expected to be an important source of specific contaminants, and ii) directly comparable food product types and concentration data. Content information for these contaminants was retrieved from risk assessments and other scientific publications (including from EFSA and the Norwegian Food Safety Authority).

The identified differences based on which food items that are known or expected to be an important source of specific contaminants were:

- Plant-based meat and dairy analogue products are known or expected to be a source of inorganic arsenic, cadmium, alternariol methyl ether, patulin, solanine and chaconine, T-2 and HT-2 toxin, zearalenone and acrylamide.
- Food products of animal origin are known or expected to be a source of dioxins and dioxin-like PCBs and heterocyclic aromatic amines.
- Gluten-free food products containing ingredients from potato are known or expected to be a source of solanine and chaconine.

Only directly comparable concentration data were used for the comparison of contaminant content. A single comparison could be made between plant-based meat analogues and their counterpart meat products. No comparisons between plant-based dairy analogues and dairy products and between plant-based snacks alternatives and potato-based snack products could be made. For gluten-free and gluten-containing products, four environmental contaminants were compared.

The identified differences based on comparable concentration levels are:

- Plant-based meat analogue products (dinner) had a slightly higher level of cadmium compared to their counterpart meat products.
- Gluten-free products had a higher level of lead and aluminium compared to gluten-containing products, and similar or lower level of cadmium.

Food additives

No concentration data were identified for the food additives; therefore, comparisons were made for type and sum of food additives included in the ingredient lists of the food products. Some differences were:

- A higher number of emulsifiers, stabilisers, and thickeners (ESTs) were used in the plant-based meat analogue products (dinner and bread toppings) than in the counterpart meat products.
- A lower number of antioxidants were used in the plant-based meat analogue products (dinner and bread toppings) than in the counterpart meat products.
- A higher number of food colours were used in the plant-based meat analogue products (dinner and bread toppings) than in the counterpart meat products.
- A higher number of antioxidants and food additives in the category "other food additives" were used in the plant-based dairy analogue products than in the counterpart dairy products.
- A lower number of food colours and sweeteners were used in the plant-based dairy analogue products than in the counterpart dairy products.
- A higher number of sweeteners, anti-caking agents and acidity regulators, as well as emulsifiers, stabilisers, and thickeners were used in the gluten-free products than in the counterpart gluten-containing products.
- A lower number of antioxidants were used in the gluten-free products than in the counterpart gluten-containing products.
- A lower number of flavour enhancers were used in the plant-based snacks alternatives than in the counterpart potato chips products.

The most frequently used additive category was ESTs. It is important to note that the number of additives accepted for use in the different additive categories varies and therefore might affect the total number of food additives used within each category.

Note that additional work is required to identify and make conclusions about differences between the level of additives in the selected products.

Processing methods

VKM has focused on methods that have the most pronounced impact on the raw materials and have described various forms of heat treatment, homogenisation, and fermentation. Descriptions of these methods are based on information gathered from textbooks on food processing and technology and scientific publications (see e.g. Fellows, 2022).

Some main differences identified were:

- To obtain the starting material for the plant-based beverages and ice cream, the raw material is treated with enzymes to hydrolyse starch and sometimes other components.
- All plant-based beverages on the Norwegian market are ultra-high temperature treated to inactivate enzymes and to prolong storage. Ultra-high temperature treatment is a more severe type of heat treatment (i.e. higher temperature and/or longer treatment time) than those most frequently used for milk products such as whole milk, low fat, and skimmed milk on the Norwegian market.

Among various products, plant-based cheese analogues were distinctly different from both rennet and cream cheeses. Typically, subjecting products to higher temperatures and prolonged heating may increase the potential for formation of processing-induced contaminants. Beyond temperature, factors such as product composition, typically the presence of reducing sugars, specific amino acids within proteins, and moisture content, significantly influence the generation of these compounds.

The general information provided about the processing methods in this report does not allow for a definitive conclusion whether certain products would contain a higher content of processing-induced contaminants compared to their counterparts.

Overall results

An overview of the comparisons of the content of nutrients and contaminants, as well as the processing methods is given in Table 1. An overview of the comparison of the number of food additives used is presented in Figure 1.

Table 1. Comparisons of content of nutrients and contaminants and comparison of the processing methods in analogue and gluten-free products versus meat-, dairy- and gluten-containing counterparts. *Natural toxins, environmental and process-induced contaminants identified in plant-based food products (VKM, 2022), concentration data for comparison were only available for cadmium in plant-based dinner products and their counterpart meat products. **Comparison including nuts were only performed for the nutrients. ***Contaminants in snack products were not included in this mapping report. ****Processing methods for snack products and bread toppings were not included in this mapping report. UHT: Ultra-high temperature.

Product categories (number of products)	Macronutrients	Micronutrients	Natural toxins*	Environmental contaminants*	Process-induced contaminants	Processing methods
Plant-based dairy analogues (65) compared to dairy products (97)	↑Carbohydrates ↓Protein	Varying differences depending on raw material and fortification	↑Alternariol methyl ether ↑Patulin ↑Solanine and chaconine ↑T-2 and HT-2 toxin ↑Zearalenone	↑Inorganic arsenic ↑Cadmium ↓Dioxins and dioxin-like PCBs	↑Acrylamide ↓Heterocyclic aromatic amines	Varying differences depending on product category. Plant-based beverages: milling and enzyme hydrolysis, UHT treatment. "Yoghurt": milling and enzyme hydrolysis. "Cheese":
Plant-based meat analogues (37) compared to meat products (53): dinner products	↑Carbohydrates ↑Fibre ↓Protein	↑Calcium ↑Folate ↓Vitamin A ↓Vitamin B12 ↑Vitamin E	↑Alternariol methyl ether ↑Patulin ↑Solanine and chaconine ↑T-2 and HT-2 toxin ↑Zearalenone	↑Inorganic arsenic ↑Cadmium (confirmed through comparison of concentration data) ↓Dioxins and dioxin-like PCBs	↑Acrylamide ↓Heterocyclic aromatic amines	Varying differences depending on product category. Plant-based burgers and minced meat analogues contain textured plant protein that have been extruded.

Plant-based meat analogues (16) compared to meat products (23): bread toppings	↑Carbohydrates ↓Fat ↓Protein	Not declared for the plant-based products	↑Alternariol methyl ether ↑Patulin ↑Solanine and chaconine ↑T-2 and HT-2 toxin ↑Zearalenone	↑Inorganic arsenic ↑Cadmium ↓Dioxins and dioxin-like PCBs	↑Acrylamide ↓Heterocyclic aromatic amines	Not included****
Gluten-free (60) compared to gluten-containing (139) products	↓Protein	Varying differences depending on raw material	No differences are expected for products based on the same raw materials	↑Aluminium ↑Lead ↓ or equal cadmium	No comparisons done	Similar processing.
Plant-based snacks alternatives (25) compared to potato chips and nuts (22)**	↓Fat ↑Protein	Not declared for the plant-based products	Not included***	Not included***	Not included***	Not included****

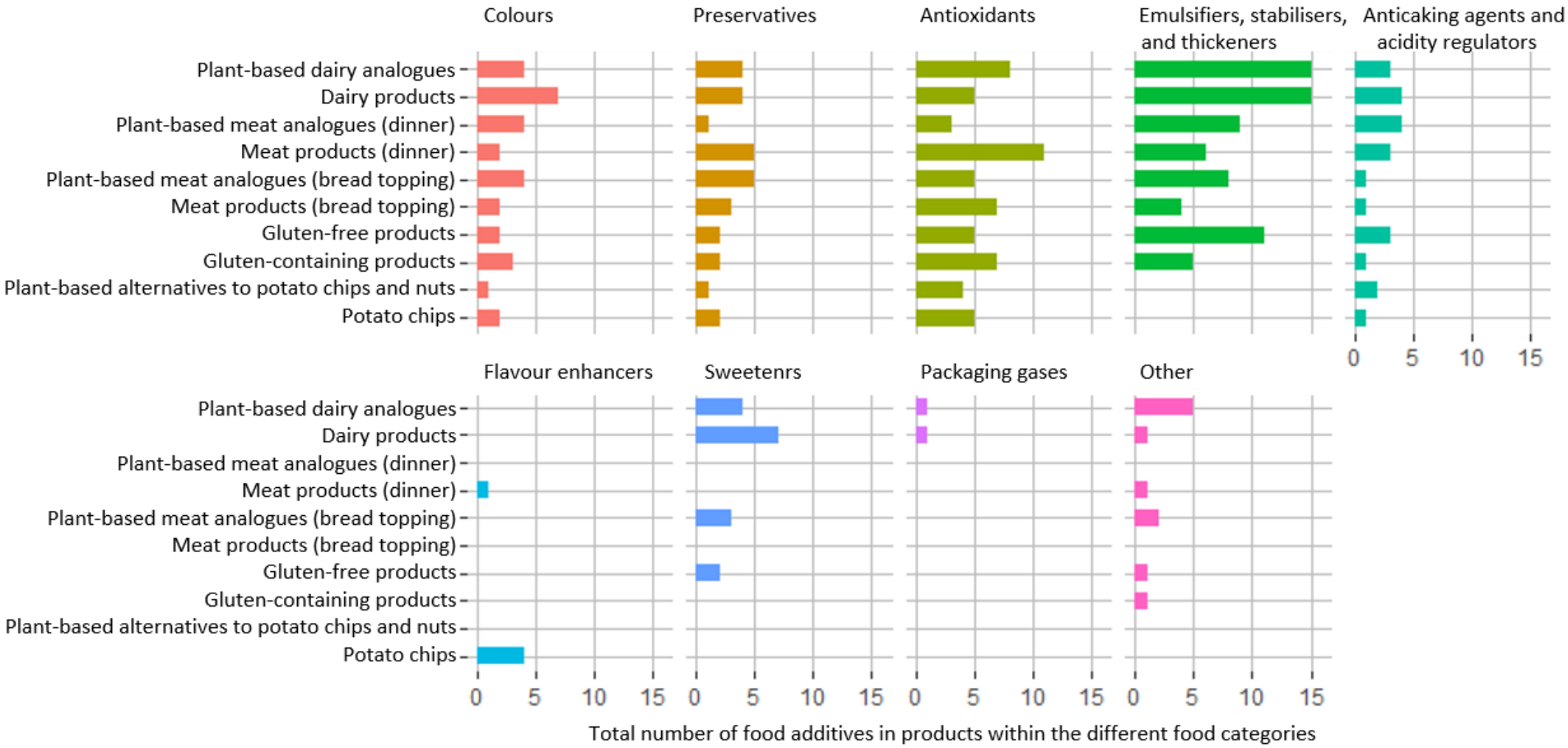


Figure 1. The total number of different food additives identified in products within the different product types for each food additive category.

Overall conclusion

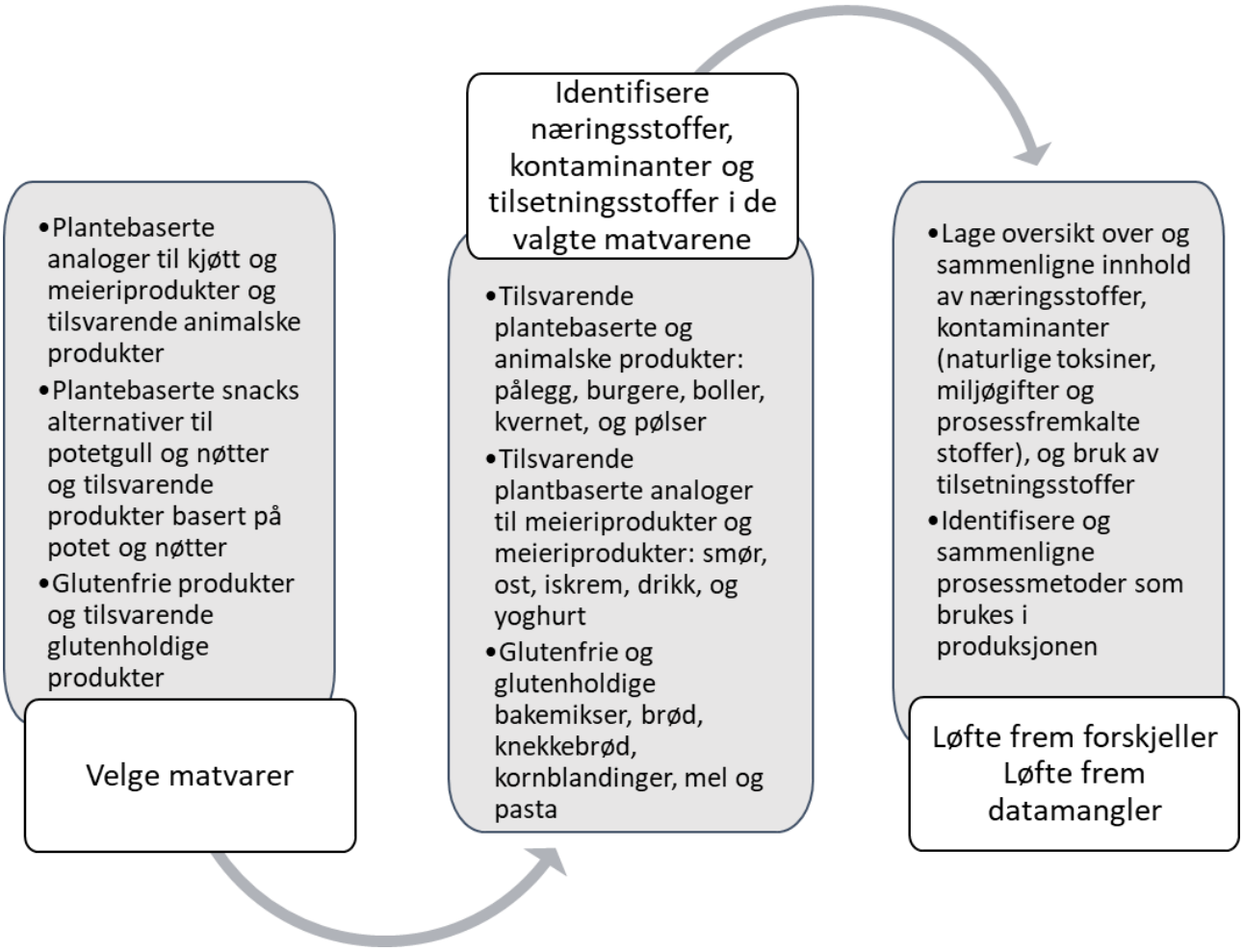
In the present report, VKM has prepared a snapshot of data on nutrients, food additives and contaminants for a selection of food products and their plant-based or gluten-free analogues. VKM identified differences in the content of nutrients, contaminants, and the use of additives in comparable product types. In general, differences in content depended on the raw materials used and any fortification of the products. Some contaminants are found in a large variety of raw materials, whereas certain contaminants are typical for certain groups of raw materials. In the data material available to VKM, concentrations of additives and information on contaminants in comparable products were missing. This report cannot be used to conclude on nutritional quality or safety of different diets. It is intended to be a starting point for identifying important factors that should be considered for safe and healthy food when food products and dietary patterns change.

Key words:
Contaminants; gluten-free; nutrients; plant-based dairy analogues; plant-based meat analogues; process-induced contaminants; Norwegian Food Safety Authority, Norwegian Scientific Committee for Food and Environment, VKM

Sammendrag på norsk

I løpet av de siste årene har en rekke plantebaserte alternativer til kjøtt- og meieriprodukter (såkalte analogprodukter), plantebaserte snacksalternativer til potetgull og nøtter, og ulike typer «fri-for»-produkter, inkludert glutenfrie produkter, kommet på markedet. Disse produktene har et annet innhold av næringsstoffer og kontaminanter, og en annen bruk av tilsetningsstoffer, sammenlignet med tilsvarende produkter av animalsk opprinnelse, tilsvarende glutenholdige produkter og tilsvarende tradisjonelle snacksprodukter. Forskjellene skyldes i hovedsak at råvarene er endret.

I denne rapporten har Vitenskapskomiteen for mat og miljø (VKM) kartlagt og sammenlignet data om innhold av næringsstoffer, bruk av tilsetningsstoffer og innhold av naturlige giftstoffer, miljøgifter og prosessfremkalte stoffer i et utvalg av produkter. I tillegg er det laget en oversikt over prosesseringsmetoder. Denne kartleggingen er ment å være et utgangspunkt for å identifisere hvilke faktorer som er viktige for å sikre trygg og sunn mat når matvarer og kostholdsmønstre endres. Rapporten kan ikke brukes til å trekke konklusjoner om ernæringsmessig kvalitet eller mattrygghet ved ulike typer kosthold. Figur 1 viser en oversikt over prosjektet.



Figur 1. Oversikt over prosjektet. De plantebaserte meierianalogene er analoger til smør, ost, iskrem, melk og yoghurt.

Matvarene ble valgt ut basert på data om kjøp og inntak for å unngå produkter som kun er på markedet i en kort periode.

Næringsstoffer

Informasjon om innhold av næringsstoffer ble hentet fra matvaretabellen til Mattilsynet og kostdatabasen til Universitetet i Oslo. For noen av matvaregruppene, spesielt plantebaserte yoghurt- og iskremanaloger og nye plantebaserte snacksalternativer, var det begrenset med data på innhold av mikronæringsstoffer. Innholdet av næringsstoffer i de inkluderte matvaretypene ble sammenlignet og følgende hovedforskjeller ble funnet:

- Det var lavere innhold av de fleste mikronæringsstoffer i plantebaserte drikker sammenlignet med melk.
- Plantebasert «ost» inneholdt karbohydrater i form av stivelse, svært lite protein og hadde lavere innhold av mikronæringsstoffer enn ost.
- Generelt inneholdt middagsproduktene av kjøtt og de plantebaserte analogproduktene omtrent samme gjennomsnittlige nivåer av protein, med noe større variasjon i produktgruppen plantebaserte analogprodukter. I tillegg har animalsk protein høyt nok innhold av alle de essensielle aminosyrene til at produktene er gode kilder til protein. De plantebaserte produktene har generelt mer varierende aminosyreprofiler, med lavere nivåer av noen essensielle aminosyrer, avhengig av råvaren. De animalske produktene er kilder til mettet fett, mens noen av de plantebaserte produktene er kilder til umettede fettsyrer.
- Mange av de animalske produktene inneholdt vitamin A. De plantebaserte kjøttanalogene hadde lavere innhold av vitamin A. Innholdet av vitamin E i de plantebaserte produktene varierte med råvarene.
- De plantebaserte analogene til kjøtt inneholdt noe mer kalsium enn tilsvarende animalske produkter.
- Glutenfrie produkter hadde lavere innhold av protein enn glutenholdige produkter.
- De plantebaserte alternativene til potetchips og nøtter hadde høyere innhold av protein og lavere innhold av fett.

Kontaminanter

De inkluderte matvaretypene er viktige kilder til totalt 28 kontaminanter. VKM har sammenlignet hvilke produkttyper som er kilder til gitte kontaminanter ut ifra i) kunnskap om hvilke matvarer som er kjent eller forventet å være en viktig kilde til spesifikke kontaminanter og ii) bruk av konsentrasjonsdata for spesifikke kontaminanter i bestemte typer av matvarer. Informasjon om mengden av de ulike kontaminantene i mat ble funnet i vitenskapelige publikasjoner og rapporter (fra blant annet EFSA og Mattilsynet).

Følgende forskjeller ble identifisert med utgangspunkt i hvilke matvarer som er kjent eller forventet å være en viktig kilde til bestemte kontaminanter:

- plantebaserte kjøtt- og meierianalogprodukter er kjent eller forventet å bidra til eksponering for uorganisk arsen, kadmium, alternariol metyleter, patulin, solanin og chakonin, T-2- and HT-2-toksin, zearalenon og akrylamid.
- matvarer av animalsk opprinnelse er kjent eller forventet å være viktige kilder til dioksiner og dioksinlignende PCB samt heterosykliske aromatiske aminer.

- glutenfrie matvarer som inneholder ingredienser fra potet er kjent eller forventet å være viktige kilder til solanin og chakonin.

For plantebaserte analoger til kjøtt og tilsvarende produkter av kjøtt ble det identifisert direkte sammenlignbare konsentrasjonsdata for innhold av miljøgiften kadmium. For glutenfrie og glutenholdige produkter ble det funnet direkte sammenlignbare data for fire miljøgifter. For resten av kontaminantene ble det ikke funnet sammenlignbare konsentrasjonsdata. Forskjellene som ble funnet var:

- plantebaserte analogprodukter til kjøtt hadde noe høyere innhold av kadmium enn de tilsvarene produktene av kjøtt.
- de glutenfrie produktene hadde høyere innhold av bly og aluminium, og likt eller lavere innhold av kadmium.

Tilsetningsstoffer

VKM fant ingen data på mengde av ulike tilsetningsstoffer som var brukt i ulike produkter. VKM valgte derfor i stedet å sammenligne antall og type tilsetningsstoffer i de ulike matvaretypene. Noen forskjeller som ble funnet var:

- Det ble brukt flere konsistensmidler i plantebaserte analoger til kjøtt (pålegg og middagsprodukter) enn i tilsvarende produkter av kjøtt.
- Det ble brukt færre antioksidanter i plantebaserte analoger til kjøtt (pålegg og middagsprodukter) enn i tilsvarende produkter av kjøtt.
- Det ble brukt flere matfargestoffer i plantebaserte analoger til kjøtt (pålegg og middagsprodukter) enn i tilsvarende produkter av kjøtt.
- Det ble brukt flere antioksidanter og tilsetningsstoffer i kategorien «andre» i plantebaserte meierianaloger enn i tilsvarende meieriprodukter.
- Det ble brukt færre matfargestoffer og søtstoffer i plantebaserte meierianaloger enn i tilsvarende meieriprodukter.
- Det ble brukt flere søtstoffer, antiklumpemidler og surhetsregulatorer samt konsistensmidler i glutenfrie produkter enn i tilsvarende glutenholdige produkter.
- Det ble brukt færre antioksidanter i glutenfrie produkter enn i tilsvarende glutenholdige produkter.
- Det ble brukt færre smakstilsetninger i plantebaserte alternativer enn i tilsvarende potetchips-produkter.

Konsistensmidler var kategorien med flest tilsetningsstoffer. Det er viktig å merke seg at antallet tilsetningsstoffer som er godkjent for bruk i de forskjellige kategoriene av tilsetningsstoffer varierer, og at dette kan påvirke det totale antallet tilsetningsstoffer som er brukt innenfor hver kategori. For å kunne sammenligne mengden av tilsetningsstoffer i ulike produkter må man ha konsentrasjonsdata.

Prosesseringsmetoder

VKM har fokusert på metoder som har størst innvirkning på råvarene, inkludert ulike former for varmebehandling, homogenisering og fermentering. Beskrivelsene av de ulike prosesseringsmetodene er basert på lærebøker om matforedling og teknologi og vitenskapelige publikasjoner (se for eksempel Fellows (2022)).

Noen hovedforskjeller som er identifisert er:

- For å få utgangsmaterialet til de plantebaserte drikkene og iskremene, behandles råvaren med enzymer for å hydrolysere stivelse og noen ganger andre komponenter.
- Alle plantebaserte drikker på det norske markedet er behandlet med ultrahøy temperatur for å inaktivere enzymer og for å forlenge holdbarhet. Denne behandlingen gjøres ved høyere temperatur og/eller lengre tid enn den varmebehandlingen som oftest brukes for melkeprodukter som helmelk, lettmelk og skummet melk på det norske markedet.

Blant de inkluderte produktene skiller plantebaserte osteanaloger seg ut med prosessemetoder som er svært forskjellige fra fremstilling av både løpe- og kremost. Å eksponere produkter for høyere temperaturer og lengre oppvarming kan øke risikoen for at det dannes prosessinduserte kontaminanter. Utover temperatur kan faktorer ved produktets sammensetning, som tilstedeværelse av reduserende sukker, spesifikke aminosyrer i proteiner og vanninnhold, også i stor grad påvirke dannelsen av disse forbindelsene.

Den generelle informasjonen som gis om prosessmetodene i denne rapporten er ikke tilstrekkelig til å trekke en endelig konklusjon om eventuell dannelse av prosessfremkalte stoffer.

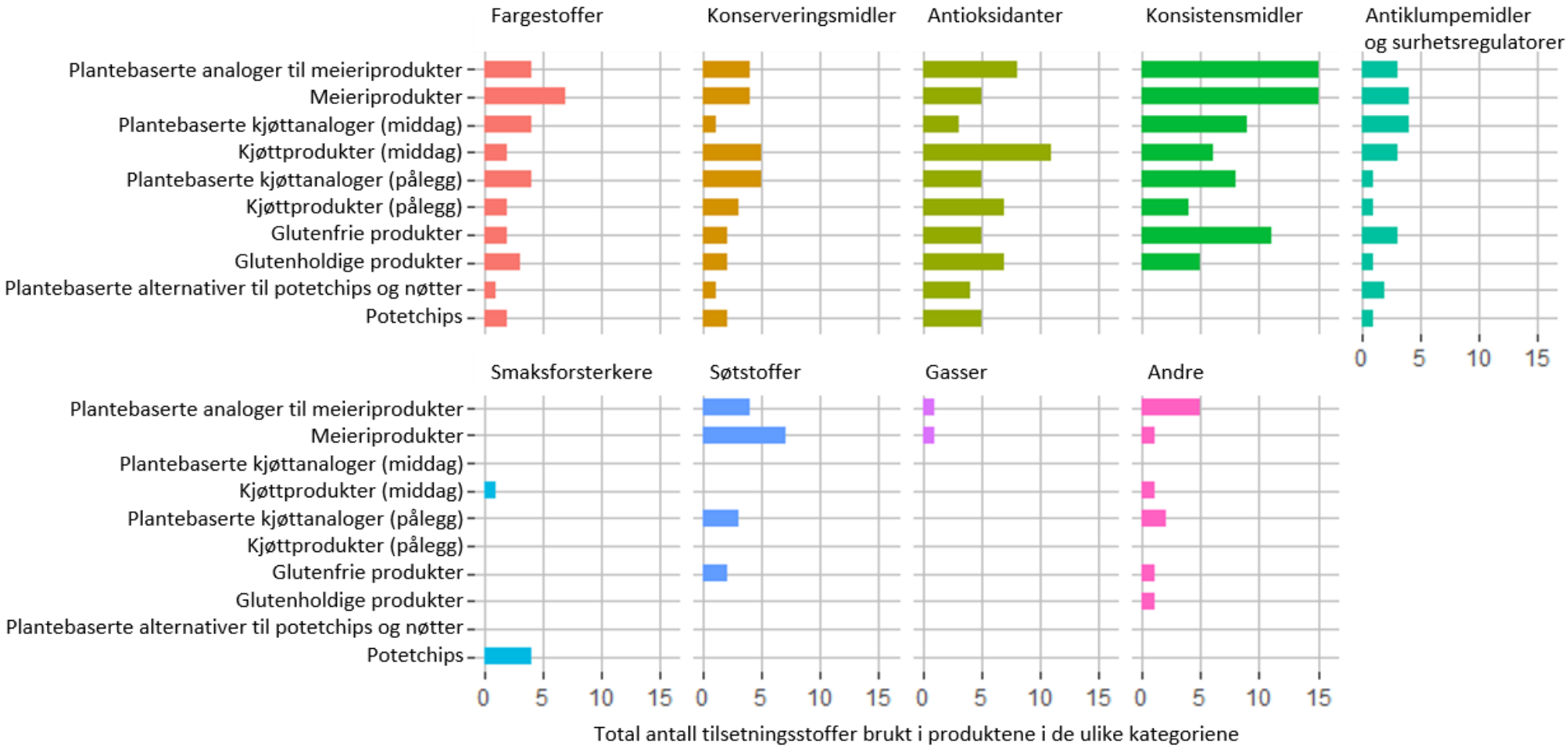
Oversikt over resultatene

Resultatene fra sammenligningene av innholdet av næringsstoffer, kontaminanter, bruk av tilsetningsstoffer, og prosesseringsmetoder er vist i tabell 1 og figur 1.

Tabell 1. Sammenligning av innhold av næringsstoffer, kontaminanter og prosesseringsmetoder. *De naturlige toksinene, miljøgiftene og prosessfremkalte stoffene er fra VKM et al. (2022); det var kun konsentrasjonsdata tilgjengelig for sammenligning for kadmium i plantebaserte kjøttanaloger og tilsvarende kjøttprodukter. **Det er kun for næringsstoffer at nøtter ble inkludert. ***Det er ikke sett på kontaminanter i snacksprodukter. ****Det er ikke sett på prosesseringsmetoder for snacksprodukter og pålegg.

Produktkategorier (antall produkter)	Makronæringsstoffer	Mikronæringsstoffer	Naturlige toksiner*	Miljøgifter*	Prosessfremkalte stoffer*	Prosesseringsmetoder
Plantebaserte meierianaloger (65) sammenlignet med meieriprodukter (97)	↑Karbohydrater ↓Protein	Forskjellene varierer avhengig av råvarene og berikning	↑Alternariol metyleter ↑Patulin ↑Solanin and chakonine ↑T-2 og HT-2 toksin ↑Zearalenon	↑Unorganisk arsen ↑Kadmium ↓Dioxiner og dioksin-lignende PCB	↑Akrylamid ↓Heterosykliske aromatiske aminer	Forskjeller avhenger av produktkategori. Plantedrikker: forbehandling av råvaren, kun løselig del av benyttes, enzymer kan tilsettes for å hydrolysere stivelse. Produktene er UHT behandlet. «Yoghurt»: forbehandling av råvaren, enzymer kan tilsettes for å hydrolysere stivelse før fermentering. Faste «oster»: de ulike ingrediensene blandes, ingen «ysteprosess».
Plantebaserte kjøttanaloger (37) sammenlignet med kjøttprodukter (53): middagsprodukter	↑Karbohydrater ↑Fiber ↓Protein	↑Kalsium ↑Folat ↓Vitamin A ↓Vitamin B12 ↑Vitamin E	↑Alternariol metyleter ↑Patulin ↑Solanin and chakonine ↑T-2 og HT-2 toksin ↑Zearalenon	↑Unorganisk arsen ↑Kadmium (bekreftet ved sammenligning av data) ↓Dioxiner og dioksin-lignende PCB	↑Akrylamid ↓Heterosykliske aromatiske aminer	Forskjeller avhenger av produktkategori. Plantebasert deig og burgere inneholder teksturert planteprotein som er ekstrudert.
Plantebaserte kjøttanaloger (16) sammenlignet med	↑Karbohydrater ↓Fett ↓Protein	Ikke deklarert for de plantebaserte produktene	↑Alternariol metyleter ↑Patulin	↑Unorganisk arsen	↑Akrylamid ↓Heterosykliske aromatiske aminer	Ikke inkludert****

kjøttprodukter (23): pålegg			↑Solanin and chakonine ↑T-2 og HT-2 toksin ↑Zearalenon	↑Kadmium ↓Dioxiner og dioksin-lignende PCB		
Glutenfrie produkter (60) sammenlignet med glutenholdige produkter (139)	↓Protein	Forskjellene varierer avhengig av råvarene	Det er ikke forventet forskjeller for produkter som er basert på same råvarer	↑Aluminium ↑Bly ↓ eller lik for kadmium	Ikke sammenlignet	Tilsvarende prosessering.
Plantebaserte snacks alternativer (25) sammenlignet med potetchips og nøtter (22) **	↓Fett ↑Protein	Ikke deklarert for de plantebaserte produktene	Ikke inkludert***	Ikke inkludert***	Ikke inkludert***	Ikke inkludert****



Figur 1. Total antall tilsetningsstoffer brukt i produktene i de ulike produktkategorier.

Konklusjon

VKM har utarbeidet et øyeblikksbilde av tilgjengelige data for et utvalg matvarer. VKM identifiserte forskjeller i innhold av næringsstoffer, kontaminanter og bruk av tilsetningsstoffer i de sammenlignbare produkttypene. Generelt var forskjeller i innholdet avhengig av råvarene som ble brukt og eventuell berikning av produktene. Noen kontaminanter finnes i et stort utvalg av råvarer, men visse kontaminanter er typiske for bestemte grupper av råvarer. I det datamaterialet som var tilgjengelig for VKM, manglet konsentrasjoner av tilsetningsstoffer og informasjon om kontaminanter i sammenlignbare produkter. Rapporten kan ikke brukes til å trekke konklusjoner om ernæringsmessig kvalitet eller mattrygghet ved ulike typer kosthold. Denne kartleggingen er ment å være et utgangspunkt for å identifisere hvilke faktorer som er viktige for å sikre trygg og sunn mat når matvarer og kostholdsmønstre endres.

Abbreviations

EFSA	European Food Safety Authority
EST	emulsifier, stabiliser, and thickener
KBS	Food composition and nutrient and food calculation system, University of Oslo
NFSA	Norwegian Food Safety Authority
UHT	ultra-high temperature
VKM	Norwegian Scientific Committee for Food and Environment

Glossary

Environmental contaminants are unwanted chemical substances that have not been intentionally added to food.

Food additives are substances that are deliberately added to food to achieve a technological purpose/outcome, such as to enhance shelf-life, enhance colour, preserve or add flavour, improve texture or appearance, or for other technological functions.

Food processing is the transformation of raw ingredients into food products. Some common food processing methods include thermal processing, mechanical processing, fermentation, preservation, packaging, and extrusion. Each method is chosen based on the desired outcome and characteristics of the food product being processed.

Food processing methods includes all methods used to turn raw materials into food products.

Free-from ("fri-for") food products are products that do not include specific components such as lactose or gluten. This could be because certain ingredients are avoided, or because certain substances are removed. These products are not necessarily plant-based and could include animal-derived components.

"Gluten-free" is a statement reserved for food sold to the final consumer that contains no more than 20 mg/kg of gluten (Regulation (EU) No 828/2014 on the requirements for the provision of information to consumers on the absence or reduced presence of gluten in food).

Natural toxins are toxic compounds, such as mycotoxins and plant toxins, that are produced by living organisms.

Plant-based products are food items made from plants such as vegetables, fruits, nuts, grains, and legumes, that do not contain any animal and animal-derived ingredients like milk, egg, or meat. Within this broad category certain products are made to mimic meat and dairy products. Terms used to describe such plant-based food

products are plant-based substitutes, alternatives, meat free, or plant-based analogues or replacers for products such as dairy products, meat burgers or meat sausages. In this report these products are described with the terms "plant-based meat analogue products" and "plant-based dairy analogue products".

Process-induced contaminants are substances that are formed in food or in food ingredients when they undergo chemical changes during processing such as fermentation, smoking, drying, refining and high-temperature cooking.

Product is an article manufactured or refined for sale. In this report the term "product" means that it is also reported to be consumed.

UpSet plot is a visualisation technique for the quantitative analysis of data sets, their intersections, and aggregates of intersections (Lex et al., 2014).

Background as provided by the Norwegian Food Safety Authority

New food products, foods with altered composition and changing eating habits affect our diet.

Several food products are available on the market because of increased demand for vegetarian products and "free-from" products. Many consumers perceive these products as healthy and/or sustainable. Such products can, for example be, "healthy" snack bars, plant-based imitation products for meat and dairy products, and plant-based snacks. New and changed foods can be produced with new food technologies and may change the use of food additives to e.g. maintain organoleptic characteristics and shelf life.

The Norwegian Food Safety Authority (NFSA) needs knowledge about nutrients, additives, contaminants such as environmental contaminants, natural toxins, and process- induced contaminants to provide current and relevant advice to consumers. NFSA needs more knowledge of which techniques may affect the composition of the final product.

Food products included in this assignment are limited to plant-based snacks, plant-based- and gluten-free food products which corresponds to meat and dairy products and products with gluten.

Plant-based foods include:
- Plant-based imitation products for meat products
- Plant-based imitation products for dairy products
- Plant-based snacks alternatives other than potato chips and nuts

Gluten-free foods include:
- Product variants used as flour, flour mixes and baked goods (including bread, cakes, biscuits, pancakes, and waffles)
- Product variants used as breakfast cereals and muesli
- Pasta

Assessment of plant-based and gluten-free products

NFSA lacks knowledge about the content of nutrients, additives, contaminants such as environmental contaminants, natural toxins, and process-induced contaminants in selected food products. Therefore, we need information about current knowledge in this field and we need to identify knowledge gaps to get an overview. We also need knowledge about techniques used in production of these food products.

Terms of reference as provided by the Norwegian Food Safety Authority

The Norwegian Food Safety Authority requests VKM to do the following:

1. To select plant-based snacks, plant-based and gluten-free products that correspond to meat and dairy products and products with gluten.

2. To prepare a justified selection of nutrients, additives, environmental contaminants, natural toxins, and process-induced contaminants to include in the mapping of the products described under point 1.

3. To map and compare the content of the food products and substances identified under point 1 and point 2 with corresponding meat- and dairy products, and products with gluten.

4. To map the techniques used in the production of food products described in point 1.

1 Introduction

In recent years, plant-based analogue products for several meat and dairy products, plant-based snacks alternatives to potato chips and nuts, and various types of "free-from" products including gluten-free products have appeared in grocery stores.

The term plant-based products include food items made from edible plant raw material, such as vegetables, fruits, nuts, grains, and legumes, that do not contain animal-derived ingredients like milk, egg, meat, or fish. Some plant-based food products are designed to specifically mimic animal-based products. These products are described by a plethora of terms: plant-based meat or dairy substitutes, alternatives, analogues, replacers, meat-free, or dairy-free (contain no milk or milk products). Although these plant-based products are designed to mimic animal-based products, it is not yet known to what extent consumers use them to replace animal-based products. To avoid confusion, in this report these products are described with the terms "plant-based meat analogue products" and "plant-based dairy analogue products".

Free-from products can include animal-derived components and are defined as products that do not include specific components such as lactose or gluten. Gluten-free products are first and foremost marketed for consumers with celiac disease or intolerance towards the gluten protein. According to the EU Regulation on the requirements for the provision of information to consumers on the absence or reduced presence of gluten in food, the statement "gluten-free" may only be used for food sold to the final consumer that contains no more than 20 mg/kg of gluten (Regulation (EU) No 828/2014). Additionally, the statement "very low gluten" may only be used for food, consisting of or containing one or more ingredients made from wheat, rye, barley, oats, or their crossbred varieties which have been specially processed to reduce the gluten content, and that contains no more than 100 mg/kg of gluten.

1.1 Nutrients, food additives and contaminants

The content of nutrients, food additives and contaminants in plant-based meat and dairy analogue products, gluten-free products and non-potato snack products differ from that found in their animal-based, gluten-containing and traditional potato snack counterparts (Norwegian Food Safety Authority and Institute of Marine Research, 2022a; Pastell et al., 2021). This is primarily due to differences in the nutritional and contaminant content in the raw materials used, different needs for food additives in the products, and the use of different processing methods. Fortification may counteract some of the differences pertaining to nutrient content.

1.2 Food processing methods

Food processing involves a series of unit operations that transform raw food materials into processed products ready for consumption. Unit operations in food processing refer to the fundamental steps or processes involved in the production, handling, and

transformation of raw food materials into finished food products. These unit operations encompass activities like sorting, cleaning, cutting, milling, and grinding, temperature treatment (cooking, pasteurisation, sterilisation, cooling and freezing), cooling, freezing, freeze-drying, mixing, homogenisation, separation, fermentation, drying, packaging and other methods of preservation not mentioned above (pickling and curing). Each unit operation serves a specific purpose, such as inactivate pathogenic microorganisms, removing impurities, preserving freshness, enhancing flavour, achieving the desired texture, or improving shelf life. By combining these unit operations in a controlled sequence, food manufacturers can ensure product safety, quality, and consistency while meeting consumer preferences. The sequence, and the specific parameters and conditions are unique for each product, and this is discussed in more detail in Section 3.5. Ultimately, food processing is essential for making a wide range of food products available to consumers in convenient and safe forms. Indeed, many unit operations in food processing are versatile and can be applied to a wide range of food products. However, the way these operations are combined, their sequence, and the specific parameters and conditions associated with them can vary significantly based on the unique characteristics of the different raw materials and requirements of each product.

Home cooking and industrial processing of foods share some common operations such as cutting and chopping, mixing, and blending, and several types of heat treatment (cooking, roasting and frying), but they also differ significantly in terms of scale, equipment, precision, and regulatory compliance.

A brief overview of some of the methods which are of relevance for the food products included in this study is described in the appendix (section 8). Many of these methods are often referred to as industrial techniques, as they necessitate specialised equipment not typically available in a standard kitchen. Moreover, this section includes a description of extrusion which is a type of processing involving several unit operations.

1.3 Aim and research questions

The aim of this project is to map data on:

- The content of nutrients, food additives, natural toxins, environmental and process-induced contaminants in a selection of plant-based meat and dairy analogue products, gluten-free products and non-potato snack products, and their animal-based, gluten-containing and traditional potato snack products counterparts.
- The processing methods used in the production of the selected products described above.

The research questions are as follows:

Topic addressed	Research question	The section where the

		questions are answered
Identification of products	Which plant-based meat and dairy analogue products have the highest market shares and/or consumption?	3.1.1
	Which gluten-free food products have the highest market shares and/or consumption?	3.1.1
	Which plant-based snack products, except traditional potato chips and nuts, have the highest market shares and/or consumption?	3.1.1
	Which animal-based and gluten-containing counterpart products to those identified in questions 1, 2, and 3, have the highest market shares and/or consumption? Which potato chips products have the highest market shares and/or consumption?	3.1.1
The content of the products	Which food additives are used in the manufacturing of the selected food products?	3.3
	For which nutrients are the selected products or their main raw materials known or expected to be an important source?	3.2
	For which contaminants (natural toxins, environmental and process-induced contaminants) are the selected products or their main raw materials known or expected to be an important source?	3.4
Processing methods	Which processing methods are used to manufacture the selected food products?	3.5
Comparison of the following products: i) plant-based meat and dairy with animal-based, ii) gluten-free with gluten-containing, and iii) non-potato plant-based chips and nuts with potato-based chips and nuts	What are the differences in nutrient content?	3.2.1, 3.2.2, 3.2.3, 3.2.4, and 4.1
	What are the differences in the contaminant content?	3.4.3 and 4.3
	What are the differences in the use and content of food additives?	3.3.3 and 4.2

	What are the differences in the use of processing methods?	3.5.1, 3.5.2, 3.5.3, 3.5.4, 3.5.5, 3.5.6 and 4.4

1.4 Delimitations

- Only food products offered for sale that are also reported consumed are included.
- The included products are not categorised according to whether it is raw, prepared, etc.
- Concentration data and data on the use of food additives are presented for the included product types are not divided into organic and conventional products.
- Only industrial processing is included.
- Food allergens, antinutrients in plant-based raw materials and microbial hazards were not included in this mapping report.
- Systematic literature searches have not been performed to identify concentration data for nutrients, food additives, or contaminants.

2 Methods

We followed principles for conducting a scoping review, as expressed in the PRISMA-ScR checklist (Tricco et al., 2018). Deviations from the checklist mainly involve choice of information sources, and literature search, because the desired information is not available in electronic databases.

With regard to identification of data (Sections 2.1, 2.2 and 2.3), a pragmatic approach was chosen, aiming to identify the "readily available" data and creating an overview that can be used as a starting point for identifying important factors that should be considered for safe and healthy food when food products and dietary patterns change. More time-consuming approaches, such as performing systematic literature searches, would most likely have identified more data. However, this was not considered necessary to create the starting point, but rather to be performed for specific topics based on the findings in this report.

A protocol was published before VKM started working on this report (VKM, 2023). Deviations from the protocol are included in the Appendix (Section 9).

2.1 Identification and selection of food products

To identify relevant products and minimise the risk of including products that were only transiently available on the market, the identification and selection of food products were based on both sales and intake data as described in Sections 2.1.1 and 2.1.2.

2.1.1 Sales data for relevant food products

To identify data on market shares and/or purchase of a product to answer research questions number 1 to 4 "Which plant-based meat and dairy analogue products have the highest market shares and/or consumption?", "Which gluten-free food products have the highest market shares and/or consumption?", "Which plant-based snack products, except traditional potato chips and nuts, have the highest market shares and/or consumption?", and "Which animal-based and gluten-containing counterpart products to those identified in questions 1, 2, and 3, have the highest market shares and/or consumption?", VKM performed the following tasks:

1. Used a report describing sales of plant-based food products and meat and dairy counterpart products in Norway in the period 2016 to 2020 (Grimsby et al., 2021).
2. Used a report from the Norwegian Food Safety Authority (NFSA) on content of selected contaminants in plant-based "bestselling" food products (Norwegian Food Safety Authority and Institute of Marine Research, 2022a).
3. Sent a request for data on market shares aimed at the food industry to NHO Mat og Drikke and to Teknologisk matforum (March 13, 2023). According to the

protocol (VKM et al., 2023), data was expected to be retrieved following a request for data from food manufacturers and grocery stores. Contact information for specific individuals was not accessible through the websites of food manufacturers and grocery stores. As our aim was to gather readily available data rather than provide a comprehensive overview, no further efforts were made to contact the food manufacturers and grocery stores.

4. Published a request for data on the VKM webpage and posted information about the request on the VKM Facebook.
5. Searched the webpages of Norwegian grocery stores containing information on "most purchased" products.

VKM included all products in the reports described in points 1 and 2.

VKM received no data from food manufacturers or grocery stores (point 3 and 4).

Regarding point 5, we identified three main grocery store chains, namely, Meny, Spar, and Joker, as well as a health food store, Sunkost, with webpages featuring search functions to filter and find the "top-selling" products. This function enabled us to identify the "most purchased" products within each relevant food category at a specific time point. The webpages were searched on separate dates by two reviewers independently. From each webpage, an overview was prepared of the ten most purchased products within all relevant categories (plant-based and gluten-free food products and their meat and dairy and gluten-containing counterpart products).

2.1.2 Consumption of relevant food products

VKM performed the following tasks to identify data on intake of relevant food products to answer research questions 1 to 4 (Section 1.3):

1. Sent a request for relevant data from the national dietary survey Norkost 4 pilot study conducted by the Norwegian Institute of Public Health and the University of Oslo) (Lene Frost Andersen, personal correspondence, March 2023). The requested data was received.
2. Used intake data from the national dietary surveys Norkost 3 (Totland et al., 2012) and Norkost 4 (pilot study).

Further description is available in Section 3.1.1.

2.2 Identification and selection of nutrients, food additives and contaminants in the selected food products

To answer research question number 5: "Which food additives are used in the manufacturing of the selected food products?", an overview of all food additives in the selected products were created using publicly available ingredient lists from the webpages of main Norwegian grocery stores.

To answer research question number 6: "For which nutrients are the selected products or their main raw materials known or expected to be an important source?", our first aim was to identify the nutrients for which the traditional animal and dairy-based and gluten-containing foods are important sources. This information was based on the two

dietary surveys Norkost 3 (Totland et al., 2012) and the Norkost 4 pilot study (2021-22).

To answer research question number 7: "For which contaminants (natural toxins, environmental and process-induced contaminants) are the selected products or their main raw materials known or expected to be an important source?", contaminants that the selected food products contain or are expected to contain were identified using a knowledge base with information on contaminant content in food items consumed by the Norwegian population (VKM, 2022). Contaminants in the food products categorised as follows in the VKM knowledge base were included in this report:

- Contaminants for which the selected food products are known to contribute moderately (10 - <25%) to the total exposure.
- Contaminants for which the selected food products are known to have a high (25 - <50%) contribution to the total exposure.
- Contaminants for which the selected food products are known to have a very high (50 - 100%) contribution to the total exposure.
- Contaminants for which the selected food products represent a major contribution to the total exposure.
- Contaminants for which the selected food products are expected (based on expert judgement) to be a major source.

Contaminants for which the selected soy-containing food items are known or expected to be an important source to the total exposure were identified using EFSA Opinions (EFSA et al., 2020a; EFSA et al., 2020b) and the EU regulation on maximum levels for certain contaminants in foodstuffs (Regulation (EC) No 1881/2006), as soy was not included in the VKM knowledge base.

All the identified contaminants are hereafter referred to as contaminants for which the selected food products are known or expected to be important sources for the total exposure.

2.3 Identification of concentration data for the relevant nutrients, food additives, and contaminants

Concentration data were identified to compare the content of nutrients, food additives, and contaminants in plant-based and gluten-free food products with the content in meat-, dairy-, and gluten-containing products (research questions 9, 10 and 11). An overview of the eligibility criteria for the concentration data is shown in Table 2.3-1.

Table 2.3-1. Eligibility criteria for concentration data.

Findings	Concentration data for selected nutrients, food additives, natural toxins, environmental- and process-induced contaminants in selected food items.
Data sources	Databases, reports, textbooks, scientific publications
Publication year	From January 2000 until June 2023

Country (sampling)	European countries
Language	Danish, English, Norwegian and Swedish

2.3.1 Concentration data for food additives

VKM performed the following tasks to identify data that could answer research questions number 5 and 11: "Which food additives are used in the manufacturing of the selected food products?" and "What are the differences in the use and content of food additives?", respectively:

1. Prepared two requests/calls for data.
    a. A request for concentration data aimed at the food industry was sent to NHO Mat og Drikke and to Teknologisk matforum (June 12, 2023). According to the protocol (VKM et al., 2023), data was expected to be retrieved following a request for data to food manufacturers and grocery stores. Contact information for specific individuals was not accessible through the websites of food manufacturers and grocery stores. As our aim was to gather readily available data rather than provide a comprehensive overview, no further efforts were made to contact the food manufacturers and grocery stores.
    b. A call for data from other European countries. This call was sent via the Norwegian EFSA focal point (June 23, 2023).
2. Published the request for data from Norwegian food manufacturers and grocery store chains on the VKM webpage.
3. Searched the webpages of relevant national and international institutions.

VKM did not identify, or receive, any concentration data for food additives.

2.3.2 Concentration data for nutrients

Based on research questions number 6 and 9: "For which nutrients are the main raw materials in the selected food products known or expected to be an important source?", and "What are the differences in nutrient content?", nutrient content information was retrieved from the food composition table of NFSA (Matvaretabellen.no) and the in-house research food composition database and calculation system KBS at the University of Oslo. When these two databases did not have information about a specific product, macronutrient content was retrieved from the product declaration and proxy micronutrient content, not declared, was compiled from either of the two food composition databases.

Plant-based meat and dairy analogue products and the gluten-free products may have different nutrient profiles and be sources of other nutrients beyond those found in their meat and dairy and gluten-containing counterpart products. Thus, all nutrients for which there are available data in the Norwegian food composition table and/or the KBS were included in the analyses. Among these nutrients, we selected and presented nutrients based on their concentration and importance for the food groups in question.

2.3.3 Concentration data for contaminants

The process for identification of data for answering research questions number 7 and 10: "For which contaminants (natural toxins, environmental and process-induced contaminants) are the selected products or their main raw materials known or expected to be an important source?" and "What are the differences in the contaminant content?", respectively, were identical with the process for identification of concentration data for food additives (Section 2.3.2).

VKM did not receive concentration data from food manufacturers or grocery stores.

VKM received/identified concentration data from the following sources:

- NFSA reports (Mattilsynet, 2017; Mattilsynet, 2018; Norwegian Food Safety Authority and Institute of Marine Research, 2021; Norwegian Food Safety Authority and Institute of Marine Research, 2022a; Norwegian Food Safety Authority and Institute of Marine Research, 2022b).
- A VKM risk-benefit assessment (VKM et al., 2022).
- EFSA Opinions and EFSA supporting publications (EFSA, 2008; EFSA, 2011; EFSA, 2014a; EFSA, 2014b; EFSA, 2015; EFSA, 2016; EFSA et al., 2017a; EFSA et al., 2017b; EFSA et al., 2017c; EFSA et al., 2017d; EFSA et al., 2016; EFSA et al., 2020b; López Sáncheza et al., 2017).
- A report from the Nordic Council of Ministers (Pastell et al., 2021)
- A publication reporting on Swedish food products (Kollander et al., 2023).

Due to potential overlap with the data identified from EFSA Opinions, VKM decided not to include the data received through the call for data from other European countries.

2.4 Identification of data on processing methods

To answer research questions number 8 and 12: "Which processing methods are used to manufacture the selected food products?" and "What are the differences in the use of processing methods?", respectively, an overview of the different methods used to manufacture the selected food products was prepared The processing methods described in this document are based on information gathered from textbooks on food processing and technology (Fellows, 2022) and research and review papers published in international peer-reviewed scientific journals (Dekkers et al., 2018).

We focus on unit operations that have the most pronounced impact on raw materials. These key operations include various forms of heat treatment, as well as homogenisation and fermentation. It is important to note that the methods we discuss are generally applicable across the industry. However, processes may vary between manufacturers, and detailed company-specific information is typically not publicly disclosed.

3 Results

3.1 Food products

3.1.1 Selected food products and their raw materials

The selection of food products was based on data on sales information and intake (Sections 2.1). This information was collected independently by two of the project group members in March and April 2023. The products were categorised in "Product categories" (e.g. analogue or conventional products) with subgroups "product types" which contain the selected food products. An overview of food product categories and product types is shown in Table 3.1.1-1.

Table 3.1.1-1. Product categories to be compared.

Analogue products	Conventional products
Plant-based meat analogue products: dinner	Meat products: dinner
Plant-based meat analogue products: bread topping	Meat products: bread topping
Plant-based dairy analogue products	Dairy products
Gluten-free products	Gluten-containing products
Plant-based snacks alternatives	Potato chips and nuts

An overview of the product types and the number of products identified for each is shown in Table 3.1.1-2. Given the constraints of the available data for product selection, this report showcases products categorised by their product types rather than by specific brands.

The main raw materials (ingredients) in the food products were identified using the ingredient lists found on the webpages of Norwegian grocery stores. Identification of the main ingredient of each product was restricted to the first item on the ingredient list, with the exception of water, which was not included. An overview of the main ingredient of each product type is shown in Table 3.1.1-2. To check if the products identified from the webpages of grocery stores also were reported to be consumed, we used the dietary intake data from the national dietary survey Norkost 3 and the pilot study of the national dietary survey Norkost 4. The comparison of the reported sold products versus reported intake was done on group level (product type) according to dietary intake data, and not necessarily on brand level for all food groups, due to available data. That means that if "Salty sweet potato snack Brand A" was identified based on data from the grocery stores, then this was checked against the dietary intake data on the food group "Salty snacks" as such, from the dietary data.

Table 3.1.1-2. Identified food product types and products, number of identified products and main ingredients.

Product type		Number of products	Main ingredient	Product type		Number of products	Main ingredient
Dairy analogue products	Plant-based "butter"	1	Rapeseed oil	**Dairy products**	Butter	19	Buttermilk, cream, dairy butter
	Plant-based "cheese"	15	Modified starch, potato, soy, vegetable fat (coconut, shea), vegetable oils (coconut, palm kernel oil, rapeseed)		Cheese	15	Milk (cow)
	Plant-based "ice cream" analogue	8	Oat, rice, soy, vegetable oils (coconut, rapeseed)		Ice cream	19	Cream, milk whole, milk skimmed
	Plant-based beverage	23	Almond, coconut, oat, rice, soy		Milk	16	Milk whole, milk semi-skimmed, milk skimmed
	Plant-based "yoghurt"	18	Coconut milk, fruit, oat, soy		Yoghurt	28	Milk whole, milk semi-skimmed, milk skimmed
Meat analogue products	Plant-based bread toppings	16	Chickpeas, rapeseed oil, vegetable fibre, wheat gluten	**Meat products**	Bread toppings	23	Beef, chicken, pork, turkey
	Plant-based burger	11	Potato, soy		Burger	18	Beef, chicken, lamb, pork
	Plant-based balls	6	Chickpeas, peas, potato, soy		Meat balls	1	Beef, pork
	Plant-based minced and pulled meat analogues	13	Peas, soy		Minced meat	5	Beef
	Plant-based sausage	6	Soy, vegetable oil (sunflower, rapeseed), wheat		Sausage	28	Beef, chicken, lamb, pork, turkey

	Plant-based schnitzel	1	Soy		Schnitzel	1	Pork
Baking mixtures, gluten-free	Buns, bread mixture, cake mixture, pancake mixture, waffle mixture	24	Rice, seeds and kernels (chia, flax, psyllium, sesame, sunflower), starch (corn, potato, rice, wheat), oat (whole grain)	**Baking mixtures, gluten-containing**	Buns, bread mixture, cake mixture, pancake mixture, waffle mixture	15	Sugar, wheat
Bread* and crisp bread, gluten-free		19	Corn, oat (whole grain), rice, seeds (brown flax seeds, chia seeds, pumpkin seeds, Sprouted broccoli seeds, sunflower seeds, yellow flax seeds), starch (corn, potato, tapioca, wheat)	**Bread and crisp bread, gluten-containing**		55	Oats, rye, spelt, sesame seeds, sunflower seeds, wheat
Breakfast cereals, gluten-free		1	Oat flakes	**Breakfast cereals, gluten-containing**		25	Barley, corn, oats, rice, rye, wheat
Flour and grains, gluten-free		8	Rice, seeds (sesame), starch (wheat), teff	**Flour and grains, gluten-containing**		21	Almonds, barley, oats, rye, spelt, wheat
Pasta, gluten-free		8	Corn, rice (whole grain)	**Pasta**		23	Durum wheat, wheat
Plant-based snacks alternatives		25	Apple, cbeans, hickpeas, lentils, nori, peas, quinoa, rice, soy, sweet potato	**Potato chips**		22	Potato, potato flour

*Includes garlic bread and pita bread.

3.2 Nutrients

The level of some selected nutrients is presented in tables when sufficient data were available. An overview of all nutrients in the selected food products is available in Supplementary Materials 1.

3.2.1 Dairy products and plant-based dairy analogues

Nutrients in plant-based beverages

The nutrient concentrations in plant-based beverages are dependent on the main ingredient of the product. Average concentrations of main nutrients are presented in Table 3.2.1-1. The carbohydrates in plant-based beverages constituted on average 48% starch (range 0 to 65%), and 52% are mono- and disaccharides (range 35 to 100%). The protein content varied from 0 to 4 g per 100 g and total fat content varied from 0 to approximately 3 g per 100 g. Saturated fat constituted on average 13% of total fat, with the exception of the coconut-based milk analogues in which saturated fat constituted 89% of total fat. The plant-based beverages also contained omega-3 and omega-6 fatty acids. Some, but not all, products contained fibre; however, in very low levels (<1%). Of the 22 different plant-based beverages in the study, 17 were fortified with one or more vitamins and/or minerals. The type and number of nutrients added to the plant-based beverages varied between products, thus the nutrient profiles differed. Plant-based beverages were most often fortified with calcium, vitamin B_2, folate, vitamin B_{12} and vitamin D. A few were fortified with iodine. When fortified with calcium the levels were between 110 and 150 mg per 100 g which is in the same range as found in different milk. Five of the products were not fortified and had low concentrations of vitamins and minerals. Further, plant-based beverages contain, with some variations depending on the main ingredient, folate, iron, potassium, magnesium, and zinc in the same range as milk.

Nutrients in milk

The national dietary surveys Norkost 3 and the pilot study of Norkost 4 show that milk contributes to 6-10% of total protein intake, 2-4% of total fat intake and 4-6% of total carbohydrate intake. With regards to micronutrients, milk contributes to intakes of riboflavin (11-19%), vitamin B_{12} (6-12%), calcium (21-31%) and iodine (14%, Norkost 4) (% of total intake). The intake of milk has decreased according to national dietary surveys, by approximately 36 and 42 percent for men and women, respectively, in the period 1993 to 2011 (Johansson and Solvoll, 1999; Totland et al., 2012) and this trend is continuing (Helsedirektoratet, 2022).

Total fat content varies with milk type from 0.1 g in skimmed milk to 3.6 g in whole milk. Saturated fat constitutes approximately 60% of total fat content in whole milk. Milk also contains protein and carbohydrates (mainly lactose), 3.5 g and 4.5 g per 100 g, respectively, as well as minerals and vitamins, the most important being calcium, iodine, and vitamin B_{12}. Only semi-skimmed milk may be fortified with vitamin D (0.4 or 0.8 mg per 100 g).

Summary and comparison of main nutrients in plant-based beverages and milk

An overview of the main nutrients in plant-based beverages and milk is given in Table 3.2.1-1.

Table 3.2.1-1. Contents of selected nutrients per 100 g in plant-based beverages and milk products. Data from www.matvaretabellen.no. RE: retinol equivalents. α–TE: α-tocopherol equivalents

Macronutrients per 100 g	**Plant-based beverage**	**Whole milk**	**Semi-skimmed milk**	**Skimmed milk**
Carbohydrates (g)	7, 48% starch	4.5	4.5	4.5
Fat (g)	1.2	3.6	0.5	0.1
Protein (g)	1.4, range 0-3.7	3.4	3.5	3.5
Vitamins and minerals per 100 g				
Calcium (mg)	109, range 2-150	130	130	130
Folate (μg)	10, range 0-39	2	4	4
Iodine (μg)	3, range 0-20	16	16	16
Iron (mg)	0.2, range 0.1-0.9	0	0	0
Magnesium (mg)	8, range 3-19	11	11	10
Vitamin A (RE)	0	7	2	1
Vitamin B_{12} (μg)	0.2, range 0-0.4	0.6	0.6	0.6
Vitamin D (μg)	0.7, range 0-1.1	0	0.67	0
Vitamin E (α-TE)	0.5, range 0-0.8	0	0	0

The main differences in nutrient content between plant-based beverages and milk are the difference in fatty acid profile; mainly saturated fatty acids in milk versus mainly unsaturated fatty acids in plant-based beverages, except for coconut-based analogues. The total amount of carbohydrates is a little higher in plant-based beverages, which also may contain starch, based on main ingredient, and do not contain lactose. Total protein content is comparable only between milk and soy-based analogues; however, the amino acid profiles are different. Milk has a more favourable amino acid profile, including all the essential amino acids in high enough concentrations for milk to be a good dietary source of protein. The plant-based beverages will have more varying amino acid profiles, with very low levels of some essential amino acids, depending on the raw material, making them less beneficial dietary sources of protein. The plant-based analogues generally contain less of the vitamins and nutrients which milk is a source to in the diet, if not fortified. However, the plant-based beverages contain some additional vitamin E, folate, and iron which is not present in milk.

Nutrients in plant-based cheese analogues

The average nutrient concentrations of plant-based cheese analogues are presented in Table 3.2.1-2. Based on data from the NFSA food composition table (n=4) (matvaretabellen.no), plant-based cheese analogues contained on average, per 100 g, <0.5 g protein, 22 g total fat of which 74% was saturated fat, and 18 g carbohydrates of which 98% was starch and 3 g of fiber. Micronutrient contents were declared for six products, which on average was 206 mg calcium, 4.5 μg vitamin D and 1.4 μg vitamin B_{12}. Based on data from the NFSA food composition table (matvaretabellen.no), this food group had on average, per 100 g, 19 RE vitamin A, 1.5 α-tocopherol equivalents (α-TE) vitamin E and 0.1 µg iodine.

Nutrients in cheese

Cheese is a traditional and frequently used food in the Norwegian diet. The intake has increased in the last two decades according to the latest national dietary surveys. Generally, cheese is a source of total fat, saturated fat, protein, calcium, iodine, riboflavin, folate, vitamin B_{12} and vitamin A. The nutrient content in the included cheese products in the present mapping is presented in Table 3.2.1-2.

Summary and comparison of main nutrients in plant-based cheese analogues and cheese

An overview of the main nutrients in plant-based cheese analogues and cheese is given in Table 3.2.1-2.

Table 3.2.1-2. Contents of selected nutrients per 100 g in plant-based cheese analogues and cheese. Data from www.matvaretabellen.no. RE: retinol equivalents; α–TE: α-tocopherol equivalents.

Macronutrients per 100 g	Plant-based cheese analogues	Cheese
Carbohydrates (g)	18, 98% starch	1
Fat (g)	22, 74% saturated fat	24, 64% saturated fat
Protein (g)	<0.5	25
Vitamins and minerals per 100 g		
Calcium (mg)	206	687
Folate (µg)	0	30
Iodine (µg)	0.1	27
Vitamin A (RE)	19	189

Values for plant-based cheese analogues are based on four cheese analogue products in the NFSA Food composition table, October 2023.

The main differences in macronutrient content between plant-based cheese analogues and cheese were the contents of carbohydrates and protein. The cheese products contained practically no carbohydrates while plant-based cheese analogues contained on average 18 g per 100 g, of which 98% was starch. Cheese contained on average 25

g protein per 100 g, while plant-based cheese analogues contained less than 1 g protein per 100 g. The total fat content was on average quite similar, and the plant-based cheese analogues also contained saturated fat, due to the use of coconut and shea fat. Both cheese and plant-based cheese analogues contained vitamin A; however, the content in the plant-based analogues constituted only 10% of that found in cheese. The plant-based cheese analogues also had lower content of calcium (on average 30% of the calcium level found in cheese), and they contained almost no iodine. Both product groups contained small amounts of vitamin E.

Nutrients in plant-based yoghurt analogues

The 16 plant-based yoghurt analogues in the present mapping contained, based on the declared values, on average per 100 g, 363 kJ, 4.5 g total fat of which 53% was saturated fat, 3 g protein, 7 g carbohydrates of which 77% was mono- and disaccharides, 2 g starch, and 2 g dietary fiber. The NFSA food composition table included at the time of this mapping, only one product, with oat as main ingredient. The micronutrient profile of this product includes 1.1 µg vitamin D, 0.29 mg riboflavin, 9 µg folate, 0.4 µg vitamin B_{12}, 120 mg calcium, 44 mg potassium, 6 mg magnesium, 0.1 mg zinc, and 23 µg iodine.

As the recipe and main ingredient vary between the plant-based yoghurt analogue products, the micronutrient profile of the oat-based product in the Norwegian food composition table may not be representative for this group. Therefore, more information about the micronutrient content of these products is warranted.

Nutrients in yoghurt

Generally, yoghurts are sources of protein, calcium, and iodine in the Norwegian diet. Based on the yoghurt products in the NFSA food composition table (Matvaretabellen.no, October 2023) yoghurt contained on average, per 100 g, 297 kJ, 2 g total fat, of which 65% is saturated, 5 g protein, 8 g carbohydrates of which 85% is mono- and disaccharides, 130 mg calcium and 16 µg iodine.

Nutrients in plant-based ice cream analogues

Eighteen plant-based ice cream analogues were included in the present mapping. The average nutrient contents of these products, based on product declarations, were 11 g fat, of which 70% was saturated fat, 29 g carbohydrates, of which 72% was mono- and disaccharides and 28% was starch, and 1.5 g protein. Five products declared fiber and one product declared 14 g of polyols. From the NFSA food composition table, the micronutrient contents of one plant-based ice cream analogue have the following contents of, per 100 g, 4 µg folate, 6 mg calcium, 1.2 mg iron, 66 mg potassium, 25 mg magnesium, and 0.2 mg zinc. As the recipe and main ingredient vary between the ice cream analogue products, the micronutrient profile of the single product in the Norwegian food composition table is probably not representative for this group. Therefore, more information about the micronutrient content of these products is warranted.

Nutrients in ice cream

Ice cream is either based on cream, whole milk, or skimmed milk. The nutrient contents of the 19 products included in the present mapping are for macronutrients based on available product declarations, and the micronutrient contents are estimated based on the ice cream products found in the NFSA food composition table (n=11, Matvaretabellen.no, October 2023). The average contents of nutrients, per 100 g, were 10 g total fat, of which 7 g was saturated fatty acids, 5 g protein, 25 g carbohydrates of which 84% was mono-and disaccharides. Two products contained fiber (5 and 8 g) and one product contained sugar alcohols (polyols) (11 g). Based on estimates from Matvaretabellen.no, (n=11), ice cream, on average, also contained approximately 76 RE vitamin A, 108 mg calcium and 8 μg iodine, in addition to other vitamins and minerals found in milk.

3.2.2 Meat and plant-based meat analogues

Nutrients in plant-based meat analogues

The included products were composite recipes with main ingredients soy, peas, potato, rapeseed oil, wheat, and other vegetables. The nutrient content of these products varied with ingredients. On average, they had less total and saturated fat compared to the meat products, higher content of carbohydrates, which was mainly starch, and same or less concentration of protein. In addition, some of the plant-based analogue products contained fiber. Nutrient concentrations of plant-based meat analogues are presented in Table 3.2.2-1 and 3.2.2-2.

Nutrients in poultry and poultry products

The traditional poultry products include chicken filet, burgers, sausages, and nuggets. The nutrient contents of these food products vary with ingredients. Generally, chicken and poultry products are sources of protein, selenium, B-vitamins including thiamin, riboflavin, niacin, vitamin B_6, and B_{12}. Also, the fatty acid profile is beneficial with regard to lower levels of saturated fat and higher levels of unsaturated fat as compared to red meat. The included chicken products had, based on data from the NFSA (matvaretabellen.no). The nutrient concentrations of poultry and poultry products are presented in Table 3.2.2-1.

Nutrients in red meat and read meat products

The included traditional red meat products were derived from mutton and lamb, beef, and pork. They included burgers, cheeseburgers, beef, bacon, sausages, breaded steaklets, and minced meat. The nutrient contents of these products varied with ingredients and main meat ingredient. Generally, red meat is a dietary source of protein, iron, zinc, vitamin A, thiamin, riboflavin, vitamin B_6 and B_{12}. It is also a source of saturated fatty acids. Minced meat from beef is generally found in two categories defined according to fat content, usually 5% and 14% fat. Meat products from pork have generally lower contents of saturated fat than those of mutton, lamb, and beef. The nutrient concentrations of red meat and red meat products are presented in Table 3.2.2-1.

Summary and comparison of main nutrients in plant-based analogue products and meat and poultry

An overview of the main nutrients in plant-based meat analogue products and meat products is given in Tables 3.2.2-1 (dinner products) and 3.2.2-2 (bread toppings).

Table 3.2.2-1. Contents of selected nutrients per 100 g in plant-based meat analogues and meat products. Data from www.matvaretabellen.no. RE: retinol equivalents; α–TE: α-tocopherol equivalents.

Macronutrients per 100 g	**Plant-based meat analogue products (burgers, minced, sausages, tofu, "bacon", meatball analogue)**	**Meat products, poultry (filet, burger, nuggets, and sausages)**	**Red meat products (burgers, minced meat, meatballs, snitzel/ steaklets)**
Fat (g)	10, range 2-16, 23% saturated, 51% mono-unsaturated,24% poly-unsaturated fat	13, 27% saturated, 49% mono-unsaturated, 18% poly-unsaturated fat	15, range 5-17, 40% saturated, 44% mono-unsaturated, 11% poly-unsaturated fat
Carbohydrates (g)	7, range 1-26, 83% starch	5*	3
Fibre (g)	5, range 0-7		
Protein (g)	13, range 5-19	18	17, range 11-21
Vitamins and minerals per 100 g			
Calcium (mg)	94, range 29-280	23	38, range 5-91
Folate (µg**)**	61, range 12-120	11	5
Iron (mg)	3, range 0.6-3.8	1	1
Selenium (µg)	6	10	6
Vitamin A (RE)	5, range 0-38	31, range 7-84	17, range 4-51
Vitamin B_{12} (µg)	0.02	0.6	1
Vitamin E (α-TE)	2		

*Mainly starch in products added flours.

Table 3.2.2-2. Contents of selected nutrients per 100 g in plant-based bread topping analogues for meat and meat bread toppings. Data from www.matvaretabellen.no. RE: retinol equivalents.

Macronutrients per 100 g	**Plant-based bread topping analogues (n=2)**	**Meat bread toppings***	**Plant-based paté bread topping analogues**	**Liver paté bread toppings****
Fat (g)	15, range 10-100% saturated fatty acids	16, 37% saturated fatty acids	17, 12% saturated fatty acids	17, 22% saturated fatty acids
Carbohydrates (g)	11	2	13	6
Fibre (g)	7	0	4	0.7
Protein (g)	8	16	5	10

Vitamins and minerals per 100 g	Not declared		Not declared	
Folate (μg)		4		242
Iron (mg)		1		6
Selenium (μg)		9		20
Vitamin A (RE)		6		3029
Vitamin B_{12} (μg)		1		7
Vitamin C (mg)		21		36

Range is given for nutrients with wide variation in concentrations for that food group. Values for plant-based bread topping and plant-based paté bread topping analogues were taken from online product declarations, if available. Nutrient data for meat and liver paté toppings were taken from the NFSA food composition table.
*Ham, chicken, salami.
**Both pork and chicken liver.

The main difference between the meat products and the plant-based analogue products, with regard to macronutrients, is the higher content of unsaturated fat, and the content of starch in the analogue products. Also, the protein contents in plant-based products are generally lower and do not have the same amino acid profile as the animal-based products. Meat-based products will, based on their main ingredient meat, have more favourable amino acid profiles, including all the essential amino acids in high enough concentrations for meat-based products to be good dietary sources of protein. The plant-based analogues will have more varying amino acid profiles, with very low levels of some essential amino acids, depending on the main ingredient/raw material, making them less beneficial dietary sources of protein. In addition, the plant-based meat analogues contain less of the B vitamins, except for folate which is higher in the analogues. Also, the plant-based analogues have, on average, less vitamin A, equal concentrations of iodine and higher concentrations of calcium, iron, and magnesium, than the traditional meat products. For the plant-based bread topping analogues nutrient concentration data are scarce and more data is warranted.

3.2.3 Gluten-free and gluten-containing products

Nutrients in flours without gluten

The nutrient concentrations of flours without gluten, based on data from the NFSA food composition table (Matvaretabellen.no, version 2022), are presented in Table 3.2.3-1.

Nutrients in flours with gluten

Cereals, the seeds (grains) of plants in the grass family, are sources of energy, carbohydrates, protein, fiber, vitamin E, folate, and iron in the Norwegian diet. Wheat is the most frequently used flour, but also spelt, oats, rye and barley are used. Spelt is an older sub-species of modern wheat. The grains are divided into three main parts, the endosperm, the germ, and the bran. The endosperm contains mainly starch and some storage protein (gluten). The germ contains vitamins, minerals, fat, and protein,

while the bran contains mostly fiber, some protein, and minerals. Rice and rice flour were not included in the present mapping. The included cereal flours were both white flour (mostly endosperm) and wholegrain flours, and the nutrient concentrations are presented in Table 3.2.3-1.

Summary and comparison of main nutrients in flour with and without gluten

An overview of the main nutrients in gluten-free and gluten-containing flour is given in Table 3.2.3-1.

Table 3.2.3-1. Contents of selected nutrients per 100 g in gluten-free and gluten-containing flour. Data from www.matvaretabellen.no. α–TE: α-tocopherol equivalents.

Macronutrients per 100 g	**Flours without gluten**	**Flours with gluten**
Carbohydrates (g)	79, 96% starch	56, 97% starch
Fat (g)	1.2	3
Fibre (g)	7, range 2-17	14, range 3-49
Protein (g)	3	12
Vitamins and minerals per 100 g		
Folate (µg)	20	39
Iron (mg)	3.9	3.6
Thiamine (mg)	0.2	0.4
Vitamin E (α-TE)		0.7
Zinc (mg)		2.6

The main differences between these two product groups are the lower content of protein and fiber in gluten-free flours as compared to the gluten-containing wholegrain flours. Gluten-free flours contain the same amount of iron, and less other micronutrients, as compared to wholegrain flours.

Nutrients in baking mixes with and without gluten

Baking mixes with and without gluten are based on gluten-containing and gluten-free flours, respectively, thus the nutrient content relies on the main ingredients. In the Norwegian food composition table (Matvaretabellen.no), there are three gluten-free flour mixes for cake, bread, and waffles, respectively. They show the same tendencies for low protein content and high content of starch as shown for the gluten-free flours. More nutritional data on this product group is warranted.

Nutrients in bread and crisp bread, gluten-free

The nutrient concentrations in gluten-free bread and crisp breads are presented in Table 3.2.3-2, based on data from the NFSA food composition table, which have three

entries of gluten-free crips breads and six entries of ready-made retail gluten-free breads, rolls, ciabatta, and baguettes.

Nutrients in bread and crisp bread with gluten

Bread and crisp bread are sources of energy, carbohydrates, protein, fiber, vitamin E, folate, and iron in the Norwegian diet. The wholegrain content of the product influences the concentration of all nutrients; more wholegrain results in more nutrients, except carbohydrates which are found in the germ of the seeds and constitute the main nutrient in white flour. Based on data from the NFSA food composition table, on average per 100 g, bread and crisp bread provides between 980 to 1537 kJ, approximately 9 to 12 g of protein, 3 to 10 g of total fat, 34 to 50 g of carbohydrates, of which 92 to 98% are starch. The nutrient contents in bread and crisp breads are presented in Table 3.2.3- 2. The fiber content varies from approximately 4 to 12 g per 100 g.

Summary and comparison of main nutrients in bread and crisp bread with and without gluten

An overview of the main nutrients in gluten-containing and gluten-free bread and crisp bread is given in Table 3.2.3-2.

Table 3.2.3-2. Contents of selected nutrients per 100 g gluten-free and gluten-containing bread and crisp bread. Data from www.matvaretabellen.no. White-bread: 0-25% wholegrain; Semi white bread, 26-50% wholegrain; Semi wholegrain bread, 51-75% wholegrain; Wholegrain bread, 76-100% wholegrain.

Macronutrients per 100 g	**Bread and crisp bread without gluten**			**Bread and crisp bread with gluten**				
	White bread	Dark bread	Crisp bread	White bread	Semi white bread	Semi wholegrain bread	Wholegrain bread	Crisp bread
Carbohydrates (g)	46, 83% starch	53, 87% starch	71, 95% starch	47, 98% starch	44, 97% starch	41, 95% starch	34, 92% starch	50, 94% starch
Fat (g)	4	2.5	6.7	4.6	3.1	3.4	4.1	10
Fibre (g)	6	6	11	3.7	5.5	5.9	7.5	11.2
Protein (g)	2.9	1	5.6	8.5	8.4	9.7	11.3	12
Vitamins and minerals per 100 g								
Folate (µg)	23	48	32	32	33	29	50	60
Iron (mg)	0.9	1.7	1.6		1.5	1.7	2.3	3.4
Thiamine (mg)	0.06	0.24	0.1	0.2	0.2	0.3	0.4	0.4

The main difference in nutrient intake between bread and crisp bread with and without gluten was the protein content which was lower in the gluten-free products. Wholegrain gluten-containing bread and crips bread also contained on average more folate, thiamine and iron, than the comparable gluten-free products.

Nutrients in breakfast cereals, with and without gluten

Based on the products presented in the NFSA food composition table, the nutrients in breakfast cereals, with and without gluten, are presented in Table 3.2.3-3.

Table 3.2.3-3. Contents of selected nutrients per 100 g gluten-free and gluten-containing breakfast cereals. Data from www.matvaretabellen.no.

Macronutrients per 100 g	Breakfast cereals without gluten	Breakfast cereals with gluten
Carbohydrates (g)	74, 87% starch, 13% mono-and disaccharides	70, 77% starch, 23% mono- and disaccharides
Fat (g)	1.5	5.0
Fibre (g)	8.5	7.7
Protein (g)	7.0	9.7
Vitamins and minerals per 100 g		
Folate (µg)	198	26
Iron (mg)	4.4	3.0
Thiamine (mg)	1.4	0.2

The main difference between gluten-containing and gluten-free breakfast cereals, on group level, based on the products in the NFSA food composition table, is the higher contents of fat and sugar (mono-and disaccharides) in the gluten-containing products and the higher contents of thiamine and folate in the gluten-free products.

Nutrients in pasta, gluten-free and gluten-containing

Dry pasta with and without gluten is quite similar both in macro- and micronutrient content, except for the protein content which is nearly halved in gluten-free pasta (Matvaretabellen.no).

3.2.4 Potato chips and nuts and plant-based snacks alternatives

Nutrients in plant-based snacks alternatives to potato chips and nuts

New plant-based snack alternatives were identified, and nutrient content was based on available nutrient values from online product declarations. The average nutrient concentrations of these products are presented in Table 3.2.4-1.

Nutrients in potato chips and nuts

Based on data from NFSA food composition table the nutrient concentrations of potato chips and nuts prepared as snacks, are presented in Table 3.2.4-1.

Table 3.2.4-1. Contents of selected nutrients per 100 g in new plant-based snacks alternatives to potato chips and nuts. Data from the Norwegian food composition table and online product declarations. α–TE: α-tocopherol equivalents.

Macronutrients per 100 g	**Plant-based snacks alternatives to potato chips**	**Snack beans**	**Potato chips**	**Nuts prepared as snack**
Carbohydrates (g)	58, range 46-73, mono-disaccharides: 7, range 1-19	43, range 37-60, mono-disaccharides: 4, range 3-5	54, range 50-63, mono-disaccharides: 0.6, range 0-1.5	6, range 7-72, mono-disaccharides: 6, range 3-8
Fat (g)	22, range 14-32	19, range 17-19	27, range 18-32	40, range 6-55
Fibre (g)	6, range 4-8	10, range 3-12	7, range 3-14	8, range 4-11
Protein (g)	8, range 2-18	22, range 13-25	5, range 4-8	20, range 9-29
Vitamins and minerals per 100 g	Not declared	Not declared		
Folate (µg)			39	60
Calcium (mg)			17.5	47
Iron (mg)			1.3	2.5
Niacin (mg)			4.0	8.0
Vitamin C (mg)			14.5	1
Vitamin E (α-TE)			4.8	3.5

Nuts are nutrient dense foods, and sources of unsaturated fat, protein, vitamins, and minerals, which is reflected in the nutrient concentrations of nuts prepared as snacks. The main ingredients in the new plant-based snack alternatives are legumes such as beans, lentils, and peas. This will give rise to high protein and fiber content in these products. The micronutrient concentrations of the new plant-based snacks alternatives were not available, thus more information on this is warranted. We speculate that the micronutrient contents of these products will be the result of which main ingredients are used and any effect on these from processing.

3.3 Food additives

3.3.1 Food additives in the selected food products

The food additives used in the selected food products were identified using the ingredient lists on the webpages of Norwegian grocery stores. In total, the selected food products contained 97 different food additives. An overview of the number of food additives in the different additive categories is shown in Table 3.3.1-1. Emulsifiers, stabilisers, and thickeners (ESTs) was the most frequently used additive category. An overview of all food additives (the E numbers) identified in the ingredient lists of the selected food products is shown in Section 6, Appendix I. An overview of

the names of the different food additives is available in the report "Class names and the international numbering system for food additives" (Codex Alimentarius, 2021).

When the ingredient lists of food products contained the terms "antioxidant", "enzyme", or "modified starch", it was not possible to identify the specific food additive, and these are therefore not included in the mapping. Food additives with E numbers ranging from 300-399 are antioxidants. There are two enzymes that can be used as food additives, E 1103, and E 1105. Modified starch includes the food additives E 1404, E 1410, E 1412, E 1413, E 1414, E 1420, E 1422, E 1440, E 1442, E 1450, and E 1451.

Table 3.3.1-1. Food additive categories and number of food additives within a category that are used in the selected food products.

Food additive category	Number of food additives
Emulsifiers, stabilisers, thickeners (ESTs)	25
Antioxidants	18
Preservatives	12
Anti-caking agents and acidity regulators	11
Food colours	9
Sweeteners	8
Other	8
Flavour enhancers	4
Packaging gases	2

3.3.2 Concentration data for the food additives

No concentration data were identified through the searches of the webpages of relevant national and international institutions. VKM did not receive any concentration data for food additives in response to the call for data (Section 2.3.2).

3.3.3 Comparison of food additives

VKM was not able to compare the amount of food additives in the selected food products, as no concentration data were identified. The comparisons were therefore restricted to the number and type of food additives used in the selected products.

3.3.3.1 Comparison of food additives in plant-based meat analogues and meat products

The plant-based meat analogues contained 37 different food additives and the meat products contained 31 different food additives (Figure 3.3.3.1-1). The most widely used food additive category in plant-based meat analogue products was ESTs (11 different). The most widely used food additive category in meat products was antioxidants (11 different).

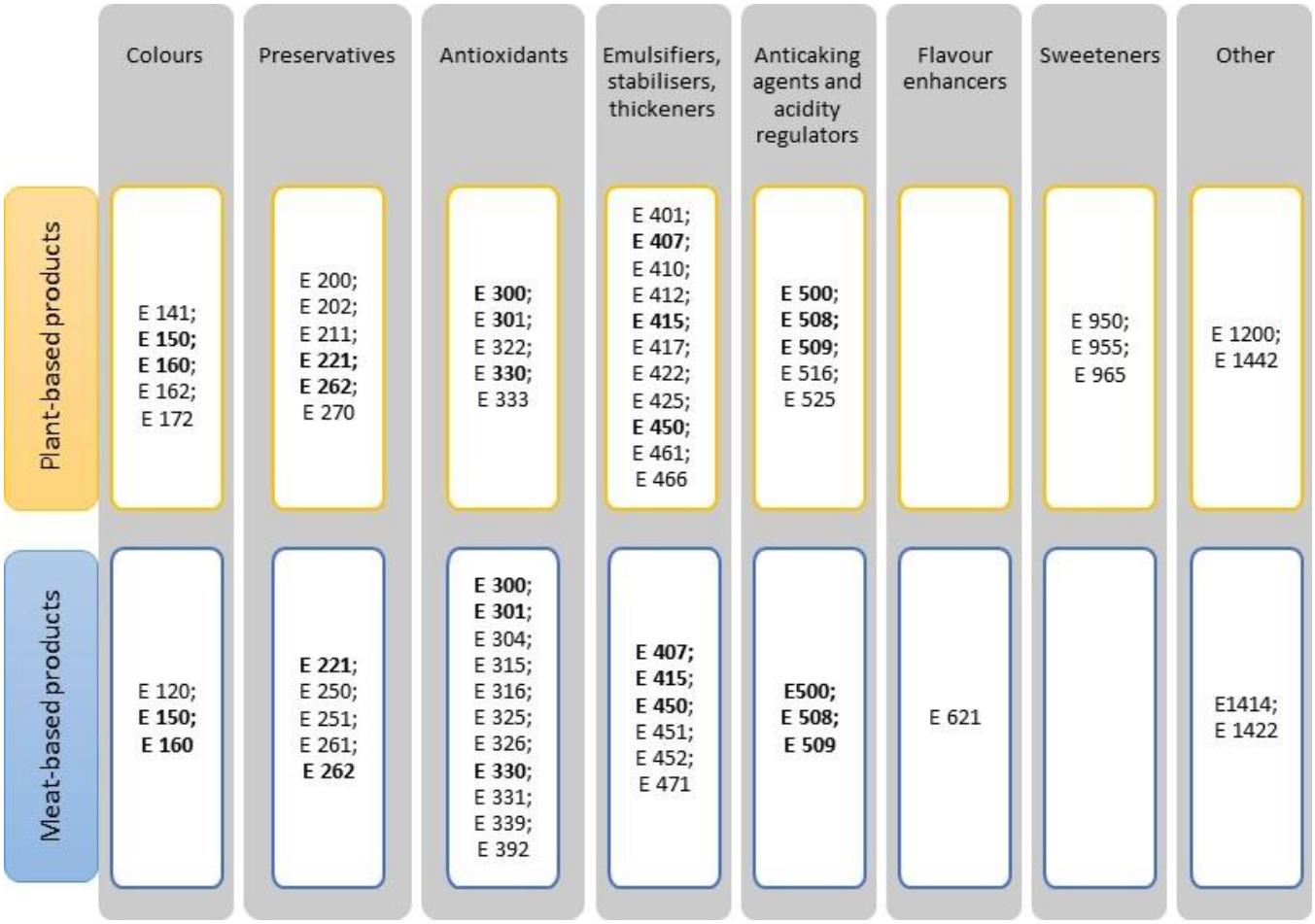


Figure 3.3.3.1-1. Food additives represented by E numbers in plant-based analogue products (top row) and the meat counterpart products (bottom row). Additives present in both plant-based and meat-based food products are marked in bold fonts.

The maximum number of food additives in a single product was found in meat burgers and plant-based sausages (Table 3.3.3.1-1). The number of food additives in a single product ranged from zero to 10.

An overview of the food additives identified in the different products is illustrated in an UpSet plot (Figure 3.3.3.1-2). Meat sausages and plant-based bread toppings contained the highest number of different food additives (Figure 3.3.3.1-2, bars to the left).

The number of food additives within the different food additive categories for the included food types is presented in Figure 3.3.3.1-3. The E numbers for all food additives in the plant-based meat analogues and the meat products are shown in Tables 3.3.3.1-2 and 3.3.3.1-3, respectively. The food additive identified in the maximum number of product types (seven) was E 450. The food additives E 1422 and E 525 were identified in minced meat and plant-based schnitzel, respectively (Figure 3.3.3.1-2, Table 3.3.3.1-2 and 3.3.3.1-3). A set of four food additives were identified in plant-based bread toppings and plant-based sausages (E 172, E 425, E 401, and E 410), and a different set of four additives was shared between meat sausages and meat-based bread toppings (E 120, E 315, E 325, and E 392). Fourteen additives were

found exclusively in plant-based bread toppings (E 141, E 200, E 202, E 211, E 270, E 307, E 333, E 417, E 422, E 950, E 955, E 965, E 1200, and E 1442).

Table 3.3.3.1-1. The number of products, and minimum (min) and maximum (max) number of food additives within each product type. *Number of products lacking information on food additives.

Product type	Plant-based products			Meat products		
	Number of products	Number of food additives		Number of products	Number of food additives	
		Min	Max		Min (n)	Max (n)
Bread toppings	16	2	7	23	2	7
Burger	10 (1*)	1	4	18	0	10
Balls	6	0	4	1	0	0
Minced and pulled	12 (1*)	0	4	5	0	9
Sausages	6	2	10	28	0	8
Schnitzel	1	4	4	1	4	4

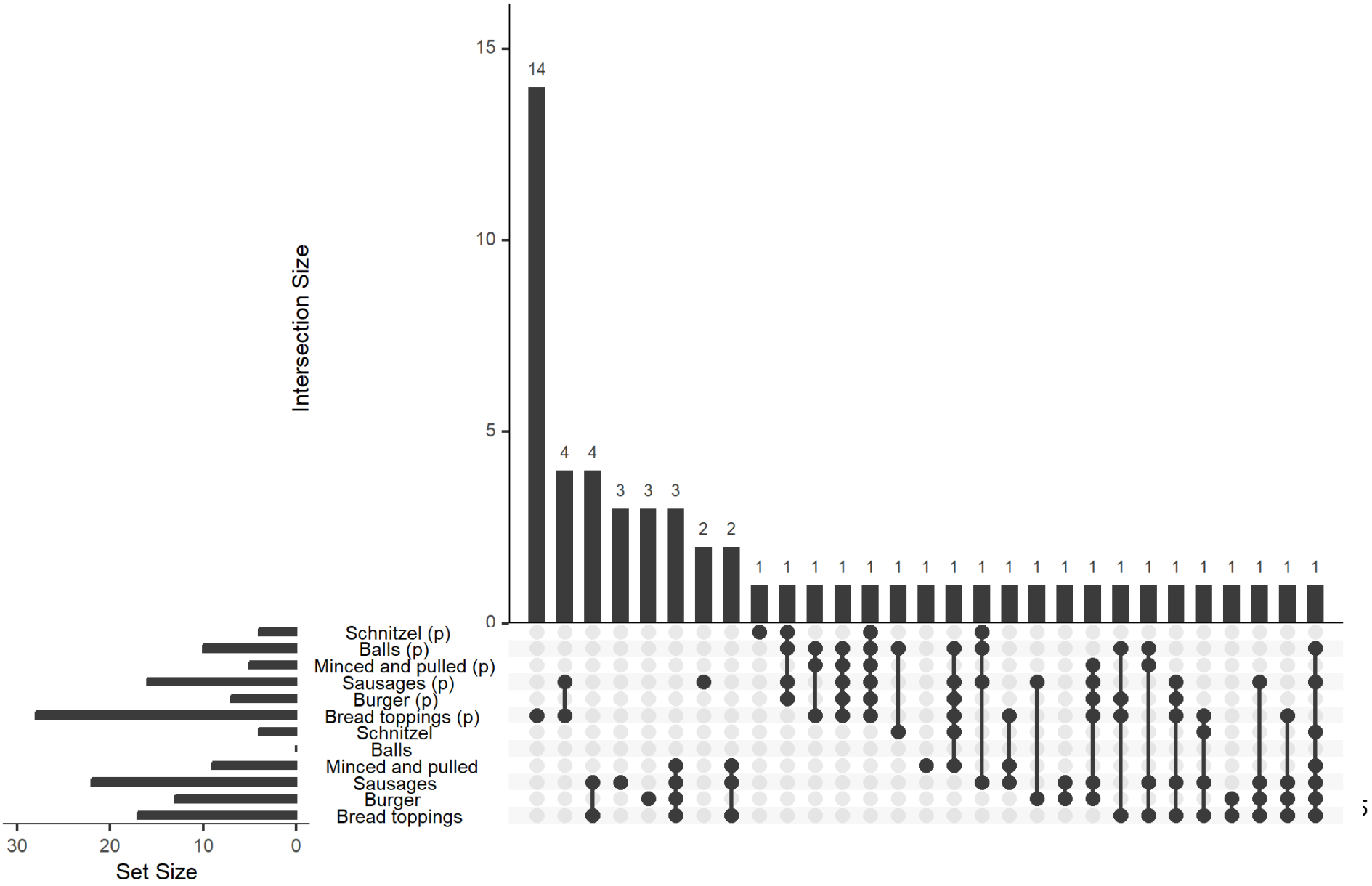

Intersection Size
15
10
5
0
14
4 4
3 3 3
2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Schnitzel (p)
Balls (p)
Minced and pulled (p)
Sausages (p)
Burger (p)
Bread toppings (p)
Schnitzel
Balls
Minced and pulled
Sausages
Burger
Bread toppings
30
20
10
0
Set Size

Figure 3.3.3.1-2. The number of different food additives identified in products within the different product types plant-based analogues vs meat-based products ((p): plant-based products). "Set size" shows the total number of different food additives found in products within each product type. E.g. for plant-based schnitzel (Schnitzel (p)), the total number is four. Black dots show the product type for which a food additive has been identified. When the same food additive was identified in more than one product type, lines join the dots. "Intersection size" represents the number of food additives that were present in the products marked by the dot(s) below the bar. E.g. for plant-based schnitzel (Schnitzel (p)), the first dot shows a food additive unique for plant-based schnitzel. The second dot shows a food additive which is present in plant-based schnitzels, plant-based balls, plant-based sausages, and plant-based burgers. The third dot shows a food additive present in all the plant-based product types, etc. The numbers on the top of each bar of the interaction size indicates the number of food additives corresponding to each dot or group of dots joined by lines. E.g., the number 4 on top of the third bar from the left indicates that four food additives were identified in sausages and bread toppings.

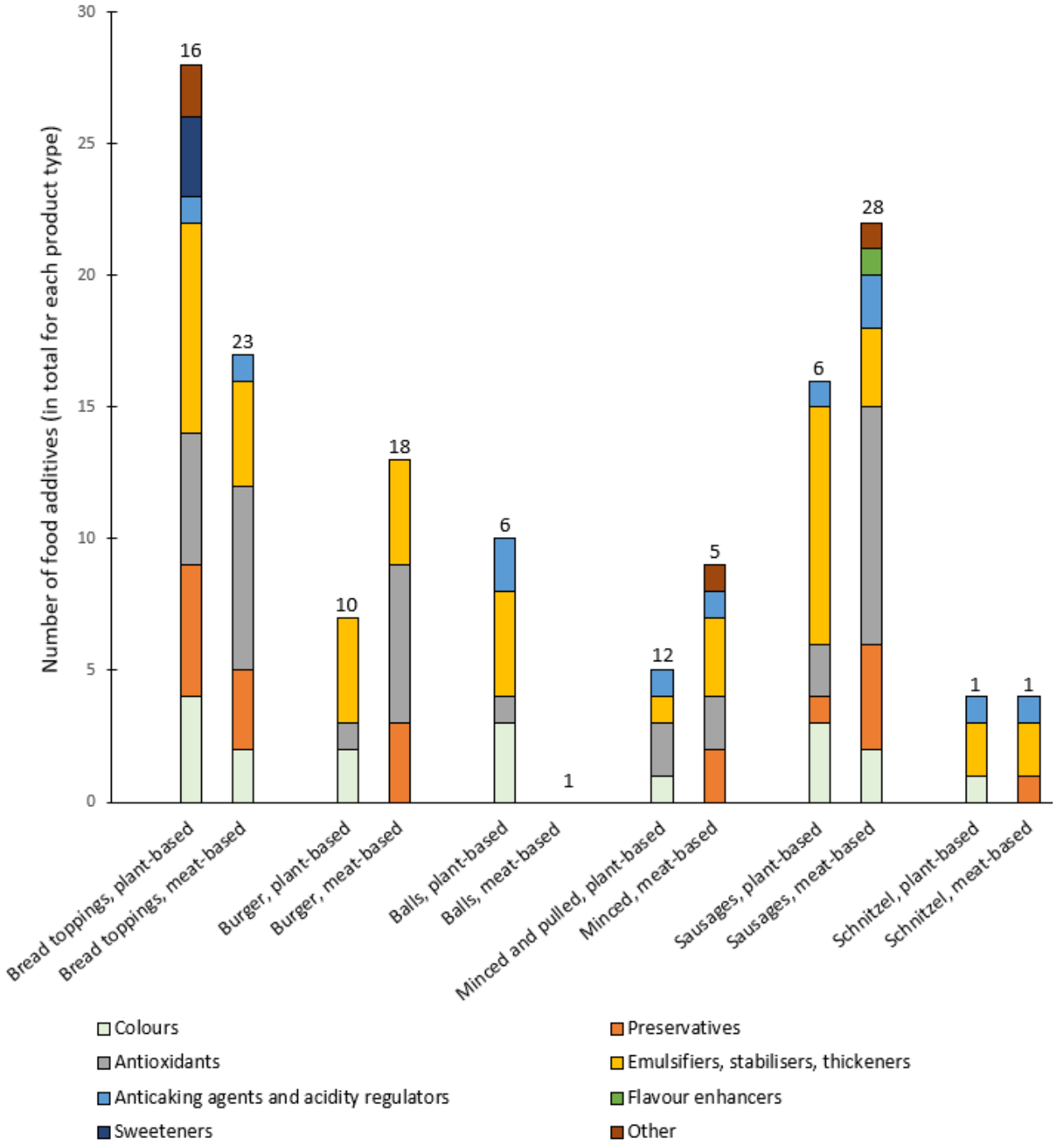


Figure 3.3.3.1-3. The number of food additives within different food additive categories for the included product types. The number of products identified for each product type is shown on top of the bars.

Table 3.3.3.1-2. Percentage of plant-based meat analogue products containing a specific E number. Sample sizes are shown in Table 3.3.3.1-1.

Food additive categories, E numbers, and name of substance	**Plant-based meat analogue products**					
	Burger	Sausages	Minced and pulled	Balls	Schnitzel	Bread toppings

Food colours						
141 Copper complexes of chlorophyll and chlorophyllins	0	0	0	0	0	6
150 Caramel colours	40	0	0	17	0	19
160 Carotenoids	0	67	0	17	100	0
162 Beetroot red	10	17	8	33	0	31
172 Iron oxides	0	50	0	0	0	19
Preservatives						
200 Sorbic acid	0	0	0	0	0	6
202 Potassium sorbate	0	0	0	0	0	25
211 Sodium benzoate	0	0	0	0	0	19
221 Sodium sulphite	0	17	0	0	0	0
262 Sodium acetate	0	0	0	0	0	13
270 Lactic acid	0	0	0	0	0	6
Antioxidants						
300 Ascorbic acid	0	0	0	0	0	13
301 Sodium ascorbate	0	17	0	0	0	0
307 Alpha-tocopherol	0	0	0	0	0	6
322 Lecithin	0	0	8	17	0	6
330 Citric acid	30	17	8	0	0	44
333 Calcium citrate	0	0	0	0	0	19
Emulsifiers, stabilisers, and thickeners						
401 Sodium alginate	0	17	0	0	0	6
407 Carrageenan	30	67	0	0	0	63
410 Locust bean gum	0	17	0	0	0	44
412 Guar gum	20	33	0	17	100	0
415 Xanthan gum	20	33	0	17	0	19
417 Tara gum	0	0	0	0	0	6
422 Glycerol	0	0	0	0	0	6

425 Konjac	0	33	0	0	0	13
450 Diphosphates	0	17	0	17	0	0
461 Methyl cellulose	60	83	17	67	100	6
466 Sodium carboxy methyl cellulose	0	17	0	0	0	0
Anti-caking agents and acidity regulators						
500 Sodium bicarbonate	0	0	0	33	0	0
508 Potassium chloride	0	0	8	17	0	0
509 Calcium chloride	0	0	0	0	0	6
516 Calcium sulfate	0	17	0	0	0	0
525 Potassium hydroxide	0	0	0	0	100	0
Sweeteners						
950 Acesulfame potassium	0	0	0	0	0	6
955 Sucralose	0	0	0	0	0	6
965 Maltitol	0	0	0	0	0	6
Other						
1200 Polydextrose	0	0	0	0	0	6
1442 Hydroxypropyl distarch phosphate	0	0	0	0	0	6

Table 3.3.3.1-3. Percentage of meat products containing a specific E number. Sample sizes are shown in Table 3.3.3.1-1.

Food additive categories, E numbers, and name of substance	**Meat products**					
	Burger	Sausages	Minced	Balls	Schnitzel	Bread toppings
Food colours						
120 Carmine	0	4	0	0	0	13
150 Caramel colours	0	0	0	0	0	9
160 Carotenoids	0	4	0	0	0	0
Preservatives						
221 Sodium sulphite	22	0	0	0	0	0

250 Sodium nitrite	6	79	20	0	0	96
251 Sodium nitrate	0	7	0	0	0	0
261 Potassium acetate	11	43	20	0	0	65
262 Sodium acetate	0	25	0	0	100	4
Antioxidants						
300 Ascorbic acid	28	29	0	0	0	13
301 Sodium ascorbate	6	11	0	0	0	48
304 Ascorbyl palmitate	22	0	0	0	0	0
315 Erythorbic acid	0	32	0	0	0	4
316 Sodium erythorbate	0	4	20	0	0	35
325 Sodium lactate	0	18	0	0	0	4
326 Potassium lactate	0	46	20	0	0	74
330 Citric acid	17	7	0	0	0	0
331 Sodium citrates	6	4	0	0	0	0
339 Sodium phosphate	6	0	0	0	0	0
392 Extracts of rosemary	0	4	0	0	0	4
Emulsifiers, stabilisers, and thickeners						
407 Carrageenan	0	4	0	0	0	17
415 Xanthan gum	0	0	20	0	100	0
450 Diphosphates	22	46	20	0	100	70
451 Potassium and sodium tri-phosphates	6	75	20	0	0	74
452 Polyphosphates	11	0	0	0	0	4
471 Mono-and Diglycerides of Fatty Acids	22	0	0	0	0	0
Anti-caking agents and acidity regulators						
500 Sodium bicarbonate	0	0	0	0	100	0
508 Potassium chloride	0	11	0	0	0	22
509 Calcium chloride	0	11	20	0	0	0
Flavour enhancers						
621 Monosodium glutamate	0	7	0	0	0	0

Other						
1414 Acetylated distarch phosphate	0	7	0	0	0	0
1422 Hydroxypropyl distarch phosphate	0	0	20	0	0	0

3.3.3.2 Comparing food additives in plant-based dairy analogues and dairy products

The dairy analogues and the dairy products contained 44 different food additives (Figure 3.3.3.2-1). ESTs was the most widely used food additive category (19 different food additives).

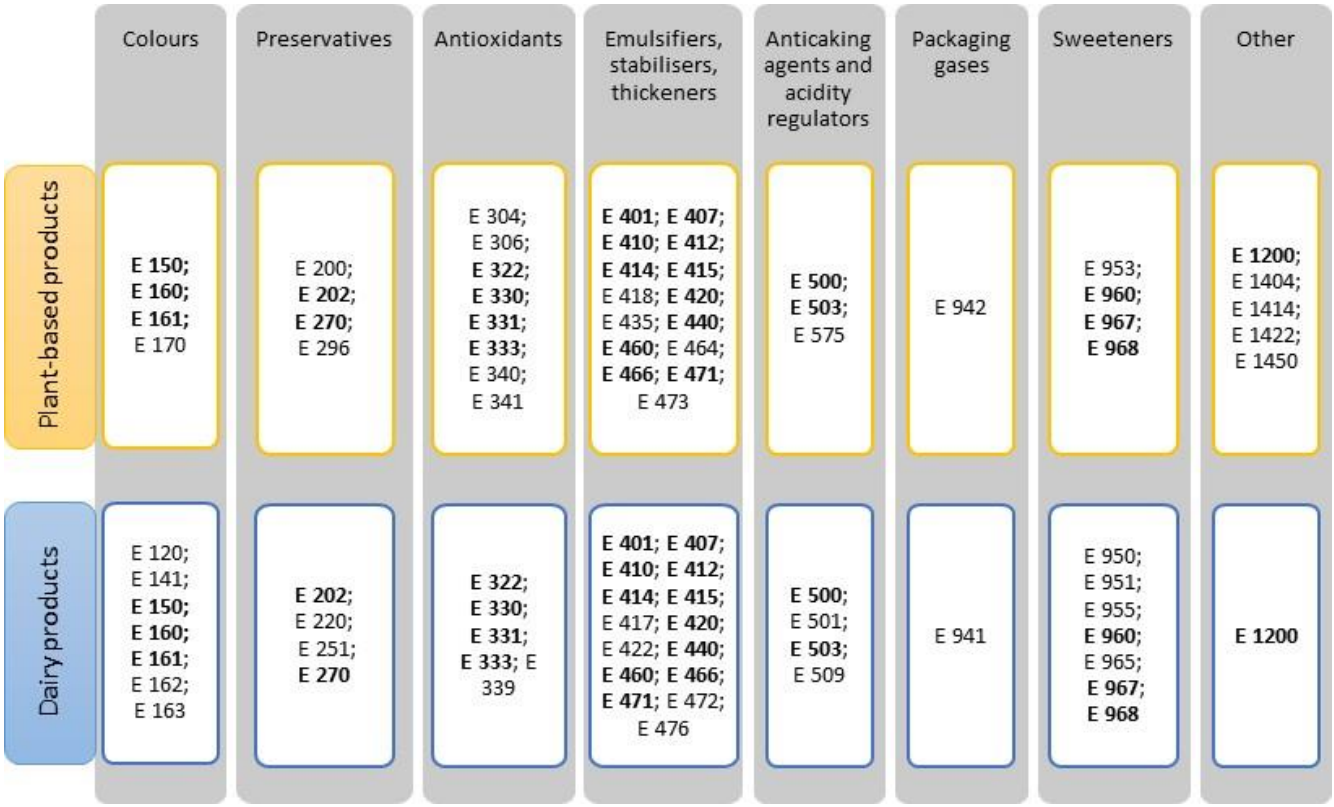


Figure 3.3.3.2-1. Food additives represented by E numbers in plant-based analogue product (top row) and the counterpart dairy products (bottom row). Additives present in both plant-based and dairy products are marked in bold fonts.

The maximum number of food additives per product were found in dairy-based ice cream and plant-based ice cream (Table 3.3.3.2-1). The number of food additives in a single product ranged from zero to 10 for the plant-based dairy analogues, and zero to 12 for the dairy products.

An overview of the food additives identified in the different products is illustrated in an UpSet plot (Figure 3.3.3.2-2). Among the dairy analogue products, plant-based ice cream and plant-based cheese contained the highest number of different food additives, whereas among the dairy products, the highest number of different food additives were identified in ice cream (Figure 3.3.3.2-2, bars to the left).

The number of food additives within the different food additive categories for the included food types is presented in Figure 3.3.3.2-3. The E numbers for all food additives in the plant-based dairy analogue products and the dairy products are shown in Tables 3.3.3.2-2 and 3.3.3.2-3, respectively. Whereas E 160 was the food additive identified in the maximum number of product types (7), E 941 was identified only in butter (Figure 3.3.3.2-2, Table 3.3.3.2-2 and Table 3.3.3.2-3).

In addition, Figure 3.3.3.2-2, Table 3.3.3.2-2 and Table 3.3.3.2-3 show that sets of eight food additives were used exclusively in plant-based "cheese" (E 200, E 435, E 464, E 575, E 942, E 1404, E 1414, and E 1450) and plant-based ice cream (E 162, E 163, E 417, E 422, E 472, E 501, E 955, and E 965). Another set of eight food additives were used exclusively in ice creams and ice cream analogues (E 150, E 401, E 460, E 466, E 500, E 503, E 967, and E 968).

Table 3.3.3.2-1. The number of products, and minimum (min) and maximum (max) number of food additives within each product type. *Number of products lacking information on food additives.

Product type	**Plant-based products**			**Product type**	**Meat products**		
	Number of products	Number of food additives			Number of products	Number of food additives	
		Min	Max			Min (n)	Max (n)
"Butter"	1	1	1	Butter	18 (1*)	0	6
"Cheese"	15	1	8	Cheese	15	0	7
"Ice cream"	8	0	10	Ice cream	19	4	12
Beverages	23	0	5	Milk	16	0	4
"Yoghurt"	18	2	7	Yoghurt	28	0	7

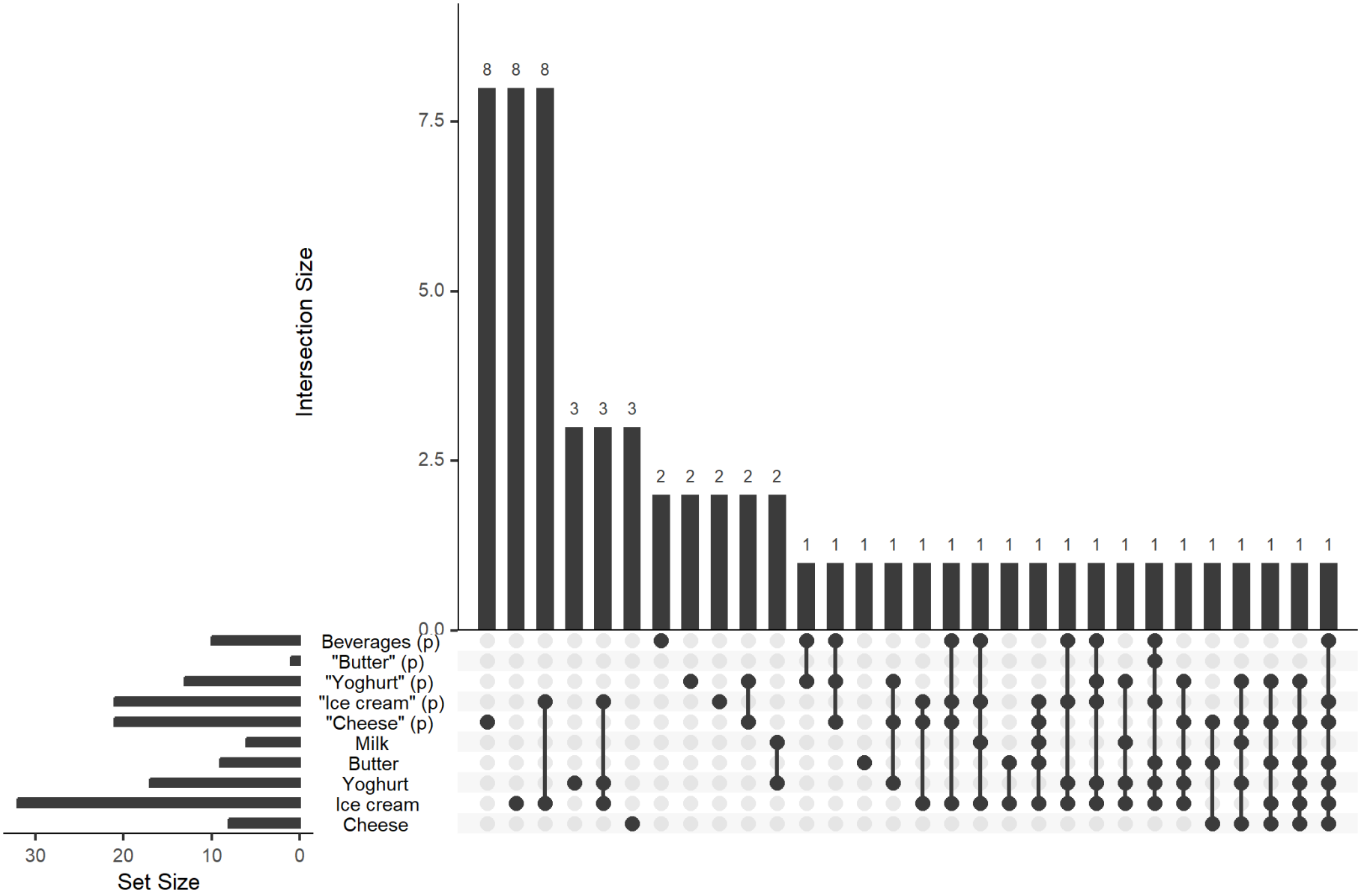

Intersection Size
7.5
5.0
2.5
0.0
8 8 8
3 3 3
2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Beverages (p)
"Butter" (p)
"Yoghurt" (p)
"Ice cream" (p)
"Cheese" (p)
Milk
Butter
Yoghurt
Ice cream
Cheese
30
20
10
0
Set Size

Figure 3.3.3.2-2. The number of different food additives identified in products within the different product types ((p): plant-based analogue product). "Set size" shows the total number of different food additives found in products within each product type. E.g. for plant-based beverages (Beverages (p)), the total number of different food additives is ten. Black dots show the product type where a food additive has been identified. When the same food additive was identified in more than one product type, lines join two or more dots. "Intersection size" represents the number of food additives that were present in the products marked by the dot(s) below the bar. E.g. for plant-based beverages (Beverages (p)), the first dot shows two food additives unique for plant-based beverages. The second dot for plant-based beverages shows that one food additive is present in plant-based beverages and plant-based yoghurt. The third dot shows one food additive that is present in plant-based beverages, plant-based yoghurt, and plant-based cheese. The fourth dot shows one food additive that is present in plant-based beverages, plant-based ice cream, plant-based cheese, and dairy-based ice cream, and so on. The numbers over each bar for interaction size indicate the number of food additives corresponding to each dot or group of dots joined by lines. E.g., the number "8" on top of the third bar from the left indicates that eight food additives were identified in ice cream and plant-based "ice cream".

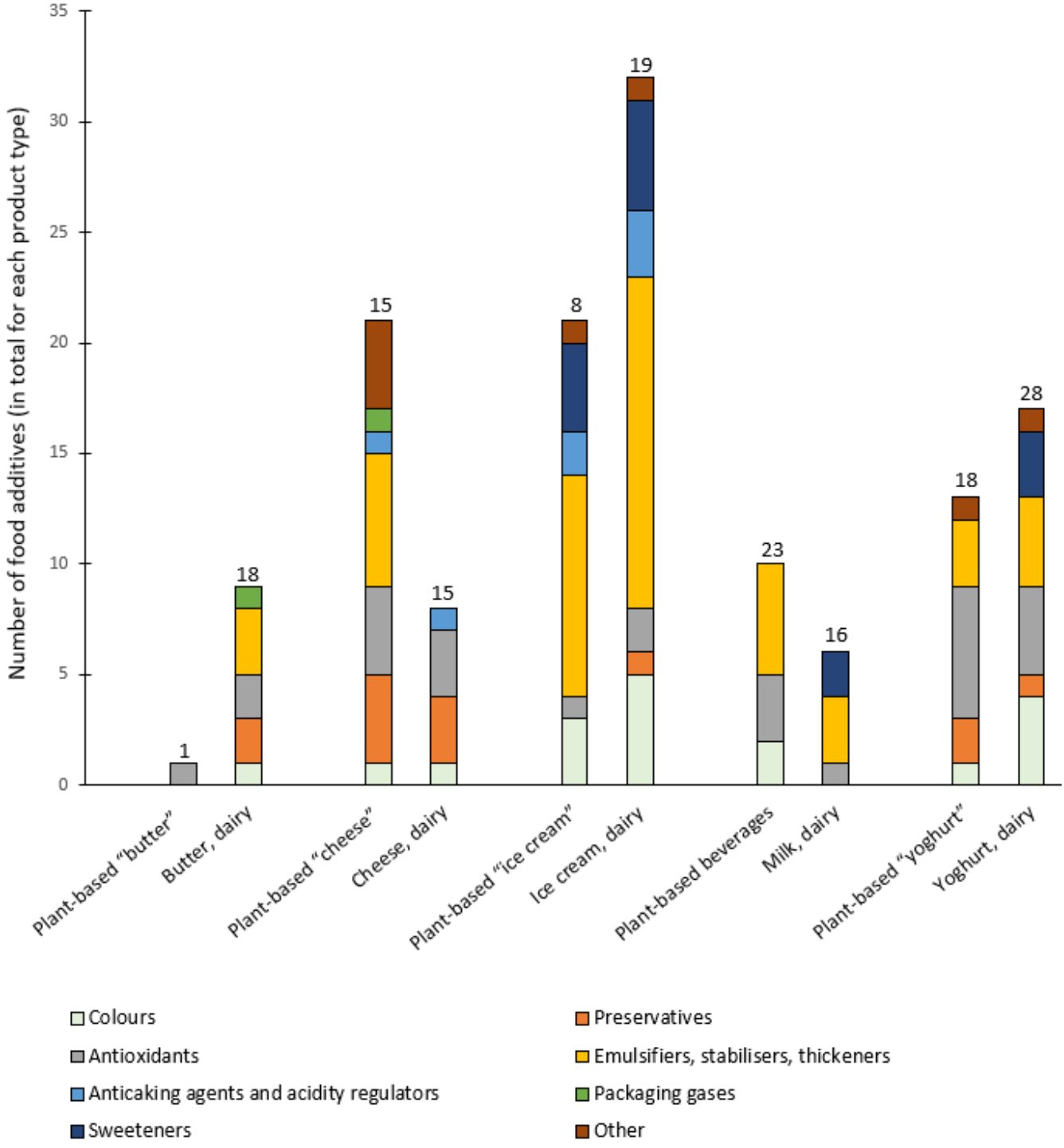


Figure 3.3.3.2-3. The number of food additives within different food additive categories for the included product types. The number of products identified for each product type is shown on top of the bars.

Table 3.3.3.2-2. Percentage of plant-based dairy analogue product containing a specific E number. Sample sizes are shown in Table 3.3.3.2-1.

Food additive categories, E numbers, and name of substance	Plant-based dairy analogue products				
	"Cheese"	"Ice cream"	"Yoghurt"	"Butter"	Beverages
Food colours					
150 Caramel colours	0	38	0	0	0
160 Carotenoids	67	13	0	0	6
161 Xanthophylls	0	13	0	0	0
170 Calcium carbonate	0	0	9	0	61
Preservatives					
200 Sorbic acid	7	0	0	0	0
202 Potassium sorbate	47	0	0	0	0
270 Lactic acid	7	0	9	0	0
296 Malic acid	7	0	9	0	0
Antioxidants					
304 Ascorbyl palmitate	0	0	39	0	0
306 Tocopherol	0	0	39	0	0
322 Lecithin	0	25	0	100	37
330 Citric acid	53	0	39	0	0
331 Sodium citrates	7	0	39	0	0
333 Calcium citrate	27	0	35	0	0
340 Potassium phosphate	0	0	0	0	61
341 Calcium phosphate	20	0	13	0	44
Emulsifiers, stabilisers, and thickeners					
401 Sodium alginate	0	25	0	0	0
407 Carrageenan	0	38	0	0	11
410 Locust bean gum	0	88	0	0	11
412 Guar gum	0	75	9	0	22
414 Acacia gum	0	0	9	0	0
415 Xanthan gum	23	13	0	0	177
418 Gellan gum	0	0	0	0	67
420 Sorbitol	13	13	0	0	0

435 Polyoxyethylene sorbitan monostearate	13	0	0	0	0
440 Pectins	7	0	74	0	0
460 Cellulose	0	13	0	0	0
464 Hydroxypropylmethylcellulose	13	0	0	0	0
466 Sodium carboxy methyl cellulose	0	13	0	0	0
471 Mono-and Diglycerides of Fatty Acids	13	88	0	0	0
473 Sucrose esters of fatty acids	0	25	0	0	0
Anti-caking agents and acidity regulators					
500 Sodium bicarbonate	0	25	0	0	0
503 Ammonium carbonate	0	13	0	0	0
575 Glucono delta lactone	7	0	0	0	0
Packaging gases					
942 Nitrous oxide	13	0	0	0	0
Sweeteners					
953 Isomalt	0	13	0	0	0
960 Steviol glycosides	0	13	0	0	0
967 Xylitol	0	13	0	0	0
968 Erythritol	0	13	0	0	0
Other					
1200 Polydextrose	0	13	0	0	0
1404 Oxidised starch	33	0	0	0	0
1414 Acetylated distarch phosphate	7	0	0	0	0
1422 Acetylated distarch adipate	47	0	22	0	0
1450 Starch sodium octenyl succinate	47	0	0	0	0

Table 3.3.3.2-3. Percentage of dairy product containing a specific E number. Sample sizes are shown in Table 3.3.3.2-1.

Food additive categories, E numbers, and name of substance	**Dairy products**				
	Cheese	Ice cream	Yoghurt	Butter	Milk
Food colours					
120 Carmine	0	0	4	0	0

141 Copper complexes of chlorophyll and chlorophyllins	0	0	4	0	0
150 Caramel colours	0	37	0	0	0
160 Carotenoids	47	74	4	50	0
161 Xanthophylls	0	5	4	0	0
162 Beetroot red	0	11	0	0	0
163 Anthocyanins	0	5	0	0	0
Preservatives					
202 Potassium sorbate	13	0	0	33	0
220 Sulphur dioxide	0	0	4	0	0
251 Sodium nitrate	40	0	0	0	0
270 Lactic acid	13	5	0	17	0
Antioxidants					
322 Lecithin	0	53	11	50	0
330 Citric acid	7	11	14	11	0
331 Sodium citrates	20	0	4	0	6
333 Calcium citrate	0	0	4	0	0
339 Sodium phosphate	13	0	0	0	0
Emulsifiers, stabilisers, and thickeners					
401 Sodium alginate	0	5	0	0	0
407 Carrageenan	0	89	0	0	19
410 Locust bean gum	0	21	4	0	0
412 Guar gum	0	89	4	0	0
414 Acacia gum	0	5	4	0	6
415 Xanthan gum	0	11	0	0	0
417 Tara gum	0	5	0	0	0
420 Sorbitol	0	5	0	0	0
422 Glycerol	0	5	0	0	0
440 Pectins	0	26	7	11	0
460 Cellulose	0	11	0	0	0

466 Sodium carboxy methyl cellulose	0	79	0	0	0
471 Mono-and Diglycerides of Fatty Acids	0	95	0	50	6
472 Acetic acid esters	0	5	0	0	0
476 Polyglycerol polyricinoleate	0	16	0	6	0
Anti-caking agents and acidity regulators					
500 Sodium bicarbonate	0	26	0	0	0
501 Potassium carbonates	0	5	0	0	0
503 Ammonium carbonate	0	11	0	0	0
509 Calcium chloride	40	0	0	0	0
Packaging gases					
941 Nitrogen	0	0	0	6	0
Sweeteners					
950 Acesulfame potassium	0	0	14	0	6
951 Aspartame	0	0	14	0	6
955 Sucralose	0	16	0	0	0
960 Steviol glycosides	0	5	4	0	0
965 Maltitol	0	16	0	0	0
967 Xylitol	0	11	0	0	0
968 Erythritol	0	21	0	0	0
Other					
1200 Polydextrose	0	16	4	0	0

3.3.3.3 Comparing food additives in gluten-free and gluten-containing products

The gluten-free products contained 26 different food additives, and the gluten-containing products contained 19 different food additives (Figure 3.3.3.3-1). ESTs (11 different food additives) represented the most frequently used food additive category in gluten-free food products, whereas antioxidants (seven different food additives) represented the most frequently used food additive category in gluten-containing products.

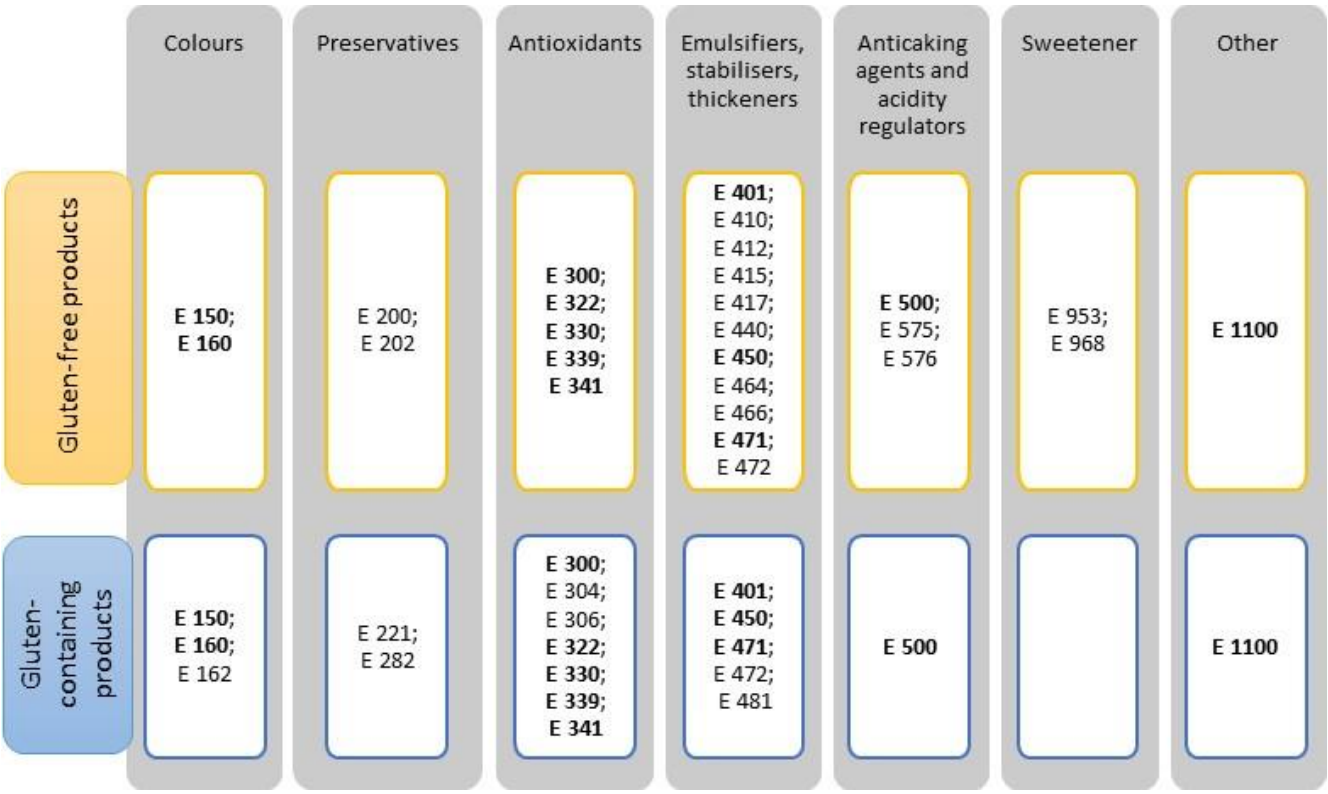


Figure 3.3.3.3-1. Food additives represented by E numbers in gluten-free (top row) and counterpart gluten-containing products (bottom row). Additives present in both gluten-free and gluten-containing products are marked in bold.

The maximum number of food additives per product was found in bread and crisp bread for both gluten-containing and gluten-free products (Table 3.3.3.2-1). The number of food additives in a single product ranged from zero to six for the gluten-free products and zero to eight for gluten-containing products.

An overview of the food additives identified in the different products is illustrated in an UpSet plot (Figure 3.3.3.3-2). Baking mixtures were the gluten-free product type containing the highest number of different food additives (16). Bread and crisp bread were the gluten-containing product type containing the highest number of different food additives (12) (Figure 3.3.3.3-2, bars to the left).

The number of food additives within the different food additive categories for the included food types is presented in Figure 3.3.3.3-3. The E numbers for all food additives in the gluten-free and counterpart gluten-containing products are shown in (Tables 3.3.3.3-2 and 3.3.3.3-3). Whereas E 300 was the food additive identified in the maximum number of product types (5), E 417 was found only in gluten-containing flour (Figure 3.3.3.2-2, Table 3.3.3.3-2 and 3.3.3.3-3).

Table 3.3.3.3-1. The number of products, and minimum (min) and maximum (max) number of food additives within each product type. *Number of products lacking information on food additives.

Product type	Gluten-free products	Gluten-containing products

	Number of products	Number of food additives		Number of products	Number of food additives	
		Min (n)	Max (n)		Min (n)	Max (n)
Baking mixtures	24	0	5	15	0	3
Bread and crisp bread	19	0	6	49 (6*)	0	8
Breakfast cereals	1	0	0	25	0	4
Flour and grains	8	0	4	19 (2*)	0	1
Pasta	8	0	2	23	0	0

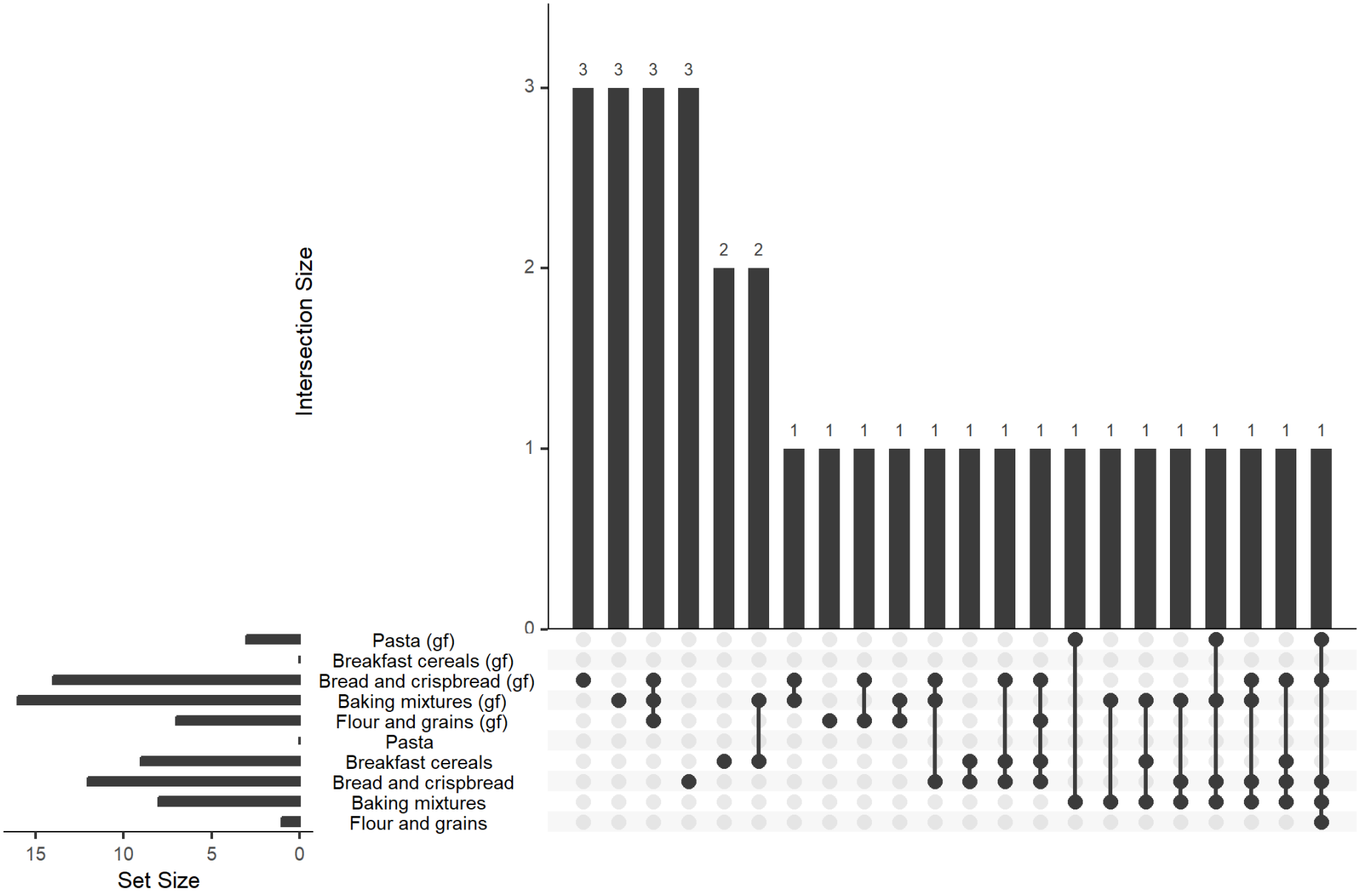

Intersection Size
3
2
1
0
3 3 3 3 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Pasta (gf)
Breakfast cereals (gf)
Bread and crispbread (gf)
Baking mixtures (gf)
Flour and grains (gf)
Pasta
Breakfast cereals
Bread and crispbread
Baking mixtures
Flour and grains
15
10
5
0
Set Size

Figure 3.3.3.3-2. The number of different food additives identified in products within the different product types ((gf): gluten-free). "Set size" shows the total number of different food additives found in products within each product type. E.g. for gluten-free pasta (Pasta (gf)), the total number of different food additives in these products is three. Black dots show the product type where a food additive has been identified. When the same food additive was identified in more than one product type, this is shown by the lines joining two or more dots. "Intersection size" represents the number of food additives that were present in the products marked by the dot(s) below the bar. E.g. for gluten-free pasta (Pasta (gf)), the first dot shows one food additive which is present in gluten-free pasta and gluten-containing baking mixtures. The second dot shows one food additive that is present in gluten-free pasta, gluten-free baking mixtures, gluten-containing bread, and gluten-containing baking mixtures. The third dot shows one food additive that is present in gluten-free pasta, gluten-free bread, gluten-containing bread, gluten-containing baking mixtures, and gluten-containing flour. The numbers on the top of each bar for interaction size indicates the number of food additives corresponding to each dot or group of dots joined by lines. E.g., the number (3) on top of the third bar from the left indicates that three food additives were identified in gluten-free bread and crisp bread, gluten-free baking mixtures, and gluten-free flour and grains.

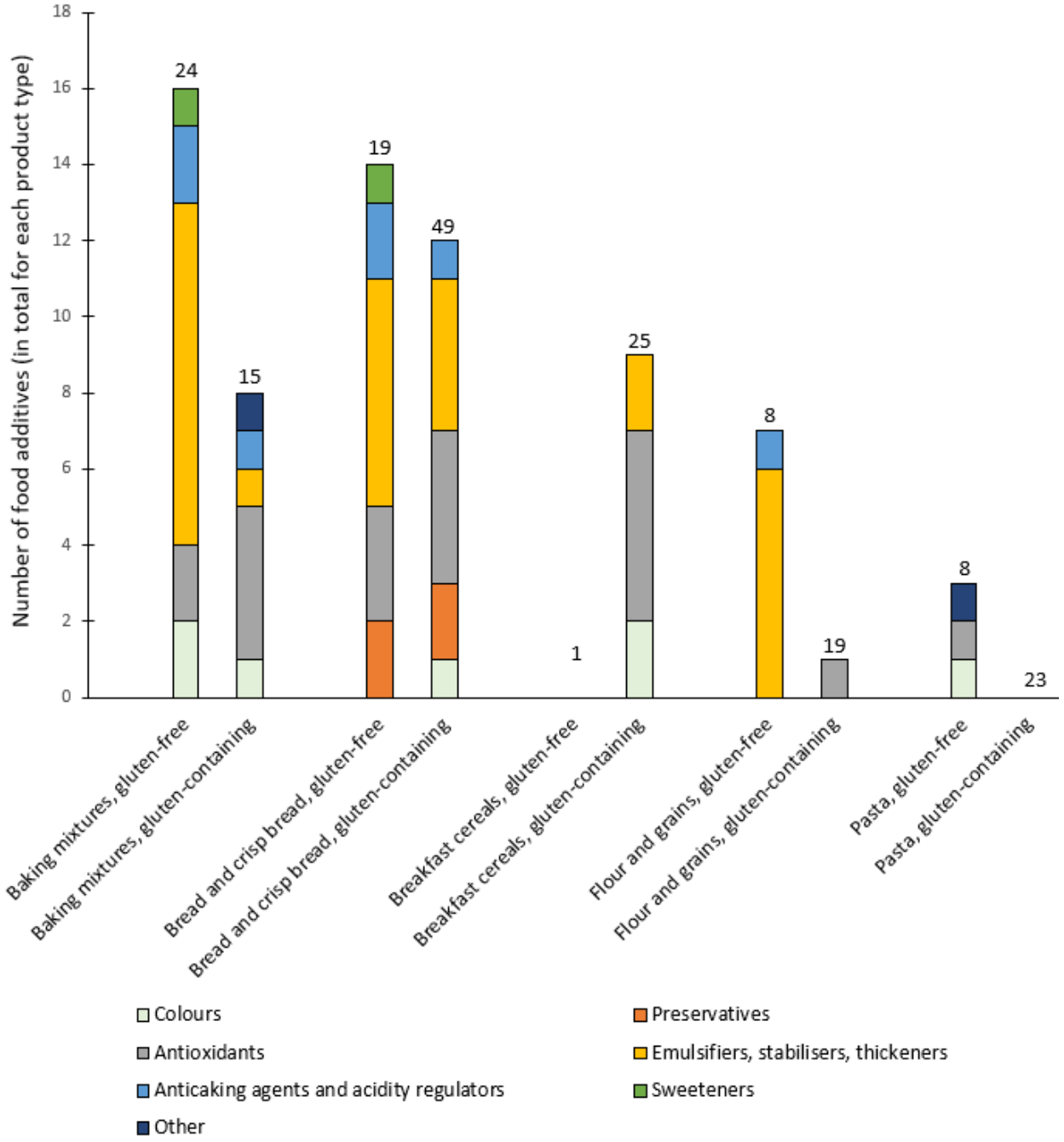


Figure 3.3.3.3-3. The number of food additives within different food additive categories for the included product types. The number of products identified for each product type is shown on top of the bars.

Table 3.3.3.3-2. Percentage of gluten-free product containing a specific E number. Sample sizes are shown in Table 3.3.3.3-1.

Food additive categories, E numbers, and name of substance	**Gluten-free products**				
	Flour and grains	Baking mixture	Bread and crispbread	Breakfast cereals	Pasta

Food colours					
150 Caramel colours	0	4	0	0	0
160 Carotenoids	0	8	0	0	13
Preservatives					
200 Sorbic acid	0	0	5	0	0
202 Potassium sorbate	0	0	5	0	0
Antioxidants					
300 Ascorbic acid	0	0	5	0	25
322 Lecithin	0	0	16	0	0
330 Citric acid	0	0	5	0	0
339 Sodium phosphate	0	8	0	0	0
341 Calcium phosphate	0	8	0	0	0
Emulsifiers, stabilisers, and thickeners					
401 Sodium alginate	0	4	0	0	0
410 Locust bean gum	25	4	0	0	0
412 Guar gum	13	17	42	0	0
415 Xanthan gum	25	8	26	0	0
417 Tara gum	25	0	0	0	0
440 Pectins	0	4	0	0	0
450 Diphosphates	0	8	21	0	0
464 Hydroxypropyl-methylcellulose	13	33	53	0	0
466 Sodium carboxy methyl cellulose	0	4	37	0	0
471 Mono-and Diglycerides of Fatty Acids	13	0	32	0	0
472 Acetic acid esters	0	4	0	0	0
Anti-caking agents and acidity regulators					
500 Sodium bicarbonate	0	50	21	0	0
575 Glucono delta lactone	0	21	0	0	0
576 Sodium gluconate	13	0	5	0	0
Sweeteners					

953 Isomalt	0	0	5	0	0
968 Erythritol	0	4	0	0	0
Other					
1100 Amylase	0	0	0	0	25

Table 3.3.3.3-3. Percentage of gluten-containing product containing a specific E number. Sample sizes are shown in Table 3.3.3.3-1.

Food additive categories, E numbers, and name of substance	**Gluten-containing products**				
	Flour and grains	Baking mixture	Bread and crispbread	Breakfast cereals	Pasta
Food colours					
150 Caramel colours	0	0	0	4	0
160 Carotenoids	0	20	2	0	0
162 Beetroot red	0	0	0	4	0
Preservatives					
221 Sodium sulphite	0	0	2	0	0
282 Calcium propionate	0	0	4	0	0
Antioxidants					
300 Ascorbic acid	26	40	39	0	0
304 Ascorbyl palmitate	0	0	2	4	0
306 Tocopherol	0	0	0	20	0
322 Lecithin	0	0	4	12	0
330 Citric acid	0	7	2	4	0
339 Sodium phosphate	0	20	0	0	0
341 Calcium phosphate	0	13	0	4	0
Emulsifiers, stabilisers, and thickeners					
401 Sodium alginate	0	0	0	4	0
450 Diphosphates	0	0	2	0	0
471 Mono-and Diglycerides of Fatty Acids	0	0	22	4	0
472 Acetic acid esters	0	7	24	0	0

481 Sodium stearoyl lactate	0	0	2	0	0
Anti-caking agents and acidity regulators					
500 Sodium bicarbonate	0	33	2	0	0
Other					
1100 Amylase	0	33	0	0	0

3.3.3.4 Comparing food additives in potato chips and plant-based snacks alternatives

The plant-based alternative snack products contained eight different food additives, and the potato chips products contained 14 different food additives (Figure 3.3.3.4-1). The largest number of food additives used in these products belonged to the category antioxidants (seven different).

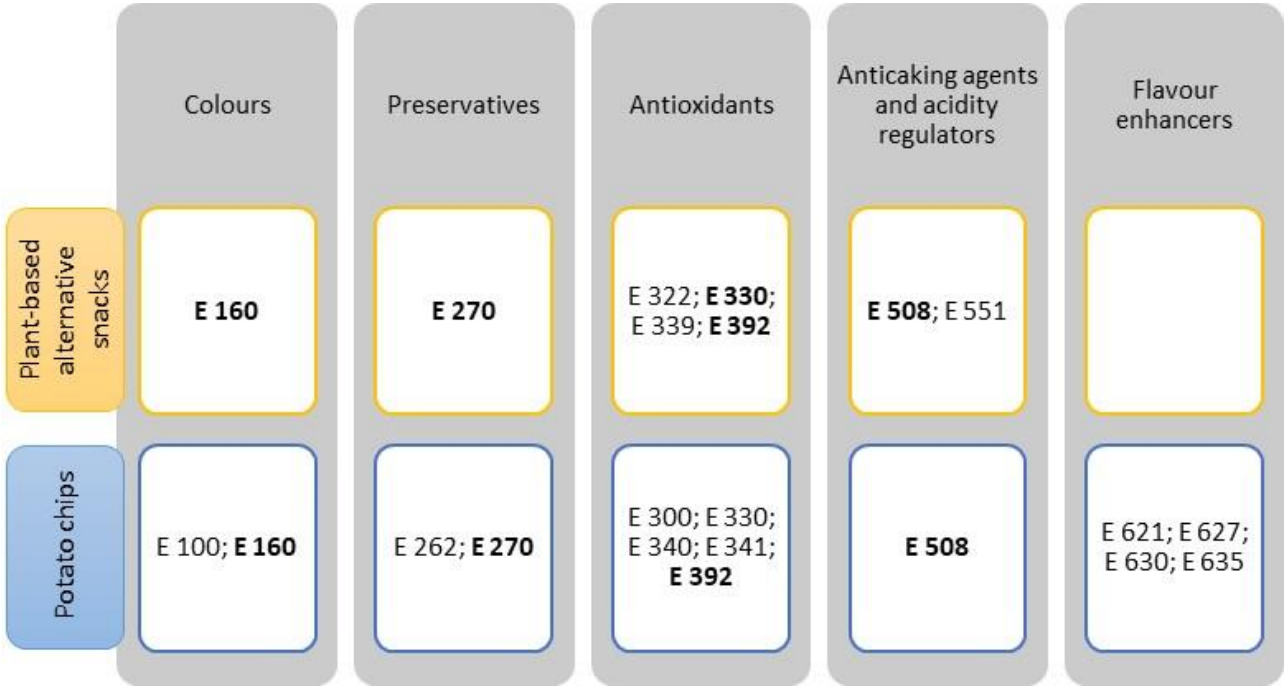


Figure 3.3.3.4-1. Food additives represented by E numbers in potato chips products bottom row) and counterpart products based on other plant ingredients (top row). Additives present in both plant-based alternative snack products and potato-based snack products are marked in bold.

The maximum number of food additives in a single product is shown in Table 3.3.3.4-1. The number of food additives in a single product ranged from zero to three in the plant-based alternative snack products, and zero to eight in potato chips products.

An overview of the food additives identified in the different products is illustrated in an UpSet plot (Figure 3.3.3.4-2). The E numbers for all food additives in the plant-based alternative snack products and the potato-based snack products are shown in Tables 3.3.3.4-2 and 3.3.3.4-3.

Five food additives were used in both product types (E 508, E 330, E 392, E 270, and E 160; Figure 3.3.3.4-2, Table 3.3.3.4-1 and 3.3.3.4-2). E 551, E 322, and E 339 were found only in the plant-based snacks alternatives.

The number of food additives within the different food additive categories for the included food types is presented in Figure 3.3.3.4-3.

Table 3.3.3.4-1. The number of products, and minimum (min) and maximum (max) number of food additives within each product type.

Plant-based snacks alternatives			**Potato chips**		
Number of products	Number of food additives		Number of products	Number of food additives	
	Min (n)	Max (n)		Min (n)	Max (n)
25	0	3	22	0	8

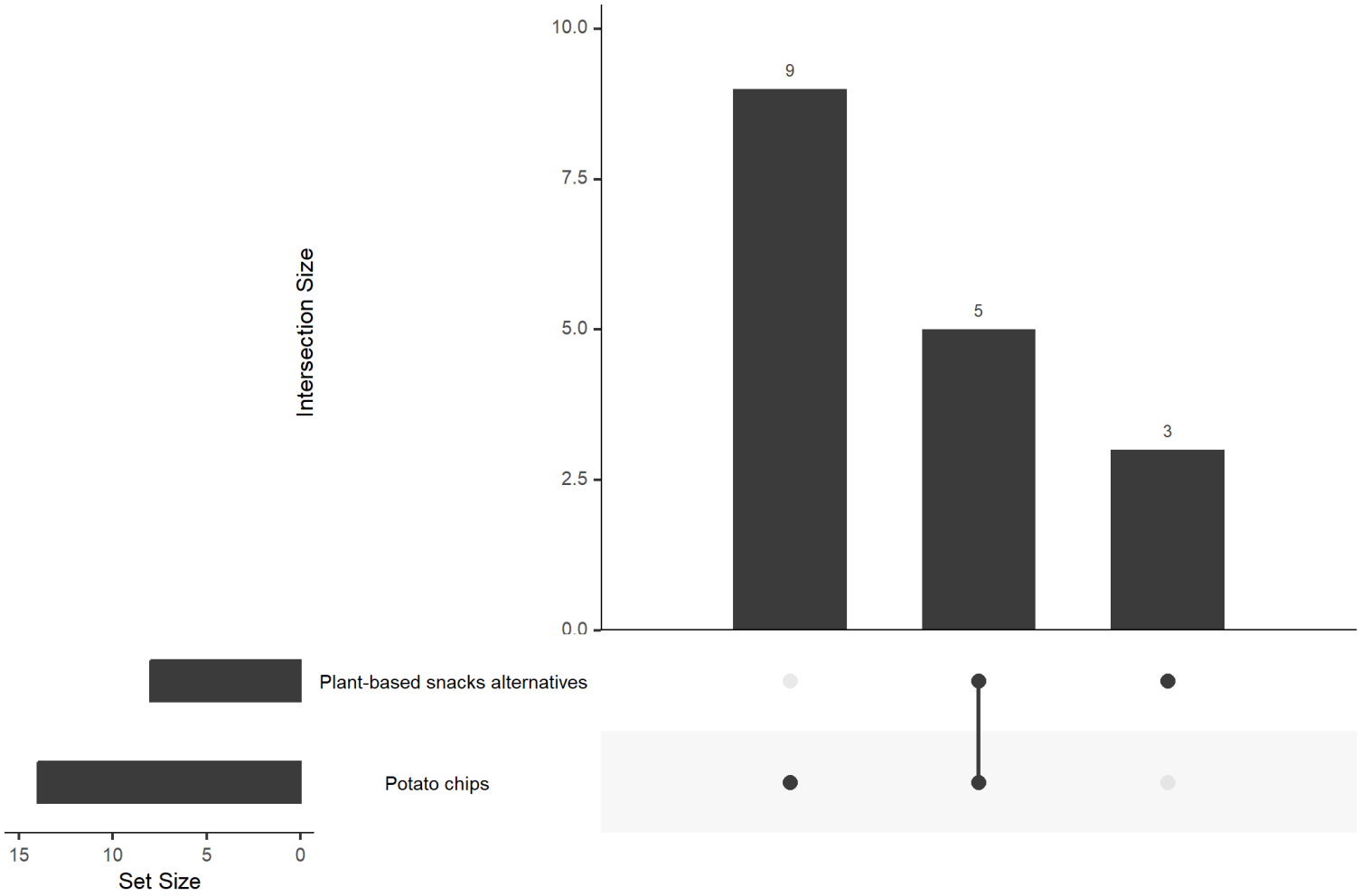


Figure 3.3.3.4-2. The number of different food additives identified in products within the different product types (Plant-based snacks alternatives to potato chips and nuts). "Set size" indicates the total number of different additives found in products within each product type. E.g. for plant-based snacks alternatives, to

total number of different food additives in these products is eight. Black dots show the product type where a food additive has been identified. When the same food additive was identified in more than one product type, this is shown by the lines joining two or more dots. "Intersection size" represents the number of food additives that were present in the products marked by the dot(s) below the bar. E.g. for plant-based snacks alternatives, the first dot shows five food additives that are present in plant-based snacks alternatives and potato chips. The second dot shows three food additives that are unique for plant-based snacks alternatives. The numbers on the top of each bar for interaction size indicate the number of food additives corresponding to each dot or group of dots joined by lines. E.g., the number 3 on top of the third bar from the left indicates that three food additives were identified in potato chips.

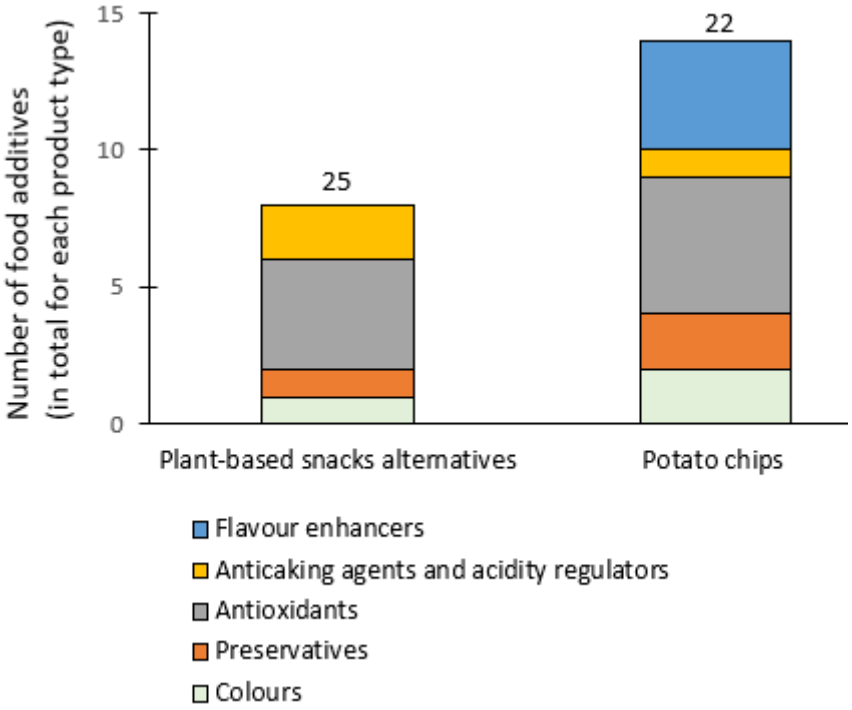


Figure 3.3.3.4-3. The number of food additives within different food additive categories for the included product types. The number of products identified for each product type is shown on top of the bars.

Table 3.3.3.4-2. Percentage of plant-based snacks alternatives containing a specific E number. Sample sizes are shown in Table 3.3.3.4-1.

Food additive categories, E numbers, and name of substance	Plant-based snacks alternatives
Food colours	
160 Carotenoids	20
Preservatives	
270 Lactic acid	12
Antioxidants	
322 Lecithin	4
330 Citric acid	48
339 Sodium phosphate	4
392 Extracts of rosemary	8
Anti-caking agents and acidity regulators	

508 Potassium chloride	4
551 Silicon dioxide	4

Table 3.3.3.4-3. Percentage of potato chips products containing a specific E number. Sample sizes are shown in Table 3.3.3.4-1.

Food additive categories, E numbers, and name of substance	Potato chips
Food colours	
100 Curcumin	14
160 160 Carotenoids	45
Preservatives	
262 Sodium acetate	9
270 Lactic acid	14
Antioxidants	
300 Ascorbic acid	5
330 Citric acid	64
340 Potassium phosphate	5
341 Calcium phosphate	5
392 Extracts of rosemary	14
Anti-caking agents and acidity regulators	
508 Potassium chloride	9
Flavour enhancers	
621 621 Monosodium glutamate	23
627 Disodium guanylate	9
630 Inosinic acid	5
635 Sodium ribonucleotides	5

3.4 Contaminants

Flow charts of the data input and results for the comparison of contaminants in selected food products on the Norwegian market are shown in Figures 3.4-1 and 3.4-2, respectively.

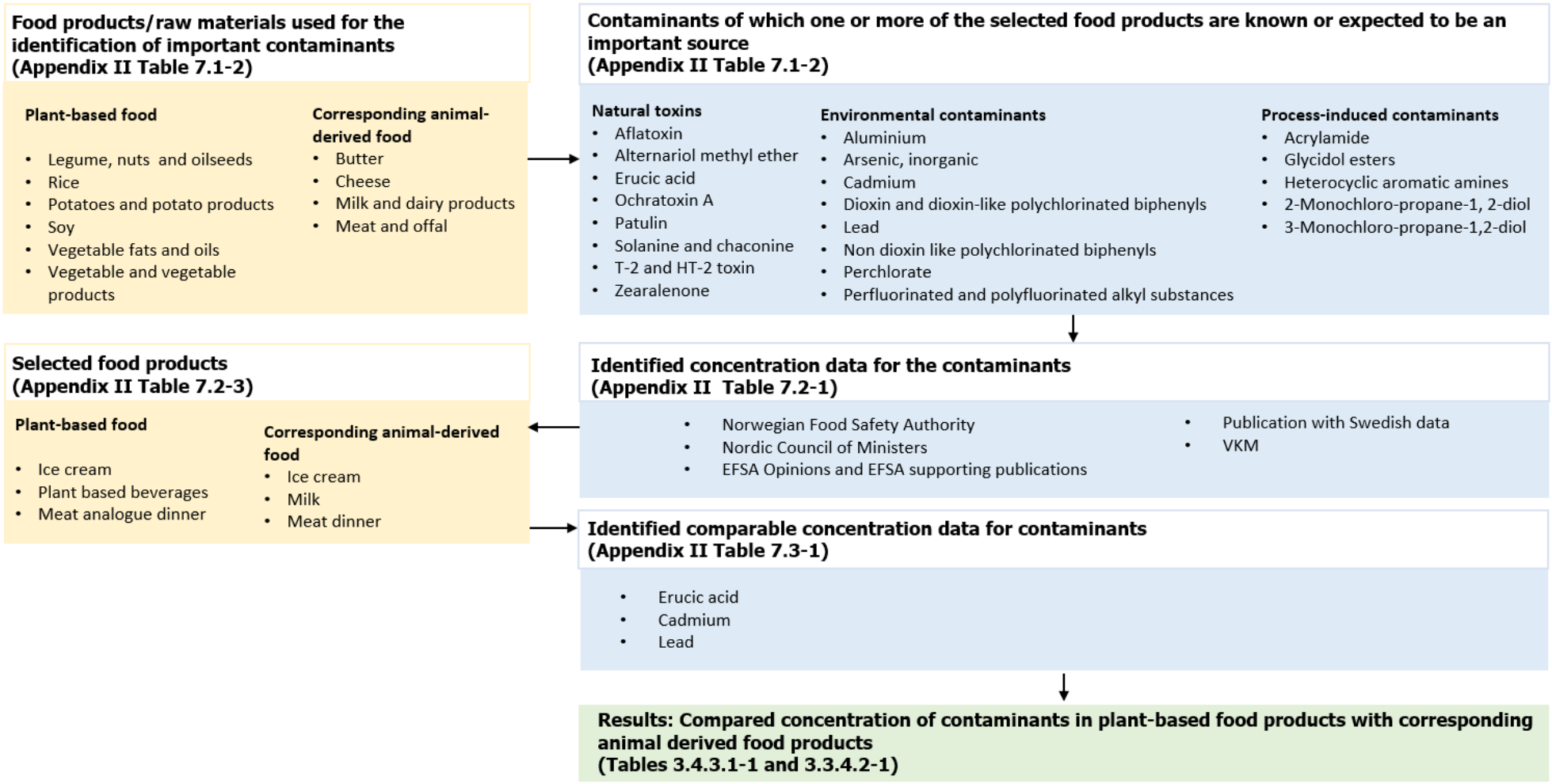


Figure 3.4-1. Flow chart of the data input and result flow for the comparison of contaminants in plant-based food products and counterpart animal-derived food products on the Norwegian market.

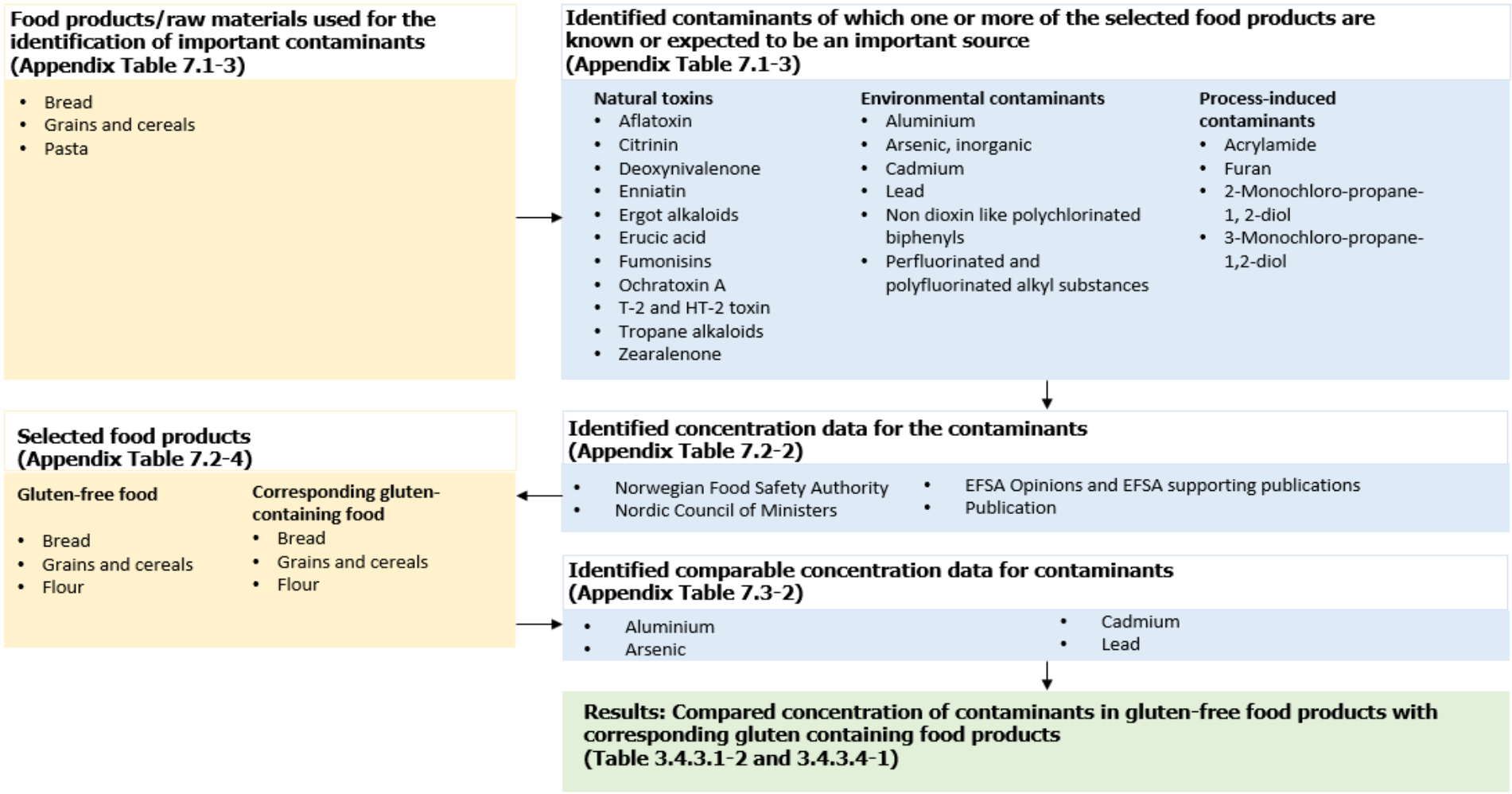


Figure 3.4-2. Flow charts of the data input and result flow for the comparison of contaminants in gluten-free food products and comparable gluten-containing food products on the Norwegian market.

3.4.1 Identified contaminants of which one or more of the selected food products are known or expected to be an important source

The VKM knowledge base (VKM, 2022) was used to identify which of the selected food products that were known or expected to be an important source for the contaminants (described in 3.1.1). For plant-based and comparable animal-derived food products, eight natural toxins, eight environmental contaminants, and five process-induced contaminants (either single contaminants or groups of contaminants) fulfilled the criteria for being an important source (known/expected) (Figure 3.4-1). For gluten-containing products, eleven natural toxins, six environmental contaminants, and four process-induced contaminants (either single contaminants or groups of contaminants) fulfilled the criteria for being an important source (known/expected) (Figure 3.4-2). The VKM knowledge base did not include gluten-free food products; however, the contaminants identified as important in gluten-containing products were assumed to be important also in gluten-free food products. In addition, potato was used as raw material in gluten-free products but not in the gluten-containing products. Potatoes were identified to be an important source for solanine and chaconine exposure.

Overviews of the included food categories and the contaminants of which food products in these categories are known or expected to be important sources for the total exposure to the contaminant are shown in Table 3.4.1-1, 3.4.1.-2 and 3.4.1.-3. Of the eight environmental contaminants, most are known or expected to be found in all included food categories. Of the 14 natural toxins, three are known or expected to be in all included food categories. Of the six process-induced contaminants, two are known or expected to be in all included food categories. Whereas food products of animal origin are known or expected to be a source to dioxins and dioxin-like PCBs and heterocyclic aromatic amines, plant-based meat and dairy analogue products are known or expected to be a source to inorganic arsenic, cadmium, alternariol methyl ether, patulin, solanine and chaconine, T-2 and HT-2 toxin, zearalenone, and acrylamide. Gluten free food products containing ingredients from potato are known or expected to be a source to solanine and chaconine.

Detailed overviews are given in Section 7, Tables 7.1-1, 7.1-2 and 7.1-3) of the important contaminants in the selected food and the extent to which a food will contribute to the total exposure to a specific contaminant, respectively.

Table 3.4.1-1. Environmental contaminants of which the food categories are known or expected to be an important source. Blue: food products of animal origin; black: plant-based meat and dairy analogues; green: gluten-free and gluten-containing food products. Empty table cells: The food category is not an important source for the specific contaminant.

Name	Food products of animal origin	Plant-based meat and dairy analogue products	Gluten-free food products	Gluten-containing food products
Aluminium	x	x	x	x
Arsenic (inorganic)		x	x	x

Cadmium		x	x	x
Dioxins and dioxin-like PCBs*	x			
Lead	x	x	x	x
Non-dioxin-like polychlorinated biphenyls**	x	x	x	x
Perchlorate	x	x		
Perfluorinated and polyfluorinated alkyl substances***	x	x	x	x

*Sum of 29 congeners.
**PCB28, PCB52, PCB101, PCB138, PCB153, PCB180.
***Sum of PFOS, PFOA, PFNA and PFHxS.

Table 3.4.1-2. Natural toxins of which the food categories are known or expected to be an important source. Blue: food products of animal origin; black: plant-based meat and dairy analogues; green: gluten-free and gluten-containing food products. Empty table cells: The food category is not an important source for the specific contaminant.

Name	Food products of animal origin	Plant-based meat and dairy analogue products	Gluten-free food products	Gluten-containing food products
Aflatoxin*	x	x	x	x
Alternariol methyl ether		x		
Citrinin			x	x
Deoxynivalenol			x	x
Enniatin**			x	x
Ergot alkaloids			x	x
Erucic acid	x	x	x	x
Fumonisins			x	x
Ochratoxin A	x	x	x	x
Patulin		x		
Solanine and chaconine		x	x	

T-2 and HT-2 toxin		x	x	x
Tropane alkaloids			x	x
Zearalenone		x	x	x

*Sum of AFB1, AFB2, AFG1, AFG2 and AFM1.

**Sum of Enniatins.

Table 3.4.1-3. Process-induced contaminants of which the food categories are known or expected to be an important source. Blue: food products of animal origin; black: plant-based meat and dairy analogues; green: gluten-free and gluten-containing food products. Empty table cells: The food category is not an important source for the specific contaminant.

Name	Food products of animal origin	Plant-based meat and dairy analogue products	Gluten-free food products	Gluten-containing food products
Acrylamide		x	x	x
Furan			x	x
Glycidol from esters	x	x		
Heterocyclic aromatic amines	x			
2-Monochloropropane-1,2-diol	x	x	x	x
3-Monochloropropane-1,2-diol	x	x	x	x

3.4.2 Concentration data for contaminants

Concentration data were identified from the following sources: Datasets from NFSA (Mattilsynet, 2017; Mattilsynet, 2018; Norwegian Food Safety Authority and Institute of Marine Research, 2021; Norwegian Food Safety Authority and Institute of Marine Research, 2022a; Norwegian Food Safety Authority and Institute of Marine Research, 2022b), a report from the Nordic Council of Ministers (Pastell et al., 2021), EFSA Opinions and EFSA supporting publications (EFSA, 2008; EFSA, 2011; EFSA, 2014a; EFSA, 2014b; EFSA, 2015; EFSA, 2016; EFSA et al., 2017a; EFSA et al., 2017b; EFSA et al., 2017c; EFSA et al., 2017d; EFSA et al., 2016; EFSA et al., 2020b; López Sáncheza et al., 2017), a publication containing Swedish data (Kollander et al., 2023), and a VKM risk-benefit assessment (VKM et al., 2022).

An overview of food types where concentration data was identified is given in Tables 3.4.2-1 to 3.4.2-9. Detailed overviews of the identified concentration data including information on the data source are included in Section 7 (Tables 7.2-1, 7.2-2, and 7.2-3). The availability of concentration data for the contaminants of which the selected food items are known or expected to be an important source according to the VKM knowledge base (VKM, 2022) is shown in Section 7 (Tables 7.2-1, 7.2-2, and 7.2-3).

Table 3.4.2-1. Animal- and plant-based food products; availability of concentration data for natural toxins. Blue colouring of table cells: concentration data were identified (plant-based products); green colouring: concentration data were identified (animal-based products). Empty table cells: Concentration data not identified.

Name	Plant-based products						Animal-based products			
	Legumes, nuts, and oilseeds	Rice	Potato and potato products	Soy	Vegetable fats and oils	Vegetables and vegetable products	Butter	Cheese	Milk and dairy products*	Meat and offal
Aflatoxin	x			x	x	x	x		x	x
Alternariol methyl ether	x	x	x		x	x				
Erucic acid	x	x	x		x	x	x	x	x	x
Ochratoxin A	x	x	x	x	x	x	x	x		x
Patulin	x					x				
Solanine and chaconine			x			x				
T-2 and HT-2 toxin	x	x			x					
Zearalenone					x					

Table 3.4.2-2. Availability of concentration data for natural toxins in prepared animal-based and plant-based food products. Blue colouring of table cells: concentration data were identified (plant-based products); green colouring: concentration data were identified (animal-based products). Open table cells: Concentration data not identified.

Name	Ice cream (animal-based product)	"Ice cream" (plant-based product)	Milk (animal-based product)	Plant-based beverages	Meat, dinner (animal-based product)	Meat analogue, dinner (plant-based product)	Meat, bread topping (animal-based product)	Meat analogue, bread topping (plant-based product)
Aflatoxin				x				
Deoxynivalenol				x		x		
Erucic acid	x	x	x	x	x	x	x	
Ochratoxin A	x			x		x		
T-2 and HT-2 toxin				x		x		
Zearalenone				x		x		

Table 3.4.2-3. Gluten-free and gluten-containing food products; availability of concentration data for natural toxins. Blue colouring: concentration data for gluten-free products were identified (); green colouring of table cells: concentration data for gluten-containing products were identified. Empty table cells: Concentration data not identified.

Name	Bread	Bread, gluten-free	Grains and cereals	Grains and cereals, gluten-free	Flour	Flour, gluten-free	Pasta	Pasta, gluten-free
Aflatoxin	x	x	x	x				
Citrinin	x		x	x	x		x	

Deoxynivalenol	x	x	x	x	x	x	x	x
Enniatin	x	x	x	x			x	x
Ergot alkaloids	x	x	x	x	x		x	
Erucic acid	x		x	x	x	x		
Fumonisins	x	x	x		x		x	x
Ochratoxin A	x		x	x			x	x
T-2 and HT-2 toxin	x		x	x			x	x
Tropane alkaloids	x	x						
Zearalenone	x	x	x	x			x	x

Table 3.4.2-4. Animal- and plant-based food products; availability of concentration data for environmental contaminants. Blue colouring of table cells: concentration data were identified (plant-based products); green colouring: concentration data were identified (animal-based products). Empty table cells: Concentration data not identified.

Name	**Plant-based products**						**Animal-based products**			
	Legumes, nuts, and oilseeds	Rice	Potato and potato products	Soy	Vegetable fats and oils	Vegetables and vegetable products	Butter	Cheese	Milk and dairy products*	Meat and offal

Aluminium	x	x	x			x	x	x	x	x
Arsenic, inorganic		x								
Cadmium	x	x	x	x		x	x	x	x	x
Dioxins and dioxin-like polychlorinated biphenyls			x			x	x	x	x	x
Lead	x	x	x			x	x	x	x	x
Non-dioxin-like polychlorinated biphenyls		x			x	x	x	x	x	x
Perchlorate	x		x		x	x		x	x	
Perfluorinated and polyfluorinated alkyl substances	x	x	x		x	x	x	x	x	x

Table 3.4.2-5. Availability of concentration data for environmental contaminants in prepared animal-based and plant-based food products. Blue colouring of table cells: concentration data were identified (plant-based products); green colouring: concentration data were identified (animal-based products). Empty table cells: Contentration data not identified.

Name	Ice cream (animal-based product)	Ice cream (plant-based product)	Milk (animal-based product)	Plant-based beverages	Meat, dinner (animal-based product)	Meat analogue, dinner (plant-based product)	Meat, bread topping (animal-based product)	Meat analogue, bread topping (plant-based product)
Cadmium				x	x	x	x	
Lead				x	x	x	x	

Table 3.4.2-6. Gluten-free and gluten-containing food products; availability of concentration data for environmental contaminants. Blue colouring: concentration data for gluten-free products were identified (); green colouring of table cells: concentration data for gluten-containing products were identified. Empty table cells: Concentration data not identified.

Contaminant	Bread	Bread, gluten-free	Grains and cereals	Grains and cereals, gluten-free	Flour	Flour, gluten-free	Pasta	Pasta, gluten-free
Aluminium	x	x	x	x	x	x		
Arsenic, inorganic	x	x	x	x				
Cadmium	x	x	x	x	x	x	x	x
Lead	x	x	x	x	x	x	x	x
Non-dioxin-like polychlorinated biphenyls			x	x				

Perfluorinated and polyfluorinated alkyl substances	x		x	x				

Table 3.4.2-7. Animal- and plant-based food products; availability of concentration data for process-induced contaminants. Blue colouring of table cells: concentration data were identified (plant-based products); green colouring: concentration data were identified (animal-based products). Empty table cells: Concentration data not identified.

Name	**Plant-based products**						**Animal-based products**			
	Legumes, nuts, and oilseeds	Rice	Potato and potato products	Soy	Vegetable fats and oils	Vegetables and vegetable products	Butter	Cheese	Milk and dairy products*	Meat and offal
Acrylamide	x		x							x
Glycidol from esters			x		x		x			x
Heterocyclic aromatic amines										x
2-monochloro-propane-1, 2-diol			x		x	x	x			x
3-Monochloro-propane-1,2-diol			x	x	x	x	x			x

Table 3.4.2-8. Availability of concentration data for contaminants in prepared animal-based and plant-based food products. Blue colouring of table cells: concentration data were identified (plant-based products); green colouring: concentration data were identified (animal-based products). Empty table cells: Concentration data not identified.

Name	Ice cream (animal-based product)	Ice cream (plant-based product)	Milk (animal-based product)	Plant-based beverages	Meat, dinner (animal-based product)	Meat analogue, dinner (plant-based product)	Meat, bread topping (animal-based product)	Meat analogue, bread topping (plant-based product)
Acrylamide				x		x		
Furan	x					x		
Glycidol from esters				x		x		
3-Monochloropropane-1,2-diol				x		x		

Table 3.4.2-9. Gluten-free and gluten-containing food products; availability of concentration data for process-induced contaminants. Blue colouring: concentration data for gluten-free products were identified (); green colouring of table cells: concentration data for gluten-containing products were identified. Empty table cells: Concentration data not identified.

Contaminant	Bread	Bread, gluten-free	Grains and cereals	Grains and cereals, gluten-free	Flour	Flour, gluten-free	Pasta	Pasta, gluten-free
Acrylamide	x	x	x		x	x		
Furan	x		x		x		x	
2-monochloro-propane-1, 2-diol	x	x	x					
3-Monochloro-propane-1,2-diol	x	x	x					

3.4.3 Comparison of contaminant content

Comparisons of the content of contaminants in animal-based and plant-based analogue products and in gluten-containing and gluten-free products were made for a selection of food products. VKM decided to restrict the comparisons to directly comparable product types, and the comparisons were further restricted based on the availability of concentration data.

Contaminant concentration data from NFSA, the Nordic Council of Ministers, EFSA and the publication reporting Swedish data were available for some comparable food products. For meat and dairy products and plant-based analogue products, comparable product types where concentration data were available are shown in Section 7 (Table 7.3-1. For gluten-containing and gluten-free products, counterpart product types where concentration data were available are shown in Section 7 (Table 7.3-2).

3.4.3.1 Data from NFSA publications

An overview of the data used for comparisons of contaminants in plant-based and animal-based food products, and in gluten-free and gluten-containing food products data is given in Tables 3.4.3.1-1 and 3.4.3.1-2 (Mattilsynet, 2017; Norwegian Food Safety Authority and Institute of Marine Research, 2022a).

The concentration data for cadmium in meat and plant-based meat analogue products indicate a higher level in the plant-based analogue products; however, it should be noted that the number of samples is low. It was not possible to compare the level of erucic acid and lead in meat and plant-based meat analogue products because almost all measurements were below the level of quantification.

It was not possible to compare the level of lead in gluten-containing and gluten-free flour because all measurements were below the level of quantification. The concentration data for cadmium indicate similar levels in gluten-free and gluten-containing products.

Table 3.4.3.1-1. Data for comparison of contaminant level in plant-based and animal-based food product types. n: Number of samples.

Product type	**Erucic acid (g per 100 g)**		**Cadmium (mg per 100 g ww)**		**Lead (mg per 100 g ww)**		**Number samples below level of quantification**	**n**
	Range	Median	Range	Median	Range	Median		
Balls: dinner; plant-based	<0.001 - <0.001	<0.001	0.0008-0.0024	0.0013	<0.001 - <0.01	0.0013	Erucic acid: 3 Cadmium: 0 Lead: 3	3
Sausage: dinner;	<0.001-0.023	<0.001	0.0007-0.0063	0.0025	<0.0008-<0.008	<0.0007	Erucic acid: 4 Cadmium: 0	5

Product type	Erucic acid (g per 100 g)		Cadmium (mg per 100 g ww)		Lead (mg per 100 g ww)		Number samples below level of quantification	n
	Range	Median	Range	Median	Range	Median		
plant-based							Lead: 5	
Balls: dinner; meat-based	<0.001 - <0.001	<0.001	<0.0002 - 0.0003	<0.0002	<0.0009 - <0.001	<0.0007	Erucic acid: 5 Cadmium: 3 Lead: 5	5
Sausage: dinner; meat-based	<0.001 - <0.001	<0.001	<0.0002 - <0.0001	<0.0002	<0.0009 - <0.001	<0.0008	Erucic acid: 13 Cadmium: 13 Lead: 12	13

Table 3.4.3.1-2. Data for comparison of contaminant level in gluten-free and gluten-containing food product types. n: Number of samples.

Product type	Cadmium (µg/kg)		Lead (µg/kg)		Number samples below level of quantification	n
	Range	Median	Range	Median		
Flour; gluten-free	0.0005 – 0.0028	0.0015	<0.002 – <0.002	<0.002	Cd: 0 Pb: 5	5
Flour; gluten-containing	0.0009 – 0.0056	0.0022	<0.002 – 0.0029	<0.002	Cd: 0 Pb: 35	36

3.4.3.2 Data from EFSA publications

An overview of the data used for comparisons of contaminants in plant-based and animal-based food products is given in Table 3.4.3.2-1 (EFSA et al., 2016).

It was not possible to compare the level of erucic acid in dairy-based and plant-based ice cream because more than 95% of the samples were below the level of quantification (left-censored). It was not possible to compare the level of erucic acid in milk with plant-based beverages because more than 70% of the samples were level of quantification for the plant-based beverages and all samples were below the level of quantification for the milk products.

Table 3.4.3.2-1. EFSA concentration data for comparison of contaminant level in plant-based and dairy food product types. LB: Lower bound; UB: Upper bound; n: Number of samples.

Product category	Product type	Erucic acid (mg/kg)		Number of samples below the level of quantification	n
		Mean, LB	Mean, UB		
Dairy analogue, (plant-based product)	Plant-based "ice cream"	0	51	97	110
	Plant-based beverage	114	304	72	18
Dairy (animal-based product)	Ice cream	1	65	96	325
	Milk (cow)	0	225	100	26

3.4.3.3 Data from a publication from the Nordic Council of Ministers

Comparisons of contaminants in gluten-free and gluten-containing products were made in the report "Are gluten-free products a healthier alternative?: A pilot study on nutrients and heavy metals" (Pastell et al., 2021). The authors concluded that "*The levels of cadmium were similar in the gluten-free and gluten-containing products. The gluten-free products contained significantly higher levels of lead compared with the gluten-containing products*".

3.4.3.4 Data from a publication containing Swedish data

An overview of the data used for comparison of contaminants in gluten-free and gluten-containing food products is given in Table 3.4.3.4-1 (Kollander et al., 2023).

The concentration data for aluminium and lead indicate a higher level in the gluten-free products. The concentration data for arsenic indicate a similar level in the gluten-containing products. The concentration data for cadmium indicate a lower level in the gluten-free products.

Table 3.4.3.4-1. Swedish concentration data for comparison of contaminant level in gluten-free and gluten-containing food types. n: Number of samples.

Product type	Aluminium (mg/kg)		Arsenic (µg/kg)		Cadmium (µg/kg)		Lead (µg/kg)		Number samples below level of quantification	n
	Range	Median	Range	Median	Range	Median	Range	Median		
Bread; gluten-free	< 4 - 62	7	1.9 – 24.5	6.5	1 - 99	13.5	< 3 - 26	14.5	As, Cd: 0 Al: 2 Cd: 1	Al, As: 15 Cd, Pb: 16
Bread; gluten-containing	0.5 – 9.5	1.35	< 4 - 9	5	11 - 80	23.5	2 - 22	3	Al, Cd: 0 As: 15 Pb: 20	Al, As, Cd: 50

Product type	Aluminium (mg/kg)		Arsenic (µg/kg)		Cadmium (µg/kg)		Lead (µg/kg)		Number samples below level of quantification	n
	Range	Median	Range	Median	Range	Median	Range	Median		
										Pb: 49

3.4.3.5 Summary of the comparison of contaminant content in counterpart food products

Comparisons of the contaminant level in food products were only made for directly comparable product types and directly comparable concentration data. In addition, to compare the level of contaminants the data must be above the level of quantification.

Data were available, but comparisons could not be made because most data were below the level of quantification for the following contaminants and food products:

- Erucic acid and lead in plant-based meat analogues and meat products (Norwegian Food Safety Authority and Institute of Marine Research, 2022a).
- Erucic acid in plant-based "ice cream" and ice cream (EFSA et al., 2016).
- Erucic acid in milk and plant-based beverages (EFSA et al., 2016).
- Lead in gluten-containing and gluten-free flour (Mattilsynet, 2017).

The comparisons were made for the following contaminants and food products:

- Cadmium in plant-based meat analogue products and meat products (Norwegian Food Safety Authority and Institute of Marine Research, 2022a). The data indicate a higher level of cadmium in the plant-based analogue products; however, it should be noted that the number of samples is low.
- Cadmium in gluten-free and gluten-containing products (Kollander et al., 2023; Mattilsynet, 2017; Pastell et al., 2021). The data from Mattilsynet (2017) and Pastell et al. (2021) indicate similar levels of cadmium in these product types, whereas the data from Kollander et al. (2023) indicate lower levels in gluten-free food products.
- Lead in gluten-free and gluten-containing products (Kollander et al., 2023; Pastell et al., 2021). The data indicate higher levels of lead in gluten-free products.
- Aluminium in gluten-free and gluten-containing products (Kollander et al., 2023). The data indicate higher levels of aluminium in the gluten-free products.
- Arsenic in gluten-free and gluten-containing products (Kollander et al., 2023). The data from indicate similar levels of arsenic in these products.

3.5 Processing methods used in the manufacturing of the selected food products

The aim of this section is to give an overview of different unit operations used in the manufacturing of the product types included in this report (Section 3.1) and to

compare the processing of 1) plant-based dairy and meat analogues with their animal-based counterparts, 2) gluten-free products with their gluten-containing counterparts, and 3) plant-based snacks alternatives with potato chips and nuts. The different processing steps (unit operations) have been described in section 1.2.

3.5.1 Milk and plant-based beverages

The processing lines for fluid oat beverages and milk products are shown in Figures 3.5.1-1 and 3.5.1-2, respectively. The oat beverage is used as an example of a plant-based beverage (European Dairy Association, 2023; Sethi et al., 2016).

Figure 3.5.1 illustrates the essential processing steps for oat beverage production to serve as a representative example for the processing of plant-based milk analogues. The process begins with the creation of a slurry by mixing milled rolled oats with water. Oats are naturally rich in starch, which can lead to product thickening during subsequent heating. To prevent this, the enzyme amylase is introduced at this stage to hydrolyse the starch. This enzymatic action not only prevents thickening but can also enhance the product's sweetness. After the starch hydrolysis process, any remaining solids or particulates are separated from the mixture, leaving behind a liquid solution. This liquid can then be enriched with a selection of ingredients, including additives, sugars, flavours, minerals, and vitamins. The next steps involve homogenisation to ensure a uniform texture, and UHT (Ultra High Temperature) treatment to inactivate microorganisms and added enzymes such as of amylase in order to extended shelf life. The final steps are cooling to the desired temperature, and aseptic packaging.

It is important to note that organic plant beverages are an exception to the above-mentioned practice. These products are typically prepared without the addition of any extra ingredients or additives.

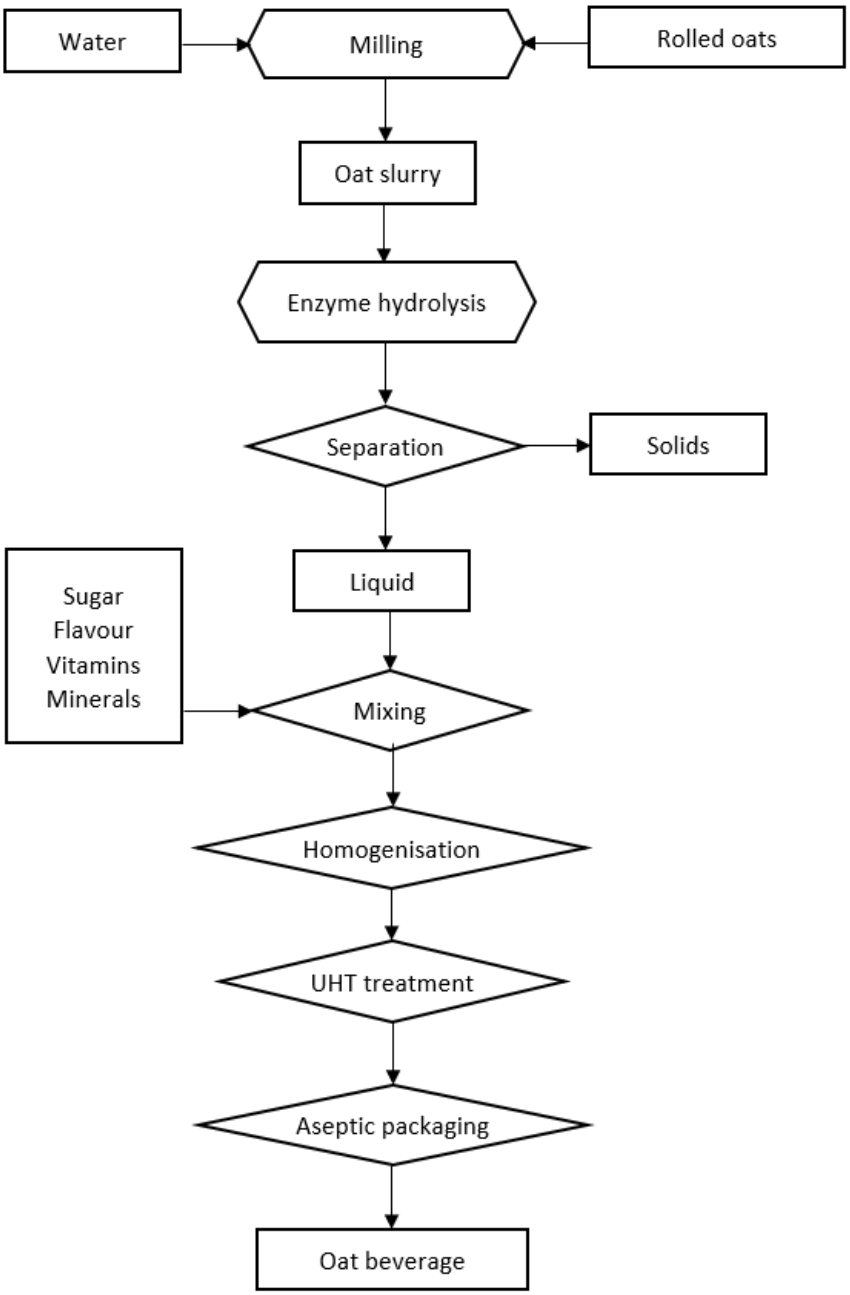


Figure 3.5.1-1. Simplified processing line for oat beverages. UHT: Ultra-high temperature. Modified from Sethi et al. (2016).

Figure 3.5.2 illustrates the essential processing steps for fluid milk products (Bylund, 2005). The most basic processing line for whole milk, typically containing around 3.5% fat, involves several essential steps at the dairy plant. These steps include homogenisation of the raw milk, followed by pasteurisation, cooling, and packaging. In modern processing lines for fluid milk products, the procedure is more comprehensive, as illustrated in Figure 3.5.1-2. Initially, the raw milk undergoes separation to yield cream and skimmed milk fractions. To produce skimmed milk, the skimmed milk fraction is subjected to pasteurisation, cooling, and subsequent packaging.

To produce skimmed, semi-skimmed, and whole milk, a process called standardisation comes into play. In standardisation, the skimmed milk and homogenised cream fractions are blended in specific ratios to achieve the desired fat content. Following standardisation, the milk is subjected to heat treatment, either pasteurisation or UHT (Ultra High Temperature) treatment, followed by cooling and packaging. UHT-treated products are filled into sterilised containers under sterile conditions to prevent contamination to achieve extended shelf life without refrigeration.

When milk requires fortification with vitamins or flavouring, such components are introduced during the standardisation process. The same holds true for stabilisers, which may be added to prevent the settling of flavouring ingredients, such as cocoa powder.

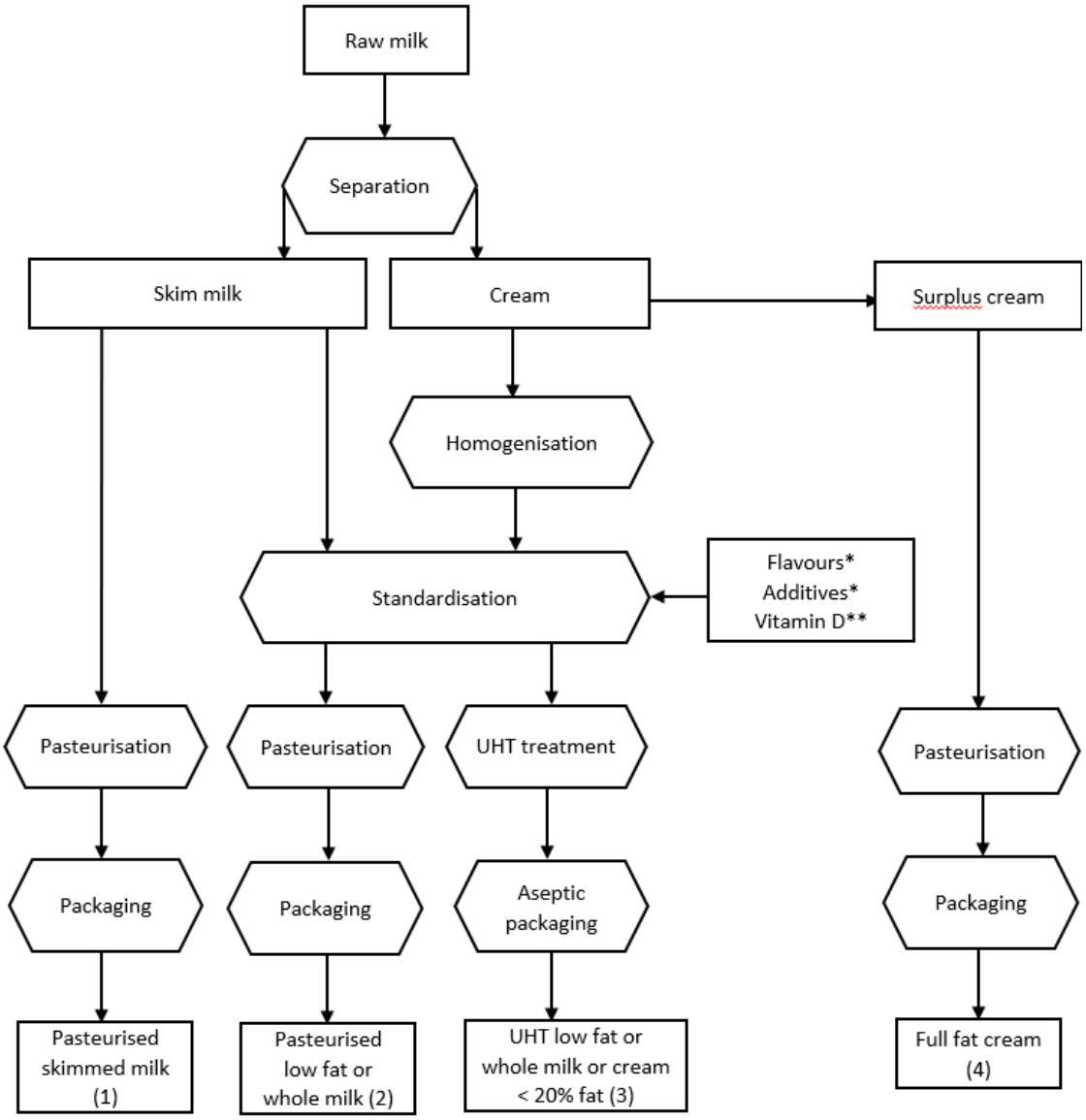


Figure 3.5.1-2. Simplified processing line for fluid milk products. 1) pasteurised skimmed milk, 2) pasteurised milks with varying fat content depending on the ratio of skimmed milk to homogenised cream in the standardisation step, 3) UHT milks and cream products with varying

fat content depending on the ratio of skimmed milk to homogenised cream in the standardisation step, 4) full fat cream. *Flavours and additives may be added to low fat UHT milk; **Pasteurised low fat milk may be fortified with vitamin D. UHT: Ultra-high temperature.

Processing of milk and plant-based beverages differ due to the distinct nature of their raw materials and the unique manufacturing requirements for each product. In milk processing, the starting material is a natural liquid that contains proteins, fat, lactose, and minerals. In contrast, plant-based beverages, like oat milk, utilise only the soluble components and smaller particles from oat grain flour. Oat grains, specifically rolled oats, serve as the starting material for oat beverages. Some plant-based beverages may involve the enzymatic hydrolysis of starch to break down components of lower molecular weight and thereby reducing the viscosity of the product. Plant-based beverages, such as oat milk, typically undergo UHT treatment for enzyme inactivation and prolonged storage. This process involves more severe heat treatments compared to the most commonly used milk products, like whole milk, low fat milk, and skimmed milk on the Norwegian market.

3.5.2 Ice cream and plant-based analogues

Figure 3.5.2-1 shows the essential processing steps for plant-based and dairy based ice cream products. The process begins with mixing of milk and cream or plant-based equivalents with sugar, stabilisers, emulsifiers, and flavourings (such as vanilla, chocolate, or fruit extracts). The ratio of milk to cream is chosen based on the desired fat content in the final product. This mixture is then pasteurised to dissolve the sugar and inactivate bacteria followed by homogenisation to evenly distribute the fat and prevent the formation of ice crystals (Bylund, 2005; Leahu et al., 2022; Walstra et al., 2005).

The ice cream base is allowed to age for several hours or overnight to improve the texture of the final product. The aged ice cream base is frozen either in a batch freezer or continuous freezer. Once the ice cream reaches the desired consistency, it is ready for packaging. It can be packaged in containers, cartons, or cones, depending on the final product. After packaging, the ice cream is placed in a freezer to harden. This step helps the ice cream maintain its shape and prevents it from melting too quickly when served. As previously described, the ice cream processing method remains the same whether it is prepared from dairy milk or a plant-based alternative.

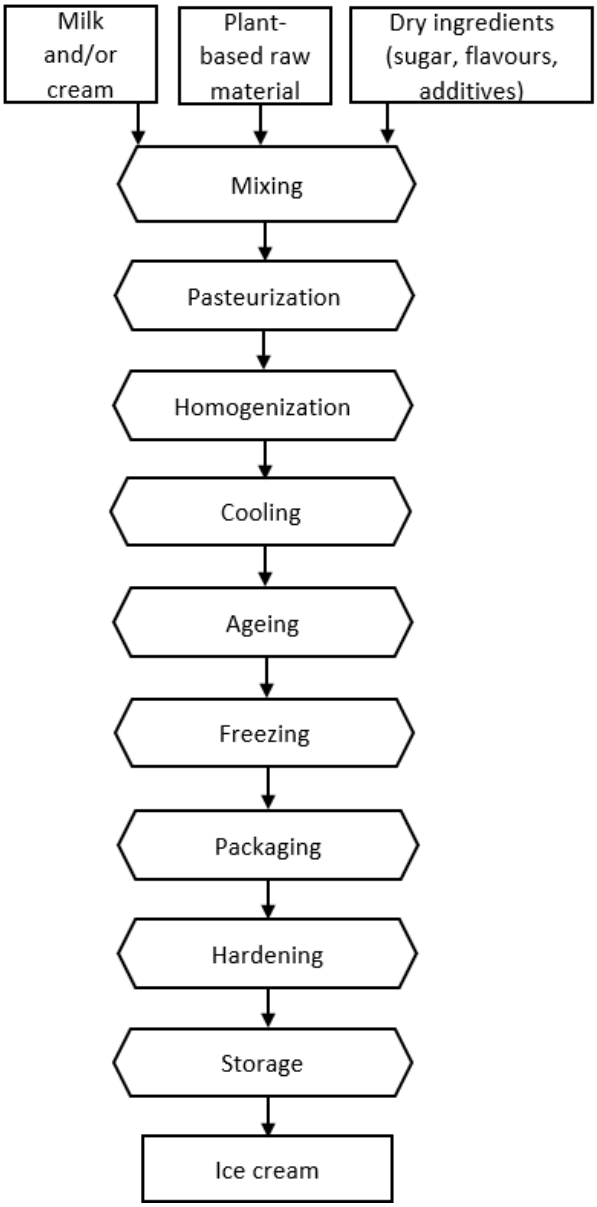


Figure 3.5.2-1. Simplified processing line for dairy-based and plant-based ice cream.

3.5.3 Yoghurt and plant-based analogues

The processing line for yoghurts and plant-based counterparts is shown in Figure 3.5.3-1.

The initial steps in the production of plant-based "yoghurt" are similar to those used in processing of plant beverages as described in section 3.5.1, pre-treatment of the seeds, dehulling and the preparation of a slurry of milled beans (e.g. faba beans) and water. This blend is pasteurised to inactivate microorganisms (Montemurro et al., 2021; TetraPak). Amylase may be added to hydrolyse the starch and improve texture. Additional oil and protein may be added before the mix is homogenised, heated, inoculated with starter culture and fermented. From the inoculation step and onwards

the processing is similar to the production of yoghurt made from milk as described below.

The initial steps in the production of yoghurt are similar to those used in processing of milk as described in Section 3.5.1, namely, separation, standardisation, homogenisation and pasteurisation (Walstra et al., 2005). Milk powder is often added during the standardisation step to increase protein content and improve texture. After heating, the milk is cooled to the optimal fermentation temperature and inoculated with the selected starter culture and fermented for a specific period, typically 4-8 hours, depending on the desired yoghurt texture and flavour. During fermentation, the bacteria multiply and produce organic acids and flavour compounds. The production of acids lowers the pH of the product and causes the milk or the plant-based raw material to thicken. Once the desired level of fermentation is achieved, the yoghurt is cooled to stop the fermentation process. Flavourings, such as jam or vanilla are added before the product is packaged into containers.

As mentioned earlier, the processing methods for traditional yoghurt and plant-based "yoghurt" diverge primarily at the initial stage where the raw materials are prepared. Traditional yoghurt production begins with readily available milk, while in the case of plant-based "yoghurt," seeds, peas, or nuts must first undergo grinding to create a slurry.

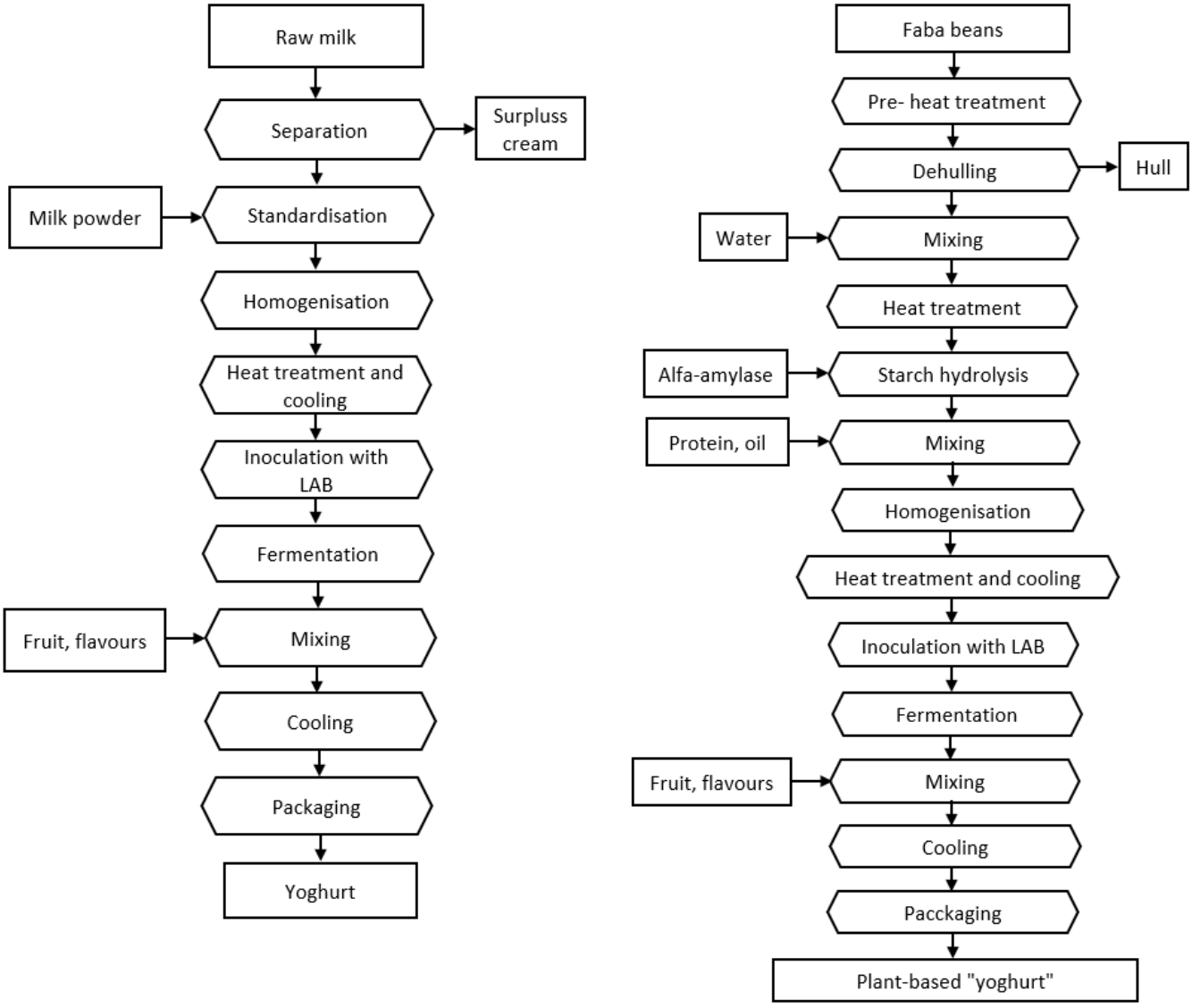


Figure 3.5.3-1. Generic flow diagram for production of yoghurt (to the left) and plant-based yoghurt analogue made from faba beans (to the right). Modified from Jiang et al. (2020).

3.5.4 Cheese and plant-based analogues

Cheese is commonly categorized based on its type, such as rennet, fresh, or processed, as well as its texture, spanning from soft to hard variations (Fox et al., 2017a).

This section describes the most important processing steps in the production of rennet and fresh cheese using Gouda cheese and cream cheese as examples. In this report process cheese will not be included.

In the production of rennet cheese, the process begins with standardization of the cheese milk to obtain the desired fat content. The milk is then pasteurized to inactivate harmful bacteria and cooled before the addition of a starter culture of selected lactic acid bacteria. Then rennet is added to coagulate the milk. This causes the milk to

curdle and form a gel-like substance (curds) from the liquid (whey). The curds are cut to release more whey and then heated at a specific temperature. The whey is drained off, leaving the curds behind. The curd fraction is placed into molds, pressed and shape the cheese. The cheese is soaked in a solution of salt (brine) and aged (matured) at controlled temperatures and humidity levels for a specific duration. During this time, the cheese develops its taste, texture, and aroma. Once fully aged, the cheese is cut, and packaged for distribution and sale.

In the production of cream cheese, the initial process steps are similar to the production of rennet cheese; standardization and pasteurization. Then a starter culture of selected lactic acid bacteria is added to the milk to start the fermentation and acidification process. This causes the milk to curdle to separate into curds and liquid (whey). The curds are then separated from the whey. Gentle draining or pressing helps remove excess whey, contributing to the cheese's creamier texture. Depending on the desired texture and flavor profile, cream, salt or seasonings may be added to the curds. Fresh cheeses are typically consumed relatively soon after production, without an extensive aging period. They might be packaged in containers or served immediately.

The production of plant-based cheese analogues starts with melting the fat (70–85°C) followed by mixing with water and stabilizers such as proteins and starches to establish a stable emulsion. Then salt, flavour compounds and food additives such as stabilizers and acidifiers are added. Subsequently, the hot molten mass is poured into molds and cooled at 4°C to solidify. It is then ready for consumption, either on its own or as an ingredient in various food products (Fox et al., 2017b; Mohd Shukri et al., 2022).

3.5.5 Meat and plant-based analogues

The processing of meat products such as minced meat, burgers, meat balls and sausages and their plant-based counterparts follows the same steps, which are described below (Kyriakopoulou et al., 2021).

For the meat-based products, the process begins with the selection of raw meat, which can include beef, pork, chicken, or a combination thereof. The meat is trimmed to remove excess fat and connective tissue. Meat with various content of fat is selected to achieve the desired fat content in the final product.

The trimmed meat is passed through a grinder to break it down into smaller pieces. The size of the grind can vary depending on the desired texture of the final product. Minced meat products are packaged in plastic containers and sold either cooled or frozen.

In the grinding step, various spices, salt, and other additives such as stabilisers and starch may be added to the ground meat.

The seasoned meat mixture used in burgers and meat balls is formed into patties of the desired size and thickness. The mixture used in sausages is typically stuffed into

casings, which can be made from natural or synthetic materials. Most sausages on the Norwegian market are heat-treated before cooling and packaging.

Burgers and meat balls can be packed and sold either cooled or frozen or heat-treated. Meat balls can also be canned to prolong shelf-life.

The ingredients used in plant-based meat analogues are mixed in a similar way as for the meat-based products. However, as the properties of the plant-based ingredients differ from their meat-based counterparts, so does the use of additives; emulsifiers and stabilisers are added to achieved proper texture during handling of the product prior to cooking and during cooking and consumption (Kyriakopoulou et al., 2021). As most plant-based ingredients used in such products are low in fat, fat or oil is most often added to obtain the desired fat content of the final product. Most often a combination of cocoa fat and rape seed oil is used. To achieve a texture similar to meat-based minced meat and burgers, texturised plant-based protein is added to the plant-based products. Extrusion is the most commonly used commercial technique to transform plant-based materials into fibrous products (Dekkers et al., 2018)

Plant-based minced meat is readily available in the Norwegian market and is typically sold refrigerated. Similarly, plant-based meatballs are also commonly found in the chilled section. On the other hand, most plant-based burgers are sold frozen. All these products require cooking before consumption.

3.5.6 Plant-based snacks alternatives to potato chips and nuts

The processing of potato chips, as well as chips made from other roots and tubers, shares several essential steps. These key processing stages remain largely consistent irrespective of the specific raw materials employed. The process begins with the selection and washing of the raw materials. Peeling may be included to remove the skin before the roots are sliced uniformly to ensure consistent chip thickness. The slices may be blanched in hot water or steamed to remove excess starch and set the colour. The blanched potato slices are then deep-fried in vegetable oil or another suitable frying oil at high temperatures. After frying, the chips pass through a seasoning drum or conveyor, where seasonings such as salt, spices, or other flavourings are applied evenly. The chips are allowed to cool on a conveyor or in a cooling tunnel before excess oil is removed, and the chips are dried to achieve the desired crispness before they are packaged into bags or containers.

3.5.7 Gluten-containing and gluten-free bread products

The processing on an industrial scale for making the most common types of breads made from gluten containing flours and gluten-free bread types is described below (Melini et al., 2017; Yano, 2019). The most important processing steps are similar regardless of the raw materials used. While the basic steps are similar, the choice of ingredients and specific techniques in gluten-free bread making are adjusted to compensate for the lack of gluten, resulting in bread with different characteristics in terms of texture and structure.

The first step in (gluten-containing traditional) bread making involves mixing of all ingredients in large industrial mixers; wheat flour, water, yeast, and salt. Sometimes additional ingredients are added, like flour based on other cereal grains such as rye or oat, whole grains, sugar, fats, and certain additives to improve the quality of the bread.

The mixed ingredients are transferred to high-capacity industrial dough kneaders to develop the gluten network and to form a strong, elastic dough. The dough is placed to rise in fermentation tanks for a period of bulk fermentation. During this time, yeast ferments the sugars, producing carbon dioxide gas, which causes the dough to rise. After fermentation the dough is divided into smaller portions of the desired weight for individual loaves or bread products. These smaller doughs are allowed to rest to relax the gluten and allow for easier shaping, before the dough is shaped into the desired bread product form, such as loaves, buns, or rolls and placed in proofer chambers where they undergo a final rise. The proofed dough is transferred to large industrial ovens on trays or conveyor belts for baking at specific temperatures and humidity levels to achieve the desired crust and internal structure of the bread. The freshly baked bread is cooled on conveyors or racks before packaging and distribution to retailers or consumers.

Gluten is a protein found in wheat, barley, rye, and related grains. Gluten-free bread uses alternative flours like rice flour, almond flour, tapioca starch, or a blend of gluten-free flours. These flours lack gluten, so alternative binders and thickeners are often necessary. Binders may include xanthan gum, guar gum, or psyllium husk powder to provide structure and prevent crumbling. Gluten-free bread products may be denser than traditional products due to the absence of gluten, and additional rising agents such as baking powder may be used.

Moreover, starch fractions may be prepared from various raw materials (such as rice, tapioca, or wheat) and used as ingredients in gluten-free products. The method of preparation depends on the raw material, but the most common steps included soaking with subsequent grinding to prepare a slurry. The starch fraction in the form of starch granules is separated from the slurry by means of one or more fractionation techniques such as centrifugation or sedimentation. The starch fraction is then washed before removal of excess water and drying and packaging. Starch products made from gluten-containing cereal grains such as wheat should be subjected to regular testing and verification of the gluten content to ensure that it consistently meets the gluten-free standard.

4 Discussion and conclusions

The overall purpose was to compare and highlight the differences in contents of nutrients, food additives and contaminants in food product types within the food categories included in this report, as well as the processing methods used in their production. This knowledge is needed by the NFSA to provide current and relevant advice to consumers. The included product categories are plant-based meat analogue products (dinner), meat products (dinner), plant-based meat analogue products (bread topping), meat products (bread topping), plant-based dairy analogue products, dairy products, gluten-free products, gluten-containing products, plant-based snacks alternatives, and potato chips and nuts.

4.1 Methodological considerations

Systematic literature searches were not performed, instead VKM chose a pragmatic approach in obtaining information about the product contents. Available sales data from websites were used. It is, however, likely that more comprehensive data on sales and market shares would have changed the selection of the included food products. Therefore, the included products are presented on the product type level instead of brand level. A systematic search may also have resulted in identification of concentration data for food additives and additional concentration data for nutrients and contaminants. Despite these limitations, VKM assume that products that transiently appear on the market were not included and that the level of a number of substances in some of the selected food products were comparable. This was supported by the comparison of the selected products with reported intake in the national dietary surveys. According to dietary intake data, all product types were reported to be consumed. Due to the limitations in the selection of products, comparisons were made on group level.

A strength of this report is the structured approach and the inclusion of substances of importance for both safe and healthy food, as well as the overview of the processing methods. Furthermore, the level of nutrients, natural toxins, environmental and process-induced contaminants were mapped and compared, when possible, for all included food product types. Mapping and comparison were also performed for the food additives and the processing methods likely to be used to produce the plant-based and gluten-free food products and their meat- and dairy-containing and gluten-containing counterpart products.

4.2 Nutrients

Different types of raw materials are sources of different types and levels of nutrients as shown in Section 3.2. The nutritional content of a food item is largely determined by its raw materials as shown in Section 3.2. A few main differences in the nutritional composition of the included product types were identified in this report. Depending on the main ingredients, non-fortified plant-based beverages have lower levels of most of

the micronutrients for which milk is an important dietary source. These are e.g. calcium, iodine, riboflavin, and vitamin B_{12}. The same tendency of lower micronutrient contents was seen in plant-based cheese analogues, with less calcium, iodine, vitamin A and folate as compared to cheese. Furthermore, plant-based cheese analogues contained almost no protein, but a fair amount of carbohydrates in the form of starch. However, both plant-based beverages and cheese analogues are sources of unsaturated fatty acids, except when they are based on coconut fat. Similar differences have been reported in other studies comparing the nutritional profile of meat and dairy products and their plant-based analogues (Bohrer, 2019; Costa-Catala et al., 2023; Pastell et al., 2021; Yang et al., 2023). Notable differences between meat and plant-based meat analogues are the protein amino acid profiles. Also, animal-based products are sources of vitamin A, of which plant-based meat analogues have less. Plant-based meat analogues are sources of unsaturated fat, which is beneficial. The most notable difference between gluten-free and gluten-containing cereal products is the protein contents which is low in the gluten-free products. For some of the food groups, particularly plant-based yoghurt and ice cream analogues and new plant-based snack alternatives, data on micronutrient content are scarce and warranted.
A varied and mainly plant-based diet is in line with the new Nordic Nutrition Recommendations (Blomhoff et al., 2023). An intake of a broad range of vegetables, including legumes, wholegrain cereals, fruit, nuts, and seeds, will contribute to a healthy and predominantly plant-based diet in compliance with the nutrient recommendations.

4.3 Food additives

Different types of food additives are used to turn different types of raw materials into products having the desired properties such as food colour and consistency, and to prolong shelf life. Since concentration data were lacking, the total amount of additives cannot be compared. The comparison of food additives was restricted to the number and type found in the ingredient lists of the selected products, as no concentration data were identified. Additional work is required to identify and conclude on differences in use of additives in these products.

4.4 Contaminants

Few data sources were used for the identification of contaminants of which the selected food items are known or expected to be an important source of exposure. It is likely that inclusion of more data sources would have given a more comprehensive overview of important contaminants. For a mapping of concentration data and comparison of the level of contaminants in counterpart product types, VKM consider that contaminants of importance for the selected food products have been identified.

Comparisons of the contaminant level in food products were made based on i) knowledge on which food items that are known or expected to be an important source of specific contaminants, and ii) for directly comparable food product types and directly comparable concentration data (See Sections 5.3.1 and 5.3.2).

For the majority of the included environmental and process-induced contaminants, food products in all the food categories in this report are known or expected important sources contributing to the total exposure to contaminants. However, there are some differences as described in Section 3.4.1. It is likely that e.g. with increased consumption of plant-based food products, the exposure to dioxins and dioxin-like PCBs and heterocyclic aromatic amines is reduced, whereas the exposure to inorganic arsenic, cadmium, alternariol methyl ether, patulin, solanine and chaconine, T-2 and HT-2 toxin, and zearalenone is increased. The only comparison made for plant-based meat analogue products and the counterpart meat products was the level of cadmium, which was slightly higher in the former. This is in line with the VKM database (VKM, 2022), plant-based food products were identified as important sources for cadmium, whereas meat products were not identified as important sources. This is also in line with the exposure assessment of EFSA from 2012 which identified vegetables and vegetable products as main sources of cadmium exposure (EFSA, 2012). Mihalache et al. (2023) evaluated the risk of replacing meat with plant-based analogues with respect to mycotoxin exposure.

Based on the VKM knowledge base, gluten-containing food products were identified as important sources for the total exposure to 21 contaminants (VKM, 2022). It was not possible to pinpoint which of these are important also for gluten-free products. However, as several raw materials are the same, VKM assumed that contaminants important for gluten-containing products may also be important for gluten-free products. Comparisons of contaminant content in gluten-free and gluten-containing food products were made for aluminium, arsenic, cadmium, and lead. Due to lack of directly comparable concentration data, VKM were not able to compare the level of the remaining contaminants identified as important in these product types. The data indicated similar levels of arsenic and similar or lower levels of cadmium in gluten-free food products. The data indicated higher levels of lead and aluminium in gluten-free product types.

In this report, no comparisons were made for snack products, natural toxins or process-induced contaminants due to lack of directly comparable concentration data. The content of contaminants in a food item is largely determined by the contaminant content of the raw materials, except for process-induced contaminants. In addition, contaminants may end up in the food through e.g. leakage from food contact materials and through production by mycotoxins during storage. Some types of contaminants are found in most foods, whereas other are found in more specific types of raw materials and therefore only present in food products including this raw material.

4.5 Processing methods

Several differences in the processing methods for the included product types were identified in this report.

When comparing plant-based dairy analogues and dairy products (milk versus plant-based beverages, yoghurt versus plant-based "yoghurt", cheese versus plant-based

"cheese", and ice cream versus plant-based "ice cream") the most noticeable differences in the processing methods are related to the distinct nature of the raw materials. Milk is a natural liquid containing proteins, fat, lactose, and minerals, whereas for the plant-based products initial processing steps are needed to produce a fraction of the soluble components (for plant-based beverages and plant-based ice cream) or a slurry prepared from the raw material (plant-based "yoghurts").

To obtain the starting material for the plant-based beverages and ice cream, the raw material is treated with enzymes to hydrolyse starch and sometimes other components, and this process step is unique for the plant-based products and is not used in processing of milk since milk does not contain starch. If enzymes are used, the final product is always treated with UHT pasteurisation to inactivate these. All plant-based beverages on the Norwegian market are UHT-treated to inactivate enzymes and to prolong storage.

The production of meat products such as minced meat, burgers, meatballs, and sausages, as well as their plant-based analogues, generally involves similar processing steps. However, the resulting characteristics of these products depend significantly on the choice of ingredients, food additives, and how these components are affected by the processing methods employed. The content of plant-based burgers and minced meat differ from the other plant-based meat analogues in that they contain texturised (extruded) plant protein in addition to protein-rich plant-based flours.

The processing of potato chips, as well as chips made from other roots and tubers, shares the most important essential steps. Hence, differences in product quality will depend on the processing (such as frying temperature, length of the frying step, reuse of frying oil) more than the raw material.

The fundamental processing steps for both gluten-containing (traditional) products and gluten-free products are similar, which suggests that the overall effect of the processing itself on the final products may be minimal.

Whether the differences in the processing methods are related to differences in the nutritional content, the use of food additives, or the content of contaminants, have not been evaluated in this mapping report. Such comparisons are outside the scope of this mapping report.

4.6 Data gaps

The following data are needed to fill in data gaps in this report:

- A more comprehensive selection of food products requires data on market shares.
- More food composition data for the new meat and dairy analogue products, as well as for the new snack products are needed.

- Comparisons of the content of nutrients, contaminants and food additives require directly comparable concentration data.

4.7 Overall conclusion

In the present report, VKM has prepared a snapshot of data on nutrients, food additives and contaminants for a selection of food products and their plant-based or gluten-free analogues. VKM identified differences in the content of nutrients, contaminants, and the use of additives in comparable product types. In general, differences in content depended on the raw materials used and any fortification of the products. Some contaminants are found in a large variety of raw materials, whereas certain contaminants are typical for certain groups of raw materials. In the data material available to VKM, concentrations of additives and information on contaminants in comparable products were missing. This report cannot be used to conclude on nutritional quality or safety of different diets. It is intended to be a starting point for identifying important factors that should be considered for safe and healthy food when food products and dietary patterns change.

5 References

Alam M.S., Kaur J., Khaira H., Gupta K. (2016) Extrusion and Extruded Products: Changes in Quality Attributes as Affected by Extrusion Process Parameters: A Review. Critical Reviews in Food Science and Nutrition 56:445-473. DOI: 10.1080/10408398.2013.779568.

Blomhoff R., Andersen R., Arnesen E.K., Christensen J.J., Eneroth H., Erkkola M., Gudanaviciene I., Halldorsson T.I., Høyer-Lund A., Lemming E.W., Meltzer H.M., Pitsi T., Schwab U., Siksna I., Thorsdottir I., Trolle E. (2023) Nordic NutritionRecommendations 2023. Copenhagen: Nordic Counsil of Ministers, https://pub.norden.org/nord2023-003/nord2023-003.pdf.

Bohrer B.M. (2019) An investigation of the formulation and nutritional composition of modern meat analogue products. Food Science and Human Wellness 8:320-329. DOI: https://doi.org/10.1016/j.fshw.2019.11.006.

Bylund G. (2005) Dairy Processing Handbook Tetra Pak Processing Systems AB S-221 86 Lund, Sweden.

Codex Alimentarius. (2021) Class names and the international numbering system for food additives Food and Agriculture Organization of the United Nations and the World Health organization, https://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXG%2B36-1989%252FCXG_036e.pdf.

Costa-Catala J., Toro-Funes N., Comas-Basté O., Hernández-Macias S., Sánchez-Pérez S., Latorre-Moratalla M.L., Veciana-Nogués M.T., Castell-Garralda V., Vidal-Carou M.C. (2023) Comparative Assessment of the Nutritional Profile of Meat Products and Their Plant-Based Analogues. Nutrients 15:2807.

Dekkers B.L., Boom R.M., van der Goot A.J. (2018) Structuring processes for meat analogues. Trends in Food Science & Technology 81:25-36. DOI: https://doi.org/10.1016/j.tifs.2018.08.011.

EFSA. (2008) Polycyclic Aromatic Hydrocarbons in Food - Scientific Opinion of the Panel on Contaminants in the Food Chain. EFSA Journal 6:724. DOI: https://doi.org/10.2903/j.efsa.2008.724.

EFSA. (2011) Scientific Opinion on the risks for public health related to the presence of zearalenone in food. EFSA Journal 9:2197. DOI: https://doi.org/10.2903/j.efsa.2011.2197.

EFSA. (2012) Cadmium dietary exposure in the European population. EFSA Journal 10:2551. DOI: https://doi.org/10.2903/j.efsa.2012.2551.

EFSA. (2014a) Scientific Opinion on the risks for human and animal health related to the presence of modified forms of certain mycotoxins in food and feed. EFSA Journal 12:3916. DOI: https://doi.org/10.2903/j.efsa.2014.3916.

EFSA. (2014b) Scientific Opinion on the risks to human and animal health related to the presence of beauvericin and enniatins in food and feed. EFSA Journal 12:3802. DOI: https://doi.org/10.2903/j.efsa.2014.3802.

EFSA. (2015) Scientific Opinion on acrylamide in food. EFSA Journal 13:4104. DOI: https://doi.org/10.2903/j.efsa.2015.4104.

EFSA. (2016) Risks for human health related to the presence of 3- and 2-monochloropropanediol (MCPD), and their fatty acid esters, and glycidyl fatty acid esters in food. EFSA Journal 14:e04426. DOI: https://doi.org/10.2903/j.efsa.2016.4426.

EFSA, Arcella D., Gergelova P., Innocenti M.L., Steinkellner H. (2017a) Human and animal dietary exposure to T-2 and HT-2 toxin. EFSA Journal 15:e04972. DOI: https://doi.org/10.2903/j.efsa.2017.4972.

EFSA, Arcella D., Gómez Ruiz J.Á., Innocenti M.L., Roldán R. (2017b) Human and animal dietary exposure to ergot alkaloids. EFSA Journal 15:e04902. DOI: https://doi.org/10.2903/j.efsa.2017.4902.

EFSA, Knutsen H.K., Alexander J., Barregård L., Bignami M., Brüschweiler B., Ceccatelli S., Cottrill B., Dinovi M., Edler L., Grasl-Kraupp B., Hogstrand C., Hoogenboom L., Nebbia C.S., Oswald I.P., Petersen A., Rose M., Roudot A.-C., Schwerdtle T., Vleminckx C., Vollmer G., Chipman K., De Meulenaer B., Dinovi M., Mennes W., Schlatter J., Schrenk D., Baert K., Dujardin B., Wallace H. (2017c) Risks for public health related to the presence of furan and methylfurans in food. EFSA Journal 15:e05005. DOI: https://doi.org/10.2903/j.efsa.2017.5005.

EFSA, Knutsen H.K., Alexander J., Barregård L., Bignami M., Brüschweiler B., Ceccatelli S., Cottrill B., Dinovi M., Grasl-Kraupp B., Hogstrand C., Hoogenboom L., Nebbia C.S., Oswald I.P., Petersen A., Rose M., Roudot A.-C., Schwerdtle T., Vleminckx C., Vollmer G., Wallace H., De Saeger S., Eriksen G.S., Farmer P., Fremy J.-M., Gong Y.Y., Meyer K., Naegeli H., Parent-Massin D., Rietjens I., van Egmond H., Altieri A., Eskola M., Gergelova P., Ramos Bordajandi L., Benkova B., Dörr B., Gkrillas A., Gustavsson N., van Manen M., Edler L. (2017d) Risks to human and animal health related to the presence of deoxynivalenol and its acetylated and modified forms in food and feed. EFSA Journal 15:e04718. DOI: https://doi.org/10.2903/j.efsa.2017.4718.

EFSA, Knutsen H.K., Alexander J., Barregård L., Bignami M., Brüschweiler B., Ceccatelli S., Dinovi M., Edler L., Grasl-Kraupp B., Hogstrand C., Hoogenboom L., Nebbia C.S., Oswald I., Petersen A., Rose M., Roudot A.-C., Schwerdtle T., Vollmer G., Wallace H., Cottrill B., Dogliotti E., Laakso J., Metzler M., Velasco L., Baert K., Ruiz J.A.G., Varga E., Dörr B., Sousa R., Vleminckx C. (2016) Erucic acid in feed and food. EFSA Journal 14:e04593. DOI: https://doi.org/10.2903/j.efsa.2016.4593.

EFSA, Schrenk D., Bignami M., Bodin L., Chipman J.K., del Mazo J., Grasl-Kraupp B., Hogstrand C., Hoogenboom L., Leblanc J.-C., Nebbia C.S., Nielsen E., Ntzani E., Petersen A., Sand S., Schwerdtle T., Vleminckx C., Marko D., Oswald I.P., Piersma A., Routledge M., Schlatter J., Baert K., Gergelova P., Wallace H. (2020a) Risk assessment of aflatoxins in food. EFSA Journal 18:e06040. DOI: https://doi.org/10.2903/j.efsa.2020.6040.

EFSA, Schrenk D., Bodin L., Chipman J.K., del Mazo J., Grasl-Kraupp B., Hogstrand C., Hoogenboom L., Leblanc J.-C., Nebbia C.S., Nielsen E., Ntzani E., Petersen A., Sand S., Schwerdtle T., Vleminckx C., Wallace H., Alexander J., Dall'Asta C., Mally A., Metzler M., Binaglia M., Horváth Z., Steinkellner H., Bignami M. (2020b) Risk assessment of ochratoxin A in food. EFSA Journal 18:e06113. DOI: https://doi.org/10.2903/j.efsa.2020.6113.

European Dairy Association. (2023) Milk VS Plant based beverages https://eda.euromilk.org/fileadmin/user_upload/Public_Documents/EDA_Position_papers_-_Fact_Sheets/Fact_sheets/EDA_Q_A_Milk_vs_plant_based_beverages.pdf.

Fellows P.J. (2022) Food Processing Technology. Principles and Practice. 5th Edition - June 18, 2022 Woodhead Publishing, https://shop.elsevier.com/books/food-processing-technology/fellows/978-0-323-85737-6.

Fox P.F., Guinee T.P., Cogan T.M., McSweeney P.L.H. (2017a) Fundamentals of Cheese Science. Second Edition Springer Nature.

Fox P.F., Guinee T.P., Cogan T.M., McSweeney P.L.H. (2017b) Processed Cheese and Substitute/Imitation Cheese Products, in: P. F. Fox, et al. (Eds.), Fundamentals of Cheese Science, Springer US, Boston, MA. pp. 589-627.

Grimsby S., Gonera A., Ueland Ø. (2021) Salgsutvikling for nye plantebaserte produkter. Rapport 39, Nofima, https://nofima.brage.unit.no/nofima-xmlui/handle/11250/2837983.

Helsedirektoratet. (2022) Utviklingen i norsk kosthold. Rapport IS-3054, https://www.helsedirektoratet.no/rapporter/utviklingen-i-norsk-kosthold/Utviklingen%20i%20norsk%20kosthold%202022%20-%20Kortversjon.pdf/_/attachment/inline/b8079b0a-fefe-4627-8e96-bd979c061555:e22da8590506739c4d215cfdd628cfaaa3b2dbc8/Utviklingen%20i%20norsk%20kosthold%202022%20-%20Kortversjon.pdf.

Jiang Z.-Q., Wang J., Stoddard F., Salovaara H., Sontag-Strohm T. (2020) Preparation and Characterization of Emulsion Gels from Whole Faba Bean Flour. Foods 9:755.

Johansson L., Solvoll K. (1999) Norkost 1993-94 og 1997 Landsomfattende kostholdsundersøkelser blant menn og kvinner i alderen 16-79 år, Statens råd for ernæring og fysisk aktivitet, Institutt for ernæringsforskning, Universitetet i Oslo.

Kollander B., Rodushkin I., Sundström B. (2023) Multi-Element Assessment of Potentially Toxic and Essential Elements in New and Traditional Food Varieties in Sweden. Foods 12:1831.

Kyriakopoulou K., Keppler J.K., van der Goot A.J. (2021) Functionality of Ingredients and Additives in Plant-Based Meat Analogues. Foods 10:600.

Leahu A., Ropciuc S., Ghinea C. (2022) Plant-Based Milks: Alternatives to the Manufacture and Characterization of Ice Cream. Applied Sciences 12:1754.

Lex A., Gehlenborg N., Strobelt H., Vuillemot R., Pfister H. (2014) UpSet: Visualization of Intersecting Sets. IEEE Transactions on Visualization and Computer Graphics 20:1983-1992. DOI: 10.1109/TVCG.2014.2346248.

López Sáncheza P., de Nijsa M., Spanjerb M., Pietric A., Bertuzzic T., Starski A., Postupolski J., Castellari M., Hortós M. (2017) Generation of occurrence data on citrinin in food. EFSA Supporting Publications 14:1177E. DOI: https://doi.org/10.2903/sp.efsa.2017.EN-1177.

Mattilsynet. (2017) Analyse av brød, knekkebrød og frokostblandinger, https://mattilsynet-xp7prod.enonic.cloud/api/_/attachment/inline/3f648304-

e827-48a3-a93b-32610c93b8fd:b6579baf8215bea336408727f15326a5f58a78ea/Rapport%202017_%20N%C3%A6ringstoffer,%20tungmetaller,%20akrylamid%20og%20mykotoksin%20i%20br%C3%B8d,%20knekkebr%C3%B8d%20og%20frokostblandinger.pdf.

Mattilsynet. (2018) Analyser av arsen, tungmetaller og næringsstoffer i risprodukter, https://mattilsynet-xp7prod.enonic.cloud/api/_/attachment/inline/0949e533-59d2-42fa-82da-0faf23ee5075:e9b510ab7e509ec60cb2bb63d2e5dcbaf49b0310/Rapport%202018_%20Analyser%20av%20arsen,%20tungmetaller%20og%20n%C3%A6ringsstoffer%20i%20risprodukter.pdf.

Melini F., Melini V., Luziatelli F., Ruzzi M. (2017) Current and Forward-Looking Approaches to Technological and Nutritional Improvements of Gluten-Free Bread with Legume Flours: A Critical Review. Comprehensive Reviews in Food Science and Food Safety 16:1101-1122. DOI: https://doi.org/10.1111/1541-4337.12279.

Mihalache O.A., Dellafiora L., Dall'Asta C. (2023) Assessing the Mycotoxin-related Health Impact of Shifting from Meat-based Diets to Soy-based Meat Analogues in a Model Scenario Based on Italian Consumption Data. Exposure and Health 15:661-675. DOI: 10.1007/s12403-022-00514-z.

Mohd Shukri A., Alias A.K., Murad M., Yen K.-S., Cheng L.-H. (2022) A review of natural cheese and imitation cheese. Journal of Food Processing and Preservation 46:e16112. DOI: https://doi.org/10.1111/jfpp.16112.

Montemurro M., Pontonio E., Coda R., Rizzello C.G. (2021) Plant-Based Alternatives to Yogurt: State-of-the-Art and Perspectives of New Biotechnological Challenges. Foods 10. DOI: 10.3390/foods10020316.

Norwegian Food Safety Authority, Institute of Marine Research. (2021) Analyse av næringsstoffer, tungmetaller og mykotoksiner i korn, https://mattilsynet-xp7prod.enonic.cloud/api/_/attachment/inline/ab1e2905-1762-4e8d-9440-6d0565b5ce65:5df4fd2205ee60cfd5c0f5817a9c46dc94733bfc/Rapport_%20Analyser%20av%20n%C3%A6ringsstoffer,%20tungmetaller%20og%20mykotoksiner%20i%20kornprodukter%202021.pdf.

Norwegian Food Safety Authority, Institute of Marine Research. (2022a) Analyse av næringsstoffer og uønskede stoffer i plantebaserte middagsprodukter og drikker, Norwegian Food Safety Authority, https://mattilsynet-xp7prod.enonic.cloud/api/_/attachment/inline/7d9fc8db-bd4f-4bf9-93ea-35e07ea4c1c3:f66e97a97355f3c0ae9f3a3ca5a5e7163d9c4fab/Rapport_%20Analyser%20av%20n%C3%A6ringsstoffer%20og%20u%C3%B8nskede%20stoffer%20i%20plantebaserte%20middagsprodukter%20og%20drikker%202021.pdf.

Norwegian Food Safety Authority, Institute of Marine Research. (2022b) Analyse av næringsstoffer og uønskede stoffer i vegan- og fiskepålegg, tran, pepperoni og tørket frukt, https://mattilsynet-xp7prod.enonic.cloud/api/_/attachment/inline/1304195b-d0e2-451b-a22b-b8ba92efc1e7:b9fe162c5716d1ce5adbd3cae7c977406d65377e/Rapport_%20Analyser%20av%20n%C3%A6ringsstoffer%20og%20u%C3%B8nskede%20stoffer%20i%20vegan-

og%20fiskep%C3%A5legg,%20tran,%20pepperoni%20og%20t%C3%B8rket%20frukt%202022.pdf.

Pastell H., Kollander B., Valsta L., Järvinen J. (2021) Are gluten-free products a healthier alternative?: A pilot study on nutrients and heavy metals Nordic Council of Ministers, http://norden.diva-portal.org/smash/get/diva2:1542657/FULLTEXT02.pdf.

Regulation (EC) No 1881/2006. Commission Regulation (EC) No. 1881/2006 setting maximum levels for certain contaminants in foodstuffs, https://leap.unep.org/countries/eu/national-legislation/commission-regulation-ec-no-18812006-setting-maximum-levels.

Regulation (EU) No 828/2014. Commission Implementing Regulation (EU) No 828/2014 of 30 July 2014 on the requirements for the provision of information to consumers on the absence or reduced presence of gluten in food, European Union, https://eur-lex.europa.eu/eli/reg_impl/2014/828/oj.

Sethi S., Tyagi S.K., Anurag R.K. (2016) Plant-based milk alternatives an emerging segment of functional beverages: a review. J Food Sci Technol 53:3408-3423. DOI: 10.1007/s13197-016-2328-3.

Singh S., Gamlath S., Wakeling L. (2007) Nutritional aspects of food extrusion: a review. International Journal of Food Science & Technology 42:916-929. DOI: https://doi.org/10.1111/j.1365-2621.2006.01309.x.

TetraPak. White paper. Plant-based yoghurt-style products. The role of ingredients and process control, https://www.tetrapak.com/content/dam/tetrapak/publicweb/gb/en/insights/documents/Plant-based_yoghurt_style-products_white_paper.pdf.

Totland T.H., Melnæs B.K., Lundberg-Hallén N., Helland-Kigen K.M., Lund-Blix N.A., Myhre J.B., Johansen A.M.W., Løken E.B., Andersen L.F. (2012) Norkost 3 En landsomfattende kostholdsundersøkelse blant menn og kvinner i Norge i alderen 18-70 år, 2010-11. , Universitetet i Oslo, Mattilsynet og Helsedirektoratet https://www.helsedirektoratet.no/rapporter/norkost-3-en-landsomfattende-kostholdsundersokelse-blant-menn-og-kvinner-i-norge-i-alderen-18-70-ar-2010-11/Norkost%203%20en%20landsomfattende%20kostholdsundersokelse%20blant%20menn%20og%20kvinner%20i%20Norge%20i%20alderen-18-70%20%C3%A5r%202010-11.pdf/_/attachment/inline/b7bafaab-6059-4450-8d76-c3ed9f3eaf3f:be251cd1153cf1ae8e4c46eedddc13b36da3d11d/Norkost%203%20en%20landsomfattende%20kostholdsundersokelse%20blant%20menn%20og%20kvinner%20i%20Norge%20i%20alderen-18-70%20%C3%A5r%202010-11.pdf.

Tricco A.C., Lillie E., Zarin W., O'Brien K.K., Colquhoun H., Levac D., Moher D., Peters M.D.J., Horsley T., Weeks L., Hempel S., Akl E.A., Chang C., McGowan J., Stewart L., Hartling L., Aldcroft A., Wilson M.G., Garritty C., Lewin S., Godfrey C.M., Macdonald M.T., Langlois E.V., Soares-Weiser K., Moriarty J., Clifford T., Tunçalp Ö., Straus S.E. (2018) PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med 169:467-473. DOI: 10.7326/m18-0850.

VKM. (2018) Routine for approval of risk assessments (in Norwegian), Norwegian Scientific Committee for Food and Environment, https://vkm.no/download/18.433c8e05166edbef03bbda5f/1543579222271/Rutine%20for%20godkjenning%20av%20risikovurderinger.pdf.

VKM. (2019) Criteria for authorship and scientific responsibility in VKM's statements (in Norwegian), Norwegian Scientific Committee for Food and Environment, https://vkm.no/download/18.48566e5316b6a4910fc2dbd6/1561035075341/VKMs%20forfatterskapskriterier_revidert%20versjon%2020.06.2019.pdf.

VKM. (2022) Food and chemical substances relevant for monitoring, in: N. S. C. f. F. a. Environment (Ed.), https://vkm.no/download/18.3eba7778181165b6b20e2a49/1654753293375/Kopi%20av%20Kunnskapsbase_u%C3%B8nskede%20kjemiske%20stoffer_matvarer_final_08.06.2022.xlsx.

VKM, Andersen L.F., Berstad P., Bukhvalova B., Carlsen M., Dahl L., Goksøyr A., Jakobsen L.S., Knutsen H.K., Kvestad I., Lillegaard I.T., Mangschou B., Meyer H., Parr C.L., Rakkestad K.E., Rasinger J., Sengupta S., Skeie G., Starrfelt J., Ulven S.M., Agdestein A., Bodin J., Bruzell E., Elvevoll E., Hessen D.O., Husøy T., Krogdahl Å., Nilsen A.M., Skjerdal T., Steffensen I.-L., Strand T.A., Velle G., Wasteson Y., Alexander J. (2022) Benefit and risk assessment of fish in the Norwegian diet, https://vkm.no/download/18.7ef5d6ea181166b6bb6a110c/1654589000550/Benefit%20and%20risk%20assessment%20of%20fish%20in%20the%20Norwegian%20diet%207.6.22.pdf.

VKM, Devold T.G., Andreassen M., Carlsen M.H., Denison E., Mathisen G.H., Rasinger J.D., Svendsen C., Bruzell E., El Yamani N., Granum B., Husøy T. (2023) Protocol for mapping of nutrients, food additives and contaminants in plant-based and gluten-free food products, Norwegian Scientific Committee for Food and Environment, https://vkm.no/download/18.57a9b20e186922bca19b21f8/1678277751351/Protocol%20for%20mapping%20of%20nutrients,%20food%20additives%20and%20contaminants%20in%20plant-based%20and%20gluten-free%20food%20products_final_08.03.2023.pdf.

Walstra P., Walstra P., Wouters J.T.M., Geurts T.J. (2005) Dairy Science and Technology (2nd ed.). CRC Press. https://doi.org/10.1201/9781420028010.

Yang Y., Zheng Y., Ma W., Zhang Y., Sun C., Fang Y. (2023) Meat and plant-based meat analogs: Nutritional profile and in vitro digestion comparison. Food Hydrocolloids 143:108886. DOI: https://doi.org/10.1016/j.foodhyd.2023.108886.

6 Appendix I: Food additives

An overview of all food additives in the selected food products is shown in Table 6-1.

Table 6-1. Food additives in the selected food products (from ingredient lists).

Food additive categories	E number and name
Food colour	100 Curcumin
Food colour	120 Carmine
Food colour	141 Copper complexes of chlorophyll and chlorophyllins
Food colour	150 Caramel colours
Food colour	160 Carotenoids
Food colour	161 Xanthophylls
Food colour	162 Beetroot red
Food colour	163 Anthocyanins
Food colour	170 Calcium carbonate
Food colour	172 Iron oxides
Preservative	200 Sorbic acid
Preservative	202 Potassium sorbate
Preservative	211 Sodium benzoate
Preservative	220 Sulphur dioxide
Preservative	221 Sodium sulphite
Preservative	250 Sodium nitrite
Preservative	251 Sodium nitrate
Preservative	261 Potassium acetate
Preservative	262 Sodium acetate
Preservative	270 Lactic acid
Preservative	282 Calcium propionate
Preservative	296 Malic acid
Antioxidant	300 Ascorbic acid

Food additive categories	E number and name
Antioxidant	301 Sodium ascorbate
Antioxidant	304 Ascorbyl palmitate
Antioxidant	306 Tocopherol
Antioxidant	307 Alpha-tocopherol
Antioxidant	315 Erythorbic acid
Antioxidant	316 Sodium erythorbate
Antioxidant	322 Lecithin
Antioxidant	325 Sodium lactate
Antioxidant	326 Potassium lactate
Antioxidant	330 Citric acid
Antioxidant	331 Sodium citrates
Antioxidant	333 Calcium citrate
Antioxidant	339 Sodium phosphate
Antioxidant	340 Potassium phosphate
Antioxidant	341 Calcium phosphate
Antioxidant	392 Extracts of rosemary
Emulsifiers, stabilisers, and thickeners	401 Sodium alginate
Emulsifiers, stabilisers, and thickeners	407 Carrageenan
Emulsifiers, stabilisers, and thickeners	410 Locust bean gum
Emulsifiers, stabilisers, and thickeners	412 Guar gum
Emulsifiers, stabilisers, and thickeners	414 Acacia gum
Emulsifiers, stabilisers, and thickeners	415 Xanthan gum
Emulsifiers, stabilisers, and thickeners	417 Tara gum
Emulsifiers, stabilisers, and thickeners	418 Gellan gum
Emulsifiers, stabilisers, and thickeners	420 Sorbitol
Emulsifiers, stabilisers, and thickeners	422 Glycerol
Emulsifiers, stabilisers, and thickeners	425 Konjac
Emulsifiers, stabilisers, and thickeners	435 Polyoxyethylene sorbitan monostearate

Food additive categories	E number and name
Emulsifiers, stabilisers, and thickeners	440 Pectins
Emulsifiers, stabilisers, and thickeners	450 Diphosphates
Emulsifiers, stabilisers, and thickeners	451 Potassium and sodium tri-phosphates
Emulsifiers, stabilisers, and thickeners	452 Polyphosphates
Emulsifiers, stabilisers, and thickeners	460 Cellulose
Emulsifiers, stabilisers, and thickeners	461 Methyl cellulose
Emulsifiers, stabilisers, and thickeners	464 Hydroxypropylmethylcellulose
Emulsifiers, stabilisers, and thickeners	466 Sodium carboxy methyl cellulose
Emulsifiers, stabilisers, and thickeners	471 Mono-and Diglycerides of Fatty Acids
Emulsifiers, stabilisers, and thickeners	472 Acetic acid esters
Emulsifiers, stabilisers, and thickeners	473 Sucrose esters of fatty acids
Emulsifiers, stabilisers, and thickeners	476 Polyglycerol polyricinoleate
Emulsifiers, stabilisers, and thickeners	481 Sodium stearoyl lactate
Anti-caking agents and acidity regulators	500 Sodium bicarbonate
Anti-caking agents and acidity regulators	501 Potassium carbonates
Anti-caking agents and acidity regulators	503 Ammonium carbonate
Anti-caking agents and acidity regulators	508 Potassium chloride
Anti-caking agents and acidity regulators	509 Calcium chloride
Anti-caking agents and acidity regulators	516 Calcium sulfate
Anti-caking agents and acidity regulators	525 Potassium hydroxide
Anti-caking agents and acidity regulators	551 Silicon dioxide
Anti-caking agents and acidity regulators	575 Glucono delta lactone
Anti-caking agents and acidity regulators	576 Sodium gluconate
Flavour enhancer	621 Monosodium glutamate
Flavour enhancer	627 Disodium guanylate
Flavour enhancer	630 Inosinic acid
Flavour enhancer	635 Sodium ribonucleotides
Packaging gas	941 Nitrogen

Food additive categories	E number and name
Packaging gas	942 Nitrous oxide
Sweetener	950 Acesulfame potassium
Sweetener	951 Aspartame
Sweetener	953 Isomalt
Sweetener	955 Sucralose
Sweetener	960 Steviol glycosides
Sweetener	965 Maltitol
Sweetener	967 Xylitol
Sweetener	968 Erythritol
Other	1100 Amylase
Other	1200 Polydextrose
Other	1404 Oxidised starch
Other	1414 Acetylated distarch phosphate
Other	1422 Acetylated distarch adipate
Other	1442 Hydroxypropyl distarch phosphate
Other	1450 Starch sodium octenyl succinate

7 Appendix II: Contaminants

7.1 Degree of contribution to total exposure

An overview of contaminants of which the selected food items are known or expected to be an important source for the different food categories is shown in Table 7.1-1. An overview of the degree of known contribution to total exposure and the expected contribution to exposure is shown in Tables 7.1-2 and 7.1-3

Table 7.1-1. Contaminants of which the selected food items are known or expected to be an important source for the different food categories.

Contaminant type	Contaminant	Food products	Plant-based	Gluten-containing

		of animal origin	meat and dairy analogue products	food products
Environmental contaminants	Aluminium	x	x	x
	Arsenic (inorganic)		x	x
	Cadmium		x	x
	Dioxins and dioxin-like PCBs*	x		
	Lead	x	x	x
	Non-dioxin-like polychlorinated biphenyls**	x	x	x
	Perchlorate	x	x	
	Perfluorinated and polyfluorinated alkyl substances***	x	x	x
Natural toxins	Aflatoxin****	x	x	x
	Alternariol methyl ether		x	
	Citrinin			x
	Deoxynivalenol			x
	Enniatin*****			x
	Ergot alkaloids			x
	Erucic acid	x	x	x
	Fumonisins			x
	Ochratoxin A	x	x	x
	Patulin		x	
	Solanine and chaconine		x	
	T-2 and HT-2 toxin		x	x
	Tropane alkaloids			x
	Zearalenone		x	x

Process-induced contaminants	Acrylamide		x	x
	Furan			x
	Glycidol from esters	x	x	
	Heterocyclic aromatic amines	x		
	2-Monochloropropane-1,2-diol	x	x	x
	3-Monochloropropane-1,2-diol	x	x	x

*Sum of 29 congeners.
**PCB28, PCB52, PCB101, PCB138, PCB153, PCB180.
***Sum of PFOS, PFOA, PFNA and PFHxS.
****Sum of AFB1, AFB2, AFG1, AFG2 and AFM1.
***** Sum of Enniatins.

Table 7.1-2. The extent to which the food groups will contribute to the total contaminant exposure. Known contribution to total exposure (blue colouring of table cells) includes the categories VH=very high; H=high; M=moderate; C(E)H=estimated high; or C(M)=important (Section 2.2). Expected contribution to exposure (yellow colouring of table cells) include the category PC=expected to contribute significantly.

Contaminants	**Food product of animal origin**				**Plant-based meat and dairy analogue food products**					
	Butter	**Cheese**	**Milk and dairy products***	**Meat and offal**	**Legumes, nuts, and oilseeds**	**Rice**	**Potato and potato products**	**Soy**	**Vegetable fats and oils**	**Vegetables and vegetable products**
Natural toxins										
Aflatoxin			H					X	M	
Alternariol methyl ether									M	
Erucic acid	VH		H						VH	H
Ochratoxin A		VH		VH				X		M
Patulin										PC
Solanine and chaconine							C(M)			PC
T-2 and HT-2 toxin									M	
Zearalenone									M	
Environmental contaminants										
Aluminium		PC	PC	PC	PC	PC	PC			PC
Arsenic, inorganic						M				
Cadmium								X		M
Dioxins and dioxin-like polychlorinated biphenyls			H	M						
Lead			M							PC****

Contaminants	Food product of animal origin				Plant-based meat and dairy analogue food products					
	Butter	Cheese	Milk and dairy products*	Meat and offal	Legumes, nuts, and oilseeds	Rice	Potato and potato products	Soy	Vegetable fats and oils	Vegetables and vegetable products
Non-dioxin-like polychlorinated biphenyls	PC		PC	PC		PC			PC	PC
Perchlorate			H							VH
Perfluorinated and polyfluorinated alkyl substances				C(E)H			C(E)H			C(E)H
Process-induced contaminants										
Acrylamide							H			
Glycidol from esters	C(M)			C(M)**					C(M)	
Heterocyclic aromatic amines				PC						
2-Monochloro-propane-1, 2-diol	C(M)			C(M)**			C(M)***		C(M)	PC****
3-Monochloro-propane-1,2-diol	C(M)			C(M)**			C(M)***	X	C(M)	PC****

* Not including butter and cheese

** Fried or roast meat

*** Fried or baked potato products

**** Plant-based dinners

Table 7.1-3. The extent to which the food groups will contribute to the total contaminant exposure. Known contribution to total exposure (blue colouring of table cells) includes the categories VH=very high; H=high; M=moderate; C(E)M=estimated moderate; or C(M)=important (section 2.2). Expected contribution to exposure (yellow colouring of table cells) include the category PC=expected to contribute significantly.

Contaminants	Bread	Grains, cereals	Pasta
Natural toxins			
Aflatoxin	H	H	
Citrinin		PC	
Deoxynivalenol	H	M	M
Enniatin	VH	H	H
Ergot alkaloids	VH	M	
Erucic acid		VH	
Fumonisins	M		M
Ochratoxin A		H	
T-2 and HT-2 toxin		VH	H
Tropane alkaloids	PC		
Zearalenone	M	H	M
Environmental contaminants			
Aluminium	PC	PC	
Arsenic, inorganic		M	
Cadmium		H	
Lead		M	
Non-dioxin-like polychlorinated biphenyls		PC	
Perfluorinated and polyfluorinated alkyl substances		C(E)M	
Process-induced contaminants			

Contaminants	Bread	Grains, cereals	Pasta
Acrylamide	H	M	
Furan		C(M)	
2-monochloro-propane-1, 2-diol	C(M)		
3-Monochloro-propane-1,2-diol	C(M)		

7.2 Concentration data combined with the data on contribution

The data sources are numbered as follows in the tables:

- 1 and 2: Datasets from NFSA (Mattilsynet, 2017; Mattilsynet, 2018; Norwegian Food Safety Authority and Institute of Marine Research, 2021; Norwegian Food Safety Authority and Institute of Marine Research, 2022a; Norwegian Food Safety Authority and Institute of Marine Research, 2022b).
- 3: A report from the Nordic Council of Ministers (Pastell et al., 2021).
- 4: EFSA Opinions and EFSA supporting publications (EFSA, 2008; EFSA, 2011; EFSA, 2014a; EFSA, 2014b; EFSA, 2015; EFSA, 2016; EFSA et al., 2017a; EFSA et al., 2017b; EFSA et al., 2017c; EFSA et al., 2017d; EFSA et al., 2016; EFSA et al., 2020b; López Sáncheza et al., 2017).
- 5: A publication containing Swedish data (Kollander et al., 2023).
- 6: A VKM risk-benefit assessment (VKM et al., 2022).

An overview of the degree of known contribution to total exposure and the expected contribution to exposure and the availability of concentration data is shown in Tables 7.2-1, 7.2-2 and 7.2-3.

Table 7.2-1. Animal- and plant-based food products; availability of concentration data. Green colouring of table cells: Concentration data is available, and the food items is known or expected to be an important source for the total exposure to the contaminant. Known contribution to total exposure: VH=very high; H=high; M=moderate; C(E)H=estimated high; C(E)M=estimated moderate; C(M)=important contributor. Expected contribution to exposure: PC=expected to contribute significantly. Where concentration data is available, the cell is marked with a number of which refers to the source: 1 and 2: NFSA; 4: EFSA; 5: Publication with Swedish data; 6: VKM. -: Concentration data were not identified.

Contaminants	**Animal-based products**						**Plant-based products**			
	Butter	**Cheese**	**Milk and dairy products***	**Meat and offal**	**Legumes, nuts, and oilseeds**	**Rice**	**Potato and potato products**	**Soy**	**Vegetable fats and oils**	**Vegetables and vegetable products**
Natural toxins										
Aflatoxin	4		H/4	4	4			X/-	M/-	4
Alternariol methyl ether					4	4	4		M/4	4
Erucic acid	VH/1;4	1;4	H/4	4	4	1	4		VH/1;4	H/-
Ochratoxin A	4	VH/4		VH/4	4	4	4	X/-	4	M/4
Patulin										PC/-
Solanine and chaconine							C(M)/-			PC/-
T-2 and HT-2 toxin					4	4			M/4	
Zearalenone									M/4	
Environmental contaminants										
Aluminium	5	PC/5	PC/5	PC/5	PC/5	PC/5	PC/5			PC/5
Arsenic, inorganic						M/1;5				
Cadmium	5	5	5	2;5	5	1;5	5	X/-		M/5

Contaminants	Animal-based products						Plant-based products			
	Butter	Cheese	Milk and dairy products*	Meat and offal	Legumes, nuts, and oilseeds	Rice	Potato and potato products	Soy	Vegetable fats and oils	Vegetables and vegetable products
Dioxins and dioxin-like polychlorinated biphenyls	6	6	H/6	M/6			6			6
Lead	5	5	M/5	2;5	5	1;5	5			PC****/5
Non-dioxin-like polychlorinated biphenyls	PC/4	4	PC/4	PC/4		PC/-			PC/4	PC/-
Perchlorate		4	H/4		4		4		4	VH/4
Perfluorinated and polyfluorinated alkyl substances	4;6	6	6	C(E)H/4;6	4	6	C(E)H/6		4;6	C(E)H/4;6
Process-induced contaminants										
Acrylamide				4	4		H/4			
Glycidol from esters	C(M)/4			C(M)**/4			4		C(M)/4	
Heterocyclic aromatic amines				PC/-						
2-monochloro-propane-1, 2-diol	C(M)/4			C(M)**/4			C(M)***/4		C(M)/4	PC****/-
3-Monochloro-propane-1,2-diol	C(M)/4			C(M)**/4			C(M)***/4	X/-	C(M)/4	PC****/-

*Not including butter and cheese.

Table 7.2-2. Gluten-containing and gluten-free food products; availability of concentration data. Green colouring of table cells: Concentration data is available, and the food items is known or expected to be an important source for the total exposure to the contaminant. Known contribution to total exposure: VH=very high; H=high; M=moderate; C(E)H=estimated high; C(E)M=estimated moderate; C(M)=important contributor. Expected contribution to exposure: PC=expected to contribute significantly. Where concentration data is available, the cell is marked with a number of which refers to the source: 1: NFSA; 3: Nordic Council of Ministers; 4: EFSA; 5: Publication with Swedish data; 6: VKM. -: Concentration data were not identified.

Contaminant	Bread	Bread, gluten-free	Grains and cereals	Grains and cereals, gluten-free	Flour	Flour, gluten-free	Pasta	Pasta, gluten-free
Natural toxins								
Aflatoxin	H/-	H/-	H/4	H/-				
Citrinin	4		PC/4	PC/-	PC/-		4	
Deoxynivalenol	H/1;4	H/-	M/1;4	M/-	1	1	M/-	M/-
Enniatin	VH/-	VH/-	H/4	H/-			H/4	H/-
Ergot alkaloids	VH/4	VH/-	M/4	M/-	4		4	
Erucic acid	1;4		VH/1;4	VH/-	1	1;4		
Fumonisins	M/4	M/-	4		4		M/-	M/-
Ochratoxin A	4		H/4	H/-			4	4
T-2 and HT-2 toxin	4		VH/4	VH/-			H/4	H/-
Tropane alkaloids	PC/-	PC/-						
Zearalenone	M/4	M/-	H/4	H/-			M/-	M/-
Environmental contaminants								
Aluminium	PC/3;5	PC/3;5	PC/3;5	PC/3	PC/3	PC/3		

Contaminant	Bread	Bread, gluten-free	Grains and cereals	Grains and cereals, gluten-free	Flour	Flour, gluten-free	Pasta	Pasta, gluten-free
Arsenic, inorganic	5	5	M/-	M/-				
Cadmium	1;3;5	3;5	H/1;3;5	H/3	1;3	1;3	1;5	1
Lead	1;3;5	3;5	M/1;3;5	M/3	1;3	1;3	1;5	1
Non-dioxin-like polychlorinated biphenyls			PC/-	PC/-				
Perfluorinated and polyfluorinated alkyl substances	6		C(E)M/4	C(E)M/-				
Process-induced contaminants								
Acrylamide	H/1	H/4	M/1;4	M/-	1	1		
Furan	4		C(M)/4	C(M) /-	4		4	
2-monochloro-propane-1, 2-diol	C(M)/4	C(M) /-	4					
3-Monochloro-propane-1,2-diol	C(M)/4	(M) /-	4					

Table 7.2-3. Availability of concentration data for contaminants in prepared animal-based and plant-based food products. Where concentration data is available, the cell is marked with a number of which refers to the source: 1: NFSA; 4: EFSA; 5: Publication with Swedish data.

Contaminants	Ice cream (animal-based product)	"Ice cream" (plant-based product)	Milk (animal-based product)	Plant-based beverages	Meat, dinner (animal-based product)	Meat analogue, dinner (plant-based product)	Meat, bread topping (animal-based product)	Meat analogue, bread topping (plant-based product)
Natural toxins								
Aflatoxin				1				

Deoxynivalenol				1		1		
Erucic acid	4	4	4	1;4	1	1	1	
Ochratoxin A	4			1; 4		1; 4		
T-2 and HT-2 toxin				1		1		
Zearalenone				1		1		
Environmental contaminants								
Cadmium				1	1	1; 5	1	
Lead				1	1	1; 5	1	
Process-induced contaminants								
Acrylamide				1		1		
Furan	4					1		
Glycidol from esters				1		1		
3-Monochloropropane-1,2-diol				1		1		

7.3 Data for comparison of contaminants in food

Comparisons of the content of contaminants in animal-based and plant-based analogue products and in gluten-containing and gluten-free products were made for a selection of food products. VKM decided to restrict the comparisons to directly comparable product types, and the comparisons were further restricted based on the availability of concentration data.

Contaminant concentration data from NFSA, the Nordic Council of Ministers, EFSA and the "publication" (data sources 1, 3, 4 and 5) for some comparable food products were available. For meat and dairy products and plant-based analogue products, comparable product types where concentration data are available are shown in Table 7.3-1. For gluten-containing and gluten-free products, comparable product types where concentration data are available are shown in Table 7.3-2.

Table 7.3-1. Comparable animal-based and plant-based product types where concentration data are available. 1: NFSA; 4: EFSA; 5: Publication with Swedish data.

Contaminants	Ice cream (animal-based product)	"Ice cream" (plant-based product)	Milk (animal-based product)	Plant-based beverages	Meat, dinner (animal-based product)	Meat analogue, dinner (plant-based product)
Erucic acid	4	4	4	4	1	1
Cadmium					1	1
Lead					1	1

Table 7.3-2. Comparable gluten-containing and gluten-free product types where concentration data are available. 1: NFSA; 3: Nordic Council of Ministers; 5: Publication with Swedish data.

Contaminant	Bread	Bread, gluten-free	Grains and cereals	Grains and cereals, gluten-free	Flour	Flour, gluten-free
Aluminium	PC/3;5	3;5	PC/3	3	3	3
Arsenic	3;5	3;5	3	3	3	3
Cadmium	3;5	3;5	H/3	3	1;3	1;3
Lead	3;5	3;5	M/3	3	1;3	1;3

8 Appendix III: Processing methods

Heat treatment in food processing is primarily to improve texture, food safety and shelf life by inhibiting enzymes and the growth of unwanted microorganisms present in the raw materials. Heat treatment includes processes such as pasteurisation and ultra-high temperature (UHT) treatment. Other methods to prolong shelf life are briefly mentioned below (see preservation methods).

- Pasteurisation is a specific heat-treatment applied to food products to eliminate certain microorganisms; first and foremost, human pathogens and bacteria causing food spoilage. The combination of time and temperature applied should be sufficient to inactivate *Mycobacterium tuberculosis* in milk. High temperature short time (HTST) pasteurisation is 72 °C for 15 s for skimmed milk and whole milk. Pasteurised milk products must be stored cold and have a shelf-life of 1-3 weeks.

- UHT treatment is a specific heat treatment applied to food products to inactivate all microorganisms including spores and enzymes. The specific duration and temperature parameters vary based on the product. For instance, UHT processing of milk typically entails heating for 1–8 seconds at temperatures ranging from 135 to 154°C. A UHT product can be stored at room temperature and has a shelf life of several months. The limiting factors determining shelf life for UHT products are normally physical and chemical processes such as settling of particles and lipid oxidation instead of bacterial growth or unwanted enzymatic processes.

Fermentation is a biological process used in food processing that involves the controlled growth of microorganisms (usually bacteria, yeast, or moulds) to transform various raw materials with the aims to enhance flavour, texture, nutritional value, and shelf life. Some examples of fermented foods include yoghurt, cheese, cured meat products, sourdough bread, kimchi, sauerkraut, beer, and wine.

Preservation methods are techniques used to extend shelf life and maintain the quality of food products by preventing or slowing down the growth of spoilage microorganisms and the degradation of certain food components. These methods are essential for ensuring food safety, reducing food waste, and allowing food to be stored and transported over extended periods. Some examples of preservation methods include heat treatment (or thermal processing) as described above, refrigeration, freezing, drying, salting, adding a high concentration of sugars, fermentation, and the use of certain additives.

Milling involves the reduction of the particle size of solid food materials. This unit operation is commonly applied to cereal grains, nuts, and seeds to yield a diverse range of flours. Prior to milling, sorting, cleaning, and in some cases, hulling procedures are carried out on the raw materials. Cereal grain flour in particular, is the primary ingredient in an array of products, including bread, biscuits, cakes and pasta.

Furthermore, flours derived from cereal grains, nuts, and seeds serve as the foundational components in the manufacturing of plant-based beverages.

Different types of milling processes, such as stone or roller milling, are used to achieve specific particle size distributions in and properties of the final food product.

Fractionation involves the separation or isolation of specific components or fractions from a mixture based on differences in properties such as solubility, density, size, or chemical composition. In food processing, fractionation is commonly used to separate and isolate components such as starch, proteins, fats, and fibres from raw materials such as grains and seeds. Fractionation can be based on differences in densities of flour particles, so-called dry fractionation, or based on differences in solubility in various liquids, termed wet fractionation.

Extrusion is a process where a mixture of ingredients is subjected to high pressure and heat. The mixture is pushed through a shaped die, which gives the product its final form, and the heat and pressure cause the ingredients to interact and form a cohesive dough. Extrusion can be used to produce a wide range of food and feed products, including breakfast cereals, snacks, pasta, pet food, and aquatic feed. The process offers several advantages, including a high degree of automation, uniform product quality, and the ability to incorporate various ingredients and nutrients into the final product. During extrusion proteins denature, and most studies in this field report an increase in protein and starch digestibility after extrusion (Alam et al., 2016; Singh et al., 2007). Extrusion is used to produce meat-like fibre particles from the protein-rich fractions obtained from fractionation of cereal grains and seeds. These products termed texturised plant proteins are used in the formulation of plant-based meat analogues to burgers and minced meat, replicating the texture of traditional meat products. Purified fractions of starch from different cereal grains and potato are used as ingredients in gluten-free baked goods and pasta.

Enzyme hydrolysis is applied in food processing to reduce the content of unwanted compounds and prevent enzyme reactions that would otherwise cause problems during processing, storage, or consumption of the products. In oat milk processing, amylase is added to hydrolyse the starch, which reduces viscosity and increases sweetness of the final product. Added enzymes must be inactivated using heat treatment.

Homogenisation is applied to stabilise oil-in-water emulsions against gravity separation and prevent creaming (where fat accumulates at the product's surface). In an oil-in-water emulsion the fat is dispersed as lipid droplets within the aqueous phase. The droplets are enveloped by a protecting layer composed of proteins and/or phospholipids. The diameter of lipid droplets in a stable oil-in-water emulsion range from 0.1 µm to 10 µm. Homogenisation primarily causes disruption of the original lipid droplets leading to smaller and more numerous droplets. In the homogeniser, the liquid is forced through a small passage at high velocity. The disintegration of the original lipid droplets is achieved by a combination of turbulence and cavitation.

Separation is an industrial process applied to separate particles in a liquid based on density differences. By applying centrifugal force, oil-in-water emulsions will separate into a lipid-rich fraction and a fraction low in lipids. In dairy processing separation is used to produce skimmed milk and cream from whole milk.

9 Appendix IV: Deviations from the protocol

Individual points of contact were not available via the websites of food manufacturers and grocery stores. Therefore, requests for data were not sent directly to the food manufacturers and grocery stores.

With regard to identification of data, a pragmatic approach was chosen, aiming to identify the readily available data and creating an overview can be used as a starting point for identifying important factors that should be considered for safe and healthy food when food products and dietary patterns change. More time-consuming approaches would most likely have identified more data, but this was not considered necessary to create the starting point, but rather to be performed for specific topics based on the findings in this report. Therefore, comprehensive, systematic literature searches were not performed.

Not all steps were performed by to persons independently. This was because of the limited time available.

10 Appendix V: Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1 Title page
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	9-16
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	29-30
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	30
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	33
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g.,	33-35

		years considered, language, and publication status), and provide a rationale.	
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	33-38
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	33-38
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	33-38
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	33-38
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	39-112

Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	39-112
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	39-112
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	39-112
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	39-112
Limitations	20	Discuss the limitations of the scoping review process.	113
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	113-117
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	