PRACTICAL GUIDE

PRODUCT REFORMULATION & INNOVATION FOR BETTER HEALTH

Now also including

- A dedicated protein chapter
- Innovative upcycled ingredients
- Fresh case studies and ingredient suppliers

Foodvalley®
Shaping the Future of Food Together

VERSION 2026

This practical guide has been developed with the utmost care, combining scientifically validated information with hands-on expertise contributed by Foodvalley's partners and external stakeholders. Every effort has been made to present the content objectively and as comprehensively as possible within the limits of available project resources and the scope this format allows.

To achieve this, the guide draws on official publications, scientific research, and the practical knowledge of field experts, including ingredient suppliers, R&D consultants, and other community partners. While grounded in science, the guide is designed to be a pragmatic tool, balancing technical insight with real-world applicability.

The case studies and listed producers or suppliers have been included based on contributions from our community networks. They are intended to inspire and showcase available solutions and applications, rather than to serve as an exhaustive or independently verified overview. Foodvalley has made every effort to ensure the accuracy and relevance of the content but does not guarantee completeness or endorse specific products or suppliers. This guide is intended as a living document and may be updated as new insights, ingredients, and stakeholders emerge.

In this new edition, the supplier database has been expanded, a dedicate plant-based protein chapter has been added, upcycled ingredients are highlighted in the food industry solution subchapters to support more sustainable product development and additional case studies have been included across all nutrient chapters. In addition, feedback from the previous edition has been systematically incorporated, existing content has been reviewed and updated to ensure it remains current.

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REDESIGN FOOD FOR VALUE

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Introduction

This practical guide supports reformulation and innovation aimed at improving food products' nutritional value. It stems from Foodvalley's Healthier Food Community, The Protein Community, The Upcycling Community, The Regenerative Agriculture Community and our partners, which saw an opportunity to share pre-competitive knowledge to support R&D teams in making reformulation more efficient and successful. The guide includes information on ingredient functions and key considerations when adapting processed foods to healthier products. Key areas include salt, sugar, saturated fat and fibres, following the Dutch National Approach to Product Improvement (NAPV). In addition, a dedicated protein chapter has been included to align with the Dutch National Protein Strategy (Nationale Eiwitstrategie), providing guidance on working with more sustainable protein sources in response to national sustainability and food system transition goals. Beyond R&D, this guide helps commercial teams understand the opportunities, challenges, and trade-offs in reformulation, fostering collaboration between technical experts and business professionals.

Purpose and scope

Reformulation isn't as simple as swapping ingredients; taste, texture, mouthfeel, and appearance are deeply connected. Even small changes can impact consumer perception. Success, therefore, requires a tailored approach, balancing health improvements with functionality and appeal. Rather than offering a one-size-fits-all blueprint, this guide provides direction and inspiration to help food professionals make informed decisions that align with both health objectives and product integrity.

Alignment with NAPV and Dutch Dietary Guidelines

The NAPV helps consumers choose healthier foods by encouraging manufacturers to reformulate products. Using gradual limit values, products are grouped and assessed to set threshold levels for salt, sugar and saturated fat, and for fibre in bread. While lower levels are favoured for salt, sugar and saturated fat, fibre thresholds encourage higher fibre content. This framework supports healthier product composition and helps consumers make better choices.

In addition, reformulation efforts can support alignment with the Dutch food-based dietary guidelines; the Wheel of Five. These guidelines promote a balanced diet rich in fibre, plant-based foods, and products lower in salt, sugar and saturated fat. Considering these guidelines alongside the NAPV, can help better understand how product innovation contributes to healthier consumer choices.

The role of food additives

When looking at how reformulation can support healthier food choices, it is also relevant to reflect on the role of food additives in product development, as these often influence both nutritional quality and consumer perception. EU-approved additives (E-numbers) are strictly evaluated by EFSA and considered safe, yet public distrust and the clean-label trend drive manufacturers to reduce or replace them (European Food Safety Authority, 2026; van Gunst & Roodenburg, 2019). This can be challenging, since additives support shelf-life, texture, colour, and safety, and removing them may increase salt, sugar, or fat. In this report, we acknowledge these insights and the clean-label discussion, while noting that not all E-numbers are negative. Therefore, this guide focuses primarily on reformulation possibilities beyond additives.

Upcycled ingredients in reformulation

Furthermore, this guide highlights the role of upcycled ingredients that contribute to more sustainable food production by valorising side streams and by-products. While upcycling primarily supports sustainability goals, many of these ingredients also offer nutritional and functional benefits, such as increasing fibre and plant-based protein content or enabling reductions in salt, sugar or fat. When applied thoughtfully, upcycled ingredients can therefore support both sustainability and healthier product reformulation. In this guide, a distinction is made between ingredients that are upcycled by nature and those that can be sourced from upcycled ingredients. This distinction is indicated using a coloured dot and further explained in footnotes in the solution tables. These coloured dots provide only a simplified indication, as some reflect existing upcycled supply chains while others represent largely unrealised potential that may inspire the development of new value chains.

Using this guide in practice

Whether you're a food technologist, sales professional, or manager, this guide can support you in expanding your understanding of reformulation, innovation and available solutions. Use it as a reference, explore key topics, or dive deeper into additional resources. Share it with colleagues to spark new insights and ideas.

Will you let us know if it has been beneficial to you and if you have any suggestions to optimise the value of the guide?

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Reading Guide

This practical guide is designed to be interactive and easy to navigate, catering to both experts and non-experts interested in product reformulation and innovation.

For each macronutrient, general information, food industry solutions, relevant ingredient suppliers, and case studies are presented. The **general information** contains information on the various aspects of the macronutrient: definition, health aspects, recommended intakes, relations to Nutri-Score and NAPV, and suggestions for further readings. **Food Industry Solutions** describes functionality aspects and solutions available in the market. **Ingredient Suppliers** gives an overview of ingredient suppliers that can supply the necessary ingredients, and in **Case Studies,** you will read about challenges met and solutions found by companies working on reformulating products. The guide concludes with the technical knowledge and support available in the market that can support reformulation and innovation processes in general.

To help you find the most relevant information quickly, we have included a clickable decision tree on the next page that guides you based on your interests and needs. Throughout the document, you can always navigate back to this decision tree by clicking on ‘GO BACK TO DECISION TREE’ in the bottom right corner.

- **Start with the decision tree**: If you're unsure where to begin, use the clickable decision tree to find the section that best matches your goal. Whether you're looking for technical insights, case studies, or ingredient suppliers, the tree directs you to the right place.

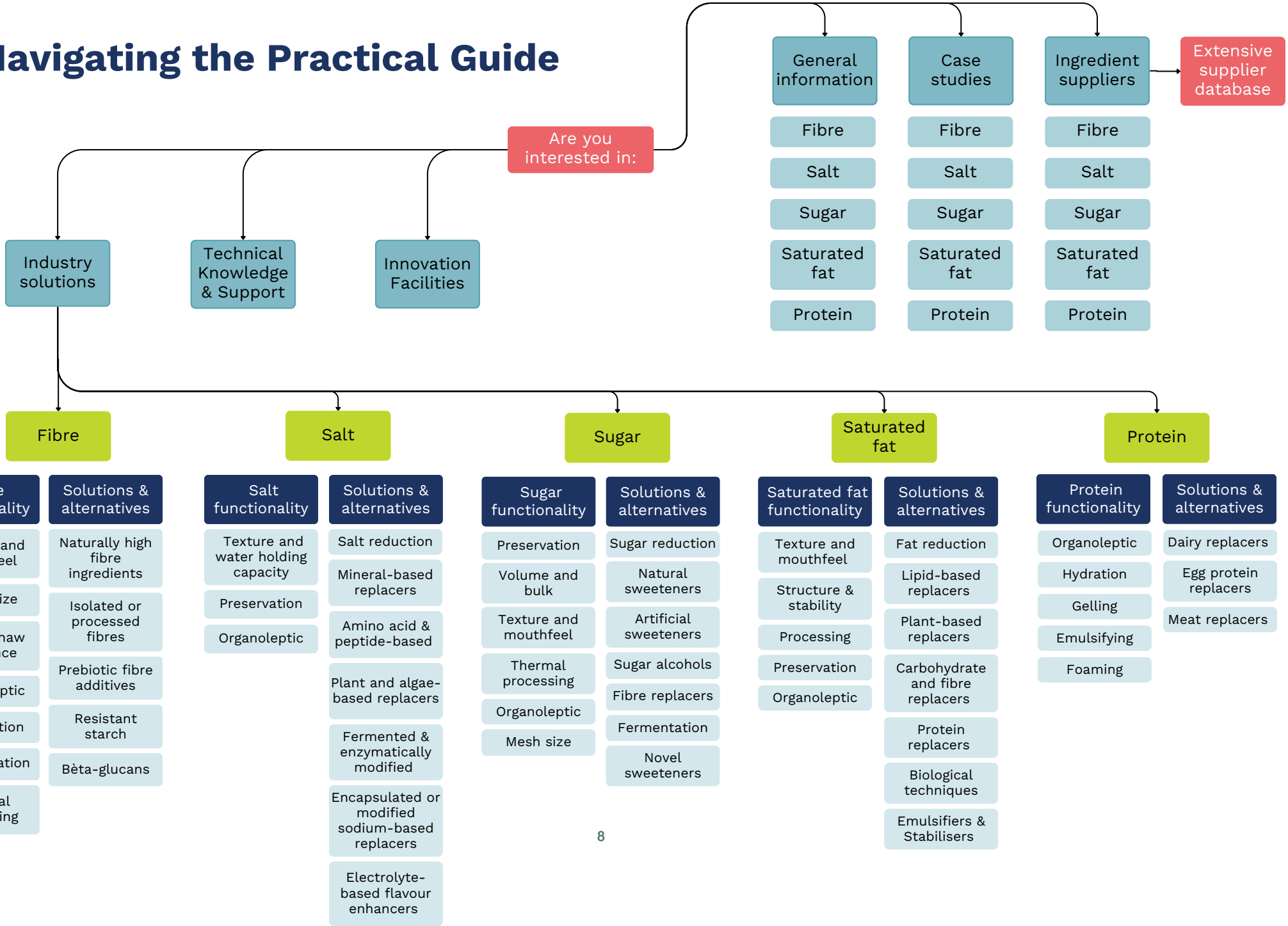
- **Follow the links**: Throughout the report, you'll find clickable links that take you directly to related sections or other relevant information.

- **Choose your depth**: Each nutrient section is structured to provide both high-level overviews and quick insights, as well as more in-depth analysis for those seeking detailed expertise.

- **Visual and interactive aids**: Key takeaways are highlighted for easy reference. Look out for tables, infographics, and case studies that bring complex topics to life and provide practical examples.

Whether you’re an experienced professional or new to product reformulation, this report is designed to help you explore at your own pace and find exactly what you need.

Navigating the Practical Guide



Fibre

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01 General Information Fibre

Background

Dietary fibre is defined by EU Regulation 1169/2011 as: “carbohydrate polymers with three or more monomeric units, which are neither digested nor absorbed in the human small intestine” (European Parliament and Council of the European Union, 2011).

Functional fibre refers to isolated, extracted, or synthetically manufactured nondigestible carbohydrates (Turner & Lupton, 2011). This classification contrasts with dietary fibre, which is naturally occurring. Functional fibres and dietary fibres together represent the total fibre content of the food (Turner & Lupton, 2011).

On average, **intakes** for adult males in Europe range from 18-24 g per day and for females 16-20 g per day (EUFIC, 2023), with little variation from one European country to another (Figure 1). In the Netherlands intake of fibre is 21 g/day on average, with a higher intake among boys/men (23 g/day) than among girls/women (18 g/day) (RIVM, 2023).

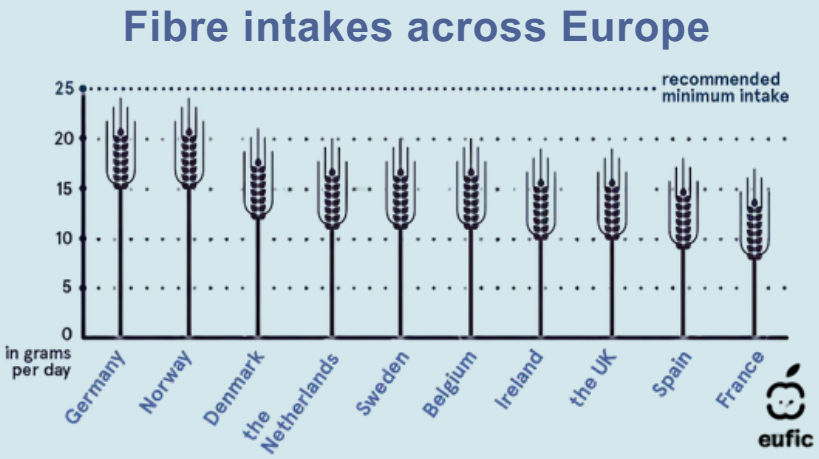

Figure 1: Fibre intakes per inhabitant across European countries in g/day (EUFIC, 2023).

In the EU, whole grain cereals, pulses, fruit, vegetables and potatoes are the most commonly consumed **sources** of dietary fibre (European Commission, 2023a). The different types of dietary fibre, examples and main sources of intake are explained in Table 1. Groups and fibre classifications are not mutually exclusive, and some fibres can be classified in two or more categories (Voedingscentrum, n.d.-a).

Table 1: Types of dietary fibre, their solubility, health effects, and examples of sources (He et al., 2022; Carlson et al., 2018).

Type of fibre	Solubility	Health effect	Examples	Sources
Soluble fibre	Soluble	Beneficial to cholesterol levels and regulation of blood sugars	Pectin, beta-glucan	Oats, beans, apples, citrus fruits
Insoluble fibre	Insoluble	Adds bulk to the stool, promoting regular bowel movements and preventing constipation	Lignin, hemicellulose	Whole grains, nuts, seeds, vegetables
Fermentable fibre	Both soluble and insoluble	Fermented in the colon, producing beneficial short-chain fatty acids	Inulin, fructooligo-saccharides	Legumes, whole grains, onions, bananas
Prebiotic fibre (subset of fermentable fibres)	Both soluble and insoluble	Serves specifically as a food source for beneficial bacteria in the colon	Galactooligo-saccharides, resistant starches	Chicory root, asparagus, leeks, bananas

Health Aspects

DIGESTION

Fibre plays a crucial role in maintaining digestive health by promoting regular bowel movements and preventing constipation (Barber et al., 2020). Soluble fibre absorbs water, softening stool, while insoluble fibre adds bulk, helping food pass more easily through the digestive tract (Guan et al., 2021; Voedingscentrum, n.d.-a).

SATIATION

Fibre increases feelings of fullness or satiation by absorbing water and expanding in the stomach, which slows down the digestion process (Hervik & Svihus, 2019). This delay in gastric emptying helps reduce overall calorie intake by decreasing hunger and promoting portion control (Hervik & Svihus, 2019; Nirmala Prasadi & Joye, 2020). Soluble fibre, in particular, is known to help control appetite and prevent overeating (Guan et al., 2021).

REDUCED RISK CARDIOVASCULAR DISEASES

High fibre intake is associated with a reduced risk of cardiovascular disease. Fibre helps lower cholesterol levels by binding to bile acids in the intestines, preventing their reabsorption (Guan et al., 2021). This can reduce plaque buildup in the arteries, ultimately lowering the risk of cardiovascular events (Barber et al., 2020).

REDUCED RISK OF TYPE 2 DIABETES

Increased fibre intake is linked to better blood sugar control and reduced risk of type 2 diabetes (Guan et al., 2021). Soluble fibre in particular helps to slow the absorption of sugar, preventing spikes in blood glucose. Additionally, fibre improves insulin sensitivity, thereby aiding in preventing diabetes (Guan et al., 2021).

REDUCED RISK OF COLON CANCER

Fibre has been shown to lower the risk of colon cancer (Barber et al., 2020). It is thought to work by increasing stool bulk and decreasing transit time, reducing the exposure of the colon to harmful substances (Nirmala Prasadi & Joye, 2020). Additionally, fibre's fermentation in the colon may protect against cancerous cell development (Guan et al., 2021).

Regulatory Framework

Dietary Recommendations

The World Health Organisation (**WHO**) recommends consuming 25 g of naturally occurring dietary fibre per day (World Health Organization, 2023a). Likewise, the European Food and Safety Authority (**EFSA**) considers an intake of 25 g of fibre per day to be adequate for normal bowel function in adults (EFSA, 2010).

Dutch recommendations for dietary fibre intake differentiate between men and women. Adult women are advised to consume at least 25 g per day and adult men at least 30 g per day.

In addition, evidence shows that adults gain increased health benefits with intakes of dietary fibre above the recommended amounts (Voedingscentrum, n.d.-a). It is important to note that the role of fibre on its own is not always clear, therefore it is important to eat whole foods rich in fibre, not only isolated fibre.

WHO and EFSA recommendations dietary fibre intake per day

> 25 g per day

Dutch recommendations dietary fibre intake per day

> 30 g per day

> 25 g per day

Health Claims

Allowed health claims in EU:

- **Source of fibre**: amount of fibre in the product ≥ 3 g/100 g product or 1.5 g/100 kcal.
- **Rich in fibre:** amount of fibre in the product is ≥ 6 g/100 g product or 3 g/100 kcal (Voedingscentrum, n.d.-a; European Commission, 2012).

In The Netherlands, the Dutch Food and Consumer Product Safety Authority (NVWA) states that the term '**wholemeal**' or '**wholegrain**' may and must be used in the name of the product only if 100% wholegrain flour is used, including cookies, crackers, pasta, or bread (Nederlandse Voedsel- en Warenautoriteit, 2024a).

Nutri-Score

Nutri-Score assigns positive points to dietary fibres in food products, up to a maximum of 5 points (RIVM, 2024).

In the Netherlands, Rijksinstituut voor Volksgezondheid en Milieu (RIVM) has provided a calculation tool for the Nutri-Score of a product.

NAPV

NAPV limit values for fibre are developed solely for the 'Bread (replacements) and breakfast cereals' category because the fibre content can be adjusted by increasing the ratio of wholemeal flour relative to refined flour (RIVM, 2022).

In other product categories there is still a lot of potential to increase fibre content. However, setting an NAPV limit value within these food groups will mainly focus on adding processed fibre (possibly in combination with adjusting the ratio of flour and/or wholemeal flour). For this reason, no limits are set for fibre content, despite a contribution of some groups of more than 3% to total fibre intake (RIVM, 2022).

Despite there being no specific targets on fibre increase in the NAPV, there still is a lot of potential to positively impact health by increasing the amount of fibres in processed foods, when using the right type of fibres or fibre rich ingredients.

NAPV developed limit values for fibre in the following product categories:

- [x] Bread(replacements) and breakfast cereals
- [ ] Dairy and plant-based alternatives
- [ ] Cheese
- [ ] Meat preparations and meat products
- [ ] Deli meats and preserved meats
- [ ] Fish
- [ ] Meat substitutes
- [ ] Spreads and cooking fats
- [ ] Soups and bouillons
- [ ] Sauces
- [ ] Savoury snacks
- [ ] Pastry & confectionary
- [ ] Drinks
- [ ] Sandwich filling

Learn more: NAPV roadmap

Further Readings

Action on Fibre Initiative - Food & Drink Federation (2023)

An industry-led effort by the Food & Drink Federation to bridge the gap between current fibre intakes and dietary recommendations. They include details on the initiative's impact, including increased availability of high-fibre products.

Carbohydrate intake for adults and children: WHO guideline

This guideline provides updated, evidence-informed guidance on the intake of carbohydrates to reduce the risk of diet-noncommunicable diseases in adults and children, with a particular focus on carbohydrate “quality”.

Dietary fibre - Institute of Food Science & Technology (2023)

Food Reformulation for dietary fibre by the Institute of Food Science & Technology (IFST) examines a multitude of aspects related to dietary fibre intake and using it in product formulation. It highlights key functional properties including how to analyse for dietary fibre.

Dutch National Food Consumption Survey (2019-2021)

This survey provides comprehensive data on the dietary habits of the Dutch population aged 1 to 79 years. It offers insights into nutrient intake, including dietary fibre, and informs public health policies and nutritional guidelines in the Netherlands.

EUR-Lex Regulation (EC) No 1924/2006 on Nutrition and Health Claims

This legislation provides the legal framework for nutrition and health claims made on foods within the EU. It specifies the conditions under which claims like "fibre-rich” can be made, ensuring that consumers receive truthful and substantiated information.

Guidance for product innovation and reformulation (2023)

Comprehensively outlines the aspects of product innovation and reformulation that may need to be considered when undertaking reformulation work.

02 Food Industry Solutions Fibre

Fibre Functionality

Functional properties describe how ingredients influence product quality by interacting with water, lipids and other components. These interactions affect texture, stability appearance and sensory perception during processing and consumption. For this reason, functional characteristics are essential for selecting and optimising ingredients in product (re)formulations. Table 2 provides an overview of key functionalities and sensory attributes to consider.

Texture and mouthfeel

Fibres, especially soluble and functional insoluble, can absorb and retain water (water binding capacity) and oil, forming a gel-like matrix that enhances creaminess or viscosity (Goff & Guo, 2019; Dhingra et al., 2012). This property helps mimic fat's mouthfeel in low-fat dairy, sauces, and dressings. However, fibres can also impact mouthfeel in a different way. Insoluble fibres may contribute to grittiness, while higher concentrations can introduce unwanted off-tones, such as bitterness and earthiness.

Freeze-thaw resistance

Fibres, particularly those from plant-based sources, can absorb water and undergo structural changes when frozen and thawed. This can lead to (undesirable) alterations in texture, consistency, and overall product quality. Ensuring that fibres maintain their functional properties during freeze-thaw cycles requires careful formulation and processing (Dhingra et al., 2012).

Mesh size

Mesh size influences the texture, solubility, and functionality of the fibre in the final product (Dhingra et al., 2012). Depending on the type of fibre, large particles may not integrate well, leading to an undesirable texture or poor dispersibility, while excessively fine fibres can cause clumping. Optimising mesh size ensures consistency, mouthfeel, and stability (Mancebo et al., 2018).

Organoleptic
The colour and appearance of a product may be affected, depending on the fibre's pH sensitivity, source, and concentration (Dhingra et al., 2012). In baked goods, dietary fibres can potentially cause dryness and weakening of gluten networks, which impacts rise, texture, and crumb structure (Gómez & Martinez, 2018).

Caloric reduction and emulsification
Fibres can replace part of the fat and sugar in formulations without significantly altering the product volume (Dhingra et al., 2012). Some have emulsifying properties that stabilise oil-in-water emulsions, reducing the need for added fats while maintaining creamy textures (Dhingra et al., 2012). Certain fibres also enhance thickening when combined with hydrocolloids like carrageenan or gelatin (Dhingra et al., 2012; Marczak & Mendes, 2024).

Thermal processing
In general, thermal processing leads to the loss of nutritional and bioactive molecules, reduces soluble compounds in fibre, and impacts colour, hydration properties, and cell integrity (Fernández-López et al., 2020).

Preservation and moisture retention
Fibres are naturally hydrophilic. This property allows fibres to hold water within the product matrix, reducing water activity and slowing down staling or drying out by preventing moisture migration and maintaining product freshness (Marczak & Mendes, 2024). However, improper processing can lead to unstable products and reduced shelf life if excess water isn't properly captured (Perez-Pirotto, 2022).

Table 2: Overview fibre functionalities and sensory attributes.

Process/product functionality	Sensory attributes
Freeze-thaw resistance, fibres can absorb water and undergo structural changes when frozen and thawed.	**Creaminess and viscosity**, fibres can create a gel-like structure ideal for creamy products.
Bulk replacer, fibres can replace part of the fat or sugar in formulations without significantly altering the product volume.	**Organoleptic properties** should be carefully considered in product formulation to obtain the desired qualities.
Preservation, fibres help slow down staling and maintain product freshness.	**Mesh size,** influences texture, solubility, and functionality of the fibre.
Certain fibres have **emulsifying properties** and can improve thickening and **stability.**	**Thermal prosessing** can affect colour and hydration properties of some type of fibres.

Fibre Solutions

The following tables provide an overview of potential ingredient solutions for reformulation, distinguishing between nutritional and functional aspects. This distinction reflects the different objectives that may drive reformulation or innovation, such as improving the nutritional profile (e.g., reducing sugar, salt, or saturated fat) versus maintaining or enhancing product functionality (e.g., texture, stability, or shelf life). The tables are intended as a starting point for identifying possible solutions. They do not represent an exhaustive list, and additional considerations may apply depending on the specific product context and formulation goals.

Naturally high fibre ingredients, fresh or dried produce, bran

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Whole Grains (Oats, Barley, Quinoa, Brown Rice)	Bread (replacements) and cereals	Enhances texture and structure in baked goods (Ma et al., 2022a).	Can make products denser and drier; May require additional moisture or binding agents (Bressiani et al., 2017).	Rich in fibre, B vitamins, and minerals (Pujol et al., 2023).	Wholegrains may increase acrylamide levels (Boyaci Gunduz, 2023).
Bran (Wheat Bran, Oat Bran, Rice Bran)	Bread (replacements) and cereals	Increases fibre content in baked goods (Tyl et al. 2021).	Can make products crumbly or dry; Requires moisture adjustments (Tyl et al. 2021).	High in insoluble fibre; Supports bowel regularity (de Vries, 2015).	Can cause digestive discomfort when consumed in large amounts (Miller et al., 2015).

Upcycled by nature

Can be sourced from upcycled ingredients

Naturally high fibre ingredients, fresh or dried produce, bran (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Green Banana (flour)	Bakery products, pasta, snacks, gluten-free products	Improves texture and viscosity; Acts as a thickening/ stabilising agent; Extends shelf life (Fida et al. 2020; Sumble & Salve, 2024).	May alter taste and colour profile; Requires formulation adjustment to achieve desired texture (Fida et al. 2020).	High in resistant starch (prebiotic effect); Low glycemic index; Source of potassium and fibre (Fida et al. 2020; Sumble & Salve, 2024).	Nutrient content may vary with processing; Can be less palatable due to astringency if not balanced (Fida et al. 2020).
Fruits	Bars and bakery products	Adds natural sweetness and moisture (Krajewska & Dziki, 2023).	Can increase water binding capacity, affecting shelf life and requiring preservation adjustments (Krajewska & Dziki, 2023).	High in soluble fibre (pectin), antioxidants, and vitamins (Fierascu et al. 2020; Krajewska et al. 2023).	Increased processing degrades nutritional quality of fruits by reducing alkalizing, antioxidant, and satiety effects (Fardet & Richonnet 2020).
Vegetables	Meat alternatives, savoury snacks	Adds bulk and texture, especially in savoury dishes (Pop et al. 2021).	May alter flavour profile and require balancing spices; Fibre can become tough when overcooked (Oyinloye & Yoon, 2020).	Provides vitamins, minerals, and both soluble and insoluble fibre (Pop et al. 2021).	Some fibres may interact with some nutrients and inhibit their absorption into the digestive system (Pop et al. 2021).

Isolated or Processed Fibre Ingredients

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Psyllium Husk (Plantago Ovata)	Bakery products, bread (replacements) and cereals	Excellent water retention and gelling properties; Good for gluten-free baking (Fradinho et al., 2020).	Can create overly gummy textures if not balanced correctly (Belorio & Gómez, 2021).	Supports heart health by lowering cholesterol (Geremew et al., 2024).	Requires adequate water intake to prevent digestive issues (Geremew Kassa et al., 2024).
Pectin	Dairy alternatives, sauces	Improves stability in beverages and acidic products and mimics mouthfeel of fat (Freitas et al., 2021).	Works best in acidic environments (pH < 3.5 for high-methoxyl pectin) (Freitas et al., 2021).	Supports digestion and gut health (Beukema et al., 2020).	While minimal, some pectin-rich products (like jams) may still be high in sugar (Blanco-Pérez et al., 2021).
Cellulose	Bakery products	Improves structure in low-carb or high-fibre bakery products (Ahmad Khorairi et al., 2023).	May result in a dry mouthfeel if used in excess.	Adds bulk without affecting glycemic response (Giuntini et al., 2022).	May interfere with mineral absorption at high levels (Baye et al., 2017).
Guar Gum (Guar Beans)	Sauces, dressings, dairy products	Thickens and stabilises foods like sauces and dressings (Jayanthi et al., 2024).	Can lead to slimy textures if overused; Sensitive to temperature changes (Jayanthi et al., 2024).	Soluble fibre helps in blood sugar control (Cassidy et al., 2018).	Can cause digestive discomfort when consumed in large amounts (Major et al., 2017).

Prebiotic Fibre Additives

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Fructooligo-saccharides (FOS)	Snacks, dairy alternatives	Adds mild sweetness without increasing calories (Bali et al., 2015).	High concentrations may cause moisture retention, affecting texture (Kherade et al., 2021; Zeng et al., 2016).	Stimulates growth of beneficial gut bacteria (Bali et al., 2015).	Can cause gas or bloating when consumed in large amounts (Miller et al., 2015).
Galactooligo-saccharides (GOS)	Dairy products	Minimal impact on taste and texture; Easily incorporated into dairy (Olivares-Tenorio et al., 2022).	Limited stability under high temperatures; may break down during cooking (Abdaltef et al., 2024).	Enhances calcium absorption and immune function (Abdaltef et al., 2024).	Not all individuals tolerate GOS well (FODMAP-sensitive people) (Varney et al., 2017).
Inulin (Chicory Root Extract)	Baked goods and dairy products	Adds creaminess and improves mouthfeel in low-fat products (Ahmed & Rashid, 2019).	pH-sensitive: Acidic environments (e.g., fruit juices) may lead to hydrolysis, reducing its functionality (Ahmed & Rashid, 2019).	Prebiotic effect supports gut microbiota (Qin et al., 2023).	Can cause gas or bloating when consumed in large amounts (Miller et al., 2015).

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Upcycled by nature
Can be sourced from upcycled ingredients

Resistant Starch (RS)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
RS1 (Occurs in whole grains, seeds)	Bread (replacements) and cereals	Adds bulk and enhances structure in baked goods (Mishra & Awasthi, 2024).	May require adjustments in cooking times or hydration for texture optimisation (Homayouni et al., 2014; Kraithong et al., 2022).	Improves blood sugar control and supports satiety (Kraithong et al., 2022).	Can cause gas or bloating when consumed in large amounts (Miller et al., 2015).
RS2 (Occurs in, raw potatoes, green bananas)	Bars and snack products	Substrate for the synthesis of short-chain fatty acids (Sumble & Salve, 2024).	Loses resistant properties when cooked, requiring careful handling (Lui et al., 2020).	Acts as a prebiotic and improves gut health (Sumble & Salve, 2024).	Can cause gas or bloating when consumed in large amounts (Walsh et al., 2022).
RS3 (Occurs in cooled cooked rice, pasta, potatoes)	Processed snacks	Adds structure to products after cooling; Enhances firmness in pasta and baked goods (Ashwar et al., 2016).	Requires cooling processes, which may complicate production (Ashwar et al., 2016).	Supports colon health and reduces post-meal glucose spikes (DeMartino & Cockburn, 2020).	Reheating may reduce the resistant starch content (Gu et al., 2020).

Resistant Starch (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
RS4 (Chemically Modified Starches)	Sauces, snacks, bakery products	Stable under various processing conditions; Good for industrial applications (Walsh et al., 2022).	May alter product labeling requirements due to chemical modifications (Walsh et al., 2022).	Provides similar health benefits to natural resistant starches (Upadhyaya et al., 2016).	Due to processing, may not be perceived as “natural” by consumers.

Classification based on: https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2011.2024 -https://www.sciencedirect.com/science/article/pii/S1756464622001645#s0010

Bèta-Glucans

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Oat Beta-Glucans	Bakery products, soups	Retains moisture and enhances viscosity in soups, beverages, and baked goods (Li et al., 2024).	Can lead to overly thick or gummy textures in high concentrations (Lante et al., 2023).	Helps lower LDL cholesterol and regulate blood sugar levels (Li et al., 2024).	Requires consistent consumption for heart health benefits (Lante et al., 2023).
Yeast Beta-Glucans	Meat alternatives	Acts as a stabilizer and emulsifier in processed foods (Zechner-Krpan et al., 2009).	May impart a slight yeast-like taste at high concentrations.	Enhances immune response and supports gut health (Sinangil et al., 2022).	Can cause digestive discomfort when consumed in large amounts (Miller et al., 2015).
Mushroom Beta-Glucans (Reishi, Shiitake, Maitake)	Meat alternatives	Used in supplements and functional beverages for health benefits (Chiozzi et al., 2021).	Earthy flavor may need masking in certain products (Zhao et al., 2022).	Supports immune function and offers antioxidant protection (Sinangil et al., 2022).	Possible allergic reactions in sensitive individuals (Singh et al., 2024a).

03 Ingredient Suppliers Fibre

An extensive (not exhaustive) overview of ingredients and ingredient suppliers is available **here**. Connect with ingredient suppliers within

Food and Health

salnova nutritec

dsm-firmenich

VAN WANKUM INGREDIENTS

herbafood

HIJO SUPERFOODS

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Are you missing any information, suppliers or ingredients? Please contact **partner@foodvalley.nl** and we can incorporate this in our next version.

04 Case Studies Fibre

Fibre enrichment and sugar reduction in gummy applications

What challenge was faced?
The challenge was to reduce sugar in gummies while increasing fibre content, driven by growing demand in the US market for healthier confectionery. Traditional fibre alternatives such as inulin can cause digestive discomfort at higher intake levels, so a more tolerable solution was required.

How was the problem solved?
FiberSMART® (based on soluble corn or tapioca fibre) was used as a sugar replacer while improving nutritional value. Sugar was replaced one-to-one with fibre, and because Fibre Smart is only ~20% as sweet as sugar, small amounts of high-intensity sweeteners (e.g. stevia or sucralose) were added to restore sweetness without adding calories.

> “Fibre can be an effective sugar replacer, providing both functional and nutritional benefits, but it cannot fully replace sweetness on its own.”

Were there any obstacles?
The main challenge was achieving the right sweetness profile. Fibre alone could replace the bulk of sugar, but not its sweetness, making the addition of sweeteners necessary.

What was the outcome?
The result was a gummy with 77.8% less sugar and 7 g of fibre, while maintaining a similar taste. In sensory tests, 76% of participants could not distinguish it from the regular product.

Key takeaways and lessons learned
Fibre can be an effective sugar replacer, providing both functional and nutritional benefits, but it cannot fully replace sweetness on its own. A key learning is to start with a one-to-one sugar replacement with a functionally similar fibre and then adjusting the sweetness.

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Calorie reduced ice-cream

What challenge was faced?
The challenge was to create a calorie-reduced ice cream by significantly lowering fat and sugar content, while preserving the indulgent taste and creamy mouthfeel.

How was the problem solved?
The key was finding the right texture by increasing water content (+8%) and cutting back sugar by 65%. A smart combination of functional citrus fibre and pectin delivered a full-bodied mouthfeel, while also supporting overrun and emulsification. This approach allowed the formulation to retain the sensory qualities of traditional ice cream despite the nutritional overhaul.

> “A well-balanced blend of fibre and pectin can successfully replace fat and sugar while preserving indulgence.”

Were there any obstacles?
Reducing fat posed a challenge, as fat is central to the ice cream's body and texture. This was addressed by incorporating functional citrus fibre. Sugar was replaced with sugar alcohols, which altered the freezing point and affected recrystallisation. The loss of structure was compensated with pectin, functional fibre, and soluble fibre to maintain creaminess and reduce ice crystal formation.

What was the outcome?
Fat was reduced by 82%, sugar by 41%, and calories by 53%, improving the product from Nutri-Score D to A. The final product featured a smoother texture and lower melting behaviour.

Key takeaways and lessons learned
A well-balanced blend of fibre and pectin can successfully replace fat and sugar while preserving indulgence. This combination is essential for achieving a creamy texture and a full-bodied mouthfeel in calorie-reduced ice cream.

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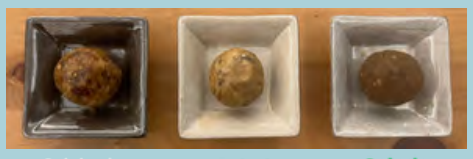
Healthy raw bar - Less fat, sugar and more fibre and resistant starch with green banana flour

What challenge was faced?

Most snack bars are high in sugar, additives, and fats. Consumers seek natural, functional foods for gut health and sustained energy, but food producers struggle to reduce sugar and fat while maintaining taste and texture.

How was the problem solved?

Saledo is developing a raw bar with Green Banana Flour (GBF), rich in resistant starch, potassium, magnesium, and fibre. GBF has water and oil holding capacities, which allows for reduced sugar and fat while ensuring a satisfying texture and supporting gut health.



Original Recipe | Saledo Recipe 2 | Saledo Recipe 1

Recipe 1	Original	Saledo	Change
Fibre	3,1	3,45	10,14%
Sugar	13,65	10,44	-30,73%
Fat	9,65	7,2	-34,03%

Recipe 2	Original	Saledo	Change
Fibre	3,1	3,15	1,59%
Sugar	13,65	10,70	-27,62%
Fat	9,65	9,575	-0,78%

Were there any obstacles?

Saledo addressed ingredient compatibility to ensure appealing texture, tackled consumer acceptance through education and tastings, and worked with Foodvalley to scale production while safeguarding product quality.

What was the outcome?

Two recipes were created: one with 30.73% less sugar, 34% less fat, and 10.14% more fibre, yielding a firmer, less sweet option; another with 27.62% less sugar, 0.78% less fat and slightly more fibre (1.59%), maintaining familiar taste and texture while reducing sugar.

Key takeaways and lessons learned

This case study reinforces how green banana flour serves as a high-fibre, lower-sugar, and gut-friendly alternative to traditional flours with its no taste oil and water-holding capacities. The key takeaway is its potential in healthier food formulations, making it ideal for better digestion, lower fat intake, and balanced blood sugar levels.

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Enrichment of beverages with soluble fibre

What challenge was faced?
Consumers increasingly seek convenient products that support gut health and immunity. The goal was to develop a beverage containing enough fibre to deliver a measurable prebiotic effect—without compromising on taste, texture, or drinkability.

How was the problem solved?
A flavourful beverage was formulated using a carefully selected blend of plant-based fibres. The fibre mix was optimised to ensure that a small, effective dose delivered proven gut health benefits, while still offering a smooth drinking experience.

> “Benicaros proves to be a highly effective and stable fibre for functional drinks, requiring just 850 mg per serving to have an impact.“

Were there any obstacles?
One limitation remains the operating regulatory framework. While clinical trials in the US support strong health claims, current EU regulations restrict claims to softer language. This influences how the product’s benefits can be communicated in the European market.

What was the outcome?
The beverage delivers gut health support in a low-dose format, maintaining both taste and functional value. The fibre Benicaros, in particular, showed excellent stability in low pH conditions, making it ideal for acidic drinks.

Key takeaways and lessons learned
Benicaros proves to be a highly effective and stable fibre for functional drinks, requiring just 850 mg per serving to have an impact. Additionally, ingredients like Allsweet Allulose offer promising solutions in other applications such as baked goods—providing sugar-like bulk with only 10% of the calories. While Allulose awaits EU novel food approval, it is already permitted in other markets and is expected to be authorised in Europe soon.

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Salt

01 — **General Information**

- Background
- Health Aspects
- Regulatory Framework
- Further Readings

02 — **Food Industry Solutions**

- Salt Functionality
- Salt Reduction Solutions

03 — **Ingredient suppliers**

Overview of ingredients and ingredient suppliers

04 — **Case Studies**

Example cases on reformulation from partners

01 General Information Salt

Background

Salt is a chemical compound made up of sodium and chloride (NaCl). It consists of 40% sodium and 60% chloride by weight (Voedingscentrum, n.d.-b). Salt is the most important source of sodium in human diets, however, when consumed in large amounts, sodium is detrimental to health. Nevertheless, small amounts of sodium are essential for the human body and necessary for the maintenance of plasma volume, acid-base balance, transmission of nerve impulses and normal cell function (WHO, 2023). Salt is defined by EU Regulation 1169/2011 as 'the salt equivalent content calculated using the formula: salt = sodium × 2,5' (European Parliament and Council of the European Union, 2011). In this report, "salt" refers to NaCl unless stated otherwise.

The **global mean intake** of salt in adults is 10.78 g/day. This is more than double the World Health Organization recommendation for adults (equivalent to < 5 g/day salt). Across the sodium reduction reformulation policies implemented in the 194 WHO Member States, bread and bread products are the primary focus. They are followed by processed meats, poultry, wild-caught meat, and fish, as well as ready-made and convenience foods (World Health Organization, 2023b).

The average salt **intake in the Netherlands** is 6.6 g/day, with a maximum recommended intake of 6 g per day. One gram of this salt intake originates from added salt during preparation and at the table, whereas 5.6 g originates from purchased food products. Intake is higher for boys/men (7.4 g/day) than for girls/women (5.9 g/day). The main **sources** of salt intake (excluding table salt) are bread, cereals, rice and pasta (25%), meat and meat substitutes (20%), dairy and dairy substitutes (17%) and sauces and flavourings (10%) (RIVM, n.d.).

Health Aspects

INCREASED BLOOD PRESSURE (HYPERTENSION)

Excess salt causes the body to retain water, increasing blood volume and raising blood pressure. Over time, this puts strain on the heart and blood vessels, increasing the risk of heart disease and stroke. Reducing salt intake can help lower blood pressure and improve heart health (Mozaffarian et al., 2014).

INCREASED RISK OF OBESITY

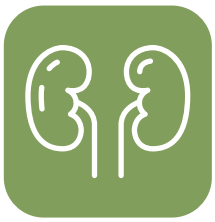
Excessive salt consumption is associated with higher calorie intake and obesity, as it enhances appetite and promotes over-consumption of processed foods. High salt intake may also alter fat metabolism and contribute to insulin resistance (Moosavian et al., 2017).

INCREASED RISK OF GASTRIC CANCER

High salt intake can damage the stomach lining, leading to inflammation and an increased risk of *Helicobacter pylori* infection, a major cause of gastric cancer (D'Elia et al., 2014).

INCREASED RISK OF OSTEOPOROSIS

Excessive salt intake promotes calcium excretion in urine, leading to decreased bone mineral density and an increased risk of osteoporosis. High sodium intake is linked to lower bone mass, especially in postmenopausal women (Cappuccio et al., 2000).



INCREASED RISK OF KIDNEY DISEASE

High sodium intake strains the kidneys by increasing blood pressure and promoting kidney damage. It accelerates the progression of chronic kidney disease and increases proteinuria, a marker of kidney dysfunction (Borrelli et al., 2020).

Regulatory Framework

Dietary Recommendations

The **WHO** and **EFSA** recommend less than 2 g/day of sodium (equivalent to less than 5 g/day salt), or just under a teaspoon (World Health Organization, 2012; Turck et al., 2019). This level is considered by EFSA as a “safe and adequate intake for the general EU population of adults,” including pregnant and lactating women.

The **Dutch dietary guidelines** advise adults to consume no more than 6 g of salt a day, equivalent to 2.4 g of sodium (Gezondheidsraad, 2015).

WHO and EFSA recommendation sodium intake per day

< 2 g per day

Dutch recommendation sodium intake per day

≤ 2.4 g per day

Health Claims

Allowed health claims in EU:

- **Low sodium/salt:** The product contains a maximum of 0.12 g of sodium, or the converted amount of salt, per 100 g or 100 ml. This does not apply to water.
- **Very low sodium/salt content:** The product contains a maximum of 0.04 g of sodium, or the converted amount of salt, per 100 g or 100 ml.
- **Sodium-free/saltless:** The product contains a maximum of 0.005 g of sodium, which is 0.0125 g of salt per 100 g.
- **No added sodium/salt:** No sodium/salt has been added to the product. The product contains a maximum of 0.12 g of sodium, or the converted amount of salt, per 100 g or 100 ml (European Commission, 2006).

Nutri-Score

The lower salt limit used by Nutri-Score is ≤90 mg salt per 100 g of product. Nutri-Score assigns negative points for salt based on the quantity present in 100 g or 100 ml of the product, up to 10 negative points can be given (RIVM, 2024).

In the Netherlands, RIVM has provided a calculation tool for the Nutri-Score of a product.

NAPV

For salt, the NAPV established limit values for multiple product categories, with specific subcategories defined for each. When possible, the lower limits of the NAPV correspond to the lowest cut-off points that Nutri-Score uses. Consult the source document for detailed values applicable to individual products (RIVM, 2022).

NAPV developed limit values for salt in the following product categories:

- [x] Bread(replacements) and breakfast cereals
- [ ] Dairy and plant-based alternatives
- [x] Cheese
- [x] Meat preparations and meat products
- [x] Deli meats and preserved meats
- [x] Fish
- [x] Meat substitutes
- [x] Spreads and cooking fats
- [x] Soups and bouillons
- [x] Sauces
- [x] Savoury snacks
- [ ] Pastry & confectionary
- [ ] Drinks
- [x] Sandwich filling

Learn more: NAPV roadmap

Further Readings

EUR-Lex Regulation (EC) No 1924/2006 on Nutrition and Health Claims

This legislation provides the legal framework for nutrition and health claims made on foods within the EU. It specifies the conditions under which claims like "reduced salt" can be made, ensuring that consumers receive truthful and substantiated information.

Technical Brief: Food Reformulation for Salt

Examines the health implications of high sodium intake and emphasizes the importance of product reformulation to reduce sodium levels in processed foods and discusses strategies for achieving this goal.

FoodDrinkEurope Guidelines: Reducing Salt in Food Products

Provides practical information for food business operators on reducing sodium content in food and beverages. It covers strategies for gradual salt reduction, alternative seasoning options, and maintaining product quality and safety during reformulation.

The use of salt substitutes to replace sodium chloride in food products: a review

This report examines salt substitutes in staple foods, highlighting innovations like low-sodium blends, flavour enhancers, and advanced techniques to reduce salt while preserving quality.

Reformulation of food and beverage products for healthier diets: WHO policy brief

Provides information and practical guidance for implementing effective policy actions to eliminate industrially produced trans-fatty acids from the food supply, reduce the energy content per portion and lower the levels of saturated fats, sugars and salt/sodium in food.

Use of lower-sodium salt substitutes: WHO guideline

Evidence-based recommendations for using lower-sodium salt substitutes to help reduce sodium intake, lower hypertension risk, and prevent noncommunicable diseases. It supports policymakers, health professionals, and stakeholders in implementing public health strategies.

02 Food Industry Solutions Salt

Salt Functionality

Functional properties describe how ingredients influence product quality by interacting with water, lipids and other components. These interactions affect texture, stability appearance and sensory perception during processing and consumption. For this reason, functional characteristics are essential for selecting and optimising ingredients in product (re)formulations. Table 3 provides an overview of key functionalities and sensory attributes to consider.

Preservation

Salt is a widely used food additive for preservation. While it does not have direct antimicrobial properties, it reduces water activity, slowing microbial growth. High salt concentrations affect microorganisms through osmotic pressure but may also lower the nutritional value of preserved foods by depleting water-soluble vitamins and minerals. As a preservation method, salting alone is insufficient for ready-to-eat products and must be combined with other techniques like drying or osmotic dehydration (Albarracín et al., 2011).

Water-holding capacity & texture

Salt plays a crucial role in improving the water-holding capacity of foods by interacting with proteins and modifying their ability to retain moisture. This helps maintain juiciness and prevents excessive moisture loss, which is particularly important in processed meats, dairy products, and baked goods (Albarracín et al., 2011). In meat products, salt helps with protein solubilisation and gel formation, contributing to a firmer texture (Desmond, 2006). In baked goods, it strengthens gluten networks, improving dough elasticity and structure (Silow et al., 2016). Additionally, in cheese production, salt plays a vital role in controlling moisture content and developing the desired texture (Guinee, 2004).

Organoleptic

Salt enhances flavour by influencing various biochemical mechanisms. It also affects enzymatic activity, either enhancing or reducing the function of certain enzymes that contribute to the development of different sensory attributes (De Man, 2023). Salt can suppress bitterness, enhance sweetness in some foods, and improve overall taste perception (Breslin & Beauchamp, 1997).

Table 3: Overview salt functionalities and sensory attributes (De Man, 2023).

Process/product functionalities	Sensory attributes
Preservation, primarily through reducing water activity.	Direct effect on **taste** i.e. salty.
Impacts the **water-holding capacity** of some meat products.	**Flavour enhancing** effect on other ingredients in food.
Breakdown of proteins for **maturation** of cheese.	Improves **texture** in bread, breakfast cereals, pickled vegetables, meat & cheese.

Salt Reduction Solutions

The following tables provide an overview of potential ingredient solutions for reformulation, distinguishing between nutritional and functional aspects. This distinction reflects the different objectives that may drive reformulation or innovation, such as improving the nutritional profile (e.g., reducing sugar, salt, or saturated fat) versus maintaining or enhancing product functionality (e.g., texture, stability, or shelf life). The tables are intended as a starting point for identifying possible solutions. They do not represent an exhaustive list, and additional considerations may apply depending on the specific product context and formulation goals.

Gradual Salt Reduction

	Functional		Nutritional	
Solution	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
(Gradual) Salt reduction	Depending on the food product category, it is possible to take out 15-25% salt without further re-engineering the flavour profile of the recipe (de Man, 2023).	Microbial growth, requiring extra preservation for safety; May affect taste; May weaken protein interactions and water-holding capacity, impacting texture (de Man, 2023; Albarracín et al., 2011).	Reduces sodium intake, supporting cardiovascular health by lowering blood pressure and subsequently risk of gastric cancer, obesity, osteoporosis, Meniere's disease, and kidney disease (World Health Organization, 2023).	Potential risk of consumers compensating by adding more salt at home; Loss of iodine intake if salt is a primary iodine source in the diet, requiring alternative fortification strategies; Reduction steps should be spread over time (2-3 years) to ensure consumer acceptablity (Hoppu et al., 2017).

Mineral-based Salt Replacers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Reduced sodium salt	Soups, sauces, snacks and meat products	Potassium chloride is frequently naturally co-present with sodium chloride or used in blends, which helps maintain a salty flavour profile (Mui, 2025).	For blends, potentially bitter, metallic and chemical tastes can emerge when NaCl is replaced too aggressively (Hoppu, 2017).	Helps reduce sodium intake and may lower blood pressure in adults (Cochrane, 2025).	May increase blood potassium slightly in adults (Brand et al., 2022).
Magnesium chloride*	Soups, sauces, bakery, dairy, fish and meat products	Enhances saltiness and contributes to texture and taste improvement; Can easily be combined with Nacl and KCl in various proportions (ratios) (Yang et al., 2024).	In high amounts identified as bitter; Less compatible in high water (bouillon) applications (ALQtaishat et al., 2022).	Essential mineral for muscle, nerve function and the vascular system (Souza et al., 2023).	High intake can cause digestive discomfort (laxative effect) (Dupont & Hébert, 2020).
Magnesium sulfate*	Processed meats and dairy alternatives	Enhances saltiness and can contribute to texture improvement; Sometimes used in combination with KCl to enhance flavor and maintain functionality (Yang et al., 2024).	Potential bitter/metallic aftertaste at high concentrations (Ecarma & Nolden, 2021).	Essential mineral for muscle and nerve function (Refahee et al., 2022).	High intake can cause digestive discomfort (laxative effect) (Dupont & Hébert, 2020).

Mineral-based Salt Replacers (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Potassium chloride (KCl)*	Bread, cheese, and meat products	Provides salty taste similar to NaCl, widely used in low-sodium formulations (van Buren et al., 2016).	Potential bitter/metallic aftertaste at high concentrations (Ecarma & Nolden, 2021).	Helps reduce sodium intake, beneficial for blood pressure (Lu et al., 2022).	Excessive intake may affect kidney function, not suitable for individuals with kidney disease (Cupisti et al., 2018).
Calcium salts (e.g., calcium chloride, calcium lactate)*	cheese, plant-based dairy, and canned vegetables	Provides a salty taste and can aid in food preservation (Kloss et al. 2015)	Potential bitter/metallic aftertaste at high concentrations (Ecarma & Nolden, 2021).	Contributes to bone health and muscle function (Trailoyke et al., 2017).	High intake may alter mineral balance in the body

*Under EU Regulation (EC) No 1333/2008, food additives must be labelled with their functional class plus either their specific name and/or E-number (e.g., “stabiliser: magnesium chloride (E511)”). These substances cannot be listed solely as regular ingredients (European Union, 2024).

Amino Acid and Peptide-Based Replacers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Yeast extracts	Plant-based meat, soups and sauces	Contain glutamates and nucleotides that enhances umami flavor, reducing the need for added salt (Tomé, 2021).	May contribute to off-flavors (Tomé, 2021).	Naturally contains B vitamins and amino acids (Tomé, 2021).	Some consumers may avoid it due to concerns over glutamates (Voedingscentrum, n.d.-d).
Hydrolyzed vegetable proteins (HVPs)	Processed sauces and meat substitutes	Provides a strong umami taste, useful in processed foods (Wang et al., 2025).	May contribute to off-flavors (Wang et al., 2025).	Source of amino acids and protein (Wang et al., 2025).	Can introduce allergens depending on the source (e.g., soy, wheat) (Wang et al., 2025).
Monosodium glutamate (MSG) and disodium inosinate/guanylate (I+G)	Sauces, ready meals, and snacks	Strong umami enhancer, effective in small amounts; Can reduce the perception of salt reduction (Maluly et al., 2017).	Some consumers may be sensitive to MSG (e.g., "Chinese restaurant syndrome" concerns) (Maluly et al., 2017).	Reduces overall sodium intake while maintaining flavor (Maluly et al., 2017).	Perceived negatively by some consumers despite scientific consensus on safety (Wang, 2018).

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Upcycled by nature
Can be sourced from upcycled ingredients

Plant and Algae-Based Salt Replacers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Seaweed and algae extracts (e.g., dulse, kelp, spirulina)	Plant-based seafood alternatives, soups, and seasonings	Naturally salty and rich in umami, enhances food flavor (Ścieszka & Klewicka, 2019; Gullón et al., 2021).	Can contribute to a fishy or seaweed-like taste if overused (Figueroa et al., 2023).	High in iodine, essential minerals, and antioxidants (Circuncisão et al., 2018; Lozano et al., 2020).	Excessive iodine intake can affect thyroid function; Capacity to accumulate several toxic metals (Lozano et al., 2020; Circuncisão et al., 2018).
Herb and spice blends	Bakery, dairy, and snack products	Provides a range of flavors, reducing the reliance on salt (e.g., garlic, onion, celery, and citrus extracts) (Petersen et al., 2024).	Flavor profile may not fully mimic salt, requiring recipe adjustments (Petersen et al., 2024).	Adds phytonutrients and antioxidants (Drewnowski, 2024).	Some herbs/spices may trigger allergies or intolerances (Śmiechowska et al., 2021).

Fermented and Enzymatically Modified Ingredients

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Fermented soy, miso, and koji extracts	Plant-based and fermented foods (e.g., tempeh, plant-based cheese)	Adds depth and complexity to flavours, mimicking saltiness (Rysová & Šmídová, 2021).	Can contribute additional fermentation-related flavors (Lin et al., 2021).	Rich in probiotics and beneficial compounds (Jang et al., 2021).	May contain naturally occurring sodium (Lin et al., 2021).
Enzyme-treated dairy proteins	Cheese and dairy	Enhances umami and salt perception in dairy and alternative products.	Limited application outside of dairy-based products.	Source of protein and essential amino acids (Patel, 2015).	Not suitable for individuals with dairy allergies (Jaiswal & Worku, 2022).

Encapsulated or Modified Sodium-Based Replacers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Salt microspheres	Bakery, snack, and processed meat	Enhances salt perception while lowering total sodium use (Dordević et al., 2017).	May require formulation adjustments for even distribution. Processing method may affect cost and availability (Dordević et al., 2017).	Helps maintain taste while reducing sodium intake (He & Tan, 2024).	
Nano-salt or salt crystals with enhanced surface area	Bakery and processed food	Improves saltiness perception with reduced sodium (Vinitha et al., 2021).	Requires specialized processing tech-nology and in some cases regulatory approval	Reduces sodium intake while preserving taste (Vinitha et al., 2021).	Consumer perception of "nano" ingredients may affect acceptance (Gómez-Llorente et al., 2022).

Electrolyte-Based Flavour Enhancers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Lactates and gluconates	Processed meats and sports nutrition	Maintains saltiness perception while reducing sodium (Ma et al., 2024).	Can have a slight sour or off-note in some applications (Ma et al., 2024).	Contribute to electrolyte balance and hydration (Li et al., 2022b).	Can cause digestive discomfort when consumed in large amounts.

03 Ingredient Suppliers Salt

An extensive (not exhaustive) overview of ingredients and ingredient suppliers is available **here**. Connect with ingredient suppliers within

Food and Health

dsm-firmenich

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World of Magnesium

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Circular Agrifood

symrise

Are you missing any information, suppliers or ingredients? Please contact **partner@foodvalley.nl** and we can incorporate this in our next version.

04 Case Studies Salt

Using vinegar as a natural enhancer in reformulation

What challenge was faced?
The challenge Burg Group faced was to reduce salt and sugar levels in ketchup while maintaining the original taste and composition as closely as possible.

How was the problem solved?
Vinegar was used to strengthen the overall flavour profile, enabling a step-by-step reduction in salt levels from 10% to 20% and ultimately 30%. Although different types of vinegar were explored, natural vinegar was selected because it is commonly already present in such food products. This also ensured that the ingredient declaration remained the same. Through this approach, Burg Group contributes to the Shift-Salt project.

Were there any obstacles?
No significant obstacles were encountered during the process.

> “Vinegar can be an effective tool to enhance flavor while reducing salt levels, but it must be carefully balanced. Furthermore, working with a single, familiar ingredient simplifies implementation.”

What was the outcome?
The final product maintained its original taste, with no noticeable differences according to both developers and tasting panels. Costs remained unchanged, and production processes were unaffected, while the Nutri-Score improved from D to C as a result of the salt and sugar reduction enabled by vinegar.

Key takeaways and lessons learned
This case shows that vinegar can be an effective tool to enhance flavor while reducing salt levels, but it must be carefully balanced. Working with a single, familiar ingredient simplifies implementation. In addition, step-by-step testing and early validation with test panels help speed up the process and improve results.

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Achieving Nutri-Score improvement without new ingredients

What challenge was faced?
A supplier of a retailer approached Dutch Spices with a specific challenge. A hamburger product needed to comply with the NAPV guidelines and required an improved Nutri-Score. To achieve this, the salt content had to be reduced. However, a key constraint was that the ingredient declaration was not allowed to change.

How was the problem solved?
The product formulation was adjusted without adding new ingredients by increasing the proportion of spices and reducing salt. Yeast, already present in the spice mix, was used more effectively as a natural flavour enhancer to compensate for the lower salt content.

> “In many cases, salt content can be reduced by up to 30% by optimising the balance of spices and flavour enhancers already present in the formulation.

Were there any obstacles?
The ingredient declaration and product price had to remain unchanged, ruling out salt alternatives. Therefore, the solution focused on optimising the existing spice mix by adjusting its composition to achieve the desired outcome.

What was the outcome?
The reformulation improved the Nutri-Score from C to B, reduced salt to below 1.2% (meeting NAPV guidelines), and only increased costs by €0.03. Market performance remained stable, indicating no negative impact on consumer acceptance.

Key takeaways and lessons learned
In many cases, salt content can be reduced by up to 30% by optimising the balance of spices and flavour enhancers already present in the formulation. Rather than immediately introducing new ingredients, it is often more effective to experiment with the ingredients that are already in the product.

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Creating a healthier cheese without compromising taste: Veendammer cheese

What challenge was faced?

The challenge was to develop a premium Dutch cheese with significantly less sodium while maintaining the rich flavour, creamy texture and quality consumers expect from a traditional Gouda style cheese.

How was the problem solved?

By partially replacing traditional salt with Nedmag's Magnesium Salt Novasal, Kaasboerderij Slob and Nedmag developed a unique 50+ cheese with lower sodium and added magnesium. Extensive product development helped optimise flavour, texture and nutritional value.

> "By replacing part of the sodium with Novasal, we created a cheese with less sodium, added magnesium and an even richer taste experience"

Were there any obstacles?

Determining the optimal level of Novasal and adapting the cheesemaking process to maintain the desired flavour profile, texture and maturation characteristics.

What was the outcome?

The result was a cheese containing just 1.2 g salt per 100 g, compared with approximately 2.0 g for regular young matured Gouda cheese. In addition, Novasal provides 110 mg magnesium per 100 g, around one third of the recommended daily intake. The cheese delivers a richer flavour and creamier mouthfeel while offering a clear nutritional benefit. Veendammer, also produced by De Venehoeve, is sold in several cheese specialty stores.

Key takeaways and lessons learned

Novasal enables cheese producers to achieve meaningful sodium reduction while adding nutritional value and maintaining the taste experience consumers expect.

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Sodium reduction in salted crackers

What challenge was faced?
Company A's salted cracker, containing 2% salt, was rated lower in consumer tests than a competitor's cracker with 2.5% salt. Company A aimed to enhance the salty flavour while reducing sodium content to 1.7%, the lowest limit set by NAPV for processed foods.

> "Saltwell is used to improve the salty taste while reducing sodium levels."

How was the problem solved?
The solution was to replace regular salt with 2.5% Saltwell, a natural, reduced-sodium salt containing 35% less sodium than standard salt but offering the same salty flavour.

Were there any obstacles?
Operational manager brought up the fact that this change resulted in a slightly higher cost in use. But the marketing- & sales department overruled this objection because they expect better sales and contribution because of improved flavour and nutrition.

What was the outcome?
The reformulated cracker delivered a flavour profile comparable to the competitor's 2.5% salt version. Company A achieved a reduced sodium content of just 1.65%, successfully meeting both taste and nutritional goals.

Key takeaways and lessons learned
In the case above, Saltwell is used to improve the salty taste while reducing sodium levels. Saltwell is a natural reduced-sodium salt with 35% less sodium compared to regular salt but with the same salty flavour profile in food applications.

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Salt reduction in meat alternatives

What challenge was faced?
The challenge was to reduce salt content in meat alternatives with 15% without compromising taste experience or consumer preference.

How was the problem solved?
Functional citrus- and apple fibre enhanced texture and increased juiciness by 11%, resulting in an amplified perception of saltiness.

Were there any obstacles?
The production process was key. Applying shear force (e,g, bowl chopper) was essential to optimise the performance of citrus fibre in achieving the desired texture and mouthfeel.

> “Functional citrus- and apple fibre enhanced texture and increased juiciness by 11%, resulting in an amplified perception of saltiness.

What was the outcome?
Salt content was successfully reduced by 25%. The improved bite and juiciness from citrus fibre, combined with tailored spice and herb blends, ensured the final product delivered on both taste and texture.

Key takeaways and lessons learned
Functional fibres, such as citrus or apple fibre, serve multiple roles, enhancing taste, improving flavour release, and supporting salt reduction. They are a valuable tool in creating great-tasting, clean-label meat alternatives.

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Salt reduction in meat products

What challenge was faced?
While processed foods are convenient for consumers, their contribution to a healthy diet is often limited, by e.g. high salt content. VION Food Group set out to lower the salt content in meat products for the British market by 30%.

How was the problem solved?
NIZO Food Research tackled this challenge with a blend of technologies. A high-throughput (HTP) screening method was used to identify the most promising salt-replacement systems. This was followed by Olfactoscan screening to detect saltiness-enhancing aromas in meat extracts. The result: a well-balanced mix of salt replacers, masking agents, enhancers, and flavourful aromas that recreated the familiar salty taste.

> “More than 30% reduction in salt, 0% compromise on taste and shelf life. In two years, VION Food Group has taken more than 800 tonnes of sodium chloride out of gammon and bacon for the UK market.”

Were there any obstacles?
Salt plays multiple roles beyond flavour—it influences shelf life, moisture retention, and even texture. Reducing it meant addressing these functions all at once. By combining ingredient knowledge with advanced screening tools, NIZO Food Research was able to overcome these hurdles without increasing production costs significantly.

What was the outcome?
More than 30% reduction in salt, 0% compromise on taste and shelf life. In two years, VION Food Group has taken more than 800 tonnes of sodium chloride out of gammon and bacon for the UK market.

Key takeaways and lessons learned
This case shows that a structured, science-based approach can yield big wins in reformulation.

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Sodium reduction in extruded savoury snacks

What challenge was faced?

A 50% sodium reduction was needed in extruded savoury snacks containing 1.2% salt. As most salt was applied via seasoning, many alternative solutions compromised flavour or introduced off-notes (bitter/metallic off-notes). The product also had to remain clean label and consistent across a wide flavour range under the same brand.

How was the problem solved?

The problem was solved by replacing 50% of the salt with NuTek's Beyond Sea Salt in both the dough and the seasoning. So the new recipe was 0,6% salt and 0,6% NuTek Beyond Sea Salt. NuTek's Beyond Sea Salt can be labelled as Sea Salt.

> "NuTek's Beyond Sea Salt is capable of achieving significant sodium reductions in already low salt recipes without compromising taste and with a clean label."

Were there any obstacles?

No problems occurred during the entire process. NuTek Beyond Sea Salt works very well in both the dough and the seasoning, giving full salty flavour without off-notes.

What was the outcome?

The outcome was a range of extruded snacks with only 0.6% salt, so a reduction of 50% of an already low salt content, with a similar taste as the original. Also the reduction was very simple and various recipes of the snack seasonings could be reduced to the desired level. The product can also be labelled as Sea Salt.

Key takeaways and lessons learned

In this case NuTek's Beyond Sea Salt is used to even further reduce products with already a low salt content without affecting the taste and properties of the final product. NuTek's Beyond Sea Salt proves to be an easy and very flexible solution in recipes with already pretty low salt contents. Similarly, NuTek's 'Salt for Life' is capable of achieving significant sodium reductions in already low salt recipes without compromising taste, functionality and microbiological stability.

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Sugar

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01 General Information Sugar

Background

Sugar, or saccharose, belongs to the family of carbohydrates. In the EU legislation, the term 'carbohydrates' refers to 'any carbohydrate which is metabolised by humans, and includes polyols' (European Commission, 2023b). European Union legislation refers to sugars as 'all monosaccharides and disaccharides present in food, but excludes polyols', while foods with no added sugars are defined as foods without 'any added monosaccharides or disaccharides', or without 'any added food containing monosaccharides or disaccharides which is used for its sweetening purposes' (Table 4) (European Commission, 2023b).

In this report, ‘sugar' refers to monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, and sugars present in honey, syrups, fruit juices and fruit juice concentrates (Figure 2).

The **intake** of total sugars of different European countries is published by the European Commission (European Commission, 2021), total sugars range between 15 and 21% of energy intake (Azaïs-Braesco et al., 2017). In the Netherlands the Voedsel Consumptie Peiling of 2019-2021 has found an average intake of mono- and disaccharides of 92 g/day, amounting to 19% of total energy intake (RIVM, 2021a).

The main **sources** of mono- and disaccharides intake in the Netherlands are: dairy and dairy substitutes (20%), fruits, nuts and olives (19%), non-alcoholic beverages (15%), confectionery (15%) and biscuits and cakes (11%) (RIVM, 2021a).

Table 4: Types of sugar, examples and sources (Turck et al., 2023; European Commission, 2023).

Class	Description	Amount of sugar molecules	Examples
Sugar	Monosacharides	One sugar molecule	Glucose, galactose, and fructose
Sugar	Disaccharides	Two sugar molecules	Sucrose, lactose, and maltose
Polysaccharides	Starches and non-starch polysaccharides	Multiple sugar molecules	Amylose, cellulose, and pectins

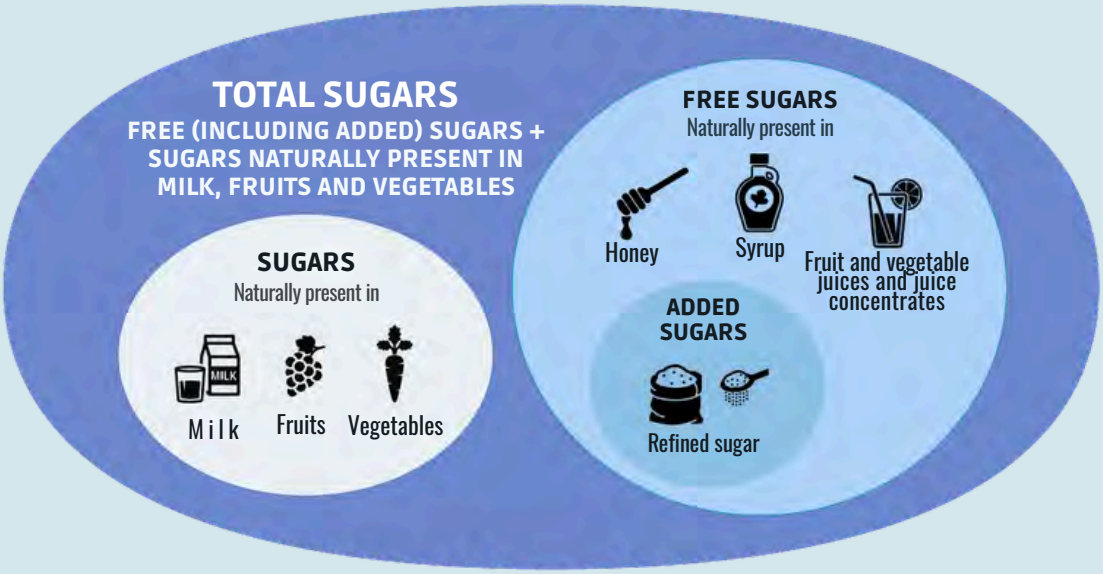

Figure 2: Classification of dietary sugars (Turck et al., 2022).

Health Aspects

INCREASED RISK OF CARDIOVASCULAR DISEASES

Research has linked diets rich in sugary and ultra-processed foods to heart disease risk factors (European Commission, 2023b). Additionally, foods high in added sugar often contain high amounts of saturated fat.

INCREASED RISK OF OBESITY

Processed foods high in sugars have been associated with unintentional weight gain or obesity (European Commission, 2023b). While some evidence suggests that high sugar intake, particularly from sugar-sweetened beverages, is associated with increased obesity risk, other research questions this link, especially for solid sugars (Yan et al., 2022).

INCREASED RISK OF POOR DENTAL HEALTH

Evidence suggests that frequently consuming sugar can negatively impact your dental health (European Commission, 2023b). Bacteria in the mouth thrive on sugar, producing acids that erode the enamel protecting the teeth, which can lead to cavity formation over time (European Commission, 2023b).

INCREASED RISK TYPE 2 DIABETES

Research indicates that higher intake of added sugars, particularly from sugar-sweetened beverages, is linked to an increased risk of type 2 diabetes in adults (Ma et al., 2022b; Meng et al., 2021). Scientists agree that high levels of sugar consumed daily increase inflammation along with decreased insulin sensitivity (Ma et al., 2022b), potentially causing blood sugar imbalances and the development of type 2 diabetes (European Commission, 2023b; Banday et al., 2020).

Regulatory Framework

Dietary Guidelines

WHO recommends limiting intake of free sugars throughout the life course. In both adults and children, WHO recommends limiting the daily intake of free sugars to less than 10% of total energy intake, and to less than 5% if possible (European Commission, 2023b).

Similarly, in Europe, different nutrition and health-related organisations have recommended to set an upper limit of daily energy (calorie) intake of (added/free) sugars (European Commission, 2023b). However, **EFSA** has not set an upper limit for recommended dietary intake of sugar (European Commission, 2023b).

In the **Netherlands** there is also no governmental guideline for sugar intake. The Health council (Gezondheidsraad) states there is no sufficient evidence to establish a separate maximum for consumption (Voedingscentrum, n.d.-c).

WHO recommendation of free sugar intake per day

< 10% energy intake per day

EFSA and Dutch recommendations of free sugar intake per day

No upper limit set

Nutrition claims

Allowed claims in EU (European Commission, 2023b):

- **Sugars-free**: may only be made where the product contains no more than 0,5 g of sugar per 100 g or 100 ml.
- **Low sugars**: may only be made where the product contains no more than 5 g of sugars per 100 g for solids or 2,5 g of sugars per 100 ml for liquids.
- **With no added sugars**: may only be made where the product does not contain any added mono- or disaccharides or any other food used for its sweetening properties. If sugars are naturally present in the food, the following indication should also appear on the label: 'CONTAINS NATURALLY OCCURING SUGARS'.

Nutri-Score

The lower sugar limit used by Nutri-Score is ≤4,5 g sugar (excluding drinks) per 100 g of product. Nutri-Score assigns negative points for sugar based on the quantity present in 100 g or 100 ml of the product, up to 10 negative points can be given for products containing 45 g or more of sugar per 100 g (RIVM, 2024).

In the Netherlands, RIVM has provided a calculation tool for the Nutri-Score of a product.

NAPV

For sugar, the NAPV established limit values for multiple product categories, with for each product category specification in subcategories. When possibile, the lower limits of the NAPV correspond to the lowest cut-off points of Nutri-Score. Consult the NAPV source document for detailed values applicable to specific products (RIVM, 2022).

NAPV developed limit values for for mono- and disaccharides in the following product categories:

- [x] Bread(replacements) and breakfast cereals
- [x] Dairy and plant-based alternatives
- [ ] Cheese
- [ ] Meat preparations and meat products
- [ ] Deli meats and preserved meats
- [ ] Fish
- [ ] Meat substitutes
- [ ] Spreads and cooking fats
- [ ] Soups and bouillons
- [ ] Sauces
- [x] Savoury snacks
- [x] Pastry & confectionary
- [x] Drinks
- [ ] Sandwich filling

Learn more: NAPV roadmap

Further Readings

Beyond Sweetness: The Functional Roles of Sugar in Foods and the Challenges in Replacing/Reducing It (2016)

An informational document on the role of carbohydrates, including sugar, in nutrition and food formulation. It discusses their functional properties, impact on health, and industry perspectives on sugar reduction.

Strategies for the Reduction of Sugar in Food Products – ScienceDirect (2023)

A scientific overview of different methods used to lower sugar content in food products while maintaining quality. The article reviews ingredient substitutions, technological processes, and regulatory considerations.

EUR-Lex Regulation (EC) No 1924/2006 on Nutrition and Health Claims

This legislation provides the legal framework for nutrition and health claims made on foods within the EU. It specifies the conditions under which claims like "low sugar" can be made, ensuring that consumers receive truthful and substantiated information.

Technical Brief: Food Reformulation for Sugar

Examines the health implications of high sugar intake and identifies major dietary sources contributing to excessive consumption. It emphasizes the importance of product reformulation to reduce sugar levels in processed foods and discusses strategies for achieving this goal.

Reformulation of food and beverage products for healthier diets: WHO policy brief

Provides information and practical guidance for implementing effective policy actions to eliminate industrially produced trans-fatty acids from the food supply, reduce the energy content per portion and lower the levels of saturated fats, sugars and salt/sodium in food.

Use of non-sugar sweeteners: WHO guideline (2023)

This guideline offers evidence-based advice on non-sugar sweeteners to support policymakers, health professionals, and stakeholders in reducing sugar intake through public health actions and interventions.

02 Food Industry Solutions Sugar

Sugar Functionality

Functional properties describe how ingredients influence product quality by interacting with water, lipids and other components. These interactions affect texture, stability appearance and sensory perception during processing and consumption. For this reason, functional characteristics are essential for selecting and optimising ingredients in product (re)formulations. Table 5 provides an overview of key functionalities and sensory attributes to consider.

Preservation

Sugar preserves food by drawing water out of microbial cells, dehydrating them through osmotic pressure. Sugar also binds water molecules, reducing water activity and inhibiting microbial growth, thereby extending shelf life (McCain et al., 2018). Reduced sugar can lead to higher water activity, encouraging microbial growth and leading to spoilage and faster drying out, impacting the freshness of the product (McCain et al., 2018; Efe & Dawson, 2022).

Texture and mouthfeel

Sugar retains water, influencing the viscosity and crispness of food (van der Sman et al., 2021). This affects the texture (moist and chewy) of baked goods (van der Sman et al., 2021). Reducing sugar can result in a drier, denser texture or an undesirable chewy, hard, or grainy texture (McCain et al., 2018).

Thermal processing

When sugar undergoes thermal processing, its functionality changes depending on temperature, time, moisture content, and the presence of other ingredients (van der Sman et al., 2021). These changes impact texture, flavour, colour, and stability in food product reformulation. Sugar also lowers freezing points in frozen products, requiring alternatives like polyols or short-chain oligosaccharides to maintain desired properties (Landikhovskaya & Tvorogova, 2021).

Organoleptic
Sugar not only adds sweetness but also enhances overall flavour perception by masking bitterness and balancing acidity (McCain et al., 2018). Reducing sugar may make these other flavours more prominent. It also affects the timing and intensity of sweetness, requiring careful selection of alternatives with similar profiles (McCain et al., 2018).

Additionally, sugar contributes to browning through the Maillard Reaction and caramelisation (McCain et al., 2018). Reducing sugar may diminish browning, affecting flavour and appearance, especially affecting baked products (Tamanna & Mahmood, 2015). Alternative reducing sugars or Maillard mimetics can help retain these properties (McCain et al., 2018).

Volume and bulk
Sugar contributes to the structure and volume of baked products by creating air pockets during creaming with fats, while also adding to the overall mass of the product. Reducing it often requires substitutes to maintain texture (McCain et al., 2018).

Mesh size
Size and type of sugar crystals influence texture, solubility, binding efficiency and processing properties (van der Sman, 2019). Fine sugar crystals create smooth textures (e.g. fondant) through rapid solubility and better dispersion. Larger crystals add crunch (e.g. cookies). Larger crystals also have better heat resistance and improve stability in dry blends. Alternative bulking agents may alter these characteristics (van der Sman, 2019).

Table 5: Overview sugar functionalities and sensory attributes.

Process/product functionalities	Sensory attributes
Texture, sugar affects the texture of a product, where a reduction can result in undesirable properties.	**Sweetness**, sugar reduction may alter the onset, intensity, and duration of sweetness.
Volume and bulk, sugar contributes to the structure and volume of products.	**Organoleptic properties** should be carefully considered in product formulation to obtain the desired qualities.
Preservation, sugar acts as a preservative and can help extend shelf life.	**Mesh size,** influences texture, solubility, and functionality of the sugar.
Stability of a product is highly dependent on type, temperature, and concentration of sugar.	**Thermal processing** can affect colour and functionality of sugar and alternatives.

Sugar Reduction Solutions*

*If based in the Netherlands, ensure use of sweeteners is in line with the legislation on additives currently in force (Nederlandse Voedsel- en Warenautoriteit, 2024b)

The following tables provide an overview of potential ingredient solutions for reformulation, distinguishing between nutritional and functional aspects. This distinction reflects the different objectives that may drive reformulation or innovation, such as improving the nutritional profile (e.g., reducing sugar, salt, or saturated fat) versus maintaining or enhancing product functionality (e.g., texture, stability, or shelf life). The tables are intended as a starting point for identifying possible solutions. They do not represent an exhaustive list, and additional considerations may apply depending on the specific product context and formulation goals.

Sugar Reduction

	Functional		Nutritional	
Solution type	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
(Gradual) Sugar reduction	Maintains product acceptability while slowly reducing sugar content; allows consumers to adjust to less sweetness over time (Hashem et al., 2019).	May require multiple iterations to achieve desired sensory properties; Potential for consumer resistance if changes are too noticeable (Ma et al., 2016).	Reduces overall sugar intake; Helps in managing calorie consumption and reducing the risk of sugar-related health issues (Ma et al., 2016).	If not managed properly, may lead to the use of alternative ingredients that could have other health implications (Ma et al., 2016).

Natural Sweeteners

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Stevia (Steviol Glycosides)	Dairy products, confectionery	200-300× sweeter than sugar; heat-stable for baking and beverages (Paola et al., 2023).	Requires blending for balanced sweetness. Still needs bulking agents in sugar replacement (Nur et al., 2021).	Zero glycemic impact; safe for diabetics (Paola et al., 2023).	Some people may experience a bitter or licorice-like lingering aftertaste (Paola et al., 2023).
Monk fruit*	Confectionery, protein bars, and dairy products	250× sweeter than sugar (Yeung, 2023).	Some variants may have a fruity or slightly caramel-like aftertaste (Yeung, 2023).	Zero glycemic impact; safe for diabetics (Kaim & Labus, 2025).	Limited supply and higher production costs (Wazir et al., 2025).

*Non-selective water extracts of the whole fruit are approved for use in the EU as traditional food ingredients. Whereas, monk fruit extract sweeteners are not approved and pending further safety evaluations and regulatory approval (EFSA Panel on Food Additives and Flavourings (FAF) et al., 2019)

Artificial Sweeteners

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Aspartame	Soft drinks, dairy products	180–200× sweeter than sugar; Taste close to sucrose (Czarnecka et al., 2021).	Not heat-stable; Breaks down at high temperatures (Czarnecka et al., 2021).	Zero glycemic impact; Safe for diabetics (Shaher et al., 2023).	Contains phenylalanine – unsafe for individuals with PKU (phenylketonuria) (Shaher et al., 2023).
Sucralose	Baked goods, dairy products	600× sweeter than sugar; Heat-stable for baking and cooking (Singh et al., 2024b).	Some consumers report a slight aftertaste; May not caramelize like sugar (Singh et al., 2024b).	Zero glycemic impact; Safe for diabetics (Aguayo-Guerrero et al., 2024).	May alter gut microbiota in excessive consumption (Aguayo-Guerrero et al., 2024).
Saccharin	Beverages	300–400× sweeter than sugar; Highly stable in acidic products (Souza et al., 2022).	Metallic or bitter aftertaste; Often blended with other sweeteners (Souza et al., 2022).	Zero glycemic impact; Safe for diabetics (Del Pozo et al., 2022).	Some consumers avoid it due to past unvalidated concerns (Castle et al., 2024).
Acesulfame K	Beverages, baked goods, dairy products	200× sweeter than sugar; Highly heat-stable (Castle et al., 2025).	Bitter aftertaste if used alone; Often blended with sucralose or aspartame (Mehat et al., 2022).	Zero glycemic impact; Safe for diabetics (Mehat et al., 2022).	May alter gut microbiota in excessive consumption (Castle et al., 2025).

Artificial Sweeteners (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Neotame	Beverages, baked goods	7,000–13,000× sweeter than sugar; Heat-stable and suitable for industrial use (Farag et al., 2022).	Requires very low concentrations for sweetness, making formulation adjustments necessary (Ibrahim, 2015).	Zero glycemic impact; Phenylalanine content is too low to affect people with PKU (phenylketonuria) (Farag et al., 2022).	May alter gut microbiota in excessive consumption (Farag et al., 2022).
Advantame	Bakery, confectionery, dairy	20,000× sweeter than sugar; Ultra-high intensity sweetener (Silva et al., 2023).	Newer sweetener; Mot as widely available in commercial consumer product.	Zero glycemic impact; Safe for diabetics (Iizuka, 2021).	Generally recognized as safe (GRAS) by the FDA and EFSA but long-term studies are limited (EFSA, 2013).

Sugar Alcohols

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Erythritol	Chocolates, sweets, beverages	70% as sweet as sugar; Provides bulk and texture (Ibrahim, 2021).	Cooling effect in mouth; May not fully replace sugar's caramelization properties (Mazi & Stanhope, 2023).	Almost zero calories (0.2 kcal/g); Does not spike blood sugar (Ibrahim, 2021).	High doses may cause bloating in sensitive individuals (Mazi & Stanhope, 2023).
Xylitol	Chewing gum, baked goods	Similar sweetness to sugar (1:1 replacement); Prevents moisture loss in baked goods (Umai et al., 2022).	May require adjustments in water activity control or blending with other sweeteners to prevent excessive moisture retention or crystallization (Radya Asasta et al., 2024).	Contains 2.4 kcal per gram, which is about 40% fewer calories than sugar (4 kcal/g) (Umai et al., 2022).	High intake can cause digestive discomfort (laxative effect) (Radya Asasta et al., 2024).
Sorbitol	candies, baked goods,	60% as sweet as sugar; Provides smooth texture (Li et al., 2022a).	Unlike sugar, Sorbitol does not participate well in the Maillard reaction or caramelization, affecting color and flavor development in baked goods (Yan et al., 2024).	Lower calorie content (2.6 kcal/g) compared to sugar (Li et al., 2022a).	High intake can cause digestive discomfort (laxative effect) (Radya Asasta et al., 2024).

Sugar Alcohols (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Maltitol	Chocolates, baked goods	90% as sweet as sugar; Provides similar mouthfeel and offers a smooth texture (Ding & Yang, 2021).	Has a slower crystallisation rate than sugar, additional tempering techniques or blending with other polyols may be necessary (DeJong & Hartel, 2020)	Lower calorie content (2.1 kcal/g) than sugar (Suna et al., 2023).	High intake can cause digestive discomfort (laxative effect) (Ding & Yang, 2021).
Mannitol	Candies, sweets	50–70% as sweet as sugar; Stable under high temperatures; Does not attract much water (Shrivastava et al., 2021).	Can make baked goods dry or crumbly, requiring additional binding agents (Sahin et al., 2018).	Low glycemic impact (Martínez-Miranda et al., 2022).	High intake can cause digestive discomfort (bloating) (Pessarelli et al., 2022).
Isomalt	Chocolate, confectionary	50% as sweet as sugar; Improves texture in sugar-free candies (Schweitzer et al., 2024).	Less sweetness than sugar; Can also cause a firmer or more brittle texture than expected (Schweitzer et al., 2024).	Low-calorie alternative (2 kcal/g) (Schweitzer et al., 2024).	High intake can cause digestive discomfort (laxative effect) (Świąder et al., 2022).

Fibre Replacers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Soluble Fibre replacers (e.g. inulin, polydextrose)	See also fibre solutions	Dissolve in water and can create a gel-like texture, helping to improve mouthfeel and stability (Rodriguez-Garcia et al., 2022).	Can create slimy textures if overused, may be sensitive to temperature or pH changes (Mensink et al., 2015).	Increase dietary fiber content; Support digestive health; Aid in satiety, potentially assisting in weight management (Sempio et al., 2024).	Can cause gas or bloating when consumed in large amounts (Miller et al., 2015).
Insoluble fibre replacers	See also fibre solutions	provide bulk and structure to products, helping with texture and stability (Soleimanian et al., 2022).	Can make products crumbly or dry if not balanced correctly; Requires moisture adjustments (Sempio et al., 2024).	Supports digestive health, reduces post-meal glucose spikes (Sempio et al., 2024).	Can cause gas or bloating when consumed in large amounts (Miller et al., 2015).
Polydextrose (synthetic polymer of glucose)	Baked goods, confectionary, dairy	Acts as a bulking agent, stabilizer, and thickener; Provides body and texture to low-calorie foods (Ünal & Arslan, 2022).	May require additional ingredients to achieve desired sweetness; Can affect the taste profile if not used correctly (Ünal & Arslan, 2022).	Low in calories; Contributes to dietary fiber intake; May aid in digestive health (Ünal & Arslan, 2022).	Can cause gas or bloating when consumed in large amounts (Miller et al., 2015).

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Fermentation

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Lactic acid fermentation	Dairy, beverages	Reduces sugar content in dairy (yogurt), vegetables (sauerkraut, kimchi), and beverages (kombucha) (Ozcan et al., 2021).	Live cultures may not survive heat processing, can alter taste by adding sourness, may require formulation adjustments (Janiszewska-Turak et al., 2024).	Increases probiotic content, supports digestion, enhances nutrient bioavailability (e.g., B vitamins) (Ozcan et al., 2021).	Some fermented products may still contain residual sugars, and excess acidity could affect tooth enamel and digestion in sensitive individuals.
Enzymatic Fermentation	Baked goods, cereals, and beverages	Breaks down starches into simpler, naturally sweet molecules for sugar reduction (Müller et al., 2021).	Needs precise enzyme control to avoid over-processing, which may impact texture (Raveendran et al., 2018).	Reduces the need for added sugars while maintaining sweetness (Müller et al., 2021).	Some enzymes may be denatured by high heat, affecting efficiency (Haspolat, 2024).

Novel Sweeteners

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Allulose*	Baked goods, confectionery	Provides bulk, texture, and freeze-thaw stability similar to sucrose (Xie et al., 2024).	Browns faster than sucrose, can lead to excessive browning or burning if not adjusted (Xie et al., 2024).	Very low in calories (~0.4 kcal/g) – ~90% fewer calories than sugar, making it useful for calorie reduction (Xie et al., 2024).	Can cause gas or bloating when consumed in large amounts (Miller et al., 2015).
Tagatose	beverages, dairy, and baked goods	Provides bulk and mouthfeel similar to sugar. Enhances browning and caramelization (Ortiz et al., 2024).	Can degrade under prolonged high temperatures, potentially affecting stability in heated applications (Bober & Nair, 2019).	Low calorie (~1.5 kcal/g) – ~60% fewer calories than sucrose, making it useful for calorie reduction (Ortiz et al., 2024).	Can cause gas or bloating when consumed in large amounts (Ortiz et al., 2024).
Trehalose	Baked goods, confectionary	Stabilizes proteins and lipids, helps preserve texture, moisture, and shelf life (Chen et al., 2022).	More expensive, and often needs blending with other sweeteners to match sugar's sweetness (Chen et al., 2022).	Metabolized more slowly than glucose, preventing rapid blood sugar spikes (Yoshizane et al., 2017).	Caloric content similar to sugar (4 kcal/g). Does not provide calorie reduction like other sugar alternatives (Chen et al., 2022).

*Allulose is not approved for use in Europe as a food ingredient because it is classified as a "novel food". EFSA is currently evaluating allulose for potential use as a food ingredient.

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Novel Sweeteners (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Stachyose	Beverages (including solid beverages), dairy products, baked goods, confectionery	With a sweetness of about 22% of sucrose, it can replace part of the sucrose to meet sweet taste demand; Good water-solubility and stable properties within a wide range of temperatures and pH values (Ta et al., 2024).	In foods with high sweetness requirements, it may be necessary to blend with other sweeteners and control the dosage to avoid affecting the food's flavor (Ta et al., 2024).	Prebtiotic; Low in calories (Yan et al., 2023).	Can cause gas or bloating when consumed in large amounts.

03 Ingredient Suppliers Sugar

An extensive (not exhaustive) overview of ingredients and ingredient suppliers is available **here**. Connect with ingredient suppliers within

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*Ingredient marketplace for food manufacturers

Circular Agrifood

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Are you missing any information, suppliers or ingredients? Please contact **partner@foodvalley.nl** and we can incorporate this in our next version.

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04 Case Studies Sugar

Fibre-based sugar reduction in bakery applications

What challenge was faced?
The reformulation aimed to reduce sugar and calories in baked products. As starch-based replacers offer limited benefits regarding calories and metabolic response, fibre was selected as a more effective alternative.

How was the problem solved?
A fibre-based approach was adopted using a soluble maize fibre as the main ingredient. This enabled up to 30% sugar reduction in a muffin and therefore supporting a 'reduced sugar' claim. Since fibre alone not fully replicates the functionality of sugar, it was combined with wheat protein and wheat starch to improve volume and texture. This resulted in the blend avanté™ 25.

> "Fibre is a powerful alternative to sugar, both nutritionally and functionally. However, sugar cannot be replaced directly; its role in the formulation must first be understood."

Were there any obstacles?
The main challenge was replicating the multiple functions of sugar. Fibre can replace bulk, but not all structural and sensory properties. Finding the optimal blend of fibre with starch and protein was therefore essential.

What was the outcome?
The result was a fibre-based solution that achieved significant sugar reduction while maintaining product quality. The concept has been validated internally and is currently being tested with customers.

Key takeaways and lessons learned
This case demonstrates that fibre is a powerful alternative to sugar, both nutritionally and functionally. However, sugar cannot be replaced directly; its role in the formulation must first be understood. A successful strategy is to combine fibre with complementary ingredients to replicate sugar's full functionality.

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Reformulating a sweet-and-sour marinade to improve Nutri-Score

What challenge was faced?
A client required the reformulation of a sweet-and-sour marinade for spareribs. The product needed reductions in both salt and sugar content in order to improve its Nutri-Score. The objective was to enhance the nutritional profile while maintaining taste and consumer acceptance.

How was the problem solved?
The reformulation initially focused on reducing sugar, but this alone did not sufficiently improve the Nutri-Score. Therefore, a broader approach was applied using a natural extract (that was already present in the ingredient mix) to mask stevia's bitterness and enhance saltiness, along with potassium chloride as a partial salt replacer.

> “ Close client collaboration helps identify reductions and suitable functional replacements.

Were there any obstacles?
The product price was not allowed to increase. This limitation restricted the use of certain alternative ingredients and required optimisation within the existing product formulation.

What was the outcome?
The new formulation was perceived as better in sensory tests but did not consistently outperform the reference in triangle testing. The Nutri-Score improved from E to C, and despite minor sensory differences, the product was successfully implemented.

Key takeaways and lessons learned
Meaningful reductions of up to 30% are possible through careful optimisation, without major taste loss. Close client collaboration helps identify reductions and suitable functional replacements.

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Sugar reduction in cookies

What challenge was faced?
The goal was to reduce sugar content by 50% in baked sand dough cookies. Traditional sugar replacers often lack the bulk, browning behaviour, and recrystallization properties of sugar, making reformulation challenging.

How was the problem solved?
The problem was solved by replacing 50% of the sugar with Anderson Advanced Ingredients Allsweet Allulose Crystals. Allulose is an all natural sugar replacer with only 10% of the calories compared to sugar but with similar bulk and baking properties.

Were there any obstacles?
No problems occurred during the development process. The reformulated dough performed well in both preparation and baking.

> “Allsweet Allulose from Anderson Advanced Ingredients is an excellent sugar replacer in many applications but is especially effective in baked applications due to similar bulk and baking properties as sugar.”

What was the outcome?
The cookies retained the original taste, texture, and bite, with 50% less sugar. The only adjustment was a 10% reduction in baking time, as Allulose browns faster due to its reducing sugar properties.

Key takeaways and lessons learned
Allsweet Allulose is a highly effective sugar alternative for baked goods, offering similar bulk and baking functionality with significantly fewer calories. While still considered a novel food in the EU, it is already approved in many other markets and is expected to gain EU approval soon.

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Saturated Fat

01 — **General Information**

- Background
- Health Aspects
- Regulatory Framework
- Further Readings

02 — **Food Industry Solutions**

- Saturated Fat Functionality
- Saturated Fat Reduction Solutions

03 — **Ingredient Suppliers**

Overview of ingredients and ingredient suppliers

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Example cases on reformulation from partners

01 General Information Saturated fat

Background

Dietary fat is an essential macronutrient that provides energy, supports cell growth, and helps the body absorb fat-soluble vitamins (A, D, E, and K). It plays a crucial role in hormone production, brain function, and maintaining overall health. WHO notes that both quantity and quality of fats are important for good health (Cattaruzza & French, 2024; World Health Organization, 2023c).

All fats are composed of molecules called fatty acids, which are chains of carbon atoms. There are different types of dietary fats, each with unique effects on the body. They comprise monounsaturated, polyunsaturated, saturated, and trans fatty acids. According to the EU Regulation 1169/2011 definition, 'saturated' means fatty acids without double bonds and 'unsaturated' includes fatty acids with one (mono-) or more (poly-) cis double bonds. Trans fats are unsaturated fatty acids that mostly come from industrial sources. They contain a double bond in trans- (instead of cis-) alignment (European Parliament and Council of the European Union, 2011). The different types of dietary fats, examples and main sources are explained in Table 6. This report focuses solely on saturated fats (SFA), in line with the NAPV guidelines.

Global SFA **intake** varies widely across countries, ranging from 2.3% to 27.5% of total energy intake, with a global average of 9.4% in 2010. In 75 of 187 countries representing 61.8% of the world's adult population, the mean intake was greater than 10% of total energy intake (Micha et al., 2014). SFA are primarily found in meats, meat products, and dairy products like butter, milk, and cheese. However, certain plant-based fats, such as cocoa butter, coconut oil, palm oil, and palm kernel oil (commonly known as tropical oils), are also high in SFA. These fats are widely used in various processed foods, including cakes, biscuits, and pastries (Cattaruzza & French, 2024).

The average **intake** of SFA in the Netherlands is 30 g/day, 13.3% of the daily energy intake. With an intake of 33 g/day it is higher for males than for females who consume 27 g/day. The contribution of SFA to energy intake is almost the same for boys/men and girls/women (13.1 and 13.5 En%/day). The main **sources** of SFA are dairy and dairy substitutes (34%), meat and meat substitutes (17%) and fats and oils (12%) (RIVM, 2021b).

Table 6: Types of dietary fat, examples and sources.

Type of fat	Description	Examples	Sources
Mono-unsaturated fat (Kris-Etherton, 1999)	Contains one double bond, beneficial for heart health	Oleic acid	Olive oil, canola oil, certain nuts, and avocados
Poly-unsaturated fat (Meyer et al., 2003)	Contains multiple double bonds, essential for body functions	Omega-3 (EPA, DHA) and Omega-6 fatty acids	Fatty fish, nuts, and plant-based oils
Saturated fat (World Health Organization, 2023c)	Contains single carbon–carbon bonds (i.e. no double bonds)	Lauric acid, Palmitic acid, Stearic acid	Fatty meat, dairy foods, and hard fats and oils such as butter, ghee, lard, palm oil and coconut oil
Trans fat (World Health Organization, 2023c; Alonso et al., 1999)	Unsaturated fatty acids with at least one double carbon–carbon bond in the trans configuration	Elaidic acid	Baked and fried foods, pre-packaged snacks, and meat and dairy foods from ruminant animals, such as cows or sheep.

Health Aspects

INCREASED RISK OF CARDIOVASCULAR DISEASES

A diet high in SFA has been associated with increased atherosclerotic cardiovascular disease risk, in large part because of an effect to raise the low-density lipoprotein cholesterol concentration. A high amount of low-density lipoprotein cholesterol is not good for the blood vessels because it contributes to plaque buildup in the arteries (Hu et al., 2001).

INCREASED RISK OF OBESITY

Consuming high amounts of SFA is associated with an increased risk of obesity, as these fats are energy-dense and can promote fat accumulation, particularly abdominal fat. Research has shown that SFA intake influences mechanisms of fat storage and appetite regulation, leading to excess weight gain and a higher risk of metabolic disorders (Risérus et al., 2009).

INCREASED RISK OF CANCER

High SFA intake has been linked to an increased risk of several cancers, including colorectal, breast, and prostate cancers. Mechanistically, SFA can promote cancer progression through pathways such as chronic inflammation and altered cell growth regulation (Mei et al., 2024).

Regulatory Framework

Dietary Recommendations

The **WHO** and the **Dutch Health Council (Gezondheidsraad)** recommend that consumed fat should primarily be unsaturated fatty acids, with no more than 10% of total energy intake coming from SFA (World Health Organization, 2023c; Gezondheidsraad, 2015).

EFSA recommends that SFA and trans fat intake should be as low as possible within the context of a nutritionally adequate diet (EFSA, 2010).

WHO and Dutch recommendation for saturated fatty acid intake

≤ 10% of total energy intake

EFSA recommendation for saturated fatty acid intake

As low as possible

Health Claims

Allowed health claims in EU on SFA:

- **Low in saturated fats**: If SFA and the trans-fatty acids in the product together do not exceed 1.5 g/100 g and 0.75 g/100 ml. No more than 10% of the energy consists of SFA and trans fatty acids.
- **Free of saturated fats**: If the sum of SFA and trans fatty acids does not exceed 0.1 g/100 g or 0.1 g/100 ml (European Commission, 2006).

Allowed health claims in the EU on fats in general:

- **Low fat**: The fat content of the product is maximum 3 g/100 g or 1.5 g/100 ml. With the exception of semi-skimmed milk: 1.8 g/100 ml.
- **Fat-free**: The fat content of the product is a maximum of 0.5 g/100 g or 0.5 g/100 ml (European Commission, 2006).

Nutri-Score

The lower SFA limit used by Nutri-Score is SFA ≤ 1 g per 100 g of product. Nutri-Score assigns negative points for SFA based on the quantity present in 100 g or 100 ml of the product. Up to 10 negative points can be given for products with 10 g or more of SFA per 100 g (RIVM, 2024).

In the Netherlands, RIVM has provided a calculation tool for the Nutri-Score of a product.

NAPV

The NAPV established limit values for multiple product categories, with specific subcategories defined for each. Consult the NAPV source document for detailed values applicable to individual products. When possible, the lower limits of the NAPV correspond to the lowest cut-off points that Nutri-Score uses (RIVM, 2022).

NAPV developed limit values for SFA in the following product categories:

- [ ] Bread(replacements) and breakfast cereals
- [x] Dairy and plant-based alternatives
- [x] Cheese
- [ ] Meat preparations and meat products
- [x] Deli meats and preserved meats
- [x] Fish
- [ ] Meat substitutes
- [ ]
- [ ] Spreads and cooking fats
- [ ] Soups and bouillons
- [x] Sauces
- [x] Savoury snacks
- [ ] Pastry & confectionary
- [x] Drinks
- [x] Sandwich filling

Learn more: NAPV roadmap

Further Readings

EU Framework for National Initiatives on Selected Nutrients

Provides guidance for member states on reducing saturated fat intake among the population. It emphasizes the importance of desinging food products to contain less SFA and encourages the use of healthier alternatives.

Recent trends in design of healthier fat replacers: Type, replacement mechanism, sensory evaluation method and consumer acceptance

Examines the rising demand for low-fat foods, challenges in maintaining quality, and fat replacer development, covering their mechanisms, sensory evaluation, and consumer acceptance to guide healthier product production.

Regulation (EC) No 1924/2006 on Nutrition and Health Claims

This regulation outlines the conditions under which nutrition claims, such as "low saturated fat," can be made.

Saturated fatty acid and trans-fatty acid intake for adults and children: WHO guideline

This guideline provides updated, evidence-informed guidance on the intake of SFA and trans-fatty acids to reduce the risk of diet-related noncommunicable diseases in adults and children, particularly cardiovascular diseases.

Reformulation of food and beverage products for healthier diets: WHO policy brief

Provides information and practical guidance for implementing effective policy actions to eliminate industrially produced trans-fatty acids from the food supply, reduce the energy content per portion and lower the levels of SFA, sugars and salt/sodium in food.

Technical Brief Food Reformulation for Fats

This brief examines the health impact of dietary fats, the need to reduce SFA and trans fats, and strategies to maintain quality and consumer acceptance in reformulated foods.

02 Food Industry Solutions Saturated fat

Fat Functionality

Functional properties describe how ingredients influence product quality by interacting with water, lipids and other components. These interactions affect texture, stability appearance and sensory perception during processing and consumption. For this reason, functional characteristics are essential for selecting and optimising ingredients in product (re)formulations. Table 7 provides an overview of key functionalities and sensory attributes to consider.

Texture and mouthfeel

SFA contribute to the creamy, smooth, and rich mouthfeel of food products, enhancing their sensory appeal. They provide lubrication, reduce dryness, and play a key role in delivering a satisfying eating experience. Additionally, SFA influence the melting behaviour of foods like chocolate and dairy products, creating a desirable texture transition when consumed (Rios, 2014).

Structure & stability

SFA provide essential structure and stability in food products by aerating batters, contributing to flakiness in pastries, and ensuring a firm yet flexible consistency in spreads and doughs. Their role in emulsification helps maintain uniformity in products like dressings and ice creams, preventing separation. The plasticity of SFA also determines the spreadability and workability of products during food processing (Rios, 2014; Cansell, 2005).

Processing

In food manufacturing, SFA play a crucial role in ensuring smooth processing by improving dough handling, extrusion, and moulding properties. Their heat stability allows for high-temperature applications like frying and baking, providing crispiness and a golden-brown finish. Fats, including SFA, also contribute to moisture retention, preventing dryness and improving the overall product consistency (Rios, 2014; Mamat & Hill, 2014; Kathleen, 1999).

Preservation

SFA help extend the shelf life of food products by preventing moisture loss, maintaining product stability, and acting as a barrier against external influences. They also contribute to oxidative stability, reducing rancidity and preserving freshness. This makes them essential for maintaining product quality over time, particularly in baked goods, snacks, and processed foods (Rios, 2014; Vieira et al., 2015).

Organoleptic

Fats, including SFA, are excellent carriers of fat-soluble flavours and aromas, intensifying the overall taste experience. They help distribute flavours evenly throughout the food, enhancing their richness and depth. Additionally, SFA can influence the release of flavours in the mouth, ensuring a longer-lasting and more enjoyable sensory experience in both sweet and savoury products (Rios, 2014).

Table 7: Overview SFA functionalities and sensory attributes.

Process/product functionalities	Sensory attributes
Thermal stability, high resistance to heat, making them ideal for frying and baking.	Direct effect on **taste** i.e. rich, smooth, and indulgent texture (e.g., in dairy, chocolate, and baked goods).
Emulsification & consistency, help stabilize emulsions in products like mayonnaise and ice cream.	**Flavour carrier,** help dissolve and release fat-soluble flavours, enhancing overall taste perception.
Aeration & structure in baked goods, essential in pastries, cakes, and biscuits for creating flakiness and volume.	Improves **texture,** solid or semi-solid consistency of products (e.g., butter, cheese, and chocolate).
More resistant to oxidation than unsaturated fats, reducing rancidity and extending **product shelf life**.	**Melting behaviour,** creating a desirable texture change when consumed (e.g., chocolate melting in the mouth).

Saturated Fat Reduction Solutions

The following tables provide an overview of potential ingredient solutions for reformulation, distinguishing between nutritional and functional aspects. This distinction reflects the different objectives that may drive reformulation or innovation, such as improving the nutritional profile (e.g., reducing sugar, salt, or saturated fat) versus maintaining or enhancing product functionality (e.g., texture, stability, or shelf life). The tables are intended as a starting point for identifying possible solutions. They do not represent an exhaustive list, and additional considerations may apply depending on the specific product context and formulation goals.

Saturated Fat Reduction

	Functional		Nutritional	
Solution type	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
(Gradual) Saturated Fat reduction	Allows for the use of alternative ingredients (functional foods) to enhance product innovation; In certain baked goods and snacks, replacing SFA with structured unsaturated fats or emulsifiers can lead to a lighter, crispier texture (Alessandrini et al., 2021).	May impact the aeration, spreadability, and stability of food structures; May lead to separation issues in emulsified products; May impact the shelf life (O'Sullivan, 2020).	Improves product healthiness (Alessandrini et al., 2021).	Fat reduction can alter texture, mouthfeel, and sensory appeal (O'Sullivan, 2020).

Lipid-Based Replacers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Mono- and diglycerides	Margarine, bakery, spreads	Improve emulsification and prevent separation in processed foods (Kara & Bor, 2019; Melchior et al., 2024).	May not fully replicate the richness or creaminess and can be influenced by processing conditions (Loi et al., 2019).	Help reduce the overall SFA content in food products (Subroto, 2020).	Fatty acid composition is influenced by the oils for production. Depending on the source oil (e.g., soybean oil, palm oil, or canola oil), they may contain varying levels of SFA and unsaturated fats (Subroto, 2020).
Structured lipids	Dairy alternatives, nutrition bars	Improve oxidative stability and shelf life compared to regular vegetable oils; Can provide similar melting behavior to traditional SFA in some food products (Zhou et al., 2022).	Some structured fats may lack traditional fat mouthfeel (Zhou et al., 2022).	Reduce the overall calorie content of food products (Hong et al., 2023).	May raise questions among some consumers, especially in clean-label or natural food markets.

Plant-Based Replacers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Avocado oils	Cooking oils, dressings, and as a butter alternative in baking	Excellent for frying and sautéing and can also replace butter and lard in various applications (Cervantes-Paz & Yahia, 2021).	Varies flavour profile; It may alter texture in large quantities; Cost and availability; Stability over time (Cervantes-Paz & Yahia, 2021).	Rich in monounsaturated fats and antioxidants (Lin & Li, 2024).	High in calories (Voedingscentrum, n.d.-e).
Nut oils	Typically used in salad dressings, marinades	Can be used as emulsifiers, when combined e.g. lecithin; Some are high in mono-unsaturated fats, which are more resistant to oxidation than polyunsaturated fats (e.g. macadamia oil) (Fernandes et al., 2017; Geng et al., 2020; Prisacaru, 2016).	Flavor profiles can vary, which may affect taste in certain applications (Costa et al., 2024).	Often rich in monounsaturated and polyunsaturated fats (Fernandes et al., 2017).	Allergen concerns (Fernandes et al., 2017).

Plant-Based Replacers (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Seed oils (e.g. flaxseed, rapeseed, sunflower seed)	Cooking oils, salad dressings, snacks, and processed foods.	Some are high in mono-unsaturated fats, which are more resistant to oxidation than polyunsaturated fats and have a neutral flavour profile (Prisacaru, 2016).	Flaxseed oil has a low smoke point, limiting its use in high-heat cooking (Joshi et al., 2022).	High in polyunsaturated fats (Kapoor et al., 2021).	Seed oils are typically high in omega-6 fatty acids, which may promote inflammation when intake outweighs omega-3 consumption (Kapoor et al., 2021; Mariamenatu & Abdu, 2021). The refining process destroys micronutrients in the oils which lowers the nutrient density (Fine et al., 2015).

Carbohydrate and Fibre Replacers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Cellulose Derivatives	Low-fat spreads, dairy products, sauces, and dressings	Improve texture and mouthfeel, providing creaminess and viscosity similar to SFA (He et al., 2021).	May lead to a rubbery texture or an unnatural mouthfeel if used in excess.	Low in calories, high in fibre, promoting digestive health (Aziz et al., 2024).	May cause digestive discomfort (e.g., bloating) in some individuals when consumed in large quantities (Borkoles et al., 2022).
Starch-Based Replacers	Baked goods, sauces, soups, and dairy alternatives	Provide bulk, structure, and viscosity; Improve texture and mouthfeel (Lin et al., 2024).	May affect the product's texture if not used in the right formulation or if overused (Lin et al., 2024).	Low in calories (Chen et al., 2020).	High glycemic index, which could affect blood sugar levels (Lal et al., 2021).
Gum & hydrocolloids (see table 'Emulsifiers & Stabilisers' for examples)	Dairy products, dressings, baked goods, and beverages	Form gels or thicken products to improve texture and stability (Pirsa & Hafezi, 2023).	Can alter texture if overused, leading to a slimy or unpleasant mouthfeel (Blok et al., 2023).	High in fibre (Kapoor et al., 2016).	Some gums may cause digestive discomfort, including bloating or gas (Borkoles et al., 2022).

Carbohydrate and Fibre Replacers (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Maltodextrins	Snacks, beverages, processed foods, and desserts	Provide a smooth mouthfeel and increase product volume, acting as a bulking agent or thickener (Hofman et al., 2016).	May affect the texture of products by making them more "starchy" or less smooth if used excessively (Valenzuela & Aguilera, 2015).	Low in calories (Grzelak et al., 2017).	High glycemic index, which could affect blood sugar levels (Hofman et al., 2016).
Beta-glucans	Cereal-based products, beverages, bakery, and snacks	Improve viscosity, texture, and moisture retention; Support gel formation (Ahmad & Kaleem, 2018).	May not provide the same level of mouthfeel or creamy texture as SFA and could affect product consistency (Ahmad & Kaleem, 2018).	High in soluble fibre (Herrera et al., 2016).	Could cause digestive discomfort in high amounts (Major et al., 2017).

Protein Replacers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Milk protein	Low-fat cheeses, yogurt, baked goods	Provide creaminess and structure (Akbari et al., 2019).	May affect the texture in certain formulations if used in excess (Akbari et al., 2019).	High-quality protein source (Goulding et al. 2020).	Not suitable for vegan or dairy-free diets and allergen concerns (Puglisi & Fernandez, 2022).
Egg protein	Low-fat mayonnaise, baked goods	Stabilize emulsions and add richness (Li et al., 2021; Razi et al. 2023).	May affect the texture in certain formulations if used in excess (Razi et al. 2023).	High-quality protein source (Puglisi & Fernandez, 2022).	Not suitable for vegan or dairy-free diets and allergen concerns (Puglisi & Fernandez, 2022).
Soy protein	Meat alternatives, dairy-free products	Enhance texture and binding properties (Thrane et al., 2017).	Potential flavour issues or a soy aftertaste that may need masking in formulations (Thrane et al., 2017).	High-quality protein source, suitable for vegan diets (Qin et al., 2022).	Allergen concerns (Wang et al., 2023).
Gelatin & collagen peptides	Low-fat dairy, desserts, confectionery	Provide elasticity and creaminess (Tang et al., 2022).	Potential flavor issues or a soy aftertaste that may need masking in formulations (Amyoony et al., 2023).	Provides collagen, which may support skin, joints, and bone health (Zhao et al., 2021).	Not suitable for vegetarian/vegan diets (Tang et al., 2022).

Upcycled by nature

Can be sourced from upcycled ingredients

Protein Replacers (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Mycoproteins	Meat alternatives	Provide a fibrous, meat-like texture (Ahmad et al., 2022).	Fermentation-related taste may require masking (Wei En Lim & Kay Chai Tay, 2024).	High in protein and fibre (Ahmad et al., 2022).	Some allergic reactions have been reported (Jacobson & DePorter, 2018).
Microencapsulated Coconut Milk & Pine Nut Protein Powder	Instant cereal products, solid beverages, baked goods, seasoning	It has a high oil-carrying capacity, with an oil content of 30g per 100g; Can replace non-dairy creamers (Ngampeerapong et al., 2018).	After opening, it should be sealed to avoid moisture.	Suitable for people with lactose intolerance; Rich in medium-chain fatty acids; Has a reasonable fatty acid ratio (Sacks et al., 2017).	Allergen concerns (Mori et al., 2022).

Emulsifiers & Stabilisers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Guar Gum	Sauces, ice cream, and salad dressings	Enhances texture and stability, provides smoothness and creaminess (Jayanthi et al., 2024).	Overuse may result in excessive viscosity or gumminess (Jayakody et al., 2022; Saha & Bhattachary, 2010).	High in fibre (Jayakody et al., 2022)	May cause digestive discomfort when used in large amounts (Major et al., 2017).
Gum Arabic (Acacia Gum)	Beverages, low-fat dressings, and ice cream	helps stabilize emulsions and improve viscosity in reduced-fat products (Prasad et al., 2022).	Can cause thickening or sliminess in high quantities (Jayakody et al., 2022; Saha & Bhattachary, 2010).	Low in calories, may have prebiotic effects (Jayakody et al., 2022).	May cause digestive discomfort when used in large amounts (Major et al., 2017).
Xanthan Gum	Beverages, salad dressings, sauces, baked goods	Improves texture, viscosity, and stabilises emulsions in fat-reduced products (Habibi & Khosravi-Darani, 2017).	Overuse can cause sliminess or unwanted viscosity (Jayakody et al., 2022; Saha & Bhattachary, 2010).	Low in calories, high in fibre (Jayakody et al., 2022)	May cause digestive discomfort when used in large amounts (Major et al., 2017).
Pectin	Jams, jellies, low-fat fruit-based desserts	Provides gelling and thickening properties, helping to maintain texture in fat-reduced foods (Freitas et al., 2021).	Overuse may lead to excessive gel formation or an overly firm texture (Kakino et al., 2017).	High in fibre (Adam et al., 2016).	May cause digestive discomfort when used in large amounts (Major et al., 2017).

Upcycled by nature

Can be sourced from upcycled ingredients

Emulsifiers & Stabilisers (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Lecithin	Margarine, dressings, bakery, spreads	Stabilizes emulsions, enhances texture and spreadability (Alhajj et al., 2020).	Overuse may cause a waxy texture or separation in products.	Rich in phospholipids (Alhajj et al., 2020).	Allergen concerns (e.g., soy or egg lecithin) (Puglisi & Fernandez, 2022; Wang et al., 2023).
Agar-Agar	Low-fat confectionery, jellies, and desserts	Provides gelling properties and firm texture without adding significant calories (Pandya et al., 2022)	Overuse may result in overly firm or rubbery texture (Pandya et al., 2022).	Low in calories (Öztürk-Kerimoğlu, 2021).	May cause digestive discomfort when used in large amounts (Major et al., 2017).

Biological Techniques

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Enzyme-Catalyzed Modification	Oils, margarine, bakery products, dairy, snacks	Enzymes such as lipases can modify the structure of fats by breaking down tri-glycerides into free fatty acids and mono-glycerides, while retaining desired properties like texture and stability (Mao et al., 2024).	Potential cost implications and complexity in controlling the final product's properties	Reduce SFA (Mao et al., 2024).	Could affect digestibility, especially if free fatty acids are released (Hama et al., 2015).
Fermentation	Dairy products, plant-based alternatives, oils, beverages	Certain microorganisms, including bacteria and fungi, can convert SFA into unsaturated fats (Adebo et al., 2022).	Potential variability in the final product and may require additional fermentation steps, which could increase production time and cost (Augustin et al., 2024).	Can increase levels of unsaturated fats like omega-3 fatty acids (Adebo et al., 2022).	Might lead to changes in taste and texture (Adebo et al., 2022).

Biological Techniques (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Plant Breeding and Selection	Oils (e.g., soybean, canola, sunflower), processed food products	Through traditional plant breeding techniques, crops can be developed that naturally produce oils with reduced levels of SFA (Qaim, 2020).	Potential challenges for scalability and timing (Qaim, 2020).	Oils with healthier unsaturated fats (Voedingscentrum, n.d.-f).	Limited control over the final fatty acid composition compared to other methods.

03 Ingredient Suppliers Saturated fat

An extensive (not exhaustive) overview of ingredients and ingredient suppliers is available **here.** Connect with ingredient suppliers within

Food and Health

- dsm-firmenich
- MCLS Europe
- Ruitenberg
- Dutch Spices
- Time-Travelling Milkman
- Ulrick+Short

Protein Transition

- ADM
- Magellan Food Ingredients
- dsm-firmenich
- MCLS Europe
- Ruitenberg
- Dutch Spices
- Time-Travelling Milkman
- colzaco

Circular Agrifood

- symrise
- Bunge

Are you missing any information, suppliers or ingredients? Please contact **partner@foodvalley.nl** and we can incorporate this in our next version.

04 Case Studies Saturated fat

Fat reduction in a béchamel sauce using a clean label starch solution

What challenge was faced?

Reducing saturated fat in béchamel sauce while maintaining a rich, indulgent and creamy mouthfeel. In addition to this nutritional target, there was a strong requirement to develop a clean label solution.

How was the problem solved?

A starch-based solution was developed using delyte™ 9, which is derived from tapioca starch. This ingredient provides a neutral flavour and allows other flavours to come through more clearly. In kitchen labs, trials were conducted to optimise the formulation. The ingredient activates at 60–70°C and in combination with water, making it suitable for hot processing applications.

> “Not only focus on reducing the ‘bad’, but also add in the ‘good’ to further optimise nutritional factors.”

Were there any obstacles?

-

What was the outcome?

The final formulation enabled a 50% fat reduction while maintaining or even improving the creaminess. The ingredient is used in sauces but has also applications in other products such as crackers or biscuits.

Key takeaways and lessons learned

This case demonstrates that fat reduction is possible without compromising sensory quality when functionality is carefully replicated. A key insight is that reformulation should not only focus on reducing the ‘bad’, which is saturated fat in this case, but also add in the ‘good’ to further optimise nutritional factors.

For more details, contact:

Yvette Muskens
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Fat reduction in crispy protein snacks

What challenge was faced?

Crispy snacks like chips and protein crisps typically contain 10–30% fat. Salnova aimed to develop savoury snacks with significantly lower fat content, while maintaining indulgent taste and texture to offer a healthier, competitive alternative.

How was the problem solved?

Instead of traditional oil coatings used to carry flavours, Salnova incorporated flavour precursors directly into the extrusion process. This method allowed flavour release during production, eliminating the need for post-processing oil application.

Were there any obstacles?

Reducing fat content led to a drier, firmer texture. Salnova carefully balanced ingredients and fine-tuned extrusion settings to maintain a pleasant mouthfeel while achieving the desired flavour and fat reduction.

> “Understanding production processes is key to meaningful reformulation. While reducing fat, it's essential to anticipate and address textural trade-offs to maintain consumer appeal.”

What was the outcome?

Fat content was reduced to 3.4%, with no compromise in overall product quality, taste, or texture.

Key takeaways and lessons learned

Understanding production processes is key to meaningful reformulation. While reducing fat, it's essential to anticipate and address textural trade-offs to maintain consumer appeal.

For more details, contact:

info@salnova-Nutritec.com

A healthy low-fat ice cream: Soybean hull dietary fibre as a fat substitute

What challenge was faced?
Fat reduction often leads to texture deterioration (e.g., reduced viscosity, poor shape retention, ice crystal coarsening, and gritty mouthfeel), posing key challenges to consumer acceptance, especially in ice cream.

How was the problem solved?
Soybean hulls, rich in insoluble dietary fibre, possess oil-holding, water-binding, and gelling properties, making them a potential natural fat substitute. Additionally, soybean hull dietary fibre offers health benefits such as regulating gut microbiota, suppressing inflammation, and modulating immune responses.

> “Green-processed soybean hull fiber, used as a fat substitute in low-fat ice cream, enhances texture, flavour, and melt resistance while supporting long-term health benefits.”

Were there any obstacles?
Green modification of non-dispersible dietary fibre extracted from soybean hulls to give it properties as a fat substitute, as well as determining the optimum percentage of dietary fibre to maximise the flavour and texture of the product.

What was the outcome?
We found that the high viscosity and viscoelasticity of soybean hull dietary fibre added to ice cream mixtures improved the shape retention and melting characteristics of low-fat ice cream, as well as the creaminess, smoothness, stickiness and coldness of the ice cream.

Key takeaways and lessons learned
There is a feasible application of dietary fibre obtained by extraction modification from soybean hulls, an agricultural by-product, as a fat substitute in low-fat ice cream. It improves shape retention, reduces ice crystals, slows melting, and improves sensory sensation in low-fat ice creams, as well as having the effect of improving intestinal health.

For more details, contact:

Dr. Yuanyuan Qu
quyuanyuan@jingwacenter.com

Foodvalley
Shaping the Future of Food Together

An Innovative margarine substitute that reduces calories but maintains creaminess

What challenge was faced?
The challenge was to develop a low-fat, low-calorie margarine alternative that keeps the familiar taste and texture while minimising calorie intake.

How was the problem solved?
This product replaces traditional hydrogenated oils with a novel stabiliser system using whey protein microgels, creating a high internal phase emulsion (HIPPE) that mimics the texture and appearance of traditional cream.

Were there any obstacles?
Determining the optimal whey protein microgels concentration that maximises delayed fat digestion while maintaining emulsion stability and the product's creamy texture and flavour.

> "An innovative, low-fat, low-calorie margarine alternative: perfectly aligned with today's health-conscious lifestyle trends."

What was the outcome?
The product successfully delayed fat digestion by 20%-30%, maintaining the flavour and smooth spreadability of a traditional margarine. It achieved a low-fat, low-calorie profile while delivering the sensory experience consumers expect from high-fat products.

Key takeaways and lessons learned
The novel low-calorie margarine substitute, leveraging pickering emulsion technology, effectively delays lipid digestion and reduces calorie intake, aligning with health-conscious dietary trends.

For more details, contact:

Dr. Yuanyuan Qu
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Protein

01 — **General Information**

- Background
- Health Aspects
- Regulatory Framework
- Further Readings

02 — **Food Industry Solutions**

- Protein Functionality
- Protein Solutions

03 — **Ingredient Suppliers**

Overview of ingredients and ingredient suppliers

04 — **Case Studies**

Example cases on reformulation from partners

01 General Information Protein

Background

Protein is a macronutrient found in food that is made up of amino acids and serves as a key building block for the body. From a nutritional perspective, **amino acids** are classified into three groups; essential, nonessential and semi-essential. Essential amino acids cannot be produced by the human body and therefore must be obtained through the diet. Semi-essential amino acids are normally synthesized by the body but may become essential during periods of stress or illness (Lopez & Mohiuddin., 2024). In addition to their amino acid content, proteins enhance the nutritional value of food products, supporting growth, repair, and maintenance of tissues.

Proteins in food can be obtained from a wide range of **sources** and are commonly grouped into three categories based on their origin. Plant-based proteins are derived from plants, including nuts, seeds, grains, as well as lower-protein sources such as seaweed and vegetables. Fungi-based sources, such as mushrooms and mycoprotein, are often grouped with plant-based proteins in dietary contexts. Animal-derived proteins come from sources such as meat, fish, dairy, eggs and insects. In addition, there is a group of novel proteins, which are produced from emerging sources such as algae and microorganisms. Some novel protein sources have already been approved for use in food products, while others are still under development. While plant-based protein consumption is increasing, the future of protein is not exclusively plant-based; balanced products that combine plant and animal proteins are increasingly adopted. These blends offer a more sustainable option while preserving taste, texture, and familiarity for consumers.

However, dietary survey data show that average protein **intake** in Europe is high and mainly derived from animal-based foods. Meat and meat products are the largest contributors to dietary protein intake, followed by dairy products such as milk and cheese. Grains and grain-based products contribute the main plant-based source of protein, while legumes, nuts, and seeds contribute smaller proportions (EFSA, 2012). Overall, animal-derived foods account for approximately 55–60% of total protein intake in European diets (Smith et al., 2024).

Health Aspects

NUTRITIONAL CONTEXT

Replacing animal-based proteins with protein sources such as plants, fungi, and novel protein sources can contribute to a nutrient-diverse diet that is higher in fibre and lower in saturated fat (Langyan et al., 2022). While the health benefits, such as improved digestive health, better blood lipid profiles, and enhanced gut microbiota diversity, are typically associated with broader dietary patterns rather than a single ingredient swap, incorporating plant and novel protein sources supports these positive nutritional trends (Egas-Montenegro et al., 2026).

CARDIOVASCULAR DISEASES

Plant-based and novel proteins support cardiovascular health through their high fibre and lower saturated fat content, which reduce cholesterol reabsorption and LDL-related atherosclerosis risk (Barber et al., 2020; Guan et al., 2021; Hu et al., 2001). Plant-based sources can improve lipid profiles, while omega-3-rich options such as algae and seeds further support heart health (Vergara Nieto et al., 2025).

TYPE 2 DIABETES

Higher plant-protein intake is linked to lower type 2 diabetes risk because fibre slows glucose absorption and improves insulin sensitivity (Guan et al., 2021). Higher daily intakes of animal proteins, particularly red and processed meats, are associated with obesity and increased diabetes risk (Anjom-Shoae et al., 2024), partly due to heme iron (Shahinfar et al., 2022). Fibre components such as beta-glucans further support diabetes management by improving blood glucose and lipid levels (Chen & Raymond, 2008).

DIGESTION

Minimally processed plant-based ingredients such as legumes provide both protein and fibre, which support digestion, promote regularity, and reduce colon cancer risk by increasing stool bulk and decreasing transit time (Barber et al., 2020; Guan et al., 2021; Nirmala Prasadi & Joye, 2020; Voedingscentrum, n.d.-b). Some plant-based proteins such as algae act as prebiotics that nourish beneficial gut bacteria (Shoham et al., 2025).

Regulatory Framework

Dietary Recommendations

International, European and Dutch authorities define protein requirements for healthy adults at comparable levels. The protein Population Reference Intake (PRI) of 0.83 grams per kilogram of body weight per day, as adopted by the **EFSA**, is aligned with global recommendations from the **WHO**. In addition, this is adopted by the **Health Council of the Netherlands** (EFSA, 2012; Gezondheidsraad, 2021; WHO, 2007).

Despite these established reference values, actual protein intake among European populations is generally higher. Dietary intake data indicate that average protein consumption in Europe exceeds these requirements for both men and women. Analyses of Western dietary patterns show that mean protein intake often reaches 150–200% of the PRI, indicating systematic overconsumption at the population level (Aiking, 2014; Andreoli et al., 2021).

EFSA recommendations dietary protein intake in g/kg per day

0.84-1.43 g/kg **0.84-1.45 g/kg**

Dutch recommendations dietary protein intake in g/kg per day

1.29 g/kg **1.16 g/kg**

Health Claims

Allowed health claims in EU:

- **Source of protein:** at least 12% of the energy value of the food is provided by protein (protein gives 4 kcal/g). (Nutrition Claims - Food Safety - European Commission, n.d.)
- **Rich in protein:** at least 20% of the energy value of the food is proved by protein (protein gives 4 kcal/g). (Nutrition Claims - Food Safety - European Commission, n.d.)

Nutri-Score

Protein can contribute up to 7 positive points in the Nutri-Score. However, protein points are only taken into account when the overall nutritional profile of a product is sufficiently favourable, to prevent products high in salt, sugar or saturated fat from achieving a favourable score based solely on protein content.

In the Netherlands, Rijksinstituut voor Volksgezondheid en Milieu (RIVM) has provided a calculation tool for the Nutri-Score of a product.

Within the NAPV framework, gradual limit values are defined for salt, sugar and saturated fat, and for fibre in bread. No specific limit values are established for protein.

Protein quality

Protein quality is determined by the availability of essential amino acids after digestion relative to human requirements. Although individual plant proteins may be limited in certain amino acids, a varied diet combining complementary plant-based sources can achieve adequate protein quality and meet the needs of most consumers (Gezondheidsraad, 2023).

Environmental aspects

Animal-based protein sources generally have higher environmental impacts than plant-based and novel alternatives, with life cycle assessments showing that plant-based meat substitutes have on average about 50% lower impacts, and minimally processed plant proteins performing even better (Smetana et al., 2023). This is illustrated by global data showing that animal products such as beef and lamb have substantially higher greenhouse gas emissions per 100 g of protein compared to plant-based sources like legumes, grains and tofu (see Figure 3) (Poore & Nemecek, 2018).

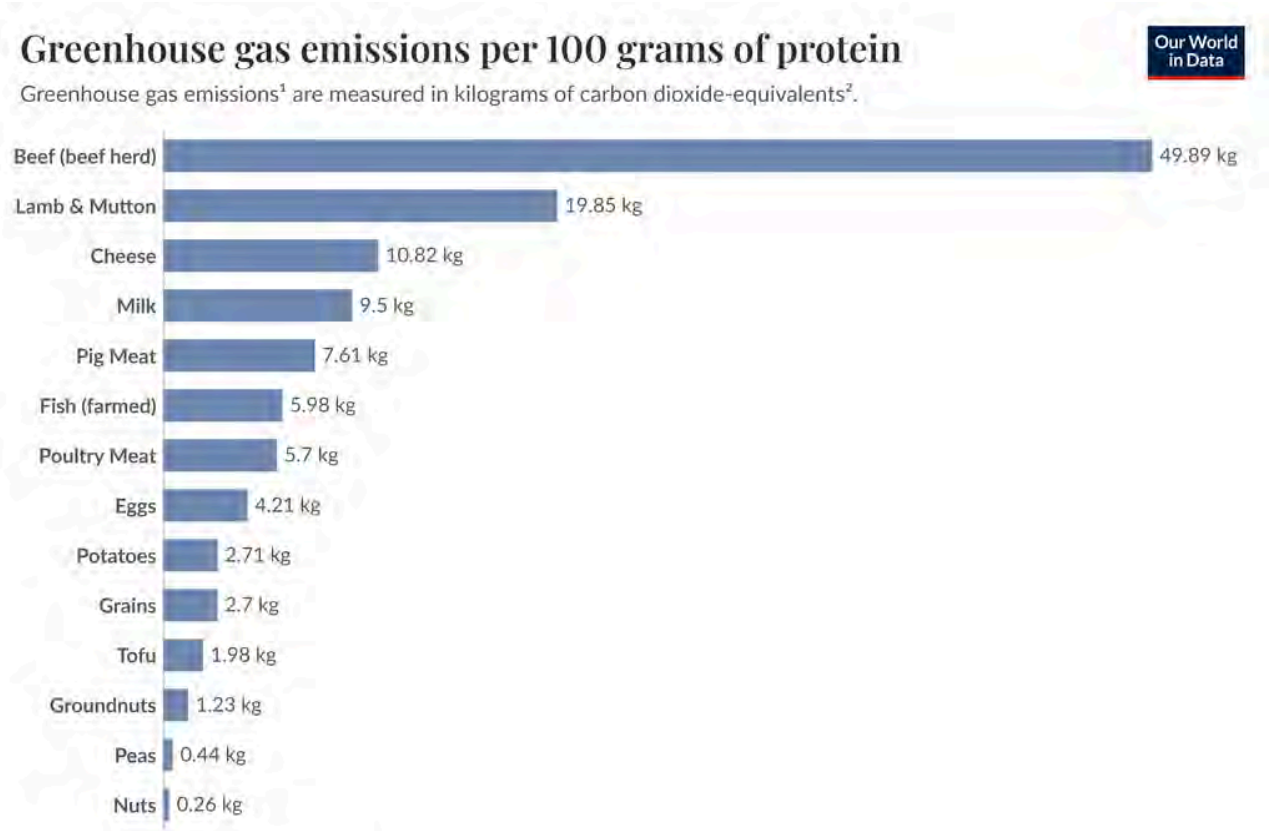

Figure 3: Greenhouse gas emissions per 100 grams of protein (Poore & Nemecek, 2018).

Further Readings

ESRS explained

This regulation establishes the ESRS, requiring companies to report comparable information on key environmental, social and governance impacts, risks and opportunities, based on double materiality.

Omnibus: Q&A on simplification omnibus I and II

This Q&A explains the EU's Omnibus package, which simplifies sustainability and investment regulations by reducing reporting burdens, adjusting scope and timelines, and protecting smaller companies from disproportionate requirements.

Protein requirements in human nutrition - WHO

Guiding principles for diets that promote human health while reducing environmental impacts, emphasizing shifts toward more plant-based foods and sustainable food systems to support both public health and planetary boundaries.

Nutrition claims - Food Safety - European Commission

This legislation provides the legal framework for nutrition and health claims made on foods within the EU. It specifies the conditions under which claims like "protein-rich" can be made, ensuring that consumers receive truthful and substantiated information.

Plant-based protein products - Pubmed (2023)

This review provides an overview of plant-based protein products, covering their processing technologies, functional and nutritional properties, health benefits, and key challenges compared with animal proteins.

Environmental impact of dietary protein sources

This Health Council report compares the environmental impacts of different dietary protein sources and eating patterns, showing how shifts toward more plant-based proteins can substantially reduce climate and environmental pressures while still supporting healthy diets.

02 Food Industry Solutions Protein

Protein Functionality

Functional properties describe how ingredients influence product quality by interacting with water, lipids and other components. These interactions affect texture, stability appearance and sensory perception during processing and consumption. For this reason, functional characteristics are essential for selecting and optimising ingredients in product (re)formulations. Table 8 provides an overview of key functionalities and sensory attributes to consider.

Organoleptic properties

Plant proteins can bind natural pigments and absorb flavour compounds through interactions that depend on protein structure, molecular size, and hydrophobicity. As a result, plant proteins influence the final appearance and taste of food products by affecting how colour and flavour compounds are retained and released during consumption (Sharan et al., 2021; Prakash et al., 2023).

Hydration properties

Plant proteins actively influence how water is absorbed, retained, and distributed in food systems. Their amino acid composition and the balance between polar and non-polar residues determine properties such as wettability, solubility, and water-holding capacity (Tarté et al., 2009). Processing conditions, including pH, ionic strength, and extraction method, further modify these hydration behaviours by altering protein structure (Prakash et al., 2023). During processing, protein unfolding and aggregation affect emulsification, viscosity, and stability, shaping product thickness and consistency, with substantial variation between plant protein sources (Wang & Xiong, 2019).

Gelling properties

Plant proteins form gels when heat, pH changes, or ionic conditions cause them to unfold and aggregate into three-dimensional networks that trap water. These gels provide structure and contribute directly to product texture. Gel strength and stability depend on protein source, concentration, molecular interactions, and processing conditions, which explains the wide variation in gelling performance among plant proteins (Khalesi et al., 2024).

Emulsifying properties

Plant proteins act as emulsifiers by adsorbing at oil–water interfaces, where their amphiphilic structure allows them to lower interfacial tension and stabilise dispersed fat droplets. Their effectiveness depends on properties such as protein solubility, molecular flexibility, and surface hydrophobicity, as well as processing conditions, all of which differ considerably among plant protein sources and can limit performance relative to animal proteins (Zhang et al., 2023). In low-fat emulsions, soy protein isolates and hydrolysates can stabilise fat droplets and promote structured fat networks, thereby enhancing textural attributes associated with creaminess, including firmness and smooth mouthfeel (Wang et al., 2022).

Foaming properties

Plant proteins stabilise foams by rapidly adsorbing at air–water interfaces, where they unfold and form cohesive interfacial films that entrap and protect air bubbles. Foam formation and stability depend on protein solubility, flexibility, surface hydrophobicity, and processing conditions. Variations in molecular structure and aggregation behaviour among plant protein sources therefore lead to wide differences in foaming capacity and foam stability (Jadhav, 2025).

Table 8: Overview protein functionalities and sensory attributes.

Process/product functionality	Sensory attributes
Water binding and hydration, plant proteins bind water and influence viscosity and moisture retention.	**Flavour and colour,** thermal treatment can affect off-flavours and colour development.
Gelling and texture, heat, pH, or ionic changes trigger protein gelation, forming networks that define firmness.	**Viscosity**, hydration and aggregation behaviour of plant proteins influence thickness and flow properties.
Emulsification, plant proteins stabilise oil-water interfaces in emulsified systems.	**Creaminess,** water binding, emulsification, and gel network formation contribute to creamy mouthfeel.
Foaming, plant proteins stabilise air bubbles by forming interfacial films.	

Protein Solutions

The following tables provide an overview of potential ingredient solutions for reformulation, distinguishing between nutritional and functional aspects. This distinction reflects the different objectives that may drive reformulation or innovation, such as improving the nutritional profile (e.g., reducing sugar, salt, or saturated fat) versus maintaining or enhancing product functionality (e.g., texture, stability, or shelf life). The tables are intended as a starting point for identifying possible solutions. They do not represent an exhaustive list, and additional considerations may apply depending on the specific product context and formulation goals. Furthermore, understanding the functional contributions of different protein sources is essential for developing balanced products.

Egg Protein Replacers

		Functional		Nutritional	
Solution	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Yeast	Bakery and sauces	Provides high emulsion stability which helps maintain consistent texture (Jach et al., 2022).	Possible consumer resistance (Jach et al., 2022).	Delivers high protein quality (PDCAAS = 1) (Cao et al., 2025).	NA
Aquafaba	Bakery and desserts	Offers excellent foaming properties (Zahir & Akhter, 2025).	Quality can vary between batches (Yazici & Ozer, 2021).	Naturally low in fat (Agregán et al., 2025).	Contains low levels of protein (Agregán et al., 2025).
Mung bean	Egg-free scramble, bakery	Provides good gelation, which helps create stable structures (Yazici & Ozer, 2021).	Can show inconsistent performance (Tarahi, 2024).	Contains a relatively high protein content (Yazici & Ozer, 2021).	Low in lysine and sulphur-containing amino acids (Zahir & Akhter, 2025).

Egg Protein Replacers (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Chlorella vulgaris (algae)	Bakery and sauces	Offers emulsifying and colouring properties, helping create stable emulsions while adding natural pigmentation (Yazici & Ozer, 2021).	Can impart a noticable green colour (Zahir & Akhter, 2025).	Contains omega-3 fatty acids such as EPA and DHA (Prates, 2025).	May act as a (rare) allergen (Wang et al., 2024).

Dairy Replacers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Precision fermentation (e.g. non-animal whey/casein)	Milk, yogurt and cheese	Mimics casein in gelation and stretch (Knychala et al., 2024).	Novel food procedure (Eastham & Leman, 2024).	These are complete proteins, containing all essential amino acids (Knychala et al., 2024).	The food matrix must be formulated carefully to mimic the nutritional profile of dairy milk (Knychala et al., 2024).
Soy	Milk and yogurt	Provides a strong gelation, which helps create stable structures (Zheng et al., 2022).	Can cause allergic reactions and beany off-flavours (Vashisht et al., 2024).	Nutritionally complete and support a balanced amino acid profile (Messina et al., 2022).	Contains ANFs such as trypsin inhibitors (Reyes-Jurado et al., 2023).
Oat	Milk and barista	Provides a creamy mouthfeel (Sethi et al., 2016).	Shows poor emulsion stability (Paul et al., 2019).	Source of beta-glucans (soluble fibre) (Scholz-Ahrens et al., 2020).	Have a relatively low protein content (Scholz-Ahrens et al., 2020).
Pea	Milk and yogurt	Can form soft gels, which help create smooth textures (Shanthakumar et al., 2022).	Can develop a beany and earthy smell (Reyes-Jurado et al., 2023).	Contains all essential amino acids (Shanthakumar et al., 2022).	Lower in sulphur-containing amino acids (Shanthakumar et al., 2022).

Dairy Replacers (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Potato	Cheese and creamers	Gelatinizes when heated and retrogrades when cooled like cheese (Leal et al., 2025).	Extraction is technically challenging (Hussain et al., 2021).	Highly digestible, supporting good nutritional availability (Herreman et al., 2020).	Has an incomplete amino acid profile, which reduces the overall protein quality (Hussain et al., 2021).
Almond	Milk and cheese	Provides a pleasant flavour (Aydar et al., 2020).	Can act as an allergen and may be prone to phase separation (Gupta et al., 2025).	Rich in vitamin E and calcium (Reyes-Jurado et al., 2023).	Almonds are a known allergen which requires careful labelling (Reyes-Jurado et al., 2023).
Sunflower seeds	Cream cheese and dairy cream	Offers good solubility, foaming, and emulsifying properties (de Oliveira Filho & Egea, 2021).	Phenolic compounds can cause dark colour when oxidized, and create bitter flavour (de Oliveira Filho & Egea, 2021).	Rich in polyunsaturated fatty acids, sulfur-containing amino acids (methionine, cysteine), vitamin E and antioxidants (Niu et al., 2025).	Contains phenolic compounds and phytates, which can reduce mineral bioavailability if not properly processed (Okaiyeto et al., 2025).

Meat Replacers

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Faba bean	Burgers and mince	Great for stabilizing foams and emulsions which helps improve texture (Asgar et al., 2010).	Can produce beany flavour notes (Asgar et al., 2010).	Provides high protein content and good protein quality (Martineau-Côté et al., 2022).	Low methionine and cysteine (Asgar et al., 2010).
Soy	Burgers and deli slices	Offers strong gelation and textural properties (Kurek et al., 2022).	Is a common allergen and sometimes negatively associatied with genetic modification and deforestation (Kurek et al., 2022).	Good amino acid composition (Kurek et al., 2022).	Contains trypsin inhibitors and lectins (Zheng et al., 2022).
Wheat	Strips and deli slices	Provides viscoelastic properties, helping create chewiness and structure (Kurek et al., 2022).	Is a common allergen (Kurek et al., 2022).	A high protein ingredient, contributing to overall nutritional value (Asgar et al., 2010).	Is low in lysine (Asgar et al., 2010).
Lentils	Crumbles and patties	Have high water-binding capacity (Asgar et al., 2010).	Can develop an earthy flavor, which may require masking (Asgar et al., 2010).	Rich in iron, phosphorus, magnesium, and B vitamins (Kurek et al., 2022).	Relatively low protein digestibility, which may reduce nutritional uptake (Asgar et al., 2010).

Meat Replacers (continued)

		Functional		Nutritional	
Solution type	**Suitable food category**	**Benefits**	**Points of attention**	**Benefits**	**Points of attention**
Mycoprotein	Fillets, mince	Has a natural fibrous texture (Khan et al., 2023).	Needs a binder (Hashempour-Baltork et al., 2020).	Contains all essential amino acids and has high digestibility (Khan et al., 2023).	May act as a (rare) allergen (Khan et al., 2023).
Jackfruit	Pulled meat	Has a natural fibrous texture (Swinkels et al., 2026).	Rapid browning upon cutting (Swinkels et al., 2026).	High in fibre and low in fat (Swinkels et al., 2026).	Low protein content (Swinkels et al., 2026).
Okara	Burgers, sausages, yoghurt	Modified okara stabilizes emulsions effectively and improving texture and consistency (Bao et al., 2021).	Native okara can produce beany flavour notes (Vong & Liu, 2016).	Has a high quality nutritional profile, phytochemicals and prebiotics potential (Asghar et al., 2023).	Is derived from soybeans and must be labeled as soy allergen (European Commission, n.d.)
(Brewer's spent grain) BSG	Burgers, sausages	Has a high water-holding capacity that improves the juiciness and tenderness (Halahlah et al, 2026).	Short shelf-life due to high moisture content and susceptibility to microbial spoilage (Nyhan et al., 2023).	High in minerals such as calcium and phosphorous and bioactive polyphenols (Eche et al., 2025).	Is derived from barley and therefore contains gluten. Due to this it requires clear allergen labeling (European Commission, n.d.)

03 Ingredient Suppliers Protein

An extensive (not exhaustive) overview of ingredients and ingredient suppliers is available **here.** Connect with ingredient suppliers within

Food and Health

dsm-firmenich

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DUTCH SPICES

Avebe

MAGELLAN FOOD INGREDIENTS

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Cano-ela Unlocking the potential of seeds

Aminola connecting values

Circular Agrifood

symrise

BUNGE

upgrain

revyve

LIVOO

PROEON

grassa

Aminola connecting values

Are you missing any information, suppliers or ingredients? Please contact **partner@foodvalley.nl** and we can incorporate this in our next version.

Foodvalley Shaping the Future of Food Together

04 Case Studies Protein

A clean-label alternative that enables dairy-like plant-based cream cheese

What challenge was faced?

Plant-based cream cheese still struggles to match dairy's smooth texture and bakeability. Many products rely on coconut oil, which is high in saturated fat but contributes to a creamy mouthfeel. The key challenge, therefore, was to reduce saturated fat while maintaining or improving creaminess.

How was the problem solved?

Time Travelling Milkman developed Oleocream™, a naturally emulsified fat ingredient and clean, additive-free sunflower emulsion that delivers dairy-like creaminess and offers a low-saturated-fat and allergen-free alternative to coconut oil.

Were there any obstacles?

Cost was a challenge as Oleocream™ carries a higher price per kilogram than coconut oil. However, this was managed in two practical ways; reducing the total amount of fat in the product or using health claims on the product that allowed the product to justify a higher price.

What was the outcome?

The reformulated cream cheese with partial replacement of coconut oil achieved excellent creaminess, with up to 88% less saturated fat and a natural increase in unsaturated fat. Furthermore, the product benefits from an 80% reduction in CO_2 emissions and improved Nutri-Score.

Key takeaways and lessons learned

Oleocream™ offers a clean-label, versatile base for multiple dairy alternatives, from crème fraîche to ice cream, without requiring new equipment as it is a natural emulsified fat ingredient. Its balance of performance, sustainability, and simplicity makes it ideal for both vegan and hybrid products.

For more details, contact:

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Replacing eggs with yeast protein in sauces and bakery applications

What challenge was faced?
Product developers needed an alternative to costly, high-risk eggs, especially under EU CO_2 reduction pressure. But existing plant-based options often caused a sticky mouthfeel, left a coating, and impaired taste.

How was the problem solved?
Revyve's Vitality yeast protein effectively mimics animal proteins. In sauces, it creates stable emulsions even at high oil levels, matching egg yolk performance at just a tenth of the dose. In low-fat sauces, it replaces both egg and starch while improving freshness. In bakery products, it works as a direct egg substitute, maintaining taste, lightness, and stability.

> "Yeast protein is valued as a functional rather than nutritional ingredient and has a neutral taste."

Were there any obstacles?
Yes, there were challenges. Dosage was counterintuitive, and early recipes missed steps like proper mixing and hydration. Some customers added the protein to hot mixtures, causing coagulation, which was solved by using a cold process first.

What was the outcome?
Demonstrations generated strong market interest. The protein performed well in high- and low-fat sauces and was easy to use under different mixing conditions. Consumer tests, including an egg-free pancake mix, showed no noticeable difference in taste or texture.

Key takeaways and lessons learned
Yeast protein is valued as a functional rather than nutritional ingredient, has a neutral taste, and provides superior stability compared with other plant proteins. Detailed process instructions are essential for consistent results.

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Foodvalley
Shaping the Future of Food Together

Replacing imported chickpeas with Dutch yellow peas in falafel

What challenge was faced?
The reformulation was not the problem, the Dutch yellow pea matched imported chickpeas. The real challenge was the value chain: with yellow peas not yet standardised, securing consistent supply and aligning production required close coordination.

How was the problem solved?
Falafval replaced imported chickpeas with locally grown, regenerative yellow peas to reduce environmental impact and support the Dutch protein chain. The peas worked directly in their recipe, and secure supply was ensured through close partnerships with the grower and processor, planning harvests and production together.

> “Collaboration and open communication are essential to make local, regenerative ingredients work at scale.”

Were there any obstacles?
Yes, working with a non-standard ingredient meant the manufacturer had to adapt to sourcing directly from a farmer. Forecasting harvest quantities and balancing demand required transparency and trust across the chain.

What was the outcome?
A tasty falafel made with regenerative Dutch yellow peas, maintaining product quality while reducing imports and environmental impact.

Key takeaways and lessons learned
Reformulation challenges often occur in the supply chain rather than the recipe. Collaboration and open communication are essential to make local, regenerative ingredients work at scale.

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Foodvalley
Shaping the Future of Food Together

Improving nutritional profiles in hybrid meat products

What challenge was faced?
The challenge was to develop hybrid chorizo and cooked ham with improved nutrition (reducing fat, calories, and salt while increasing protein) without compromising their traditional taste, texture, or sensory quality.

How was the problem solved?
Both products combined pork with plant proteins from the Like-A-Pro project (fava bean, pea, and a fermented fungi–lentil blend). Chorizo used a 50/50 pork–plant mix; cooked ham used restructured pork with similar ingredients. Hydrolysed collagen improved texture, while low-sodium salt and natural aromas maintained flavor.

> “A balanced mix of meat and plant ingredients, combined with the right processing, is key to creating high-quality hybrid products with improved nutrition and sensory appeal.”

Were there any obstacles?
The main obstacle was achieving the desired texture and bite without compromising taste. This was addressed through precise formulation and careful selection of functional ingredients.

What was the outcome?
The hybrid chorizo achieved reductions in total fat (45%), saturated fat (70%), calories (50%) and salt (20%), while increasing protein (15%) and fibre (2.5 g per 100 g). The cooked ham reduced fat by around 30% and salt by 35%. Sensory evaluations confirmed strong acceptance without compromising flavour.

Key takeaways and lessons learned
A well balanced proportion of meat and plant-based ingredients, including fermented components and natural additives such as hydrolysed compounds, aromas and reduced sodium salt, combined with appropriate technological processes, is essential to obtain high quality hybrid products with improved nutritional and sensory profiles.

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Technical Knowledge & Support

Consulting Firms

When reformulating a product, it is often unclear at the start which specific adjustments are needed that will lead to the desired outcome. Experts in product development each have their focus areas, often specialising in different macronutrients. However, these aspects are interconnected, and early consultation with the right specialists can significantly improve efficiency in both development time and costs. Seeking expert advice at an early stage helps streamline the reformulation process, ensuring that technical challenges are addressed effectively.

On the next page is a list of firms that provide expertise in product reformulation and can support various aspects of the development process.

Consulting firms **within** the Foodvalley network:

BAMBOO BRANDS The FMCG Business Boost Company	In-store market research on consumer behaviour.
Big Wave	Helps producers and private label manufacturers with market knowledge, sourcing, production and logistics.
CIBUS NEXUM	Experts in food contract maufacturing.
Food XLerator	Offers strategic support on sourcing, (new) product development, and business development for plant-based foods.
FOOD SCIENTIST FOR HIRE	Food consultant for product development, manufacturing, and food science.
Innate Motion	Purpose agency that helps leaders, brands and organisations apply more human sense to business.
NIZO FOR BETTER FOOD & HEALTH	Private and independent contract research organization specialised in food and health innovation.
Open Impact®	A digital platform for the measurement, evaluation and management of social, environmental and economic impacts.
Predi[t *By	Research and consulting partner through data and behavioural science.
prime pact	Support food companies through partnerships and collaboration.
Studio Fava	Support food companies with innovation and development challenges.

Consulting firms **within** the Foodvalley network (continued):

TNO innovation for life	Research institute aiming to make knowledge applicable for companies.
Agilery FOOD CONTRACT MANUFACTURING	Helps food and beverage brands develop and launch products by coordinating manufacturing and supply chain solutions across Europe.
TEAM TASTE MAKERS INNOVATING & IMPROVING	Helps companies turn ideas and side streams into profitable, market-ready food products.
top	Technical development partner in practical innovation solutions for the food industry.
DUTCH SPICES	Works with food professionals to develop and supply flavour solutions that improve and reformulate their products.
WAGENINGEN UNIVERSITY & RESEARCH	Research and innovation partner combining scientific expertise and full-chain knowledge to support sustainable food innovation.

Are you missing any consulting firms? Please contact **partner@foodvalley.nl** and we can incorporate this in our next version.

Innovation Facilities

Foodvalley supports leading agri-food companies by facilitating access to shared facilities and expertise and connecting them to new and innovative startups. This collaboration allows these companies to innovate and test new technologies with reduced risks in a cost-effective manner.

Check out the Facility Finder and access a unique database of research equipment and innovation facilities in agrifood, helping you accelerate innovation, maximise productivity, and collaborate with valuable partners. Whether you're looking for facilities to advance your research or aiming to share your capacity, Foodleap helps you find the right opportunities to grow and innovate.

Innovation facilities **within** the Foodvalley network:

KiCo	Co-working kitchen that offers shared, HACCP-certified facilities to help food entrepreneurs start and scale their businesses.
DIL	Research institute for product development support.
INSECTSENSE Insect Inspired Innovations	Offer ReceptomiX technology, sensation-on-chip, for objective measurement of taste and health properties, and for profiling smells and volatile compounds.
ILVO Flanders Research Institute for Agriculture, Fisheries and Food	Research institute in the agri-food sector from the Flamish government.
NIZO FOR BETTER FOOD & HEALTH	R&D centre focusing on food & health analytics, scientific consultancy and assisting in practical solutions.
WAGENINGEN UNIVERSITY & RESEARCH	(Applied) research partner providing pilot facilities and innovation infrastructure, supported by full-chain expertise, for food and biobased innovation.
1·2 taste	Ingredient marketplace for food manufacturers.
top	Technical development partner in practical innovation solutions for the food industry.

Are you missing any innovation facilities? Please contact **partner@foodvalley.nl** and we can incorporate this in our next version.

References

Abdaltef, M. J., Al-Shawi, & Al-Temimi. (2024). Galacto-oligosaccharides as functional foods and their properties. MINI REVIEW Food Research, 8(5), 219–224. https://doi.org/10.26656/fr.2017.8(5).501

Adam, C. L., Gratz, S. W., Peinado, D. I., Thomson, L. M., Garden, K. E., Williams, P. A., Richardson, A. J., & Ross, A. W. (2016). Effects of Dietary Fibre (Pectin) and/or Increased Protein (Casein or Pea) on Satiety, Body Weight, Adiposity and Caecal Fermentation in High Fat Diet-Induced Obese Rats. PLOS ONE, 11(5), e0155871. https://doi.org/10.1371/JOURNAL.PONE.0155871

Adebo, J. A., Njobeh, P. B., Gbashi, S., Oyedeji, A. B., Ogundele, O. M., Oyeyinka, S. A., & Adebo, O. A. (2022). Fermentation of Cereals and Legumes: Impact on Nutritional Constituents and Nutrient Bioavailability. Fermentation 2022, Vol. 8, Page 63, 8(2), 63. https://doi.org/10.3390/FERMENTATION8020063

Agostoni, C., Bresson, J.-L., Fairweather-Tait, S., Flynn, A., Golly, I., Korhonen, H., Lagiou, P., Løvik, M., Marchelli, R., Martin, A., Moseley, B., Neuhäuser-Berthold, M., Przyrembel, H., Salminen, S., Sanz, Y., Strain, S., Strobel, S., Tetens, I., Tomé, D., … member Anja Brönstrup, staff. (2012). Scientific Opinion on Dietary Reference Values for protein. EFSA Journal, 10(2), 2557–2559. https://doi.org/10.2903/j.efsa.2012.2557

Aguayo-Guerrero, J. A., Méndez-García, L. A., Solleiro-Villavicencio, H., Viurcos-Sanabria, R., & Escobedo, G. (2024). Sucralose: From Sweet Success to Metabolic Controversies—Unraveling the Global Health Implications of a Pervasive Non-Caloric Artificial Sweetener. Life 2024, Vol. 14, Page 323, 14(3), 323. https://doi.org/10.3390/LIFE14030323

Ahmad, A., & Kaleem, M. (2018). β-Glucan as a Food Ingredient. Biopolymers for Food Design, 351–381. https://doi.org/10.1016/B978-0-12-811449-0.00011-6

Ahmad, M. I., Farooq, S., Alhamoud, Y., Li, C., & Zhang, H. (2022). A review on mycoprotein: History, nutritional composition, production methods, and health benefits. Trends in Food Science & Technology, 121, 14–29. https://doi.org/10.1016/J.TIFS.2022.01.027

Ahmed, W., & Rashid, S. (2019). Functional and therapeutic potential of inulin: A comprehensive review. Critical Reviews in Food Science and Nutrition, 59(1), 1–13. https://doi.org/10.1080/10408398.2017.1355775

Aiking, H. (2014). Protein production: planet, profit, plus people? The American Journal of Clinical Nutrition, 100(SUPPL. 1), 483S-489S. https://doi.org/10.3945/AJCN.113.071209

Akbari, M., Eskandari, M. H., & Davoudi, Z. (2019). Application and functions of fat replacers in low-fat ice cream: A review. Trends in Food Science & Technology, 86, 34–40. https://doi.org/10.1016/J.TIFS.2019.02.036

Albarracín, W., Sánchez, I. C., Grau, R., & Barat, J. M. (2011). Salt in food processing; usage and reduction: a review. International Journal of Food Science & Technology, 46(7), 1329–1336. https://doi.org/10.1111/j.1365-2621.2010.02492.x

Alessandrini, R., He, F. J., Ma, Y., Scrutinio, V., Wald, D. S., & MacGregor, G. A. (2021). Potential impact of gradual reduction of fat content in manufactured and out-of-home food on obesity in the United Kingdom: a modeling study. The American Journal of Clinical Nutrition, 113(5), 1312–1321. https://doi.org/10.1093/AJCN/NQAA396

Alhajj, M. J., Montero, N., Yarce, C. J., & Salamanca, C. H. (2020). Lecithins from Vegetable, Land, and Marine Animal Sources and Their Potential Applications for Cosmetic, Food, and Pharmaceutical Sectors. Cosmetics 2020, Vol. 7, Page 87, 7(4), 87. https://doi.org/10.3390/COSMETICS7040087

Alonso, L., Fontecha, J., Lozada, L., Fraga, M. J., & Juárez, M. (1999). Fatty Acid Composition of Caprine Milk: Major, Branched-Chain, and Trans Fatty Acids. Journal of Dairy Science, 82(5), 878–884. https://doi.org/10.3168/jds.S0022-0302(99)75306-3

ALQtaishat, N., Saleh, M., Al-Ismail, K., & Ghoush, M. A. (2022). Effects of sodium chloride partial substitution with bitterness-treated potassium and magnesium chloride on some properties of white-brined cheese. International Journal of Dairy Technology, 75(3), 668–678. https://doi.org/10.1111/1471-0307.12867

Amyoony, J., Gorman, M., Dabas, T., Moss, R., & McSweeney, M. B. (2023). Consumer perception of collagen from different sources: An investigation using hedonic scale and check all that apply. Journal of Food Science, 88(12), 5236–5247. https://doi.org/10.1111/1750-3841.16822

Andreoli, V., Bagliani, M., Corsi, A., & Frontuto, V. (2021). Drivers of Protein Consumption: A Cross-Country Analysis. Sustainability 2021, Vol. 13, Page 7399, 13(13), 7399. https://doi.org/10.3390/SU13137399

Anjom-Shoae, J., Feinle-Bisset, C., & Horowitz, M. (2024). Impacts of dietary animal and plant protein on weight and glycemic control in health, obesity and type 2 diabetes: friend or foe? Frontiers in Endocrinology, 15, 1412182. https://doi.org/10.3389/FENDO.2024.1412182/FULL

Asasta, A. R., Armando, D. W., Tissadharma, J. C., Theo, K. A., & Nobelta, N. (2024). Sugar Alcohol: A Comparison of Xylitol and Sorbitol in Food Application. Jurnal Global Ilmiah, 1(4).

Asghar, A., Afzaal, M., Saeed, F., Ahmed, A., Ateeq, H., Shah, Y. A., Islam, F., Hussain, M., Akram, N., & Shah, M. A. (2023). Valorization and food applications of okara (soybean residue): A concurrent review. Food Science & Nutrition, 11(7), 3631. https://doi.org/10.1002/FSN3.3363

Ashoorion, V., Hosseinian, S. Z., Rezaei, N., Hajihashemi, P., Zare-Farashbandi, E., & Adibi, P. (2025). Effect of dietary patterns on functional dyspepsia in adults: a systematic review. Journal of Health, Population, and Nutrition, 44(1), 132. https://doi.org/10.1186/S41043-025-00884-5

Ashwar, B. A., Gani, A., Shah, A., Wani, I. A., & Masoodi, F. A. (2016). Preparation, health benefits and applications of resistant starch—a review. Starch - Stärke, 68(3–4), 287–301. https://doi.org/10.1002/STAR.201500064

Ati, J. el, Doggui, R., & Ati-Hellal, M. el. (2021). A Successful Pilot Experiment of Salt Reduction in Tunisian Bread: 35% Gradual Decrease of Salt Content without Detection by Consumers. International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 1590, 18(4), 1590. https://doi.org/10.3390/IJERPH18041590

Atkinson, F. S., Brand-Miller, J. C., Foster-Powell, K., Buyken, A. E., & Goletzke, J. (2021). International tables of glycemic index and glycemic load values 2021: a systematic review. The American Journal of Clinical Nutrition, 114(5), 1625–1632. https://doi.org/10.1093/AJCN/NQAB233

Augustin, M. A., Hartley, C. J., Maloney, G., & Tyndall, S. (2024). Innovation in precision fermentation for food ingredients. Critical Reviews in Food Science and Nutrition, 64(18), 6218–6238. https://doi.org/10.1080/10408398.2023.2166014

Azaïs-Braesco, V., Sluik, D., Maillot, M., Kok, F., & Moreno, L. A. (2017). A review of total & added sugar intakes and dietary sources in Europe. Nutrition Journal, 16(1), 6. https://doi.org/10.1186/s12937-016-0225-2

Aziz, T., Li, W., Zhu, J., & Chen, B. (2024). Developing multifunctional cellulose derivatives for environmental and biomedical applications: Insights into modification processes and advanced material properties. International Journal of Biological Macromolecules, 278, 134695. https://doi.org/10.1016/J.IJBIOMAC.2024.134695

Bali, V., Panesar, P. S., Bera, M. B., & Panesar, R. (2015). Fructo-oligosaccharides: Production, Purification and Potential Applications. Critical Reviews in Food Science and Nutrition, 55(11), 1475–1490. https://doi.org/10.1080/10408398.2012.694084

Banday, M. Z., Sameer, A. S., & Nissar, S. (2020). Pathophysiology of diabetes: An overview. Avicenna Journal of Medicine, 10(04), 174–188. https://doi.org/10.4103/ajm.ajm_53_20

Bao, Y., Xue, H., Yue, Y., Wang, X., Yu, H., & Piao, C. (2021). Preparation and characterization of pickering emulsions with modified okara insoluble dietary fiber. Foods, 10(12), 2982. https://doi.org/10.3390/FOODS10122982/S1

Barber, T. M., Kabisch, S., Pfeiffer, A. F. H., & Weickert, M. O. (2020). The Health Benefits of Dietary Fibre. Nutrients 2020, Vol. 12, Page 3209, 12(10), 3209. https://doi.org/10.3390/NU12103209

Baye, K., Guyot, J. P., & Mouquet-Rivier, C. (2017). The unresolved role of dietary fibers on mineral absorption. Critical Reviews in Food Science and Nutrition, 57(5), 949–957. https://doi.org/10.1080/10408398.2014.953030;JOURNAL:JOURNAL:BFSN18;WGROUP:STRING:PUBLICATION

Belorio, M., & Gómez, M. (2021). Psyllium: a useful functional ingredient in food systems. Critical Reviews in Food Science and Nutrition, 62(2), 527–538. https://doi.org/10.1080/10408398.2020.1822276;WGROUP:STRING:PUBLICATION

Beukema, M., Faas, M. M., & de Vos, P. (2020). The effects of different dietary fiber pectin structures on the gastrointestinal immune barrier: impact via gut microbiota and direct effects on immune cells. Experimental & Molecular Medicine 2020 52:9, 52(9), 1364–1376. https://doi.org/10.1038/s12276-020-0449-2

Blanco-Pérez, F., Steigerwald, H., Schülke, S., Vieths, S., Toda, M., & Scheurer, S. (2021). The Dietary Fiber Pectin: Health Benefits and Potential for the Treatment of Allergies by Modulation of Gut Microbiota. Current Allergy and Asthma Reports, 21(10), 1–19. https://doi.org/10.1007/S11882-021-01020-Z/FIGURES/4

Blok, A. E., Bolhuis, D. P., Arnaudov, L. N., Velikov, K. P., & Stieger, M. (2023). Influence of thickeners (microfibrillated cellulose, starch, xanthan gum) on rheological, tribological and sensory properties of low-fat mayonnaises. Food Hydrocolloids, 136. https://doi.org/10.1016/j.foodhyd.2022.108242

Bober, J. R., & Nair, N. U. (2019). Galactose to tagatose isomerization at moderate temperatures with high conversion and productivity. Nature Communications 2019 10:1, 10(1), 1–10. https://doi.org/10.1038/s41467-019-12497-8

Borkoles, E., Krastins, D., van der Pols, J. C., Sims, P., & Polman, R. (2022). Short-Term Effect of Additional Daily Dietary Fibre Intake on Appetite, Satiety, Gastrointestinal Comfort, Acceptability, and Feasibility. Nutrients 2022, Vol. 14, Page 4214, 14(19), 4214. https://doi.org/10.3390/NU14194214

Borrelli, S., Provenzano, M., Gagliardi, I., Michael, A., Liberti, M., Nicola, L. de, Conte, G., Garofalo, C., & Andreucci, M. (2020). Sodium Intake and Chronic Kidney Disease. International Journal of Molecular Sciences, 21(13), 4744. https://doi.org/10.3390/ijms21134744

Breslin, P. A. S., & Beauchamp, G. K. (1997). Salt enhances flavour by suppressing bitterness. Nature, 387(6633), 563. https://doi.org/10.1038/42388

Bressiani, J., Oro, T., Santetti, G. S., Almeida, J. L., Bertolin, T. E., Gómez, M., & Gutkoski, L. C. (2017). Properties of whole grain wheat flour and performance in bakery products as a function of particle size. Journal of Cereal Science, 75, 269–277. https://doi.org/10.1016/J.JCS.2017.05.001

Brouns, F. (2021). Phytic Acid and Whole Grains for Health Controversy. Nutrients 2022, Vol. 14, Page 25, 14(1), 25. https://doi.org/10.3390/NU14010025

Cansell, M. (2005). Impact de la cristallisation des corps gras sur les propriétés des produits finis. Oléagineux, Corps Gras, Lipides, 12(5–6), 427–431. https://doi.org/10.1051/ocl.2005.0427

Cappuccio, F. P., Kalaitzidis, R., Duneclift, S., & Eastwood, J. B. (2000). Unravelling the links between calcium excretion, salt intake, hypertension, kidney stones and bone metabolism. Journal of Nephrology, 13(3), 169–177.

Carene, M., Picot-Allain, N., Ramasawmy, B., & Emmambux, M. N. (2020). Extraction, Characterisation, and Application of Pectin from Tropical and Sub-Tropical Fruits: A Review. https://doi.org/10.1080/87559129.2020.1733008

Carlson, J. L., Erickson, J. M., Lloyd, B. B., & Slavin, J. L. (2018). Health Effects and Sources of Prebiotic Dietary Fiber. Current Developments in Nutrition, 2(3), nzy005. https://doi.org/10.1093/cdn/nzy005

Cassidy, Y. M., McSorley, E. M., & Allsopp, P. J. (2018). Effect of soluble dietary fibre on postprandial blood glucose response and its potential as a functional food ingredient. Journal of Functional Foods, 46, 423–439. https://doi.org/10.1016/J.JFF.2018.05.019

Castle, L., Andreassen, M., Aquilina, G., Bastos, M. L., Boon, P., Fallico, B., FitzGerald, R., Fernandez, M. J. F., Grasl-Kraupp, B., Gundert-Remy, U., Gürtler, R., Houdeau, E., Kurek, M., Louro, H., Morales, P., Passamonti, S., Batke, M., Bruzell, E., Chipman, J., … Lodi, F. (2025). Re-evaluation of acesulfame K (E 950) as food additive. EFSA Journal, 23(4). https://doi.org/10.2903/J.EFSA.2025.9317

Castle, L., Andreassen, M., Aquilina, G., Bastos, M. L., Boon, P., Fallico, B., FitzGerald, R., Fernandez, M. J. F., Grasl-Kraupp, B., Gundert-Remy, U., Gürtler, R., Houdeau, E., Kurek, M., Louro, H., Morales, P., Passamonti, S., Batke, M., Bruzell, E., Chipman, J., … Younes, M. (2024). Re-evaluation of saccharin and its sodium, potassium and calcium salts (E 954) as food additives. EFSA Journal, 22(11). https://doi.org/10.2903/j.efsa.2024.9044

Cattaruzza, A., & French, S. (2024). Food Reformulation for Fats. Institute of Food Science + Technology. .
Cervantes-Paz, B., & Yahia, E. M. (2021). Avocado oil: Production and market demand, bioactive components, implications in health, and tendencies and potential uses. Comprehensive Reviews in Food Science and Food Safety, 20(4), 4120–4158. https://doi.org/10.1111/1541-4337.12784;JOURNAL:JOURNAL:15414337;WGROUP:STRING:PUBLICATION

Chen, A., Tapia, H., Goddard, J. M., & Gibney, P. A. (2022). Trehalose and its applications in the food industry. Comprehensive Reviews in Food Science and Food Safety, 21(6), 5004–5037. https://doi.org/10.1111/1541-4337.13048

Chen, J., & Raymond, K. (2008). Beta-glucans in the treatment of diabetes and associated cardiovascular risks. Vascular Health and Risk Management, 4(6), 1265–1272. https://doi.org/10.2147/VHRM.S3803

Chen, Y., She, Y., Zhang, R., Wang, J., Zhang, X., & Gou, X. (2020). Use of starch-based fat replacers in foods as a strategy to reduce dietary intake of fat and risk of metabolic diseases. Food Science and Nutrition, 8(1), 16–22. https://doi.org/10.1002/FSN3.1303;PAGEGROUP:STRING:PUBLICATION

Chiozzi, V., Eliopoulos, C., Markou, G., Arapoglou, D., Agriopoulou, S., Enshasy, H. A. el, & Varzakas, T. (2021). Biotechnological Addition of β-Glucans from Cereals, Mushrooms and Yeasts in Foods and Animal Feed. Processes 2021, Vol. 9, Page 1889, 9(11), 1889. https://doi.org/10.3390/PR9111889

Circuncisão, A. R., Catarino, M. D., Cardoso, S. M., & Silva, A. M. S. (2018). Minerals from Macroalgae Origin: Health Benefits and Risks for Consumers. Marine Drugs 2018, Vol. 16, Page 400, 16(11), 400. https://doi.org/10.3390/MD16110400

Commission, E. (n.d.). Nutrition claims - Food Safety - European Commission. Retrieved April 14, 2026, from https://food.ec.europa.eu/food-safety/labelling-and-nutrition/nutrition-and-health-claims/nutrition-claims_en

Commission, E. (2006). Regulation (EC) No 1924/2006 of the european parliament and of the council of 20 December 2006 on nutrition and health claims made on foods. EUR-Lex

Commission, E. (2012). Nutrition Claims.

Commission, E. (2021). Overview of sugars intake across European countries. https://knowledge4policy.ec.europa.eu/health-promotion-knowledge-gateway/sugars-sweeteners-8_en

Commission, E. (2023). Dietary Fibre. In https://knowledge4policy.ec.europa.eu/health-promotion-knowledge-gateway/dietary-fibre_en#references. https://knowledge4policy.ec.europa.eu/health-promotion-knowledge-gateway/dietary-fibre_en#references

Costa, T. J., Domingues, M. R. M., & Alves, E. (2024). An overview on lipids in nuts and oily fruits: oil content, lipid composition, health effects, lipidomic fingerprinting and new biotechnological applications of their by-products. Critical Reviews in Food Science and Nutrition, 64(25), 9132–9160. https://doi.org/10.1080/10408398.2023.2208666

Cupisti, A., Kovesdy, C. P., D'Alessandro, C., & Kalantar-Zadeh, K. (2018). Dietary Approach to Recurrent or Chronic Hyperkalaemia in Patients with Decreased Kidney Function. Nutrients 2018, Vol. 10, Page 261, 10(3), 261. https://doi.org/10.3390/NU10030261

Czarnecka, K., Pilarz, A., Rogut, A., Maj, P., Szymańska, J., Olejnik, Ł., & Szymański, P. (2021). Aspartame—True or False? Narrative Review of Safety Analysis of General Use in Products. Nutrients 2021, Vol. 13, Page 1957, 13(6), 1957. https://doi.org/10.3390/NU13061957

da Silva, V. T., Mateus, N., de Freitas, V., & Fernandes, A. (2024). Plant-Based Meat Analogues: Exploring Proteins, Fibers and Polyphenolic Compounds as Functional Ingredients for Future Food Solutions. Foods, 13(14), 2303. https://doi.org/10.3390/FOODS13142303

de Cássia Ortiz, A., Fideles, S. O. M., Reis, C. H. B., Pagani, B. T., Bueno, L. M. M., Moscatel, M. B. M., Buchaim, R. L., & Buchaim, D. V. (2024). D-Tagatose: A Rare Sugar with Functional Properties and Antimicrobial Potential against Oral Species. Nutrients 2024, Vol. 16, Page 1943, 16(12), 1943. https://doi.org/10.3390/NU16121943

DeJong, A. E., & Hartel, R. W. (2020). Quantification of γ-sorbitol crystal growth rate and solubility in the presence of mannitol and maltitol. Journal of Food Science, 85(12), 4319–4326. https://doi.org/10.1111/1750-3841.15519

D'Elia, L., Galletti, F., & Strazzullo, P. (2014). Dietary Salt Intake and Risk of Gastric Cancer (pp. 83–95). https://doi.org/10.1007/978-3-642-38007-5_6

Desmond, E. (2006). Reducing salt: A challenge for the meat industry. Meat Science, 74(1), 188–196. https://doi.org/10.1016/j.meatsci.2006.04.014

Dhingra, D., Michael, M., Rajput, H., & Patil, R. T. (2012). Dietary fibre in foods: a review. Journal of Food Science and Technology, 49(3), 255–266. https://doi.org/10.1007/s13197-011-0365-5

Ding, S., & Yang, J. (2021). The effects of sugar alcohols on rheological properties, functionalities, and texture in baked products – A review. Trends in Food Science & Technology, 111, 670–679. https://doi.org/10.1016/J.TIFS.2021.03.009

Đorđević, Đ., Buchtová, H., & Macharáčková, B. (2018). Salt microspheres and potassium chloride usage for sodium reduction: Case study with sushi. Food Science and Technology International, 24(1), 3–14. https://doi.org/10.1177/1082013217718965/ASSET/1EAAA00D-B3C5-4568-9DB5-CDC8CC8779EF/ASSETS/IMAGES/LARGE/10.1177_1082013217718965-FIG13.JPG

Drewnowski, A. (2024). A novel Nutrient Rich Food (NRFa11.3) score uses flavonoids and carotenoids to identify antioxidant-rich spices, herbs, vegetables, and fruit. Frontiers in Nutrition, 11. https://doi.org/10.3389/fnut.2024.1386328

Dupont, C., & Hébert, G. (2020). Magnesium Sulfate-Rich Natural Mineral Waters in the Treatment of Functional Constipation–A Review. Nutrients 2020, Vol. 12, Page 2052, 12(7), 2052. https://doi.org/10.3390/NU12072052

Ecarma, M. J. Y., & Nolden, A. A. (2021). A review of the flavor profile of metal salts: understanding the complexity of metallic sensation. Chemical Senses, 46, 1–8. https://doi.org/10.1093/chemse/bjab043

Eche, V., Emenike, C. U., & Rupasinghe, H. P. V. (2025). Nutritional Value of Brewer's Spent Grain and Consumer Acceptance of Its Value-Added Food Products. Foods, 14(16), 2900. https://doi.org/10.3390/FOODS14162900

Efe, N., & Dawson, P. (2022). A Review: Sugar-Based Confectionery and the Importance of Ingredients. European Journal of Agriculture and Food Sciences, 4(5), 1–8. https://doi.org/10.24018/ejfood.2022.4.5.552
EFSA. (2012, February 9). EFSA sets population reference intakes for protein | EFSA. https://www.efsa.europa.eu/en/press/news/120209

(EFSA), E. F. S. A. (2010). Scientific Opinion on Dietary Reference Values for carbohydrates and dietary fibre. EFSA Journal, 8(3). https://doi.org/10.2903/j.efsa.2010.1462

(EFSA), E. F. S. A. (2013). Scientific Opinion on the safety of advantame for the proposed uses as a food additive. EFSA Journal, 11(7). https://doi.org/10.2903/J.EFSA.2013.3301

Egbert, W. R., & Payne, C. T. (2009). Plant proteins. Ingredients in Meat Products: Properties, Functionality and Applications, 111–129. https://doi.org/10.1007/978-0-387-71327-4_5/SAVE-RESEARCH
en Warenautoriteit, N. V.-. (2024). Handboek Etikettering van levensmiddelen. https://www.nvwa.nl/documenten/consument/eten-drinken-roken/etikettering/publicaties/handboek-etikettering-van-levensmiddelen

EPRS. (2024). Alternative protein sources for food and feed.

EUFIC. (2023). Recommended daily intake of fibre and fibre-rich foods to help you achieve it. https://www.eufic.org/en/whats-in-food/article/recommended-daily-intake-of-fibre-and-fibre-rich-foods-to-help-you-achieve-it

European Commission. (n.d.). Allergies - Food Safety - European Commission. Retrieved May 22, 2026, from https://food.ec.europa.eu/food-safety/campaign-2026/allergies_en

European Parliamentary Research Service. (2024). Alternative protein sources for food and feed.

Farag, M. A., Rezk, M. M., Elashal, M. H., El-Araby, M., Khalifa, S. A. M., & El-Seedi, H. R. (2022). An updated multifaceted overview of sweet proteins and dipeptides as sugar substitutes; the chemistry, health benefits, gut interactions, and safety. Food Research International, 162, 111853. https://doi.org/10.1016/J.FOODRES.2022.111853

Fardet, A., & Richonnet, C. (2020). Nutrient density and bioaccessibility, and the antioxidant, satiety, glycemic, and alkalinizing potentials of fruit-based foods according to the degree of processing: a narrative review. Critical Reviews in Food Science and Nutrition, 60(19), 3233–3258. https://doi.org/10.1080/10408398.2019.1682512

Fernandes, G. D., Gómez-Coca, R. B., Pérez-Camino, M. D. C., Moreda, W., & Barrera-Arellano, D. (2017). Chemical Characterization of Major and Minor Compounds of Nut Oils: Almond, Hazelnut, and Pecan Nut. Journal of Chemistry, 2017(1), 2609549. https://doi.org/10.1155/2017/2609549

Fernández-López, J., Botella-Martínez, C., de Vera, C., Sayas-Barberá, M. E., Viuda-Martos, M., Sánchez-Zapata, E., & Pérez-Álvarez, J. A. (2020). Vegetable Soups and Creams: Raw Materials, Processing, Health Benefits, and Innovation Trends. Plants, 9(12). https://doi.org/10.3390/plants9121769

Fida, R., Pramafisi, G., & Cahyana, Y. (2020). Application of banana starch and banana flour in various food product: A review. IOP Conference Series: Earth and Environmental Science, 443(1). https://doi.org/10.1088/1755-1315/443/1/012057

Fierascu, R. C., Sieniawska, E., Ortan, A., Fierascu, I., & Xiao, J. (2020). Fruits By-Products – A Source of Valuable Active Principles. A Short Review. Frontiers in Bioengineering and Biotechnology, 8. https://doi.org/10.3389/fbioe.2020.00319

Fine, F., Brochet, C., Gaud, M., Carre, P., Simon, N., Ramli, F., & Joffre, F. (2016). Micronutrients in vegetable oils: The impact of crushing and refining processes on vitamins and antioxidants in sunflower, rapeseed, and soybean oils. European Journal of Lipid Science and Technology, 118(5), 680–697. https://doi.org/10.1002/EJLT.201400400;SUBPAGE:STRING:ACCESS

Food additives | EFSA. (n.d.). Retrieved May 22, 2026, from https://www.efsa.europa.eu/en/topics/topic/food-additives

Freitas, C. M. P., Coimbra, J. S. R., Souza, V. G. L., & Sousa, R. C. S. (2021). Structure and Applications of Pectin in Food, Biomedical, and Pharmaceutical Industry: A Review. Coatings 2021, Vol. 11, Page 922, 11(8), 922. https://doi.org/10.3390/COATINGS11080922

Geng, M., Hu, T., Zhou, Q., Taha, A., Qin, L., Lv, W., Xu, X., Pan, S., & Hu, H. (2021). Effects of different nut oils on the structures and properties of gel-like emulsions induced by ultrasound using soy protein as an emulsifier. International Journal of Food Science and Technology, 56(4), 1649–1660. https://doi.org/10.1111/IJFS.14786

Gezondheidsraad. (2015). Advies Richtlijnen gezonde voeding 2015. https://www.gezondheidsraad.nl/documenten/adviezen/2015/11/04/richtlijnen-goede-voeding-2015

Gezondheidsraad. (2021). Voedingsnormen voor eiwitten.

Gezondheidsraad. (2024). Advies Gezonde eiwittransitie | Gezondheidsraad. https://www.gezondheidsraad.nl/documenten/2023/12/13/advies-gezonde-eiwittransitie

Giuntini, E. B., Sardá, F. A. H., & de Menezes, E. W. (2022). The Effects of Soluble Dietary Fibers on Glycemic Response: An Overview and Futures Perspectives. Foods, 11(23), 3934. https://doi.org/10.3390/FOODS11233934/S1

Goff, H. D., & Guo, Q. (2019). The Role of Hydrocolloids in the Development of Food Structure. In Handbook of Food Structure Development (pp. 1–28). The Royal Society of Chemistry. https://doi.org/10.1039/9781788016155-00001

Gómez, M., & Martinez, M. M. (2018). Fruit and vegetable by-products as novel ingredients to improve the nutritional quality of baked goods. Critical Reviews in Food Science and Nutrition, 58(13), 2119–2135. https://doi.org/10.1080/10408398.2017.1305946

Gómez-Llorente, H., Hervás, P., Pérez-Esteve, É., Barat, J. M., & Fernández-Segovia, I. (2022). Nanotechnology in the agri-food sector: Consumer perceptions. NanoImpact, 26, 100399. https://doi.org/10.1016/J.IMPACT.2022.100399

Good Food Institute. (n.d.). Defining alternative proteins | GFI. Retrieved April 14, 2026, from https://gfi.org/defining-alternative-protein/

Goulding, D. A., Fox, P. F., & O'Mahony, J. A. (2020). Milk proteins: An overview. Milk Proteins: From Expression to Food, 21–98. https://doi.org/10.1016/B978-0-12-815251-5.00002-5

Grzelak, T., Grupińska, J., Pelczyńska, M., Sperling, M., & Czyżewska, K. (2017). The merits of fat replacers in low-calorie food. Acta Scientiarum Polonorum: Hortorum Cultus, 16(2). https://doaj.org/article/6978192a4f744c57bc436aa24e15f09f

Gu, F., Li, C., Hamaker, B. R., Gilbert, R. G., & Zhang, X. (2020). Fecal microbiota responses to rice RS3 are specific to amylose molecular structure. Carbohydrate Polymers, 243, 116475. https://doi.org/10.1016/J.CARBPOL.2020.116475

Guan, Z. W., Yu, E. Z., & Feng, Q. (2021). Soluble Dietary Fiber, One of the Most Important Nutrients for the Gut Microbiota. Molecules 2021, Vol. 26, Page 6802, 26(22), 6802. https://doi.org/10.3390/MOLECULES26226802

Guan, Z.-W., Yu, E.-Z., & Feng, Q. (2021). Soluble Dietary Fiber, One of the Most Important Nutrients for the Gut Microbiota. Molecules, 26(22), 6802. https://doi.org/10.3390/molecules26226802

Guinee, T. P. (2004). Salting and the role of salt in cheese. International Journal of Dairy Technology, 57(2–3), 99–109. https://doi.org/10.1111/j.1471-0307.2004.00145.x

Gullón, P., Astray, G., Gullón, B., Franco, D., Campagnol, P. C. B., & Lorenzo, J. M. (2021). Inclusion of seaweeds as healthy approach to formulate new low-salt meat products. Current Opinion in Food Science, 40, 20–25. https://doi.org/10.1016/J.COFS.2020.05.005

Gunduz, C. P. B. (2023). Formulation and Processing Strategies to Reduce Acrylamide in Thermally Processed Cereal-Based Foods. International Journal of Environmental Research and Public Health, 20(13), 6272. https://doi.org/10.3390/ijerph20136272

Habibi, H., & Khosravi-Darani, K. (2017). Effective variables on production and structure of xanthan gum and its food applications: A review. Biocatalysis and Agricultural Biotechnology, 10, 130–140. https://doi.org/10.1016/J.BCAB.2017.02.013

Halahlah, A., Kellil, A., Peltonen, S., & Ho, T. M. (2026). A review of innovative approaches for valorizing brewing by-products for food applications and consumer perceptions. Sustainable Food Technology, 4(2), 1316–1338. https://doi.org/10.1039/D5FB00545K

Hama, S., Ogino, C., & Kondo, A. (2015). Enzymatic synthesis and modification of structured phospholipids: recent advances in enzyme preparation and biocatalytic processes. In Applied Microbiology and Biotechnology (Vol. 99, Issue 19, pp. 7879–7891). Springer Verlag. https://doi.org/10.1007/s00253-015-6845-1

Hashem, K. M., He, F. J., & Macgregor, G. A. (2019). Effects of product reformulation on sugar intake and health—a systematic review and meta-analysis. Nutrition Reviews, 77(3), 181–196. https://doi.org/10.1093/NUTRIT/NUY015

Haspolat, E. (2024). Fundamental Journal of Mathematics and Applications Temperature-Dependent Parameters in Enzyme Kinetics: Impacts on Enzyme Denaturation Article Information. Fundamental Journal of Mathematics and Applications, 7(4), 226–235. https://doi.org/10.33401/fujma.1517334

He, M., & Tan, M. (2024). Hollow salt for sodium reduction in foods: Mechanisms, influence factors, applications and challenges. Trends in Food Science & Technology, 147, 104451. https://doi.org/10.1016/J.TIFS.2024.104451

He, X., Lu, W., Sun, C., Khalesi, H., Mata, A., Andaleeb, R., & Fang, Y. (2021). Cellulose and cellulose derivatives: Different colloidal states and food-related applications. Carbohydrate Polymers, 255, 117334. https://doi.org/10.1016/J.CARBPOL.2020.117334

He, Y., Wang, B., Wen, L., Wang, F., Yu, H., Chen, D., Su, X., & Zhang, C. (2022). Effects of dietary fiber on human health. Food Science and Human Wellness, 11(1), 1–10. https://doi.org/10.1016/j.fshw.2021.07.001

Hemdane, S., Jacobs, P. J., Dornez, E., Verspreet, J., Delcour, J. A., & Courtin, C. M. (2016). Wheat (Triticum aestivum L.) Bran in Bread Making: A Critical Review. Comprehensive Reviews in Food Science and Food Safety, 15(1), 28–42. https://doi.org/10.1111/1541-4337.12176

Herrera, M. P., Gao, J., Vasanthan, T., Temelli, F., & Henderson, K. (2016). β-Glucan content, viscosity, and solubility of Canadian grown oat as influenced by cultivar and growing location. Canadian Journal of Plant Science, 96(2), 183–196. https://doi.org/10.1139/CJPS-2014-0440/ASSET/IMAGES/CJPS-2014-0440TAB6.GIF

Hervik, A. K., & Svihus, B. (2019). The Role of Fiber in Energy Balance. Journal of Nutrition and Metabolism, 2019, 1–11. https://doi.org/10.1155/2019/4983657

Hofman, D. L., van Buul, V. J., & Brouns, F. J. P. H. (2016). Nutrition, Health, and Regulatory Aspects of Digestible Maltodextrins. Critical Reviews in Food Science and Nutrition, 56(12), 2091–2100. https://doi.org/10.1080/10408398.2014.940415

Homayouni, A., Amini, A., Keshtiban, A. K., Mortazavian, A. M., Esazadeh, K., & Pourmoradian, S. (2014). Resistant starch in food industry: A changing outlook for consumer and producer. Starch - Stärke, 66(1–2), 102–114. https://doi.org/10.1002/STAR.201300110

Hong, C. R., Jeon, B. J., Park, K. M., Lee, E. H., Hong, S. C., & Choi, S. J. (2023). An Overview of Structured Lipid in Food Science: Synthesis Methods, Applications, and Future Prospects. Journal of Chemistry, 2023(1), 1222373. https://doi.org/10.1155/2023/1222373

Hu, F. B., Manson, J. A. E., & Willett, W. C. (2001a). Types of Dietary Fat and Risk of Coronary Heart Disease: A Critical Review. Journal of the American College of Nutrition, 20(1), 5–19. https://doi.org/10.1080/07315724.2001.10719008

Hu, F. B., Manson, J. E., & Willett, W. C. (2001b). Types of Dietary Fat and Risk of Coronary Heart Disease: A Critical Review. Journal of the American College of Nutrition, 20(1), 5–19. https://doi.org/10.1080/07315724.2001.10719008

Ibrahim, O. O. (2015). High intensity sweeteners chemicals structure, properties and applications. Natural Science and Discovery, 1(4), 88. https://doi.org/10.20863/nsd.97334

Iizuka, K. (2022). Is the Use of Artificial Sweeteners Beneficial for Patients with Diabetes Mellitus? The Advantages and Disadvantages of Artificial Sweeteners. Nutrients 2022, Vol. 14, Page 4446, 14(21), 4446. https://doi.org/10.3390/NU14214446

Jacobson, M. F., & DePorter, J. (2018). Self-reported adverse reactions associated with mycoprotein (Quorn-brand) containing foods. Annals of Allergy, Asthma & Immunology, 120(6), 626–630. https://doi.org/10.1016/j.anai.2018.03.020

Jadhav, H. B. (2025). Foaming properties of protein-based particles and their mixture with other food-grade particles—A review. Food Biomacromolecules, 2(3), 325–339. https://doi.org/10.1002/FOB2.70019

Jang, C. H., Oh, J., Lim, J. S., Kim, H. J., & Kim, J. S. (2021). Fermented Soy Products: Beneficial Potential in Neurodegenerative Diseases. Foods 2021, Vol. 10, Page 636, 10(3), 636. https://doi.org/10.3390/FOODS10030636

Janiszewska-Turak, E., Rybak, K., Witrowa-Rajchert, D., Pobiega, K., Wierzbicka, A., Ossowski, S., Sękul, J., Kufel, A., Wiśniewska, A., Trych, U., Szczepańska-Stolarczyk, J., Krzykowski, A., & Gramza-Michałowska, A. (2024). Influence of Heat Treatment and Lactic Acid Fermentation on the Physical and Chemical Properties of Pumpkin Juice. Molecules 2024, Vol. 29, Page 4519, 29(19), 4519. https://doi.org/10.3390/MOLECULES29194519

Jayakody, M. M., Kaushani, K. G., Vanniarachchy, M. P. G., & Wijesekara, I. (2023). Hydrocolloid and water soluble polymers used in the food industry and their functional properties: a review. Polymer Bulletin, 80(4), 3585–3610. https://doi.org/10.1007/S00289-022-04264-5/TABLES/3

Joshi, A., Hegde, • Mahabaleshwar, & Zanwar, • Anand. (2022). Flaxseed oil and palm olein blend to improve omega-6: omega-3 ratio. J Food Sci Technol, 59(2), 498–509. https://doi.org/10.1007/s13197-021-05033-4

Kaim, U., & Labus, K. (2025). Monk Fruit Extract and Sustainable Health: A PRISMA-Guided Systematic Review of Randomized Controlled Trials. Nutrients 2025, Vol. 17, Page 1433, 17(9), 1433. https://doi.org/10.3390/NU17091433

Kakino, Y., Hishikawa, Y., Onodera, R., Tahara, K., & Takeuchi, H. (2017). Gelation Factors of Pectin for Development of a Powder Form of Gel, Dry Jelly, as a Novel Dosage Form. In Chem. Pharm. Bull (Vol. 65, Issue 11).

Kapoor, B., Kapoor, D., Gautam, S., Singh, R., & Bhardwaj, S. (2021). Dietary Polyunsaturated Fatty Acids (PUFAs): Uses and Potential Health Benefits. Current Nutrition Reports, 10(3), 232–242. https://doi.org/10.1007/S13668-021-00363-3/FIGURES/3

Kapoor, M. P., Ishihara, N., & Okubo, T. (2016). Soluble dietary fibre partially hydrolysed guar gum markedly impacts on postprandial hyperglycaemia, hyperlipidaemia and incretins metabolic hormones over time in healthy and glucose intolerant subjects. Journal of Functional Foods, 24, 207–220. https://doi.org/10.1016/J.JFF.2016.04.008

Kara, H. H., & Bor, Y. (2019). A REVIEW ON: PRODUCTION, USAGE, HEALTH EFFECT AND ANALYSIS OF MONO- and DIGLYCERIDES OF FATTY ACIDS. Derg. / J. Halal & Ethical Res, 1(1), 40–47.

Kassa, M. G., Teferi, D. A., Asemu, A. M., Belachew, M. T., Satheesh, N., Abera, B. D., & Erku, E. G. (2024). Review on psyllium husk: nutritional, functional, health benefits, food industry applications, waste treatment, and potential negative effects. CyTA - Journal of Food, 22(1). https://doi.org/10.1080/19476337.2024.2409174

Khalesi, M., Glenn-Davi, K., Mohammadi, N., & FitzGerald, R. J. (2024). Key Factors Influencing Gelation in Plant vs. Animal Proteins: A Comparative Mini-Review. Gels, 10(9), 575. https://doi.org/10.3390/GELS10090575

Kherade, M., Solanke, S., Tawar, M., & Wankhede, S. (2021). Fructooligosaccharides: A comprehensive review. Journal of Ayurvedic and Herbal Medicine, 7(3), 193–200. https://doi.org/10.31254/jahm.2021.7305

Khorairi, A. N. S. A., Sofian-Seng, N. S., Othaman, R., Rahman, H. A., Razali, N. S. M., Lim, S. J., & Mustapha, W. A. W. (2023). A Review on Agro-industrial Waste as Cellulose and Nanocellulose Source and Their Potentials in Food Applications. Food Reviews International, 39(2), 663–688. https://doi.org/10.1080/87559129.2021.1926478

Kiumarsi, M., Shahbazi, M., Yeganehzad, S., Majchrzak, D., Lieleg, O., & Winkeljann, B. (2019). Relation between structural, mechanical and sensory properties of gluten-free bread as affected by modified dietary fibers. Food Chemistry, 277, 664–673. https://doi.org/10.1016/J.FOODCHEM.2018.11.015

Kloss, L., Meyer, J. D., Graeve, L., & Vetter, W. (2015). Sodium intake and its reduction by food reformulation in the European Union — A review. NFS Journal, 1, 9–19. https://doi.org/10.1016/J.NFS.2015.03.001

Kraithong, S., Wang, S., Junejo, S. A., Fu, X., Theppawong, A., Zhang, B., & Huang, Q. (2022). Type 1 resistant starch: Nutritional properties and industry applications. Food Hydrocolloids, 125, 107369. https://doi.org/10.1016/J.FOODHYD.2021.107369

Krajewska, A., & Dziki, D. (2023). Physical properties of shortbread biscuits enriched with dried and powdered fruit and their by-products: a review. International Agrophysics, 37(3), 245–264. https://doi.org/10.31545/intagr/165803

Kris-Etherton, P. M. (1999). Monounsaturated Fatty Acids and Risk of Cardiovascular Disease. Circulation, 100(11), 1253–1258. https://doi.org/10.1161/01.CIR.100.11.1253

Lal, M. K., Singh, B., Sharma, S., Singh, M. P., & Kumar, A. (2021). Glycemic index of starchy crops and factors affecting its digestibility: A review. Trends in Food Science & Technology, 111, 741–755. https://doi.org/10.1016/J.TIFS.2021.02.067

Landikhovskaya, A. v, & Tvorogova, A. A. (2021). Ice cream and frozen desserts nutrient compositions: current trends of researches. Food Systems, 4(2), 74–81. https://doi.org/10.21323/2618-9771-2021-4-2-74-81

Langyan, S., Yadava, P., Khan, F. N., Dar, Z. A., Singh, R., & Kumar, A. (2022). Sustaining Protein Nutrition Through Plant-Based Foods. Frontiers in Nutrition, 8, 772573. https://doi.org/10.3389/FNUT.2021.772573

Lante, A., Canazza, E., & Tessari, P. (2023). Beta-Glucans of Cereals: Functional and Technological Properties. Nutrients 2023, Vol. 15, Page 2124, 15(9), 2124. https://doi.org/10.3390/NU15092124

Li, J., Zhai, J., Gu, L., Su, Y., Gong, L., Yang, Y., & Chang, C. (2021). Hen egg yolk in food industry - A review of emerging functional modifications and applications. Trends in Food Science & Technology, 115, 12–21. https://doi.org/10.1016/J.TIFS.2021.06.031

Li, X.;, Wu, Y.;, Duan, R.;, Yu, H.;, Liu, S.;, Bao, Y., Li, X., Wu, Y., Duan, R., Yu, H., Liu, S., & Bao, Y. (2024). Research Progress in the Extraction, Structural Characteristics, Bioactivity, and Commercial Applications of Oat β-Glucan: A Review. Foods 2024, Vol. 13, Page 4160, 13(24), 4160. https://doi.org/10.3390/FOODS13244160

Li, X., Yang, Y., Zhang, B., Lin, X., Fu, X., An, Y., Zou, Y., Wang, J. X., Wang, Z., & Yu, T. (2022). Lactate metabolism in human health and disease. Signal Transduction and Targeted Therapy 2022 7:1, 7(1), 1–22. https://doi.org/10.1038/s41392-022-01151-3

Lim, S. W. E., & Tay, P. K. C. (2024). Meat-ing expectations? The influence of plate materials on consumer perceptions of novel mycoprotein. Food Quality and Preference, 117, 105169. https://doi.org/10.1016/J.FOODQUAL.2024.105169

Lin, X., & Li, Z. (2024). Key components and multiple health functions of avocado oil: A review. Journal of Functional Foods, 122, 106494. https://doi.org/10.1016/J.JFF.2024.106494

Lin, X., Tang, Y., Hu, Y., Lu, Y., Sun, Q., Lv, Y., Zhang, Q., Wu, C., Zhu, M., He, Q., & Chi, Y. (2021). Sodium Reduction in Traditional Fermented Foods: Challenges, Strategies, and Perspectives. Journal of Agricultural and Food Chemistry, 69(29), 8065–8080. https://doi.org/10.1021/ACS.JAFC.1C01687/ASSET/IMAGES/LARGE/JF1C01687_0003.JPEG

Liu, S., Reimer, M., & Ai, Y. (2020). In vitro digestibility of different types of resistant starches under high-temperature cooking conditions. Food Hydrocolloids, 107, 105927. https://doi.org/10.1016/J.FOODHYD.2020.105927

Loi, C. C., Eyres, G. T., & Birch, E. J. (2019). Effect of mono- and diglycerides on physical properties and stability of a protein-stabilised oil-in-water emulsion. Journal of Food Engineering, 240, 56–64. https://doi.org/10.1016/J.JFOODENG.2018.07.016

Lopez, M. J., & Mohiuddin, S. S. (2024). Biochemistry, Essential Amino Acids. StatPearls. https://www.ncbi.nlm.nih.gov/books/NBK557845/

Lu, W., Hu, Z., Zhou, X., Qin, Y., Zhang, Y., & Fang, Y. (2022). Natural biopolymer masks the bitterness of potassium chloride to achieve a highly efficient salt reduction for future foods. Biomaterials, 283, 121456. https://doi.org/10.1016/J.BIOMATERIALS.2022.121456

M, J., P, M., P, P., & Prabha, V. V. (2024). Unveiling the Potential of Guar Gum in Food Applications. Journal of Advances in Biology & Biotechnology, 27(12), 178–183. https://doi.org/10.9734/JABB/2024/V27I121765

Ma, F., Li, Y., Zhang, Y., Zhang, Q., Li, X., Cao, Q., Ma, H., Xie, D., Zhang, B., Yu, J., Li, X., Xie, Q., Wan, G., Guo, M., Guo, J., Yin, J., & Liu, G. (2024). Effects of umami substances as taste enhancers on salt reduction in meat products: A review. Food Research International, 185, 114248. https://doi.org/10.1016/J.FOODRES.2024.114248

Ma, X., Nan, F., Liang, H., Shu, P., Fan, X., Song, X., Hou, Y., & Zhang, D. (2022). Excessive intake of sugar: An accomplice of inflammation. Frontiers in Immunology, 13. https://doi.org/10.3389/fimmu.2022.988481

Ma, Y., He, F. J., Hashem, K. M., FRCP, G. A. M., Ma, Y., He, F. J., Yin, Y., Hashem, K. M., & MacGregor, G. A. (2016). Gradual reduction of sugar in soft drinks without substitution as a strategy to reduce overweight, obesity, and type 2 diabetes: a modelling study. THE LANCET Diabetes & Endocrinology, 4, 105–114. https://doi.org/10.1016/S2213-8587(15)00477-5

Major, G., Pritchard, S., Murray, K., Alappadan, J. P., Hoad, C. L., Marciani, L., Gowland, P., & Spiller, R. (2017). Colon Hypersensitivity to Distension, Rather Than Excessive Gas Production, Produces Carbohydrate-Related Symptoms in Individuals With Irritable Bowel Syndrome. Gastroenterology, 152, 124-133.e2. https://doi.org/10.1053/j.gastro.2016.09.062

Maluly, H. D. B., Arisseto-Bragotto, A. P., & Reyes, F. G. R. (2017). Monosodium glutamate as a tool to reduce sodium in foodstuffs: Technological and safety aspects. Food Science & Nutrition, 5(6), 1039–1048. https://doi.org/10.1002/FSN3.499

Mamat, H., & Hill, S. E. (2014). Effect of fat types on the structural and textural properties of dough and semi-sweet biscuit. Journal of Food Science and Technology, 51(9), 1998–2005. https://doi.org/10.1007/s13197-012-0708-x

Man, W. de. (2023). Food Reformulation for Salt. Institute of Food Science + Technology. https://www.ifst.org/sites/default/files/Food%20Reformulation%20for%20Salt%20final.pdf

Mancebo, C. M., Rodríguez, P., Martínez, M. M., & Gómez, M. (2018). Effect of the addition of soluble (nutriose, inulin and polydextrose) and insoluble (bamboo, potato and pea) fibres on the quality of sugar-snap cookies. International Journal of Food Science & Technology, 53(1), 129–136. https://doi.org/10.1111/ijfs.13566

Mao, S.;, Jiang, J.;, Xiong, K.;, Chen, Y.;, Yao, Y.;, Liu, L.;, Liu, H.;, Li, X., Mao, S., Jiang, J., Xiong, K., Chen, Y., Yao, Y., Liu, L., Liu, H., & Li, X. (2024). Enzyme Engineering: Performance Optimization, Novel Sources, and Applications in the Food Industry. Foods 2024, Vol. 13, Page 3846, 13(23), 3846. https://doi.org/10.3390/FOODS13233846

Marczak, A., & Mendes, A. C. (2024). Dietary Fibers: Shaping Textural and Functional Properties of Processed Meats and Plant-Based Meat Alternatives. Foods, 13(12), 1952. https://doi.org/10.3390/foods13121952

Mariamenatu, A. H., & Abdu, E. M. (2021). Overconsumption of Omega-6 Polyunsaturated Fatty Acids (PUFAs) versus Deficiency of Omega-3 PUFAs in Modern-Day Diets: The Disturbing Factor for Their “Balanced Antagonistic Metabolic Functions” in the Human Body. Journal of Lipids, 2021(1), 8848161. https://doi.org/10.1155/2021/8848161

Martínez-Miranda, J. G., Chairez, I., & Durán-Páramo, E. (2022). Mannitol Production by Heterofermentative Lactic Acid Bacteria: a Review. In Applied Biochemistry and Biotechnology (Vol. 194, Issue 6, pp. 2762–2795). Springer. https://doi.org/10.1007/s12010-022-03836-5

Mazi, T. A., & Stanhope, K. L. (2023). Erythritol: An In-Depth Discussion of Its Potential to Be a Beneficial Dietary Component. Nutrients 2023, Vol. 15, Page 204, 15(1), 204. https://doi.org/10.3390/NU15010204

McCain, H. R., Kaliappan, S., & Drake, M. A. (2018). Invited review: Sugar reduction in dairy products. Journal of Dairy Science, 101(10), 8619–8640. https://doi.org/10.3168/jds.2017-14347

Mehat, K., Chen, Y., & Corpe, C. P. (2022). The Combined Effects of Aspartame and Acesulfame-K Blends on Appetite: A Systematic Review and Meta-Analysis of Randomized Clinical Trials. Advances in Nutrition, 13(6), 2329–2340. https://doi.org/10.1093/ADVANCES/NMAC072

Mei, J., Qian, M., Hou, Y., Liang, M., Chen, Y., Wang, C., & Zhang, J. (2024). Association of saturated fatty acids with cancer risk: a systematic review and meta-analysis. Lipids in Health and Disease, 23(1), 32. https://doi.org/10.1186/s12944-024-02025-z

Melchior, S., Plazzotta, S., Miao, S., Manzocco, L., Nicoli, M. C., & Calligaris, S. (2024). Design of Fat Alternatives Using Saturated Monoglycerides. Food Engineering Reviews, 16(4), 635–650. https://doi.org/10.1007/S12393-024-09379-1/TABLES/2

Meng, Y., Li, S., Khan, J., Dai, Z., Li, C., Hu, X., Shen, Q., & Xue, Y. (2021). Sugar- and Artificially Sweetened Beverages Consumption Linked to Type 2 Diabetes, Cardiovascular Diseases, and All-Cause Mortality: A Systematic Review and Dose-Response Meta-Analysis of Prospective Cohort Studies. Nutrients, 13(8), 2636. https://doi.org/10.3390/nu13082636

Mensink, M. A., Frijlink, H. W., Maarschalk, K. V. D. V., & Hinrichs, W. L. J. (2015). Inulin, a flexible oligosaccharide I: Review of its physicochemical characteristics. Carbohydrate Polymers, 130, 405–419. https://doi.org/10.1016/J.CARBPOL.2015.05.026

Meyer, B. J., Mann, N. J., Lewis, J. L., Milligan, G. C., Sinclair, A. J., & Howe, P. R. C. (2003). Dietary intakes and food sources of omega-6 and omega-3 polyunsaturated fatty acids. Lipids, 38(4), 391–398. https://doi.org/10.1007/s11745-003-1074-0

Micha, R., Khatibzadeh, S., Shi, P., Fahimi, S., Lim, S., Andrews, K. G., Engell, R. E., Powles, J., Ezzati, M., & Mozaffarian, D. (2014). Global, regional, and national consumption levels of dietary fats and oils in 1990 and 2010: a systematic analysis including 266 country-specific nutrition surveys. BMJ, 348(apr14 18), g2272–g2272. https://doi.org/10.1136/bmj.g2272

Miller, P. E., Verbeke, K., & Vries, J. de. (2015). Effects of cereal fiber on bowel function: A systematic review of intervention trials. World J Gastroenterol, 21(29), 8952–8963. https://doi.org/10.3748/wjg.v21.i29.8952

Mishra, S., & Awasthi, M. (2024). Role of Resistant Starch in Food and Healthcare Industry: A Review. Asian Journal of Dairy and Food Research, (Of). https://doi.org/10.18805/AJDFR.DR-2137

Moosavian, S. P., Haghighatdoost, F., Surkan, P. J., & Azadbakht, L. (2017). Salt and obesity: a systematic review and meta-analysis of observational studies. International Journal of Food Sciences and Nutrition, 68(3), 265–277. https://doi.org/10.1080/09637486.2016.1239700

Mozaffarian, D., Fahimi, S., Singh, G. M., Micha, R., Khatibzadeh, S., Engell, R. E., Lim, S., Danaei, G., Ezzati, M., & Powles, J. (2014). Global Sodium Consumption and Death from Cardiovascular Causes. New England Journal of Medicine, 371(7), 624–634. https://doi.org/10.1056/NEJMoa1304127

Müller, D. C., Nguyen, H., Li, Q., Schönlechner, R., Schwenninger, S. M., Wismer, W., & Gänzle, M. (2021). Enzymatic and microbial conversions to achieve sugar reduction in bread. Food Research International, 143, 110296. https://doi.org/10.1016/J.FOODRES.2021.110296

Muñoz, I. L., Díaz, N. F., Noz, I. L. M., & Iaz, N. F. D. (2020). Minerals in edible seaweed: health benefits and food safety issues. Critical Reviews in Food Science and Nutrition, 62(6), 1592–1607. https://doi.org/10.1080/10408398.2020.1844637

Nirmala Prasadi, V. P., & Joye, I. J. (2020). Dietary Fibre from Whole Grains and Their Benefits on Metabolic Health. Nutrients 2020, Vol. 12, Page 3045, 12(10), 3045. https://doi.org/10.3390/NU12103045

Nur, M., Suryatiani, D. R., Dewi, R. L., & Sari, A. B. T. (2021). The effect of bulking agent and type of chocolate on the physicochemical characteristics of sucrose-free chocolate using stevia as a sweetener. IOP Conference Series: Earth and Environmental Science, 733(1), 12102. https://doi.org/10.1088/1755-1315/733/1/012102

Nyhan, L., Sahin, A. W., Schmitz, H. H., Siegel, J. B., & Arendt, E. K. (2023). Brewers' Spent Grain: An Unprecedented Opportunity to Develop Sustainable Plant-Based Nutrition Ingredients Addressing Global Malnutrition Challenges. Journal of Agricultural and Food Chemistry, 71(28), 10543–10564. https://doi.org/10.1021/ACS.JAFC.3C02489

Olivares-Tenorio, M., Orrego, D., Klotz-Ceberio, B., Palanca, C., & Tortajada-Serra, M. (2022). Galactooligosaccharides: Food technological applications, prebiotic health benefits, microbiome modulation, and processing considerations. JSFA Reports, 2(12), 578–590. https://doi.org/10.1002/JSF2.92;SUBPAGE:STRING:FULL

Organization, W. H. (2012). Guideline: sodium intake for adults and children. https://www.who.int/publications/i/item/9789241504836

Organization, W. H. (2023). WHO updates guidelines on fats and carbohydrates. https://www.who.int/news/item/17-07-2023-who-updates-guidelines-on-fats-and-carbohydrates#:~:text=WHO%20recommends%20that%20adults%20consume%20at%20least%20400,suggests%20the%20following%20intakes%20of%20vegetables%20and%20fruits%3A

O'Sullivan, M. G. (2020). Reduced-fat products and challenges. Salt, Fat and Sugar Reduction, 63–96. https://doi.org/10.1016/B978-0-12-819741-7.00003-1

Oyinloye, T. M., & Yoon, W. B. (2020). Effect of Freeze-Drying on Quality and Grinding Process of Food Produce: A Review. Processes, 8(3), 354. https://doi.org/10.3390/pr8030354

Ozcan, T., Ozdemir, T., & Avci, H. R. (2021). Survival of Lactobacillus casei and functional characteristics of reduced sugar red beetroot yoghurt with natural sugar substitutes. International Journal of Dairy Technology, 74(1), 148–160. https://doi.org/10.1111/1471-0307.12741;CTYPE:STRING:JOURNAL

Öztürk-Kerimoğlu, B. (2021). A promising strategy for designing reduced-fat model meat emulsions by utilization of pea protein-agar agar gel complex. Food Structure, 29, 100205. https://doi.org/10.1016/J.FOOSTR.2021.100205

Pandya, Y., Bakshi, M., Sharma, A., Pandya, Y. H., & Pandya, H. (2022). Agar-agar extraction, structural properties and applications: A review. The Pharma Innovation Journal, (6), 1151–1157. https://www.researchgate.net/publication/361254986

Paola, I., Sisó, S., Somaris, •, Quintana, E., Luis, •, & Zapateiro, A. G. (2023). Stevia (Stevia rebaudiana) as a common sugar substitute and its application in food matrices: an updated review. https://doi.org/10.1007/s13197-022-05396-2

Parliament, E., & of the European Union., C. (2011). Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers.

Patel, S. (2015). Emerging trends in nutraceutical applications of whey protein and its derivatives. In Journal of Food Science and Technology (Vol. 52, Issue 11, pp. 6847–6858). Springer India. https://doi.org/10.1007/s13197-015-1894-0

Perez-Pirotto, C., Moraga, G., Hernando, I., Cozzano, S., & Arcia, P. (2022). Sorption Isotherms, Glass Transition and Bioactive Compounds of Ingredients Enriched with Soluble Fibre from Orange Pomace. Foods, 11(22), 3615. https://doi.org/10.3390/foods11223615

Pessarelli, T., Sorge, A., Elli, L., & Costantino, A. (2022). The low-FODMAP diet and the gluten-free diet in the management of functional abdominal bloating and distension. Frontiers in Nutrition, 9, 1007716. https://doi.org/10.3389/FNUT.2022.1007716/EPUB

Petersen, K. S., Fulgoni, V. L., Hopfer, H., Hayes, J. E., Gooding, R., & Kris-Etherton, P. (2024). Using Herbs/Spices to Enhance the Flavor of Commonly Consumed Foods Reformulated to Be Lower in Overconsumed Dietary Components Is an Acceptable Strategy and Has the Potential to Lower Intake of Saturated Fat and Sodium: A National Health and Nutrition Examination Survey Analysis and Blind Tasting. Journal of the Academy of Nutrition and Dietetics, 124(1), 15-27.e1. https://doi.org/10.1016/J.JAND.2023.07.025

Pirsa, S., & Hafezi, K. (2023). Hydrocolloids: Structure, preparation method, and application in food industry. Food Chemistry, 399, 133967. https://doi.org/10.1016/J.FOODCHEM.2022.133967

Pop, C., Suharoschi, R., & Pop, O. L. (2021). Dietary Fiber and Prebiotic Compounds in Fruits and Vegetables Food Waste. Sustainability, 13(13), 7219. https://doi.org/10.3390/su13137219

Pozo, S. del, Gómez-martínez, S., Díaz, L. E., Nova, E., Urrialde, R., & Marcos, A. (2022). Potential Effects of Sucralose and Saccharin on Gut Microbiota: A Review. Nutrients 2022, Vol. 14, Page 1682, 14(8), 1682. https://doi.org/10.3390/NU14081682

Prasad, N., Thombare, N., Sharma, S. C., & Kumar, S. (2022). Gum arabic – A versatile natural gum: A review on production, processing, properties and applications. Industrial Crops and Products, 187, 115304. https://doi.org/10.1016/J.INDCROP.2022.115304

Prasadi, V. P. N., & Joye, I. J. (2020). Dietary Fibre from Whole Grains and Their Benefits on Metabolic Health. Nutrients, 12(10), 3045. https://doi.org/10.3390/nu12103045

Prisacaru, A. E. (2016). Effect of antioxidants on polyunsaturated fatty acids - Review. Acta Scientiarum Polonorum, Technologia Alimentaria, 15(2), 121–129. https://doi.org/10.17306/J.AFS.2016.2.12

Puglisi, M. J., & Fernandez, M. L. (2022). The Health Benefits of Egg Protein. Nutrients 2022, Vol. 14, Page 2904, 14(14), 2904. https://doi.org/10.3390/NU14142904

Qaim, M. (2020). Role of New Plant Breeding Technologies for Food Security and Sustainable Agricultural Development. Applied Economic Perspectives and Policy, 42(2), 129–150. https://doi.org/10.1002/AEPP.13044;PAGE:STRING:ARTICLE/CHAPTER

Qin, P., Wang, T., & Luo, Y. (2022). A review on plant-based proteins from soybean: Health benefits and soy product development. Journal of Agriculture and Food Research, 7, 100265. https://doi.org/10.1016/J.JAFR.2021.100265

Qin, Y. Q., Wang, L. Y., Yang, X. Y., Xu, Y. J., Fan, G., Fan, Y. G., Ren, J. N., An, Q., & Li, X. (2023). Inulin: properties and health benefits. Food & Function, 14(7), 2948–2968. https://doi.org/10.1039/D2FO01096H

Raveendran, S., Parameswaran, B., Ummalyma, S. B., Abraham, A., Mathew, A. K., Madhavan, A., Rebello, S., & Pandey, A. (2018). Applications of microbial enzymes in food industry. In Food Technology and Biotechnology (Vol. 56, Issue 1, pp. 16–30). University of Zagreb. https://doi.org/10.17113/ftb.56.01.18.5491

Razi, S. M., Fahim, H., Amirabadi, S., & Rashidinejad, A. (2023). An overview of the functional properties of egg white proteins and their application in the food industry. Food Hydrocolloids, 135, 108183. https://doi.org/10.1016/J.FOODHYD.2022.108183

Refahee, S. M., Mahrous, A. I., & Shabaan, A. A. (2022). Clinical efficacy of magnesium sulfate injection in the treatment of masseter muscle trigger points: a randomized clinical study. BMC Oral Health, 22(1), 1–7. https://doi.org/10.1186/S12903-022-02452-3/TABLES/4

Rios, R. V., Pessanha, M. D. F., de Almeida, P. F., Viana, C. L., & da Silva Lannes, S. C. (2014). Application of fats in some food products. Food Science and Technology (Campinas), 34(1), 3–15. https://doi.org/10.1590/S0101-20612014000100001

Risérus, U., Willett, W. C., & Hu, F. B. (2009). Dietary fats and prevention of type 2 diabetes. Progress in Lipid Research, 48(1), 44–51. https://doi.org/10.1016/j.plipres.2008.10.002

RIVM. (n.d.-a). Inname van eiwitten | Wat eet Nederland. Retrieved April 14, 2026, from https://www.wateetnederland.nl/resultaten/energie-en-macronutrienten/eiwitten
RIVM. (n.d.-b). Zout. Ministerie van Volksgezondheid, Welzijn en Sport.
Retrieved https://www.wateetnederland.nl/onderwerpen/zout

RIVM. (2021). Inname van koolhydraten. https://www.wateetnederland.nl/resultaten/energie-en-macronutrienten/koolhydraten

RIVM. (2022). Nieuwe criteria voor productverbetering. Zout-, verzadigd vet- en suikergehalten voor voedingsmiddelengroepen. https://www.rivm.nl/publicaties/nieuwe-criteria-voor-productverbetering
RIVM. (2024). Nutri-score voor bedrijven. Rekentool. https://www.nutriscorevoorbedrijven.nl/documenten/publicaties/2024/04/09/rekentoolf

Rodriguez-Garcia, J., Ding, R., Nguyen, T. H. T., Grasso, S., Chatzifragkou, A., & Methven, L. (2022). Soluble fibres as sucrose replacers: Effects on physical and sensory properties of sugar-reduced short-dough biscuits. LWT, 167, 113837. https://doi.org/10.1016/J.LWT.2022.113837

Rysová, J., & Šmídová, Z. (2021). Effect of Salt Content Reduction on Food Processing Technology. Foods 2021, Vol. 10, Page 2237, 10(9), 2237. https://doi.org/10.3390/FOODS10092237

Saha, D., & Bhattacharya, S. (2010). Hydrocolloids as thickening and gelling agents in food: a critical review. Journal of Food Science and Technology, 47(6), 587. https://doi.org/10.1007/S13197-010-0162-6

Sahin, A. W., Axel, C., Zannini, E., & Arendt, E. K. (2018). Xylitol, mannitol and maltitol as potential sucrose replacers in burger buns. Food and Function, 9(4), 2201–2212. https://doi.org/10.1039/c8fo00066b

Schröder, A., Sprakel, J., Boerkamp, W., Schroën, K., & Berton-Carabin, C. C. (2019). Can we prevent lipid oxidation in emulsions by using fat-based Pickering particles? Food Research International, 120, 352–363. https://doi.org/10.1016/J.FOODRES.2019.03.004

Schweitzer, L., Wouters, R., & Theis, S. (2024). Replacing sugar with the polyol isomalt: technological advances and nutritional benefits focusing on blood glucose management Original Research. https://doi.org/10.17470

Ścieszka, S., & Klewicka, E. (2019). Algae in food: a general review. Critical Reviews in Food Science and Nutrition, 59(21), 3538–3547. https://doi.org/10.1080/10408398.2018.1496319

Sempio, R., Godoy, C. S., Nyhan, L., Sahin, A. W., Zannini, E., Walter, J., & Arendt, E. K. (2024). Closing the Fibre Gap—The Impact of Combination of Soluble and Insoluble Dietary Fibre on Bread Quality and Health Benefits. Foods 2024, Vol. 13, Page 1980, 13(13), 1980. https://doi.org/10.3390/FOODS13131980

Shaher, S. A. A., Mihailescu, D. F., & Amuzescu, B. (2023). Aspartame Safety as a Food Sweetener and Related Health Hazards. Nutrients 2023, Vol. 15, Page 3627, 15(16), 3627. https://doi.org/10.3390/NU15163627

Shahinfar, H., Jayedi, A., & Shab-Bidar, S. (2022). Dietary iron intake and the risk of type 2 diabetes: a systematic review and dose–response meta-analysis of prospective cohort studies. European Journal of Nutrition 2022 61:5, 61(5), 2279–2296. https://doi.org/10.1007/S00394-022-02813-2

Sharan, S., Zanghelini, G., Zotzel, J., Bonerz, D., Aschoff, J., Saint-Eve, A., & Maillard, M. N. (2021). Fava bean (Vicia faba L.) for food applications: From seed to ingredient processing and its effect on functional properties, antinutritional factors, flavor, and color. Comprehensive Reviews in Food Science and Food Safety, 20(1), 401–428. https://doi.org/10.1111/1541-4337.12687;JOURNAL:JOURNAL:15414337;WGROUP:STRING:PUBLICATION

Shoham, S., Pintel, N., & Avni, D. (2025). Oxidative Stress, Gut Bacteria, and Microalgae: A Holistic Approach to Manage Inflammatory Bowel Diseases. Antioxidants 2025, Vol. 14, Page 697, 14(6), 697. https://doi.org/10.3390/ANTIOX14060697

Shrivastava, A., Sharma, S., Kaurav, M., & Sharma, A. (2021). Characteristics and analytical methods of Mannitol: An update. In International Journal of Applied Pharmaceutics (Vol. 13, Issue 5, pp. 20–32). Innovare Academics Sciences Pvt. Ltd. https://doi.org/10.22159/ijap.2021v13i5.42068

Silow, C., Axel, C., Zannini, E., & Arendt, E. K. (2016). Current status of salt reduction in bread and bakery products – A review. Journal of Cereal Science, 72, 135–145. https://doi.org/10.1016/j.jcs.2016.10.010

Sinangil, Z., Taştan, Ö., & Baysal, T. (2022). Beta-Glucan as a Novel Functional Fiber: Functional Properties, Health Benefits and Food Applications. Turkish Journal of Agriculture - Food Science and Technology, 10(10), 1957–1965. https://doi.org/10.24925/TURJAF.V10I10.1957-1965.5430

Singh, A. S., Singh, S., Begum, R. F., Vijayan, S., & Vellapandian, C. (2024). Unveiling the profound influence of sucralose on metabolism and its role in shaping obesity trends. Frontiers in Nutrition, 11, 1387646. https://doi.org/10.3389/FNUT.2024.1387646/XML/NLM

Smetana, S., Ristic, D., Pleissner, D., Tuomisto, H. L., Parniakov, O., & Heinz, V. (2023). Meat substitutes: Resource demands and environmental footprints. Resources, Conservation and Recycling, 190, 106831. https://doi.org/10.1016/J.RESCONREC.2022.106831

Śmiechowska, M., Newerli-guz, J., & Skotnicka, M. (2021). Spices and Seasoning Mixes in European Union—Innovations and Ensuring Safety. Foods 2021, Vol. 10, Page 2289, 10(10), 2289. https://doi.org/10.3390/FOODS10102289

Soleimanian, Y., Sanou, I., Turgeon, S. L., Canizares, D., & Khalloufi, S. (2022). Natural plant fibers obtained from agricultural residue used as an ingredient in food matrixes or packaging materials: A review. Comprehensive Reviews in Food Science and Food Safety, 21(1), 371–415. https://doi.org/10.1111/1541-4337.12875

Souza, A. C. R., Vasconcelos, A. R., Dias, D. D., Komoni, G., & Name, J. J. (2023). The Integral Role of Magnesium in Muscle Integrity and Aging: A Comprehensive Review. Nutrients 2023, Vol. 15, Page 5127, 15(24), 5127. https://doi.org/10.3390/NU15245127

Souza, P. B. A., de Fátima Santos, M., de Deus Souza Carneiro, J., Pinto, V. R. A., & Carvalho, E. E. N. (2022). The effect of different sugar substitute sweeteners on sensory aspects of sweet fruit preserves: A systematic review. Journal of Food Processing and Preservation, 46(3), e16291. https://doi.org/10.1111/JFPP.16291;JOURNAL:JOURNAL:17454549;WGROUP:STRING:PUBLICATION

Subroto, E. (2020). Monoacylglycerols and diacylglycerols for fat-based food products: a review. Food Research, pp-pp. http://www.myfoodresearch.com

Sulieman, A. M. E. H. (2018). Gum Arabic as Thickener and Stabilizing Agents in Dairy Products. Gum Arabic: Structure, Properties, Application and Economics, 151–165. https://doi.org/10.1016/B978-0-12-812002-6.00013-0

Sumbe, V., & Salve, R. V. (2024). Nutritional and Functional Potential of Green Banana Flour: A Comprehensive Review.

Suna, S., Kalkan, S., Dinç, M., & Çopur, Ö. U. (2023). Production of low calorie persimmon marmalades with stevia and maltitol: physicochemical properties and in vitro bioaccessibility of polyphenols. Journal of Food Measurement and Characterization, 17(1), 1082–1095. https://doi.org/10.1007/s11694-022-01676-9

Tamanna, N., & Mahmood, N. (2015). Food Processing and Maillard Reaction Products: Effect on Human Health and Nutrition. International Journal of Food Science, 2015, 1–6. https://doi.org/10.1155/2015/526762

Tang, C., Zhou, K., Zhu, Y., Zhang, W., Xie, Y., Wang, Z., Zhou, H., Yang, T., Zhang, Q., & Xu, B. (2022). Collagen and its derivatives: From structure and properties to their applications in food industry. Food Hydrocolloids, 131, 107748. https://doi.org/10.1016/J.FOODHYD.2022.107748

Thrane, M., Paulsen, P. v, Orcutt, M. W., & Krieger, T. M. (2017). Soy Protein: Impacts, Production, and Applications. Sustainable Protein Sources, 23–45. https://doi.org/10.1016/B978-0-12-802778-3.00002-0

Tomé, D. (2021). Yeast Extracts: Nutritional and Flavoring Food Ingredients. ACS Food Science and Technology, 1(4), 487–494. https://doi.org/10.1021/ACSFOODSCITECH.0C00131/ASSET/IMAGES/LARGE/FS0C00131_0001.JPEG

Trailoyke, A., Srivastava, A., Bhole, M., & Zalte, N. (2017). Calcium and Calcium Salts. In Article in Journal of the Association of Physicians of India. https://www.researchgate.net/publication/313717335

Turck, D., Bohn, T., Castenmiller, J., de Henauw, S., Hirsch-Ernst, K. I., Knutsen, H. K., Maciuk, A., Mangelsdorf, I., McArdle, H. J., Naska, A., Peláez, C., Pentieva, K., Siani, A., Thies, F., Tsabouri, S., Adan, R., Emmett, P., Galli, C., Kersting, M., … Vinceti, M. (2022). Tolerable upper intake level for dietary sugars. EFSA Journal, 20(2). https://doi.org/10.2903/j.efsa.2022.7074

Turck, D., Castenmiller, J., de Henauw, S., Hirsch-Ernst, K., Kearney, J., Knutsen, H. K., Maciuk, A., Mangelsdorf, I., McArdle, H. J., Pelaez, C., Pentieva, K., Siani, A., Thies, F., Tsabouri, S., Vinceti, M., Aggett, P., Fairweather-Tait, S., Martin, A., Przyrembel, H., … Naska, A. (2019). Dietary reference values for sodium. EFSA Journal, 17(9). https://doi.org/10.2903/j.efsa.2019.5778

Turner, N. D., & Lupton, J. R. (2011). Dietary Fiber. Advances in Nutrition, 2(2), 151–152. https://doi.org/10.3945/an.110.000281

Tyl, C., Bresciani, A., & Marti, A. (2021). Recent Progress on Improving the Quality of Bran-Enriched Extruded Snacks. Foods, 10(9), 2024. https://doi.org/10.3390/foods10092024

Udo, T., Mummaleti, G., Mohan, A., Singh, R. K., & Kong, F. (2023). Current and emerging applications of carrageenan in the food industry. Food Research International, 173, 113369. https://doi.org/10.1016/J.FOODRES.2023.113369

Umai, D., Kayalvizhi, R., Kumar, V., & Jacob, S. (2022). Xylitol: Bioproduction and Applications-A Review. Frontiers in Sustainability, 3, 826190. https://doi.org/10.3389/FRSUS.2022.826190/XML/NLM

Ünal, M. H., & Arslan, D. (2022). Single and combined use of isomalt, polydextrose, and inulin as sugar substitutes in production of pectin jelly. Journal of Food Processing and Preservation, 46(12), e17174. https://doi.org/10.1111/JFPP.17174

Upadhyaya, B., McCormack, L., Fardin-Kia, A. R., Juenemann, R., Nichenametla, S., Clapper, J., Specker, B., & Dey, M. (2016). Impact of dietary resistant starch type 4 on human gut microbiota and immunometabolic functions. Scientific Reports, 6, 28797. https://doi.org/10.1038/SREP28797

Valenzuela, C., & Aguilera, J. M. (2015). Effects of maltodextrin on hygroscopicity and crispness of apple leathers. Journal of Food Engineering, 144, 1–9. https://doi.org/10.1016/J.JFOODENG.2014.07.010

van Buren, L., Dötsch-Klerk, M., Seewi, G., & Newson, R. S. (2016). Dietary Impact of Adding Potassium Chloride to Foods as a Sodium Reduction Technique. Nutrients 2016, Vol. 8, Page 235, 8(4), 235. https://doi.org/10.3390/NU8040235

van der Sman, R. G. M., & Renzetti, S. (2019). Understanding functionality of sucrose in biscuits for reformulation purposes. Critical Reviews in Food Science and Nutrition, 59(14), 2225–2239. https://doi.org/10.1080/10408398.2018.1442315

van der Sman, R. G. M., & Renzetti, S. (2021). Understanding functionality of sucrose in cake for reformulation purposes. Critical Reviews in Food Science and Nutrition, 61(16), 2756–2772. https://doi.org/10.1080/10408398.2020.1786003

van Gunst, A., & Roodenburg, A. J. C. (2019). Consumer Distrust about E-numbers: A Qualitative Study among Food Experts. Foods 2019, Vol. 8, Page 178, 8(5), 178. https://doi.org/10.3390/FOODS8050178

Varney, J., Barrett, J., Scarlata, K., Catsos, P., Gibson, P. R., & Muir, J. G. (2017). FODMAPs: food composition, defining cutoff values and international application. Journal of Gastroenterology and Hepatology, 32, 53–61. https://doi.org/10.1111/JGH.13698

Vergara Nieto, Á. A., Díaz, A. H., Hernández Millán, M., & Sagredo, D. (2025). Molecular Features, Effective Sources, and Physiological Effects of Omega-3 Unsaturated Fatty Acids on Cardiovascular, Neurological, and Muscular Health, and Clinical Relevance for Several Conditions: A Narrative Review. Nutrition Reviews. https://doi.org/10.1093/NUTRIT/NUAF201

Viegas, C., Gerardo, A., Mendes, L., Ferreira, R., Damas, C., Sapata, M., & Serrano, C. (2022). Use of Microencapsulation of Aromatic Plants and Spices as a Strategy for Salt Reduction for Food and Cooking. Journal of Culinary Science and Technology, 22(5), 920–932. https://doi.org/10.1080/15428052.2022.2088435

Vieira, S. A., McClements, D. J., & Decker, E. A. (2015). Challenges of Utilizing Healthy Fats in Foods. Advances in Nutrition, 6(3), 309S-317S. https://doi.org/10.3945/an.114.006965

Vinitha, K., Leena, M. M., Moses, J. A., & Anandharamakrishnan, C. (2021). Size-dependent enhancement in salt perception: Spraying approaches to reduce sodium content in foods. Powder Technology, 378, 237–245. https://doi.org/10.1016/J.POWTEC.2020.09.079

Voedingscentrum. (n.d.-a). Eiwitten | Voedingscentrum. Retrieved April 14, 2026, from https://www.voedingscentrum.nl/encyclopedie/eiwitten.aspx

Voedingscentrum. (n.d.-b). Groente. Retrieved https://www.voedingscentrum.nl/encyclopedie/groente.aspx

Voedingscentrum. (n.d.-c). Koolhydraten. Retrieved https://www.voedingscentrum.nl/encyclopedie/koolhydraten.aspx

Voedingscentrum. (n.d.-d). Smaakversterkers. Retrieved https://www.voedingscentrum.nl/encyclopedie/smaakversterkers.aspx?enummer=326%20Kaliumlactaat

Voedingscentrum. (n.d.-e). Vetten. Retrieved https://www.voedingscentrum.nl/encyclopedie/vetten.aspx

Voedingscentrum. (n.d.-f). Vezels. Retrieved https://www.voedingscentrum.nl/encyclopedie/vezels.aspx

Voedingscentrum. (n.d.-g). Waarom is avocado gezond? Retrieved https://www.voedingscentrum.nl/nl/service/vraag-en-antwoord/gezonde-voeding-en-voedingsstoffen/waarom-is-avocado-gezond-.aspx

Voedingscentrum. (n.d.-h). Zout en natrium. Retrieved https://www.voedingscentrum.nl/encyclopedie/zout-en-natrium.aspx#blokwaar-zit-zout-(natrium)-in?

Vong, W. C., & Liu, S. Q. (2017). Changes in volatile profile of soybean residue (okara) upon solid-state fermentation by yeasts. Journal of the Science of Food and Agriculture, 97(1), 135–143. https://doi.org/10.1002/JSFA.7700;CTYPE:STRING:JOURNAL

Volksgezondheid en Milieu, R. (2021). Inname van vezel. In 2019-2021. https://www.wateetnederland.nl/resultaten/energie-en-macronutrienten/vezel

Walsh, S. K., Lucey, A., Walter, J., Zannini, E., & Arendt, E. K. (2022). Resistant starch—An accessible fiber ingredient acceptable to the Western palate. Comprehensive Reviews in Food Science and Food Safety, 21(3), 2930–2955. https://doi.org/10.1111/1541-4337.12955;CTYPE:STRING:JOURNAL

Wang, J., He, Z., & Raghavan, V. (2023). Soybean allergy: characteristics, mechanisms, detection and its reduction through novel food processing techniques. Critical Reviews in Food Science and Nutrition, 63(23), 6182–6195. https://doi.org/10.1080/10408398.2022.2029345

Wang, Q., & Xiong, Y. L. (2019). Processing, Nutrition, and Functionality of Hempseed Protein: A Review. Comprehensive Reviews in Food Science and Food Safety, 18(4), 936–952. https://doi.org/10.1111/1541-4337.12450

Wang, S., & Adhikari, K. (2018). Consumer perceptions and other influencing factors about monosodium glutamate in the United States. Journal of Sensory Studies, 33(4), e12437. https://doi.org/10.1111/JOSS.12437

Wang, Y., Kim, W., Naik, R. R., & Selomulya, C. (2023). Functionality of plant-based proteins. Engineering Plant-Based Food Systems, 79–96. https://doi.org/10.1016/B978-0-323-89842-3.00010-5

Wang, Z., Cao, Y., Fan, M., Woldemariam, K. Y., He, X., Fan, W., & Liu, Y. (2025). Synergistic improvement of hydrolyzed vegetable protein quality and flavor enhancement through multi-microbial fermentation and acid hydrolysis. LWT, 223, 117729. https://doi.org/10.1016/J.LWT.2025.117729

Warner, K. (1999). Impact of High-Temperature Food Processing on Fats and Oils (pp. 67–77). https://doi.org/10.1007/978-1-4615-4853-9_5

Wazir, M., Verma, H., Singh, J., Singh, P., & Passey, S. (2025). The Battle of Natural Sweeteners: A Comprehensive Guide to Monk Fruit and Stevia. In Current Research in Nutrition and Food Science (Vol. 13, Issue 1, pp. 24–45). Enviro Research Publishers. https://doi.org/10.12944/CRNFSJ.13.1.2

Weiner, M. L. (2016). Parameters and pitfalls to consider in the conduct of food additive research, Carrageenan as a case study. Food and Chemical Toxicology, 87, 31–44. https://doi.org/10.1016/J.FCT.2015.11.014

WHO. (2007). Protein and amino acid requirements in human nutrition. www.who.int/bookorders
Xie, X., Yu, L., Lin, Q., & Huang, D. (2024). Low-calorie d-allulose as a sucrose alternative modulates the physicochemical properties and volatile profile of sponge cake. Journal of Food Science, 89(10), 6296–6307. https://doi.org/10.1111/1750-3841.17340;WGROUP:STRING:PUBLICATION

Yan, R. R., Chan, C. B., & Louie, J. C. Y. (2022). Current WHO recommendation to reduce free sugar intake from all sources to below 10% of daily energy intake for supporting overall health is not well supported by available evidence. The American Journal of Clinical Nutrition, 116(1), 15–39. https://doi.org/10.1093/ajcn/nqac084

Yan, Y., Huang, X., Wang, X., Zhang, Y., Cui, H., Yu, J., Xia, S., & Zhu, H. (2024). Browning mechanism of sorbitol-glycine system in the presence of glycerol: Regulating conversion of sorbitol to reducing sugars and water status. Food Bioscience, 59, 103901. https://doi.org/10.1016/J.FBIO.2024.103901

Yang, S., Ma, X., Huang, Y., Lin, B., Zhang, L., Miao, S., Zheng, B., & Deng, K. (2024). Comprehensive Effects of Potassium Lactate, Calcium Ascorbate and Magnesium Chloride as Alternative Salts on Physicochemical Properties, Sensory Characteristics and Volatile Compounds in Low-Sodium Marinated Beef. Foods, 13(2), 291. https://doi.org/10.3390/FOODS13020291/S1

Yeung, A. W. K. (2023). Bibliometric analysis on the literature of monk fruit extract and mogrosides as sweeteners. Frontiers in Nutrition, 10, 1253255. https://doi.org/10.3389/FNUT.2023.1253255/BIBTEX

Yoshizane, C., Mizote, A., Yamada, M., Arai, N., Arai, S., Maruta, K., Mitsuzumi, H., Ariyasu, T., Ushio, S., & Fukuda, S. (2017). Glycemic, insulinemic and incretin responses after oral trehalose ingestion in healthy subjects. Nutrition Journal, 16(1), 1–6. https://doi.org/10.1186/S12937-017-0233-X/FIGURES/2

Zechner-Krpan, V., Petravić-Tominac, V., Panjkota-Krbavčić, I., Grba, S., & Berković, K. (2009). Potential Application of Yeast β-Glucans in Food Industry. Agriculturae Conspectus Scientificus.

Zeng, J., Hu, Y., Gao, H., Sun, J., & Ma, H. (2016). Fructooligosaccharides Impact on the Hydration and Retro-Gradation of Wheat Starch and Gel. International Journal of Food Properties, 19(12), 2682–2692. https://doi.org/10.1080/10942912.2015.1136937

Zhang, X., Wang, Q., Liu, Z., Zhi, L., Jiao, B., Hu, H., Ma, X., Agyei, D., & Shi, A. (2023). Plant protein-based emulsifiers: Mechanisms, techniques for emulsification enhancement and applications. Food Hydrocolloids, 144, 109008. https://doi.org/10.1016/J.FOODHYD.2023.109008

Zhao, H., Wang, L., Brennan, M., & Brennan, C. (2022). How does the addition of mushrooms and their dietary fibre affect starchy foods. Journal of Future Foods, 2(1), 18–24. https://doi.org/10.1016/J.JFUTFO.2022.03.013

Zhao, X., Zhang, X., & Liu, D. (2021). Collagen peptides and the related synthetic peptides: A review on improving skin health. Journal of Functional Foods, 86, 104680. https://doi.org/10.1016/J.JFF.2021.104680

Zheng, Y., Tang, L., Yu, M., Li, T., Song, H., Li, P., Li, K., & Xiong, J. (2021). Fractionation and identification of salty peptides from yeast extract. https://doi.org/10.1007/s13197-020-04836-1

Zhou, J., Lee, Y. Y., Mao, Y., Wang, Y., & Zhang, Z. (2022). Future of Structured Lipids: Enzymatic Synthesis and Their New Applications in Food Systems. Foods 2022, Vol. 11, Page 2400, 11(16), 2400. https://doi.org/10.3390/FOODS11162400

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