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Functional Foods and New Products

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Preface

This handout presents “Functional Foods and New Products”, a course designed for Master 2 students in Food Technology and Quality Control at Bouira University. The course, launched in 2017, combines theoretical lectures and practical projects, allowing students to develop new food products inspired by Algerian culinary heritage and the Mediterranean diet.

Students engage in hands-on experimentation, designing products for various consumer needs while applying scientific principles and functional ingredients. Due to limited laboratory facilities, many projects are conducted in home or university kitchens, fostering creativity and problem-solving.

The course emphasizes the preservation of traditional dietary knowledge, healthy nutrition, and sustainable practices. It also introduces students to scientific communication through written reports and oral presentations.

Ultimately, this course encourages the development of innovative, safe, and functional food products, promoting health benefits while respecting regulatory standards and providing economic opportunities.

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Chapter 1

Definition and Concepts

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1. **Introduction**

There are two primary categories of food: foods derived from eukaryotic cells, tissues, and organs, referred to as systemic foods which are digestible via endogenous mechanisms; and colonic foods, originating from prokaryotic cells within the intestinal microbiota, which are resistant to digestion yet fermentable. The human gut microbiota, composed of approximately 100 trillion microorganisms, plays a critical role in digestion by fermenting carbohydrates and putrefying proteins, as well as contributing to the synthesis of certain vitamins (notably B8, B12, and K).

The connection between the gut and the brain is continuous and bidirectional. The gut microbiota significantly influences immune function, given that 70–80% of immune cells are located in the intestinal tract. Additionally, the gut houses around 200 million neurons that maintain ongoing communication with the brain. Emerging research suggests that certain gut bacteria may affect mood and are linked to conditions such as depression. Surprisingly, depressive states may be associated with imbalances in gut flora, which supports the classification of the gut as the body's "second brain" due to its role in emotional regulation and stress management.

Functional foods have the potential to contribute positively to health and to prevent certain diseases, provided they are consumed as part of a balanced and varied diet. These foods offer health benefits beyond basic nutrition they may prevent nutrient deficiencies, support disease prevention, and promote proper growth and development.

Functional foods often include fortified options that address specific nutritional gaps (Ashwell, 2001).

Functional foods are not currently defined under European legislation. They are generally considered conventional food products intended to be consumed as part of a balanced and varied diet. These foods contain biologically active compounds that may promote health or reduce the risk of disease. They typically include products enriched with specific minerals, vitamins, fatty acids, dietary fibers, phytochemicals, antioxidants, or probiotics.

According to the Japanese definition, functional foods are those to which substances capable of regulating metabolism have been added such as antioxidant micronutrients, peptides, fibers, oligosaccharides, lactic acid bacteria, algae, etc.or from which potentially allergenic components have been removed. The concept of functional food originated in Japan in the 1980s, when governmental agencies began approving foods with scientifically validated health benefits, with the goal of improving public health at large.

According to the benchmark definition established by the International Life Sciences Institute (ILSI) in Europe, a functional food is defined as a food that, through the presence of a physiologically active ingredient, provides a health benefit beyond its basic nutritional functions.

Nevertheless, defining functional food remains problematic due to the wide range of foods involved, the variability of thresholds and limits, the lack of clear differentiation between naturally functional foods and those made functional, and the overall heterogeneity of the category.

At the Functional Foods Forum held in Strasbourg on December 1–2, 1998, it was declared that a food product may be rendered functional through one of five approaches:

1. **By removing a known or identified component** that has harmful effects on the consumer (e.g., allergenic proteins).
2. **By increasing the concentration of a naturally occurring component** in the food to levels capable of inducing beneficial effects:
    - Enhancement through a micronutrient to achieve a daily intake exceeding the recommended value (while remaining consistent with dietary guidelines for disease prevention);
    - Increasing the concentration of a non-nutritive component supported by scientific evidence for its beneficial effects.
3. **By adding a component normally absent** from the majority of food products, but whose beneficial effects have been demonstrated (e.g., non-vitamin antioxidants or prebiotic fructans).
4. **By substituting a component** typically a macronutrient whose excessive consumption is associated with adverse health effects (e.g., fat), with another component that has recognized health benefits (e.g., chicory-derived inulin).

5. **By improving the bioavailability** of existing food components, or by modifying them, to enhance their recognized beneficial effects.

The core concept of a functional food lies in the combination of a basic food matrix with a functional ingredient. These functional components may include essential fatty acids (omega-3 and omega-6), phytosterols, prebiotic dietary fibers, probiotics, vitamins, and minerals.

When discussing functional foods, several related terms frequently emerge:

- **"Nutraceutical"**: Refers to the bioactive element within a food that is extracted and offered in capsule or tablet form.
- **"Alimental-medicinal product" (in French, *alicament*)**: A portmanteau of "aliment" (food) and "médicament" (medicine), the term reflects a traditional medicinal perspective that attributes curative properties to certain foods; yogurt being one of the earliest examples due to its content of lactic ferments.
- **"Tonic food"**: Describes a food believed to restore normal levels of vitality, reduce fatigue, and promote recovery of health.
- **"Prebiotics"**: Non-digestible, short-chain polysaccharide food compounds that, upon being metabolized by gut microbiota, modulate the composition and/or functionality of the intestinal microbiome, thereby conferring physiological benefits to the host. Examples include inulin and oligofructose, which may help prevent colorectal cancer.
- **"Probiotics"**: Also referred to as live microbial supplements or ferments, these are viable microorganisms that, when ingested in adequate amounts, exert a beneficial effect on the host by improving intestinal microbial balance. Lactobacilli, for instance, aid in compensating for lactase deficiency, help prevent colon cancer, and reduce blood cholesterol levels.

2. Categories of functional foods

Contemporary consumers are increasingly seeking more than mere nutritional value in the foods and beverages they consume. According to a study conducted by FlavorSum investigating consumer interest in and expectations for functional food products, approximately two-thirds of American consumers and three-quarters of Canadian consumers express a desire for their food and beverage choices to contribute to specific health goals.

There are several categories of food and drink that may provide additional health benefits. However, the most popular functionalities are those that pose the fewest barriers to

consumer trial. Functional foods deliver key nutrients that may help protect against disease, especially due to their high antioxidant content (Diplock et al., 1999). These molecules help neutralize harmful compounds known as free radicals, thereby preventing cellular damage and reducing the risk of chronic diseases such as cardiovascular disorders and cancer.

2.1. Cereal-based bakery products

Consumers increasingly demand gluten-free or allergen-free products, but they also associate cereal-derived dietary fiber with digestive and cardiovascular health. Cereal-based baked goods also serve functional purposes in promoting energy, enhancing physical performance, and supporting weight management.

2.2. Non-dairy cold beverages

Some consumers' associate non-dairy cold beverages often characterized by citrus, melon, or spiced flavor profiles with immune support or pain relief, presenting a promising avenue for innovation. Additionally, spiced, playful, and sweet flavor notes are often linked to enhanced energy and alertness.

2.3. Confectionery

For some individuals, there is a perceived link between sweets and cognitive health or pain relief. Products such as chocolate, gummies, and hard candies are naturally associated with mood enhancement and emotional well-being. The versatility of confectionery products allows them to adapt to a wide variety of flavor profiles and consumer preferences.

2.4. Milk-based (or dairy alternative) beverages

Consumers generally agree that dairy-alternative beverages may support weight control, cardiovascular health, relaxation, and the maintenance of hair and nail health.

2.5. Hot beverages

Hot drinks such as tea, coffee, and hot chocolate are considered potential vehicles for enhancing mood, boosting energy, promoting relaxation, and increasing alertness. Producers can connect with consumers by offering a range of flavor profiles, although pleasure and enjoyment remain the most cited benefits.

2.6. Ice cream and frozen desserts

Within the category of functional frozen desserts, consumers seek lactose-free options and digestive health benefits. These sweet, cold treats are also associated with emotional wellness and improved mood.

2.7. Yogurt

Natural yogurt is commonly associated with weight management and the health of skin, hair, and nails. Like ice cream, yogurt provides a versatile base that pairs well with a wide variety of flavor profiles. For lactose-free yogurt, consumers tend to favor flavors that are fun, playful, spiced, or botanically inspired.

Identifying the specific health benefits and flavor profiles consumers seek in functional foods is only one aspect of new product development. It is also essential to incorporate health-promoting ingredients that are either already familiar to consumers or introduced in a way that clearly communicates their functional value.

Among more than 24 scientifically evaluated ingredients, only the benefits of common ingredients such as fiber and protein are widely recognized by consumers. Other functional components, including antioxidants, caffeine, and melatonin, are known to a lesser extent.

Here is what consumers say when asked to associate specific ingredients with functional benefits:

- Among the ingredients that boost the immune system are antioxidants, ginger, and turmeric.
- For cardiovascular health, consumers look for omega 3-6-9 or antioxidants.
- Brain health is also linked to omega 3-6-9 and Ginkgo biloba.
- The main ingredients cited for digestive health are fiber and *Lactobacillus bulgaricus* (probiotics/prebiotics).
- For an energy boost, consumers turn to two main functional ingredients: caffeine and proteins.
- People seeking a feeling of relaxation look for ingredients such as melatonin and lavender.
- Ingredients with anti-inflammatory properties include turmeric, Indian saffron, and antioxidants.
- Collagen, curcumin, and omega 3-6-9 are believed to promote joint health.
- Longevity or anti-aging is associated with collagen and antioxidants.

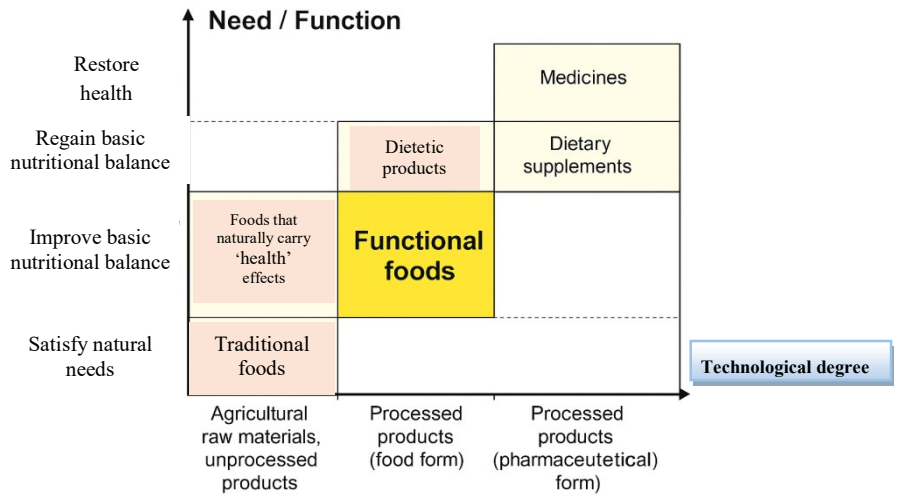
- Finally, alertness is primarily supported by caffeine, although two out of ten consumers mentioned nootropics as an ingredient likely to produce results.

To increase consumer acceptance of innovative products containing less familiar ingredients, it may be necessary to provide additional information through packaging, messaging, or advertising.

For instance, one-quarter of consumers do not naturally associate spices such as saffron or cinnamon with functional benefits. Furthermore, approximately 20% of consumers are unfamiliar with the functional roles of L-theanine, nootropics, turmeric, or *Streptococcus thermophilus*.

3. Positioning of functional foods

Functional foods have beneficial health effects that go beyond basic nutritional properties. The bioactive components they contain promote health and well-being and contribute to reducing the risk of certain chronic diseases related to metabolic syndrome.



Source: 12th Conference of the International Association of Strategic Management, 2002

Figure 1: Positioning of functional foods according to need and technological level

3.1. Traditional foods

Substances which, when ingested by a living organism, are capable of ensuring its maintenance, growth, and meeting its energy requirements.

3.2. Health foods

This category includes all foods that have a health effect, either in terms of prevention by reducing risks, or in terms of balancing micronutrients. According to Figure 1, this includes:

- Dietary supplements
- Dietetic foods
- Functional foods

3.3. Dietary supplements

Products intended to be ingested in addition to the regular diet in order to compensate for actual or presumed deficiencies in daily intake.

They are capsules, pills, or edible substrates containing vitamins, minerals, and other types of ingredients.

Dietary supplements are subject to their own regulations but also fall under the regulation concerning claims. However, therapeutic claims are strictly reserved for medicines. Therefore, such claims cannot be used for dietary supplements. Only health claims may be used, provided that manufacturers comply with the conditions of use in accordance with European regulations.

3.4. Dietetic foods

Foods tuffs intended for special dietary use:

- That are clearly distinguishable from regular foodstuffs due to their particular composition or the specific processes used in their manufacture;
- That are suitable for a declared nutritional objective;
- That are marketed in a way that indicates they meet this objective.

3.5. Functional foods

Natural food to which a component has been added, or foods in which the bioavailability of one or more components has been increased, or a combination of these cases.

3.6. Medicines

Substances or compositions that possess curative or preventive properties with respect to human or animal diseases.

4. Development strategy for functional foods

The development strategy of a functional food involves several critical and interdependent phases, ranging from the identification of bioactive compound to market introduction. This approach relies on both solid scientific foundations and a thorough understanding of regulatory requirements and consumer expectations.

4.1. Identification of the Bioactive Compound

Identifying a natural compound, such as polyphenols found in red fruits and their antioxidant activities (Zhu *et al.,* 2023), or a derived compound, such as bioactive peptides from pea proteins with antihypertensive effects (Wang *et al.,* 2024), that exerts potential health benefits beyond its basic nutritional value constitutes the first step. This stage is based on methodological approaches including:

• **Phytochemical screening**: UHPLC-MS and GC-MS techniques used to isolate and quantify bioactive molecules.

• **In silico modeling**: prediction of interactions between the compound and biological targets.
• **Bioactive compound databases** (e.g., FoodBioactives DB).

4.2. Biological Validation (in vitro / in vivo)

To validate the biological effects of a bioactive compound in a whole organism, its biological activity must first be assessed in vitro using cellular or enzymatic models through:

• Antioxidant assays (DPPH, FRAP)

• Modulation of inflammatory pathways (NF-κB, COX-2)

• Impact on gene expression

Subsequently, these effects are evaluated in vivo using animal models (rats, mice) for validation, with monitoring of biomarkers (inflammation, lipids, glucose) and preliminary toxicological studies. Examples include studies on the anti-inflammatory effects of curcumin extracts in murine models of colitis, as well as the impact of resistant fibers on gut microbiota modulation in obese mice (Martinez *et al.,* 2023; Lee *et al.,* 2024).

4.3. Clinical trials

To evaluate the effects of functional ingredients or bioactive compounds in humans, clinical trials are conducted under controlled conditions. These trials ensure safety, efficacy, and large-scale validation according to randomization criteria, as demonstrated in recent studies such as Smith *et al.,* (2025) on the effects of prebiotics on the human microbiota. They are typically performed using a double-blind design and with appropriately defined sample sizes.

Common outcome measures in clinical trials include physiological parameters (blood glucose, cholesterol), inflammatory biomarkers, and quality of life. An example is the study conducted by Nguyen *et al.,* (2024) on the impact of plant-derived omega-3 on cardiovascular health.

4.4. Technological formulation

Different techniques are used during the formulation of functional foods, such as encapsulation (microparticles, nanoemulsions), including the application of protein-based nanoemulsions for polyphenols (Li *et al.,* 2024), microencapsulation by spray-drying, and controlled release within the gastrointestinal tract. These approaches aim to ensure the stability and bioactivity of the functional ingredient.

Microbiological safety can also be ensured through fermentation processes, which enhance the bioavailability of bioactive compounds (Garcia *et al.,* 2023), particularly in the case of probiotics, while also improving the palatability of the food product.

However, several challenges are associated with these techniques, including matrix–ingredient interactions, process compatibility, and the preservation of biological activity after processing.

4.5. Regulatory validation

Several international organizations, such as the European Food Safety Authority (EFSA), the Food and Drug Administration (FDA), and the Codex Alimentarius Commission, work to ensure compliance with national and international standards for functional foods prior to their market introduction.

The main aspects evaluated include product safety, the collection of robust scientific evidence supporting health claims, and the control of labeling and authorized statements.

Examples of regulatory frameworks include Regulation (EU) 2015/2283 on novel foods, as well as EFSA-approved health claims (e.g., cardiovascular health, digestive function, etc.).

4.6. Market positioning

Recent trends, including the rapid growth of fiber- and probiotic-enriched foods (Global Functional Foods Market, 2024) and the increasing consumption of plant-based products, require market segmentation to define product uniqueness and establish an effective communication strategy in order to create a competitive advantage.

To achieve this, several strategic axes are considered when developing a functional food according to consumer needs and target groups, including digestive health, cardiovascular health, anti-aging, and weight management.

The main tools used to position a functional food in the market include:

- SWOT analysis
- Consumer marketing studies
- Trend assessment (personalized nutrition, clean label)

Chapter 2

Novel Food Products

In this chaptere

1. Regulation of functional foods
2. Exploitation of Genetics
3. Emerging Technologies
4. Fourth-Range Products (Minimally Processed Fresh Products)
5. Innovative Meat Products
6. Reduced Products

1/ The regulation of functional foods

The potential problem with functional foods lies in certain terms that do not have formal definitions approved by the U.S. Food and Drug Administration (FDA), such as “natural,” “net carbohydrates,” or “functional food,” although many claims found on food and beverage packaging including “low in sodium” and “low in fat” are used by companies. It should be noted that some statements are vague and may be misleading, such as “an added ingredient may relieve mental and physical stress.” Many functional foods use health claims due to the presence of ingredients that have not been rigorously studied in humans to generate solid data that justify them.

Another often overlooked factor is that studies frequently use high concentrations or forms of an ingredient that are not found in foods, such as the amount of a nutraceutical like turmeric added to a food or beverage, which remains lower than the amount studied, but may be available in supplement form. In other cases, care must be taken not to consume too much of a given ingredient. For example: fibers such as inulin or chicory, which are now commonly added, can cause stomach discomfort, especially bloating and gas.

It is important to know what the products offer depending on the specific needs of each individual; in other words, there is no universal need for functional foods. And just because a food is functional does not mean it is necessarily healthy. A food may contain added omega-3s and also be high in sugar, sodium, saturated fats, or calories.

Let us not forget that by nature, functional foods tend to be processed, which increases the likelihood that they contain other additives that are not so good for health. Ultra-processed foods, including sodas, sweetened cereals, baked goods, and packaged snacks, are often associated with obesity, high blood pressure, high cholesterol, and certain cancers. Although functional foods can also fit into a balanced diet, they are not panaceas and will not compensate for poor health habits or existing health problems.

The commercialization of functional foods requires the use of claims in accordance with regulations, which serves as a safeguard to ensure consumer protection and information. The regulations applicable to health foods are based on two fundamental requirements: not misleading the consumer, and not encroaching on the domain of medicine, if one wishes to remain in the category of foodstuffs. As foodstuffs, functional foods are subject to rules relating to safety, labeling, presentation, and civil liability. They are also subject to more specific legislation. The multiplicity of these regulations creates difficulties, and their implementation sometimes lacks coherence.According to EU Directive No. 13 of 2000, it is prohibited to attribute preventive, curative, or healing properties to foodstuffs. Regulation

(EC) No. 1924/2006 defines a claim as “any message or representation, not mandatory under Community or national legislation, including a representation in the form of images, graphics or symbols, in any form, which states, suggests, or implies that a food has particular characteristics.”

The so-called “generic functional claims” under Article 13 first paragraph, of this regulation concerning nutrition and health claims relate to the role of a nutrient or other substance in growth, development, and body functions (psychological and behavioral functions), weight loss and weight control, satiety, or the reduction of the energy value of the diet. They do not concern child development or health, or the reduction of disease risk.EFSA has compiled references relating to approximately 3,300 health claim entries into consolidated reference lists. Due to their large number, the compilation includes all references submitted for the main entries of health claims that the European Commission had asked EFSA to evaluate as a priority. EFSA’s scientific assessments help ensure the validity and accuracy of claims made in the context of food labeling and advertising relating to nutrition and health, and help consumers make healthy dietary choices. Claims are based on two principles: no food shall be described or presented in a way that is false, misleading, deceptive, or likely to create a mistaken impression about its nature; and the person marketing the food must be able to justify the claims made.

Under the label of functional foods, four main categories of claims can be distinguished, as shown in Figure 2 below.

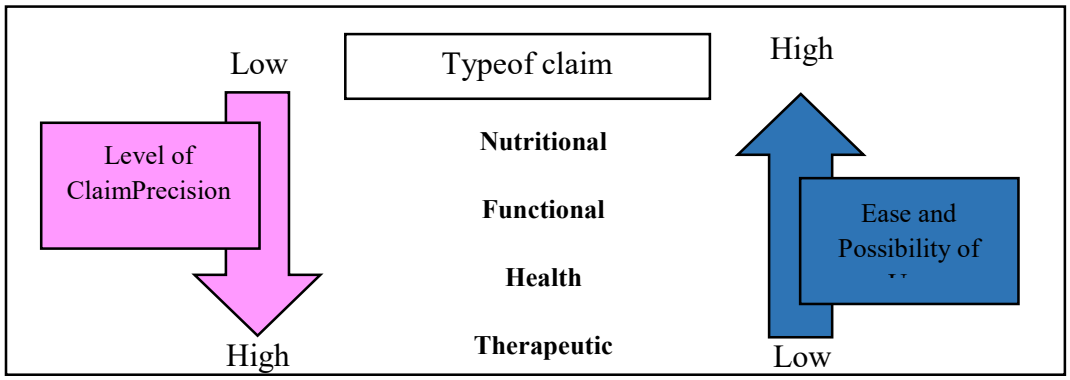


Figure 2: The level of use of the different types of claim.

1.1/ Nutritional claim

It is quantitative and asserts that a food product possesses specific beneficial nutritional properties due to the energy or nutrients it provides, to a lesser, greater, or unchanged extent. Only the nutritional claims listed in the Annex of Regulation (EC) No. 1924/2006 may be used, provided they comply with the conditions established in the Regulation [1]. If all of these claims are naturally met by the product without addition or removal during production, they must be accompanied by the term “naturally”; for example: “naturally high in fiber.”

Examples of nutritional claim statements include: “no added salt,” “high in protein,” “source of magnesium,” etc.

1.2/ Functional claim

It describes the effects of a nutrient on the normal functions of the body. An example would be: “Calcium strengthens bones.”

1.3/ Health claim

A health claim is considered to be any message or representation that is not mandatory under legislation, which states, suggests, or implies a relationship between a food or one of its components and health [1]. It describes the improvement of a function in a way that is beneficial to health.

Regulation (EC) No. 1924/2006 distinguishes between three types of health claims, each subject to distinct procedures and provisions:

A. Claim referring to the reduction of a risk factor in the development of a disease (Article 14.1.a)

Example: “Barley beta-glucan has been shown to lower/reduce blood cholesterol levels. High cholesterol is a risk factor in the development of coronary heart disease.”

B. Claim referring to children's development and health (Article 14.1.b)
Example: “Calcium is needed for normal growth and development of bone in children.”

C. Claim other than those listed above (Article 13): relates to the role of a nutrient or other substance in:

- Growth, development, and the functions of the body
- Psychological and behavioralfunctions
- Weight loss, weight control, reduction of hunger, increased satiety, or reduction of the energy content of the diet

Example: “Vitamin C contributes to the normal function of the immune system”

1.4/ Therapeutic claim

In the message of this claim, the food product is presented as possessing properties for the prevention, treatment, or cure of a disease. It should be noted that there is no specific legal status for such claims, and differences exist across European legislation. For example, under French law, which is very strict, this type of claim is prohibited.

As an example of a therapeutic property in a claim aimed at individuals with high cholesterol, one might cite: “Lowers blood cholesterol levels.”

The use of such claims has been regulated since July 1st, 2007. Only certain nutritional and health claims are authorized. Therapeutic claims, on the other hand, are prohibited. According to the opinion issued in 1998 by the French National Food Council, the following principles are considered essential for guiding decisions on claims:

- The goal of avoiding the “medicalization” of food should be pursued;
- Information made available to consumers, especially labeling claims, must be clear and understandable;
- The development of claims must not create the impression that “miracle products” exist;
- The use of health claims must be verifiable and effectively monitored within the framework for combating misleading advertising;
- Freedom of commerce and industry must be safeguarded;
- Consumers’ ability to make clear and autonomous choices must be guaranteed by the overall system.

2. Exploitation of Genetics

The exploitation of genetic approaches has become a major lever for improving nutritional quality, food safety, and the sustainability of food systems. Advances in plant and animal biotechnology make it possible to enhance micronutrient content, improve lipid and protein composition, and develop products tailored to the nutritional needs of populations. These strategies rely on conventional breeding, molecular genetics, and synthetic biology to address global challenges related to food security and malnutrition.

2.1/ Biofortification

Biofortification is a strategy aimed at increasing the concentration of essential micronutrients (iron, zinc, vitamin A, folates, etc.) in staple crops to combat nutritional deficiencies, often referred to as "hidden hunger." It can be achieved through conventional breeding, marker-assisted selection, or modern biotechnological approaches (Bouis and Saltzman, 2017).

Recent programs have improved provitamin A content in maize, iron and zinc levels in wheat, and protein quality in legumes. Current research increasingly integrates biofortification with genome editing technologies to accelerate crop nutritional improvement. Targeted enhancement of nutrients such as iron and folates represents a promising approach to reducing global micronutrient deficiencies (Garg, *et al.,* 2023).

2.2/ Genome Editing (CRISPR)

Genome editing technologies, particularly the CRISPR-Cas9 system, have revolutionized genetic improvement in crops and food products. Unlike traditional transgenic approaches, CRISPR enables precise modifications in DNA to improve agronomic and nutritional traits, such as stress resistance, nutrient content, and protein or lipid quality (Jaganathan, *et al.,* 2023).

These tools are currently applied to major crops such as rice, wheat, maize, and oilseeds, targeting genes involved in nutrient metabolism and fatty acid biosynthesis. This approach contributes to strengthening global food security in the face of population growth and climate constraints.

2.3/ Omega-3 Enriched Animal Products

The enrichment of animal-derived products with omega-3 fatty acids is an important nutritional strategy to improve food quality (Calder, 2023). This can be achieved through dietary modification (e.g., flaxseed, algae, or marine oils) or genetic selection to enhance fatty acid deposition in animal tissues.

Omega-3 enriched eggs, milk, and meat contribute to improving dietary lipid balance and reducing the risk of cardiovascular diseases. These innovations are part of a broader functional nutrition approach aimed at preventing metabolic disorders.

3. Emerging technologies

Emerging technologies in the food sector play a crucial role in processing, preservation, and enhancement of the nutritional and functional properties of foods. They aim to maintain sensory quality while ensuring microbiological safety and the stability of bioactive compounds.

3.1/ Extrusion cooking

Extrusion cooking is widely used in the food industry for mixing, texturizing, and rapid thermal processing of food products. This process involves high temperature and short time treatment, allowing enzyme inactivation and microbial reduction while preserving a significant portion of nutrients. Recent studies indicate that extrusion can also enhance the bioavailability of bioactive compounds, such as polyphenols and dietary fibers, by modifying plant cell structures (Kumar, *et al.,* 2025)..

3.2/ High Hydrostatic Pressure (HPP)

High hydrostatic pressure is a non-thermal food processing technology that applies high pressure to inactivate microorganisms while preserving nutritional and sensory qualities. It also modifies protein structures and improves textural properties.

This technique is particularly used for fruit juices, dairy products, and ready-to-eat foods, as it extends shelf life without altering taste or color (Mazri *et al.,* 214).

3.3/ Encapsulation

Encapsulation involves entrapping bioactive compounds within a protective matrix to improve their stability, bioavailability, and resistance to environmental or digestive conditions. Food-grade polysaccharides such as alginate, pectin, and maltodextrin are commonly used as wall materials to stabilize active compounds and enable controlled release.

This technology is widely applied for incorporating vitamins, probiotics, and polyphenols into functional foods (Siqueira de Oliveira, *et al.,* 2025).

3.4/ Nanoemulsions

Nanoemulsions are colloidal systems characterized by nanoscale droplets that enhance the solubility and bioavailability of lipophilic compounds such as vitamins and antioxidants. They are also used as delivery systems in functional foods and nutraceuticals.

Recent research highlights their ability to improve the stability of sensitive ingredients and facilitate their absorption in the human body (Alam, *et al.,* 2023).

3.5/ Sous-vide cooking

Sous-vide cooking involves cooking food at low temperatures in vacuum-sealed packaging. This method preserves sensory qualities, nutrients, and texture while minimizing losses associated with conventional cooking. It is widely used in modern gastronomy and in the production of ready-to-eat foods.

4. Fourth-Range Products (Minimally Processed Fresh Products)

Fourth-range products include fresh fruits and vegetables that are washed, cut, and packaged for immediate consumption. These products meet consumer demand for healthy, convenient, and minimally processed foods while retaining their nutritional properties.

4.1/ Microbiological safety

A major challenge for these products is controlling microbial contamination. Washing, disinfection, modified atmosphere packaging, and non-thermal technologies are used to limit the growth of pathogenic microorganisms.

4.2/ Cold chain management

Strict cold chain management is essential to maintain product quality and safety. Temperature abuse can lead to rapid microbial growth and deterioration of sensory and nutritional properties (Zhang, *et al.,* 2024).

5. Innovative meat products

Innovations in meat products aim to address environmental, nutritional, and ethical concerns associated with conventional meat consumption.

5.1/ Plant-based substitutes

Plant-based meat alternatives are produced from plant proteins (soy, pea, wheat) and mimic meat texture and flavor using technologies such as high-moisture extrusion (Kyriakopoulou, *et al.,* 2023). These products are rapidly expanding due to the growing demand for sustainable diets.

5.2/ Cultured meat

Cultured meat is produced from animal cells grown in bioreactors. This technology aims to reduce the environmental impact of livestock production and improve animal welfare. It represents one of the most significant innovations in modern food biotechnology.

5.3/ Nitrite reduction strategies

Nitrites are traditionally used in processed meats for their antimicrobial properties and role in color stabilization. However, due to potential health risks, research is focused on natural alternatives such as plant extracts rich in nitrates and innovative processing technologies.

6. Reduced products

Reduced products are developed to address metabolic diseases such as obesity, diabetes, and cardiovascular disorders.

6.1/ Sugar reformulation (Polyols and Sweeteners)

Sugar reformulation aims to reduce simple sugar content while maintaining sensory properties. Polyols (xylitol, sorbitol, maltitol) and high-intensity sweeteners are commonly used to lower caloric intake while preserving sweetness.

6.2/ Fat reformulation strategies

Fat reduction can be achieved through lipid substitutes, structured emulsions, and advanced formulation techniques that preserve texture and palatability (Chazelas, *et al.,* 2023).

Chapter 3

Metabolic syndrome, Probiotics and Prebiotics

In this chapter

1- Life factors related to metabolic syndrome
2- Metabolic syndrome consequences
3- Oxidative stress
4- Antioxidants
5- Probiotics
6- Prebiotics
7- Synbiotics and Postbiotics
8- Regulatory Status
9- Perspectives and nutritional challenges

1/ Life factors related to metabolic syndrome

Metabolic syndrome corresponds to the coexistence of several metabolic disorders, including three of the five factors in the same individual. They arecentralor abdominal obesity, hyper triglyceridemia, low High-Density Lipo protein cholesterol (HDLc), hyperglycemia and the elevated blood pressure (Eckel, 2015). According tothe IDF harmonisation consensuscriteria in 2009, the metabolic syndrome diagnostic is made when at least three of the following five criteria are present : abdominal obesity (correspondinga waistlinemore than or equal to94 cm for men and 80 cm for women), a triglyceridémiamore than or equal to 1,50 g/l (or 1,7mmol/l) and/or aspecific lipid-lowering treatment taking; an HDL-cholestérol levelless than or equalto 0,40g/l (1,03 mmol/l) formenand 0,50 g/l (1,29 mmol/l) for womenand/ora specific lipid-lowering treatment taking; a blood pressure more than or equal to 130/85 mmHgorahigh blood pressure (HTA) in treatment;a high blood sugar, more than or equal to 1 g/l (5,6 mmol/l) or an antidiabetic treatment taking.

The metabolic syndrome has been the subject of various definitions over the past 10 years. It is aclinical and biologicalentity recognizedby the World Health Organisation (WHO) in 1998, the National Cholesterol Education Program-Adult Treatment Panel III (NCEP-ATP III) in 2001 (NCEP, 2002), the International Diabetes Federation (IDF) in 2005 (Alberti *et al.,* 2005), then theIDF in 2009 harmonisation consensus (Alberti *et al.,* 2009). Its prevalencedependson age, the population ethnicoriginand especially the diagnostic criteria presented. It variates between 17,9 and 80% within the diabetic population (André*et et al.,* 2007, Kelliny *et al.,* 2008).

2/ Metabolic syndrome consequences

Metabolic syndrome, considered a cardiovascular risk factor, represents a major public health issue. It increases the already high risks in diabetic patients. Apart from hyperglycemia, hypertension is the most frequently observed component of metabolic syndrome, followed by hypoHDLemia, abdominal obesity, and hypertriglyceridemia in both sexes. Other cardiovascular risk factors associated with diabetes include dyslipidemia, followed by overweight or obesity, albuminuria, and smoking. Overweight or obesity is the cardiovascular risk factor most significantly correlated with metabolic syndrome (Sitraka *et al.,* 2020).

The association of other factors such as metabolic syndrome further increases vascular risk in diabetic patients who are already at high risk. Moreover, diabetes is the leading cause of cardiovascular mortality (ADA, 2010). The risks of cardiovascular disease (figure 3) and death associated with metabolic syndrome are multiplied by 1.7 and 1.3, respectively (UKPDS, 1998; Gami *et al.,* 2007).

The rise in obesity and diabetes, the exponential increase in the prevalence of metabolic síndrome which is recognized as a major cardiovascular risk factorpromotes the development of atherosclerosis and endothelial dysfunction. Metabolic syndrome is also associated with a prothrombotic and pro-inflammatory state (Shaw, 2006).

The prevalence of metabolic syndrome is very high among the diabetic population (Alexander et *al.,* 2003). Individuals with metabolic syndrome are three to five times more likely to develop type 2 diabetes, and hyper glycemia it self is one of the components of metabolic syndrome (Alexander *et al.,* 2003; Shin *et al.,* 2013). This highlights the importance of systematically screening for metabolic syndrome in patients with type 2 diabetes, as well as managing the various cardiovascular risk factors through education, proper dietary monitoring, adequate physical activity, andpharmacological treatmentto reduce the impact of metabolic syndrome in individuals with type 2 diabetes and decreasing the associated cardiovascular risks and complications.

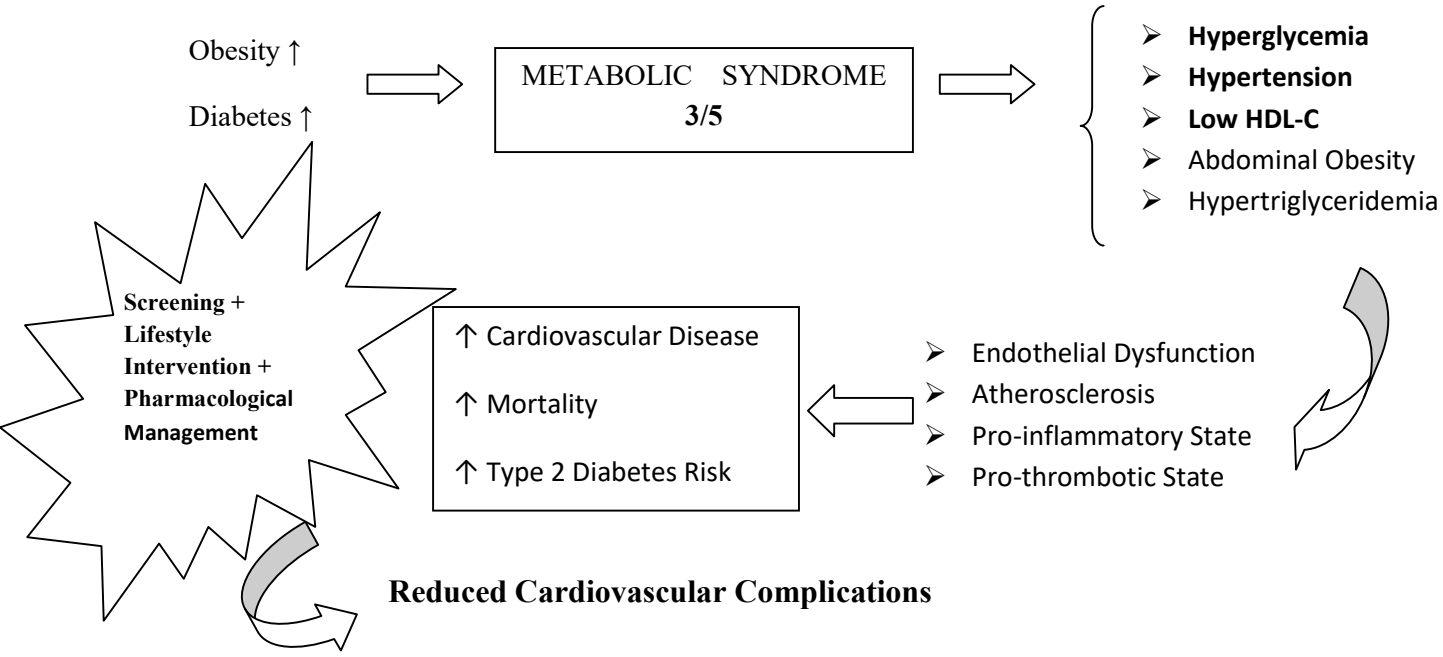


Figure 3: Metabolic Syndrome: A Major Cardiovascular Risk Factor in Type 2 Diabetes

3/ Oxidative stress

Oxidative stress happens when the balance between free radicals and antioxidants is disrupted in favor of cellular metabolism byproducts, it corresponds to an excess of highly reactive molecules relative to the available antioxidants in the body. There are two types of free radicals: endogenous, generated during energy production by mitochondria, and exogenous, resulting from stress, fatigue, intense physical exercise, tobacco and alcohol consumption, air pollution, ionizing radiation, etc.

Oxidative stress corresponds to cells damage caused by free radicals, which a significant portion of have reactive oxygen species (Figure 4), these can be produced by various factors such as pollution, unbalanced diet, modern life stress, smoking, alcohol, medications, sun exposure, pollution, intense physical activityor, conversely, sedentary behavior, inflammation and a weakened immune system, etc. They can attack DNA, disrupting replication and causing mutations and cancer; damage proteins, leading to rheumatoid arthritis; peroxidize lipids, causing atherosclerosis; and oxidize cellular carbohydrates, resulting in diabetes complications. Prolonged and repeated excess of free radicals leads to irreversible damage with inflammatory and degenerative processesat the cellular level by cell death, at the tissue level by arterial hardening, cardiovascular problems, and collagen degradation.Free radicals are a group of highly unstable and particularly toxic molecules at the cellular level, as they destabilize other molecules by stealing electrons. The three most well-known free radicals, as shown in Figure 4 and table I, are the superoxide anion (O_2^-), the hydroxyl radical (OH^-), and hydrogen peroxide (H_2O_2) (Milbury and Richer, 2008; Sebbar *et al.,* 2023).

Table I : Main Reactive Oxygen Species (ROS)

ROS	**Chemical Formula**	**Characteristics**
Superoxide anion	O_2-	Primary ROS generated during mitochondrial respiration
Hydrogen peroxide	H_2O_2	Relatively stable ROS that can generate more reactive species
Hydroxyl radical	OH	Most reactive and damaging ROS
Peroxyl radicals	ROO	Involved in lipid peroxidation
Singlet oxygen	$^1O_2$	Highly reactive oxygen form

Oxidative stress is a silent threat that causes accelerated aging of cells by altering their genetic code, potentially initiating cancerous transformations and increasing the risk of serious diseases such as Parkinson's disease, Alzheimer's disease, diabetes, fibromyalgia, sleep apnea syndrome, arthritis, allergies, and more (table II). To decrease and understand its harmful effects, it is essential to determine the level of chemical oxidation undergone by our bodies.

To assess and monitor oxidative stress level in the body, a blood testcalled oxidative stress profileis essential. This test provides an objective measurement of oxidative stress and can serve as a tool for assessing well-being and taking preventive measures. The oxidative stress profile includes the evaluation of various markers related to oxidative stress, such as levels of free radicals, antioxidant enzymes, and cellular damage.

Table II : Biological Targets and Consequences of Oxidative Stress

Target Molecule	**Oxidative Damage**	**Possible Consequences**
DNA	Mutations, strand breaks	Cancer, accelerated aging
Proteins	Structural alteration, enzyme inactivation	Arthritis, cellular dysfunction
Lipids	Lipid peroxidation	Atherosclerosis, cardiovascular diseases
Carbohydrates	Glycoxidation	Diabetic complications
Cell membranes	Loss of integrity	Cell death

Completely eliminating oxidative stress is impossible. Instead, maintaining a balance is key, as free radicals are essential for certain vital functions of the body and antioxidants. However, there are ways to prevent and reduce its impact by adopting a balanced diet rich in natural antioxidants and by ensuring the intake of nutrients that neutralize free radicals, such as trace elements.Among these trace elements is selenium, found in complete cereals, garlic, wheat germ, onions, and broccoli. Selenium acts as an enzymatic antioxidant activator. It is a component of selenoproteins, which have important enzymatic functions. As a cofactor for selenium-dependent glutathione peroxidases, it helps maintain cell membrane integrity by limiting oxidative damage to lipids, lipoproteins, and DNA. Other essential trace elements include copper, manganese, and zinc, which serve as cofactors for the antioxidant enzyme superoxide dismutase. Zinc, found in meat, eggs, dairy products, cereals, and oysters, has photoprotective functions, is essential for wound healing, and helps maintain skin elasticity through its role in the synthesis of collagen and keratin. It also plays a role in cell growth and division.

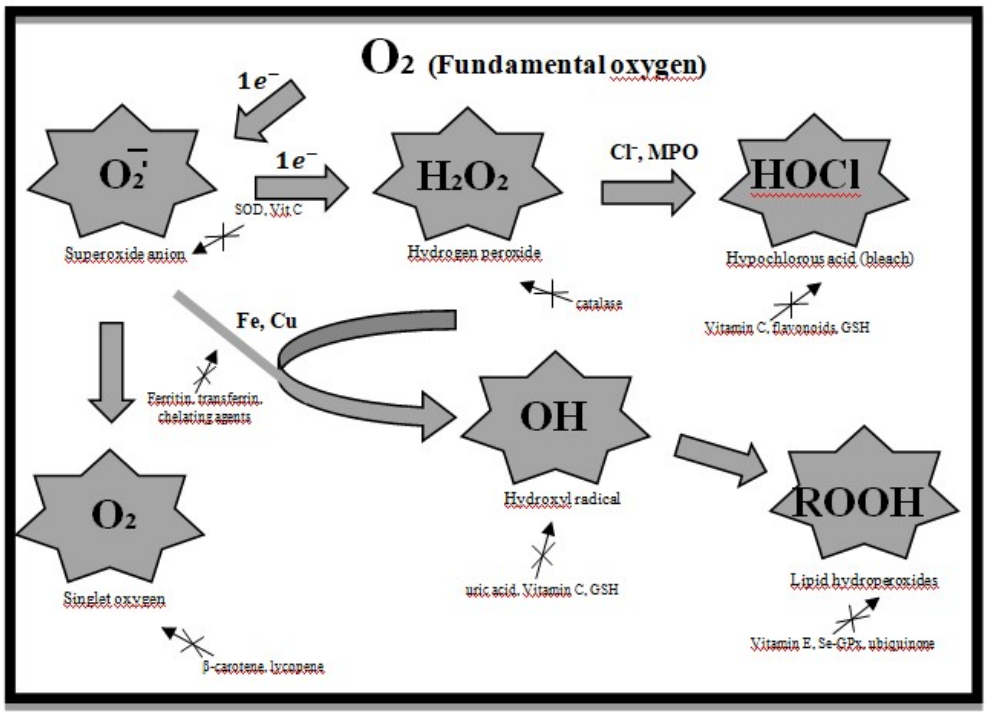


Figure 4: Regulation of reactive oxygen species production by antioxidant defense systems (MILBURY and RICHER, 2008).

4/Antioxidants

Oxidation is the process that causes metals to rust, vegetables and fruits to wilt, and fats to become rancid. It alters the taste and color of food.

Each antioxidant molecule can only react with a single free radical. Therefore, it is essential to constantly replenish antioxidant resources. Antioxidants are found in our enzymatic system and rely on cofactors such as copper (Cu), manganese (Mn), magnesium (Mg), zinc (Zn), selenium (Se), and vitamins; vitamin E or tocopherol: is a fat-soluble vitamin that protects unsaturated fatty acids, proteins, and DNA from oxidation. It is found in sunflower oil, walnut oil, peanut, sesame, olive oil, almonds, kale, salsify, and bell peppers.… vitamin C or ascorbicacid,is a water-soluble vitamin that works in synergy with vitamin E. It stimulates collagen synthesis, which prevents transcutaneous water loss and body cannot synthesize it. Beta-carotene or provitamin A offers protective effects against UV rays. A deficiency may cause dry skin and thickening of the stratum corneum. It is essential for cell growth and skin integrity. It is found in carrots, apricots, tomatoes, bell peppers, and spinach.Polyphenols and flavonoids help neutralize and trap free radicals, combat cellular aging, and protect cells from damage caused by oxidative stress and macromolecule oxidation. They play a key role in maintaining the balance between free radicals and the body's defenses by strengthening the immune system and fighting fatigue.Some antioxidants are produced endogenously by the body, while others must be obtained through food. Nutritional intake of antioxidants is central to maintaining good health. These include vitamins, trace elements, and micronutrients (Sebbar *et al.,* 2023). Therefore, adopting a balanced diet rich in natural antioxidants is essential to prevent oxidative stress and maintain good health. Colorful fruits and vegetables, nuts, seeds, and legumes are excellent sources of antioxidants.It is also important to consume a diverse range of foods to benefit from a wide range of exogenous antioxidants with different properties, such as vitamins C and E, carotenoids, ubiquinone (coenzyme Q_{10}), flavonoids, glutathione, and lipoic acid, in addition to endogenous antioxidants such as enzymes (superoxide dismutase, glutathione peroxidase, catalase), proteins (ferritin, transferrin, ceruloplasmin, albumin), and systems that repair oxidative damage like endonucleases. Trace elements such as selenium, copper, manganese, and zinc are not antioxidants themselves, as they do not trap free radicals. However, they are essential cofactors for antioxidant enzymes such as superoxide dismutases (SOD) and glutathione peroxidases (GPx).

Among the health benefits of antioxidants are: Isoflavones, a subgroup of phytoestrogens found mainly in flax seeds and soy beans, may reduce the risk of cancer and coronary disease.Phytosterols, plant-based compounds structurally similar to cholesterol (but not absorbed by the body), reduce cholesterol absorption and thereby lower the risk of cardiovascular disease. Fish oils, rich in essential fatty acids, help reduce the risk of heart attacks and cardiovascular disease. However, since the quantities of essential fatty acids in fish are often low, foods such as margarine, pasta, and bread are often fortified with omega-3 fatty acids. Hyaluronic acid, found in rooster combs, is a key component of the extracellular matrix. A deficiency leads to skin laxity and thinning. It significantly contributes to cell proliferation and migration and helps hydrate tissues by filling the spaces between skin cells. Plant biodiversity supports health through dietary fibers and micronutrients that offer general protection to the body. Their numerous digestive benefits include maintaining the microbiota and eliminating cholesterol. Additionally, to the anticancer role, they help to prevent overweight and diabetes, maintain acid–base balance, and offer antioxidant and anti-inflammatory protection. They also help combat hypertension and cardiovascular disease, slow down aging, and help prevent osteoporosis, eye diseases, and skin aging, contributing to the prevention of many cancers.

5/ Probiotics

5.1. FAO/WHO Definition

Probiotics are defined by the FAO/WHO as *"live microorganisms which, when administered in adequate amounts, confer a health benefit on the host."* This definition remains the international reference and emphasizes three essential criteria: viability, adequate dosage, and scientifically demonstrated health benefit. Recent consensus statements further clarify that the term "probiotic" should only be used when strain-specific clinical evidence is available (Hill *et al.,* 2014; Salminen *et al.,* 2021).

The probiotic concept has evolved with advances in microbiome research, highlighting the central role of gut microbial balance in human health. Current research increasingly integrates omics technologies (metagenomics, metabolomics) to better characterize probiotic-host interactions (Zmora *et al.,* 2019).

5.2. Selection Criteria

The selection of probiotic strains is based on strict scientific and technological criteria:

- **Resistance to gastric acidity and bile salts**, ensuring survival through the gastrointestinal tract.
- **Ability to adhere to intestinal epithelial cells**, which promotes colonization and competitive exclusion of pathogens.
- **Demonstrated safety status**, such as QPS (Qualified Presumption of Safety) in Europe or GRAS (Generally Recognized as Safe) in the United States.
- **Technological stability**, including resistance to processing, storage, and environmental stresses.

Whole-genome sequencing is now widely used to assess safety and exclude transferable antibiotic resistance genes (Sanders *et al.,* 2018).

5.3. Main Strains

The most studied probiotic genera include:

- *Lactobacillus* spp. (recently reclassified into several genera, including *Lacticaseibacillus* and *Lactiplantibacillus*)
- *Bifidobacterium* spp.
- *Saccharomyces boulardii*

These strains are commonly incorporated into dairy products, fermented foods, and dietary supplements, with strain-specific effects documented in clinical trials (O'Callaghan & van Sinderen, 2016).

5.4. Mechanisms of Action

Probiotics exert their beneficial effects through multiple complementary mechanisms:

Microbial Competition

They compete with pathogenic microorganisms for nutrients and adhesion sites on the intestinal mucosa, thereby limiting pathogen colonization.

Bacteriocin Production

Certain strains produce antimicrobial peptides (bacteriocins) that inhibit harmful bacteria, contributing to microbiological homeostasis.

Immune Modulation

Probiotics interact with gut-associated lymphoid tissue (GALT), modulating cytokine production and enhancing both innate and adaptive immune responses (Plaza-Díaz *et al.,* 2019).

Short-Chain Fatty Acid (SCFA) Production

Through fermentation processes, probiotics and commensal bacteria produce SCFAs (acetate, propionate, butyrate), which play a key role in maintaining intestinal barrier integrity and regulating metabolic pathways (Koh *et al.,* 2016).

5.5. Clinical Applications

The clinical relevance of probiotics has been demonstrated in several conditions:

- **Antibiotic-associated diarrhea (AAD)**: Strong evidence supports the preventive effect of specific strains such as *Saccharomyces boulardii* (McFarland, 2015).
- **Irritable bowel syndrome (IBS)**: Certain multi-strain formulations reduce symptom severity (Didari *et al.,* 2015).
- **Allergies**: Early-life probiotic supplementation may reduce the risk of atopic dermatitis (Wang *et al.,* 2020).
- **Obesity and metabolic disorders**: Modulation of the microbiota–metabolism axis influences energy harvest, inflammation, and insulin sensitivity (Cani *et al.,* 2019).

Success Story: Activia and Probiotics

Background: Probiotics are live microorganisms that can provide beneficial effects on digestive health when consumed in adequate amounts.

Innovation: The Activia yogurt range was developed by incorporating specific probiotic strains designed to improve the balance of the intestinal microbiota.

Outcome: Through effective scientific communication and marketing strategies, Activia has become one of the world's leading brands in the functional food market.

Key Takeaway: The success of a functional food depends not only on its effectiveness but also on consumer trust and the scientific validation of its health benefits.

6/ Prebiotics

Prebiotics are defined as substrates selectively utilized by host microorganisms conferring a health benefit (Gibson *et al.,* 2017). They are typically fermentable fibers that stimulate beneficial bacteria growth.

Major prebiotics include:

- Inulin
- Fructo-oligosaccharides (FOS)
- Galacto-oligosaccharides (GOS)
- Resistant starch

Their fermentation results in SCFA production, improved mineral absorption, and modulation of glycemic response. The ability of a functional food to stimulate SCFA production is now a key criterion in the development of products enriched with fiber and prebiotics. Physiological role of SCFAs is at diferent level:

a) Intestinal Health

Butyrate is the primary energy source for colonocytes.

It strengthens the intestinal barrier.

It reduces local inflammation.

b) Immune Regulation

SCFAs modulate cytokine production and promote regulatory T cells (Tregs).

c) Metabolism and Obesity

Propionate contributes to glycemic regulation.

Acetate participates in lipid metabolism.

SCFAs influence the gut–brain axis and satiety.

7/ Synbiotics and Postbiotics

Synbiotics combine probiotics and prebiotics to enhance microbial survival and activity. Recent classifications distinguish complementary and synergistic synbiotics (Swanson *et al.,* 2020).

Postbiotics refer to preparations of inanimate microorganisms and/or their components that confer health benefits. These include cell wall fragments, metabolites, and bioactive compounds, offering improved stability and safety compared to live probiotics (Salminen *et al.,* 2021).

8/ Regulatory Status

In the European Union, health claims related to probiotics must comply with the strict scientific evaluation of the European Food Safety Authority (EFSA). To date, no probiotic health claim has been officially authorized due to insufficient strain-specific evidence.

Regulatory frameworks worldwide require:

- Strain identification
- Demonstration of safety
- Clinical efficacy supported by randomized controlled trials

The increasing demand for functional foods highlights the need for harmonized international regulations.

9/ Perspectives and nutritional challenges

In the field of probiotics, prebiotics, and gut microbiota research, future perspectives are increasingly shaped by advances in microbiome science, biotechnology, and personalized nutrition. The integration of multi-omics approaches (metagenomics, metabolomics, transcriptomics) is expected to provide deeper insight into host–microbe interactions and enable the development of next-generation functional foods tailored to individual microbiota profiles.

One major perspective lies in personalized nutrition, where dietary interventions and probiotic supplementation are customized according to microbiome composition, genetic background,

and metabolic status. This precision approach could improve the efficacy of interventions targeting obesity, metabolic syndrome, inflammatory disorders, and immune-related diseases.

Another promising direction concerns next-generation probiotics, including newly identified commensal strains such as *Akkermansia muciniphila* and *Faecalibacterium prausnitzii*, which show strong anti-inflammatory and metabolic regulatory potential. Their development requires rigorous safety assessment and advanced cultivation technologies.

The expansion of postbiotics represents an additional strategic perspective. Since postbiotics contain non-viable microbial cells or their metabolites, they offer improved stability, safety, and regulatory flexibility compared to live probiotics, making them particularly attractive for industrial applications.

From a technological standpoint, innovative delivery systems such as microencapsulation and nanoencapsulation will enhance microbial viability and targeted release within the gastrointestinal tract. These technologies are crucial for maintaining functional activity during processing and storage.

Finally, regulatory harmonization at the international level remains a key challenge. Stronger clinical evidence, standardized methodologies, and clear definitions will be essential to support health claims and ensure consumer trust.

Overall, the future of microbiota-based functional foods lies at the intersection of precision nutrition, advanced biotechnology, and evidence-based regulation, opening new opportunities for preventive and therapeutic strategies in public health.

It has been observed that, compared to our ancestors, our caloric intake has decreased, and so has the amount of vitamins and minerals for the same portion of food. This is due to the impact of dietary transition on health, driven by the industrialization of agriculture and food supply, the abandonment of traditional dietary patterns, and the high intake of calories from animal sources and empty calories. As a result, the epidemic of obesity and degenerative diseases is increasingly on the rise.

Among the limitations of the dominant agri-food system, we find:

*/ A food supply poorly adapted to human needs:

- An excess of animal products and highly processed foods with low nutritional value
- Insufficient access to fruits and vegetables, good processed products, and balanced fats

*/ The disappearance of farmers

*/ Excessive greenhouse gas emissions

*/ Widespread environmental pollution

*/ Loss of biodiversity and unacceptable animal farming conditions

To address these issues, and in line with a food ethic that respects both humanity and life—for food security and the planet's health—it is essential to adopt preventive nutritionthat serves human well-being. This allows people to live longer, but more importantly, to live healthier lives, as it contributes to increasing healthy life expectancy for both men and women (the latter still enjoying a significantly longer healthy life span).To truly address environmental challenges and reduce their impact, it is necessary not only to consider the production phase of a new functional food but also the entire life cycle of the product, including its use and potential reuse.It is also crucial to initiate a new dietary transition by adapting food processing and distribution chain to meet human nutritional needs, promoting agroecology to protect the environment and preserve rural employment, maintaining natural biodiversity through animal-friendly farming practices and byensuring clear education on sustainable diets that benefit both people and the planet.

For optimal organ function, disease prevention, and preservation of the human phenotype, it is vital to recognize and apply the universal foundations of preventive nutrition, which include: moderating caloric intake, emphasizing a diverse plant-based diet, limiting calories from animal sources, balancing essential fatty acid intakeand reducing consumption of ultra-processed foods. The theoretical basics of preventive nutrition are composedof balanced energy intakewith carbohydrates from complex plant-based sources with minimal refined sugars, diverse protein sources both plant and animal, healthy fats rich in mono unsaturated fatty acids and balanced omega-6/omega-3 ratios, A non-energy fraction made up of at least 30 g/day of dietary fiber, essential vitamins (B, C, A, D, E, K), minerals (K, Ca, Mg...), trace elements (Fe, Zn, Cu, Se, Cr...), and protective micronutrients such as carotenoids, polyphenols, and phytosterols.

However, it is necessary to overcome the obstacles related to the development of preventive nutrition: insufficient popularization level, poorly designed nutrition education, almost non-existent nutritional monitoring, overexposure to degraded food products, diet too rich in animal-based calories andlimited access to fruits, vegetables, and healthy fats.Nutritional guidelines are often insufficient, as they are based on a form of nutritionalism, overshadowed by widespread food marketing. According to the National Nutrition and Health Program, people are advised to eat five fruits and vegetables a day, starchy foods at each meal, three dairy products per day, one to two servings daily of meat, fish or eggs, limited intake of fats, sugary products, salt, and alcohol and unlimited water intake. However, we are now in the age of nutrition serving industrial products, where public information focuses more on individual nutrients than on overall dietary patterns, leading to a dependency on processed foods, loss of food autonomy, and difficulty making informed dietary choices without a global vision of food systems.

The excesses of the industrial food processing chain

Industrial food processing has led to the breakdown of eating behaviors in the face of total absence of agri-food sector supervision regarding nutritional quality requirements this has resulted in food fractionation, excessive use of sugar, fat, empty calories, and salt, manipulation of taste, aggressive food marketing, and an over abundance of low-quality products. The limits of industrial food mean that each item, despite being composed of a wide variety of energetic and non-energetic constituents within a complex matrix, cannot be reduced to the sum of its main components. Reconstructed foods resulting from food cracking differ significantly from their original forms, making it necessary to return to real, whole foods.

Large food distribution has a significant influence on the food environment, which in turn greatly affects human behavior and health. Due to an imbalanced flow of food and beverages and insufficient access (in terms of price and quality) to fruits and vegetables, the large presence of processed products negatively impacts dietary balance.This observation highlights the urgent need to promote sustainable dietary models, such as the Mediterranean diet, rich in grains, legumes, fruits and vegetables, fish, and olive oil, Asian dietbased on rice, soy, fruits, and vegetables and diets composed of a wide variety of natural plant-based foods, or foods with minimal processing while retaining their nutritional quality, along with a moderate intake of animal products.

Consequences of Industrial Food Rich in Empty Calories

Poor control over the consumption of foods high in refined carbohydrates and fats is responsible for the rise in obesity, the development of oxidative stress, and the increase in inflammatory diseases, cardio vascular conditions, and cancers.

The carbohydrate question:

- A significant and essential physiological need;
- A cultural devaluation of starchy foods: bread, potatoes, legumes, etc.;
- Poor alternatives to complex carbohydrates: excessive intake of simple sugars and too many refined cereal products;
- Wasteful conversion of amino acids into glucose in high-protein diets.

The protein question:

- An excessive cultural emphasis on animal products, despite our relatively low protein requirements;
- A poor understanding of the nutritional potential of plant-based biodiversity;
- Increasing the consumption of plant-based proteins also boosts fiber and micronutrient intake, with a highly beneficial impact on health.

The lipid question:

- Only two types of fatty acids are essential: omega-6 and omega-3;
- Conventional fat sources are of very poor quality, consisting mainly of refined oils and animal fats;
- Like olive oil, the use of other oils in virgin form should be encouraged and generalized;
- Fish fats are highly beneficial, but their availability remains limited.

The dietary fiber question

- The intestine hosts a vast bacterial flora; the quality of the microbiota within the intestinal contents is crucial for health;

- Maintaining a healthy microbiota requires a highly varied intake of dietary fiber, and thus a diet rich in plant-based foods;
- Current dietary fiber intake is far too low;
- Animal products contribute little to microbiota maintenance.

The consequences of reduced fiber intake include: impaired satiety regulation, faster absorption of nutrients, disrupted digestive transit, increased intestinal permeability, poor microbiota maintenance, and impaired digestive elimination of cholesterol.

The micronutrient question

- The term includes all minerals, vitamins, trace elements, antioxidants, and micro-components that play a protective role in the body;
- Due to agricultural productivism, industrial food processing, and the abundance of calorie-dense products, the food chain overall results in insufficient micronutrient intake;
- Dietary supplements are generally ineffective.

The acid-base balance question

- The body needs to maintain an acid-base balance;
- Certain foods are acidifying, such as meat, processed meats, and salty products;
- Fruits and vegetables, including potatoes, have an alkalizing effect due to their content of potassium-based organic acids;
- A general rule: acidifying foods should be balanced with alkalizing plant-based foods.

Current limitations of biologic production

Abiological diet to be sustainable, it must clearly differ from the conventional model by including fewer animal products and better-processed foods considering ecological impact, nutritional quality, diversity in plant production (grains, legumes, oils), absence of pesticides (fruits and vegetables), and for short circuits predominance. Sustainable food is the key to a safer lifestyle because it ensures better nutrition, more effective health management, and environmental improvement through the development of biological farming and a new agroecology based on the economic valorization of the food sector, the creation of new jobs, the preservation of rural communities, and a healthy balance between urban and rural

areas.However, there are certain limitations, such as: lower agronomic efficiency, a still-limited food supply, high retail prices, distant sourcing and the industrial biological products following the same logic as the conventional system.

To give food a new bioethical dimension, it is necessary to ensure food security and food sharing, preserve nature, soil fertility, and biodiversity, avoid the instrumentalization of animal life, safeguard the health potential of food and expose factors that denature or impoverish it, recognize and deepen the benefits of food, give food a central role in health management, empower and inform people of their rights and responsibilities regarding food, raise awareness among food chain actors of their role in ensuring food quality, and encourage them to treat the food sector as a cultural exceptionjust like culture, health and food should not be treated as a mere commodity, this approach helps ensure that all farmers retain the right to feed their populations, fighting against junk food, the excesses of industrialization, and dietary uniformity. Giving citizens the responsibility to sustain their agriculture, culture, and health through food will also prompt healthcare professionals to take greater responsibility in prevention and nutritional guidance.

Chapter 4

Dietary Fiber

In this chapter

1- Definition and classification of Dietary Fiber
2- Dietary Fiber Content
3- Fermentative Fate of Dietary Fiber and Resistant Starch
4- Main Physiological Properties of Dietary Fiber and Resistant Starch
5- Nutritional Recommendations
6- Nutritional Claims

1/ Definition and classification of dietary fiber

Dietary fiber is defined as non-digestible carbohydrates and associated compounds, including lignin, that resist hydrolysis by human digestive enzymes in the small intestine and reach the colon intact. According to the definition adopted by the Codex Alimentarius Commission, dietary fiber includes carbohydrate polymers with ten or more monomeric units that are neither digested nor absorbed in the small intestine and that provide a demonstrated physiological benefit (Codex Alimentarius, 2019). Modern definitions therefore extend beyond chemical resistance to digestion and incorporate evidence-based physiological effects such as improved bowel function, glycemic modulation, cholesterol reduction, and colonic fermentation (Stephen *et al.,* 2017).

From a classification perspective, dietary fibers may be categorized according to several complementary criteria. The traditional distinction between soluble and insoluble fiber is based on water solubility and physicochemical behavior. Soluble fibers, such as pectins and β-glucans, dissolve or swell in water and are associated with significant metabolic effects, particularly cholesterol lowering and glycemic control. Insoluble fibers, primarily cellulose and certain hemicelluloses, contribute mainly to fecal bulk and intestinal transit regulation (Dahl & Stewart, 2015). Another important classification concerns fermentability. Highly fermentable fibers, including inulin and fructooligosaccharides, are extensively metabolized by colonic microbiota, whereas poorly fermentable fibers, such as some forms of cellulose, exert primarily mechanical effects. Viscosity represents an additional functional property, as viscous fibers can influence gastric emptying, nutrient absorption kinetics, and satiety.

2/ Dietary fiber content

The fiber content of foods depends largely on botanical origin and technological processing. Whole grains, legumes, fruits, vegetables, and oilseeds represent the main natural sources of dietary fiber. Industrial refining processes, particularly in cereal production, substantially reduce fiber content by removing bran and germ fractions rich in cellulose and hemicelluloses.

Contemporary food reformulation strategies aim to restore or enhance fiber content through the incorporation of isolated fibers or functional ingredients such as β-glucans and resistant starch. The growing interest in functional foods has encouraged the development of fiber-

enriched matrices designed to improve nutritional quality without compromising sensory properties (Reynolds *et al.,* 2019). These innovations reflect increasing recognition of fiber as a critical component of preventive nutrition.

3/ Fermentative fate of dietary fiber and resistant starch

Dietary fibers and resistant starch escape enzymatic digestion in the small intestine and reach the colon, where they serve as substrates for gut microbiota. Colonic fermentation is a complex anaerobic process leading to the production of short-chain fatty acids (SCFAs), mainly acetate, propionate, and butyrate, as well as gases such as hydrogen, carbon dioxide, and methane (Makki *et al.,* 2018).

Resistant starch refers to the fraction of starch that is not digested in the small intestine. It is classified into five categories (RS1 to RS5) based on structural and physicochemical characteristics. Retrograded starch (RS3), formed during cooling after cooking, exhibits increased resistance to amylase digestion. Resistant starch is of particular metabolic interest because it promotes butyrate production, a key metabolite for colonic health (Lockyer & Nugent, 2017). The fermentative profile of fibers and resistant starch directly influences microbiota composition and metabolic outputs.

4/ Main physiological properties of dietary fiber and resistant starch

Dietary fiber exerts multiple interrelated physiological effects. At the intestinal level, insoluble fibers increase stool bulk and decrease transit time, thereby contributing to constipation prevention and reducing mucosal exposure to potentially harmful compounds. Butyrate produced through fermentation serves as the primary energy source for colonocytes and plays a crucial role in maintaining intestinal barrier integrity while exerting local anti-inflammatory effects (Koh *et al.,* 2016).

Metabolically, soluble and viscous fibers slow carbohydrate digestion and glucose absorption, reducing postprandial glycemic peaks. Large-scale meta-analyses have demonstrated that higher fiber intake is associated with a significant reduction in cardiovascular disease and type 2 diabetes risk (Reynolds *et al.,* 2019). Mechanisms include bile acid binding, reduction of LDL cholesterol levels, and improved insulin sensitivity.

In addition, SCFAs modulate immune function by influencing cytokine production and promoting the differentiation of regulatory T cells, illustrating the close interaction between diet, microbiota, and immune homeostasis (Makki *et al.,* 2018). Emerging evidence also highlights the involvement of SCFAs in the gut–brain axis, suggesting roles in appetite regulation and body weight management.

5/ Nutritional recommendations

International guidelines generally recommend a daily fiber intake of 25–30 grams for adults, with a balanced combination of soluble and insoluble fibers. These recommendations are supported by strong epidemiological evidence demonstrating that high fiber intake is associated with reduced all-cause mortality and lower incidence of chronic diseases, including cardiovascular disorders, diabetes type 2, and colorectal cancer (Reynolds *et al.,* 2019). Gradual increases in fiber consumption are advised to minimize gastrointestinal discomfort, and adequate hydration is essential to optimize physiological benefits.

6/ Nutritional claims

Within the European Union, fiber-related claims are regulated by Regulation (EC) No 1924/2006 on nutrition and health claims. A food may be labeled as a “source of fiber” if it contains at least 3 g of fiber per 100 g, and as “high in fiber” if it contains at least 6 g per 100 g. Health claims must be scientifically substantiated and evaluated by the European Food Safety Authority (EFSA). This regulatory framework aims to ensure transparency, protect consumers, and guarantee that claims are based on robust scientific evidence.

Chapter 5

Metabolism of Natural Xenobiotics from Edible Plants

In this chapter

1- Introduction
2- Main Bioactive Compounds
3- Applications in Novel Food Products
4- Case Studies
5- Challenges and Perspectives
6- Conclusion

1/ Introduction

In recent decades, the concept of functional foods has gained a central position in scientific research and food industry innovation. These foods, beyond their basic nutritional role, are formulated to provide specific physiological benefits**,** contributing to the prevention of chronic diseases and the improvement of well-being. In this context, aromatic and medicinal plants attract particular interest due to their richness in bioactive compounds and their long history of use in traditional health practices and food preservation.

Plants such as rosemary, thyme, turmeric, mint, and oregano are known for their diverse phytochemical profiles**,** including polyphenols, flavonoids, essential oils, and other secondary metabolites. These molecules exhibit antioxidant, antimicrobial, anti-inflammatory, hypolipidemic, and immunomodulatory properties, making them ideal candidates for the development of innovative and health-promoting food products. For example, a recent review emphasized the antimicrobial and antioxidant potential of essential oils, and also highlighted how nano-encapsulation can improve their stability and controlled release in food matrices (Égger *et al.,* 2025).

From an industrial perspective, incorporating extracts from aromatic and medicinal plants into various food matrices (dairy, meat, beverages, snacks, cereals) not only meets the growing consumer demand for natural and healthy products**,** but also provides a sustainable alternative to synthetic additives**.** Moreover, some of these plants help improve food stability, shelf life, and sensory quality, for instance by reducing lipid oxidation or microbial growth. A comprehensive recent review showed that essential oils and their major components can act as natural antimicrobials in foods, and that edible coatings with encapsulated essential oils can help overcome sensory concerns (Tomasa *et al.,* 2024).

However, despite their advantages, the use of aromatic and medicinal plants in functional foods still faces several scientific and technological challenges**:** the volatility of essential oils, the low bioavailability of certain polyphenols, possible alterations in sensory properties, and regulatory constraints regarding their incorporation. In particular, studies on polyphenols report poor water solubility and limited bioavailability, which limit their physiological effects unless specific delivery or formulation strategies are employed (Ciupei *et al.,* 2024).

This chapter aims to explore the main bioactive compounds of aromatic and medicinal plants, their current and emerging applications in the development of novel food products, and the perspectives and technological innovations that can further enhance the valorization of these natural resources in the functional foods of tomorrow.

2/ Main bioactive compounds

Aromatic and medicinal plants are rich sources of diverse bioactive compounds. These secondary metabolites are responsible for many of the health-promoting properties of functional foods derived from plants. Below are the principal classes of bioactive compounds, with examples, their mechanisms of action, and recent research findings.

2.1. Polyphenols

Polyphenols are key candidates for the development of functional foods and nutraceuticals, but their successful application depends on technological innovations that overcome their limitations in solubility and bioavailability. Polyphenols are a large group of compounds characterized by multiple phenolic rings and hydroxyl groups. They include phenolic acids, flavonoids, tannins, stilbenes, etc. Their structures often confer strong antioxidant activity but also low water solubility and limited bioavailability (Ji, 2024). In his research, the **s**tudy objective is
to present recent advances on the diversity, extraction, and biological activities of plant-derived polyphenols with perspectives ; improvement of polyphenol bioavailability and stability through encapsulation and novel formulation technologies.

Mechanisms of action

- **Antioxidant :** Scavenging free radical ; reactive oxygen species (ROS), cellular protection against oxidative stress because it is reducing.
- **Anti-inflammatory :** Modulating inflammatory nd regulation of molecular pathways (NF-κB, MAPK).
- **Anticancer :** inhibition of cell proliferation and induction of apoptosis and potentially regulating metabolism (lipid, glucose).
- **Anti-obesity and metabolic** : Interacting with gut microbiota, which can modulate health effects with modulation of lipid and glucose metabolism.

Aqueous phenolic extracts of spices are a promising natural alternative to synthetic preservatives in the food industry, combining safety, effectiveness, and antioxidant/antimicrobial properties. A review study in MDPI was published in 2023 to systematically evaluate the bioactive potential of aqueous phenolic extracts from selected spices (oregano, thyme, rosemary, clove, etc.) and their possible applications in the food industry. Aqueous extracts are safer, more sustainable, and more consumer-friendly compared to organic solvent-based extracts. However, there is a variability depending on species, geographical origin, extraction method, and the need for in vivo studies to confirm effects. The comparative analysis of multiple studies measuring total phenolic content, antioxidant capacity, and antimicrobial activity showed a strong correlation between total phenolic content and antioxidant activity (DPPH, ABTS, FRAP assays), several aqueous extracts showed effective antimicrobial activity**,** especially against *E. coli*, *Staphylococcus aureus*, and *Listeria monocytogenes and i*n some cases, the effectiveness was comparable to or even greater than synthetic additives used as preservatives.

2.2. Essential oïls and volatile compounds (Terpenes, Monoterpenes, Sesquiterpenes, Phenolics)

Essential oïls (EOs) are complex mixtures of volatile organic compounds including monoterpenes (e.g. limonene), sesquiterpenes, phenolic compounds (e.g. thymol, carvacrol), alcohols, esters, ketones, etc. These compounds are often lipophilic. Recent research on essential oils (EOs) from aromatic and edible plants emphasizes both their bioactive potential and the technological innovations required to optimize their use in food, health, and pharmaceutical applications.

Mechanisms of action

- **Antimicrobial:** disrupt cell membranes of bacteria, fungi.
- **Antioxidant:** prevent lipid oxidation in foods or in biological systems.
- **Anti-inflammatory:** modulate inflammatory mediators.
- **Possibly anticancer** or cytotoxic effects against certain tumor cell lines.

Essential oils from oregano, thyme, rosemary, and sage were chemically profiled. The dominant constituents—carvacrol, thymol, and 1,8-cineole—demonstrated strong antioxidant, antimicrobial, anti-inflammatory, and cytotoxic activities. These findings confirm the importance of Mediterranean Lamiaceae species as natural sources of

bioactive compounds with potential of major EO constituents for functional food development and therapeutic applications (Spréa *et al.,* 2024).

The review on Unlocking the Potential of Essential Oïls in Aromatic Plants (2025) emphasizes technological progress in EO processing and application, ensuring their stability, safe integration, and large-scale applicability in food and health industries. Innovations include supercritical fluid extraction and microwave-assisted extraction (greener, more efficient methods), as well as encapsulation and nanoemulsion technologies to enhance EO stability, solubility, and bioavailability**.** It also highlights regulatory considerations and the emerging role of artificial intelligence in optimizing extraction processes and product development.

The essential oils, particularly from Mediterranean Lamiaceae, are strategic candidates for next-generation functional foods, nutraceuticals, and natural preservatives**,** provided that challenges of formulation and regulation are addressed through advanced technologies.

3/ Other classes: Alkaloids, Bioactive peptides, and others

3.1 Alkaloids and miscellaneous metabolites

These are nitrogen-containing compounds, often with potent bioactivity. Some alkaloids have antimicrobial, neuroprotective, or anticancer properties.

Bioactive peptides

Small protein fragments (peptides) released from plant proteins (or seeds) that can have antioxidant, antimicrobial, or metabolic effects (hypoglycemic). A recent study on cumin (*Cuminum cyminum* L.) seeds identified multiple peptides with antimicrobial, antioxidant, and blood sugar regulating (hypoglycemic) effects.

4/ Bioavailability, stability, and technological considerations

While these compounds show considerable potential, their efficacy in food systems and in vivo often depends on:

- **Extraction method**: Green extraction methods (microwave, ultrasound, supercritical fluids) yield higher purity and better retention of actives compounds.

- **Formulation**: Encapsulation, nano-emulsions, and edible coatings can help protect volatile compounds, improve delivery, reduce degradation or loss of activity.
- **Interaction with food matrix**: Food components (lipids, proteins) can bind or inactivate bioactives; this affects availability and sensory properties.

Table III: Bioactive Compound – Example – Health Effects and Applications

Compound / Class	Source Plants	Key Health/Biological Effects	Possible Food/Nutraceutical Applications
Thymol and Carvacrol	Thyme, Oregano	Antimicrobial, antioxidant, anti-inflammatory	Natural preservatives; flavoring agents; functional beverages/snacks
Rosmarinic Acid / Carnosol	Rosemary, Salvia spp.	Anti-oxidant, anti-inflammatory, cardioprotective effects	Fortified oils; health drinks; herbal supplements; functional dairy
Polyphenols (e.g., flavonoids, phenolic acids)	Spices (rosemary, thyme, oregano, clove etc.)	Antioxidant; modulation of glucose & lipid metabolism; antimicrobial	Spice extracts as natural additives; functional food ingredients
Bioactive Peptides	Cumin seeds	Antimicrobial, antioxidant, hypoglycemic effects	Use in nutraceuticals; possibly as protein supplements

5/ Challenges and Perspectives

Perspectives 2026: Megatrends Shaping the Future of Food

The agri-food industry is undergoing rapid transformation driven by evolving consumer demands regarding health, sustainability, and well-being. By 2026, several megatrends are expected to strongly influence the development of functional foods and food innovations.

1. The Clean Label Movement

Consumers are increasingly seeking products made with natural, recognizable ingredients and free from artificial additives. This trend is driving the development of innovative technological solutions aimed at replacing synthetic preservatives, colorants, and antioxidants with natural alternatives derived from plants, fruits, and agri-food by-products.

2. Foods Supporting Sleep and Mental Well-Being

The relationship between nutrition and mental health is attracting growing attention. Foods enriched with bioactive compounds capable of promoting sleep quality, relaxation, stress management, and cognitive performance represent a rapidly expanding market. Ingredients rich in tryptophan, magnesium, polyphenols, and probiotics are the focus of extensive research in this field.

3. Circular Economy and By-Product Valorization

Reducing food waste has become a major challenge worldwide. The valorization of agricultural and food-processing by-products, such as fruit peels, seeds, and plant residues, makes it possible to obtain high-value ingredients rich in dietary fiber, antioxidants, and functional compounds, while contributing to the sustainability of food systems.

4. Personalized Nutrition

Advances in nutrigenomics, artificial intelligence, and digital technologies are paving the way for nutrition tailored to the specific needs of each individual. This approach aims to optimize disease prevention and health maintenance through personalized nutritional recommendations.

5. Active and Intelligent Packaging

Packaging is no longer limited to protecting food products. New generations of active packaging incorporate natural substances capable of extending shelf life, while intelligent packaging systems enable real-time monitoring of product quality and freshness throughout storage and distribution.

6/ Conclusion :

These megatrends illustrate the transition toward healthier, more sustainable, and increasingly consumer-centered food systems. Functional foods, natural ingredients, and innovative technologies will play a key role in addressing the health, environmental, and economic challenges of the coming years. Food industry professionals will need to integrate these developments to design products that meet the growing expectations of modern society.

Pedagogical evaluation, practical work, and exercises

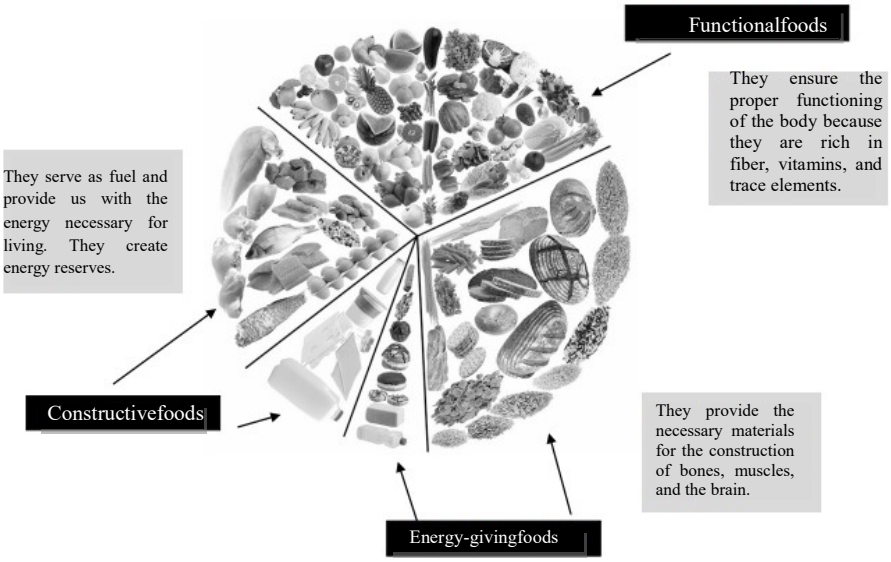
PW1: Nutrition: Exercises to solve

Types of foods:

To ensure proper growth and development of the body, humans require both water and food to survive. In a balanced diet, there are:

- ✓ **Body-building foods**
- ✓ **Protective or functional foods**
- ✓ **Energy-providing foods**

Each of these food categories plays a distinct role in maintaining the proper functioning of the human body.



Nutrients:

Food provides nutrients to living organisms. These are organic substances that the body uses as a primary source of energy. There are several types of nutrients.

Water:

Water is the only essential beverage for living organisms. The human body is composed of 60% to 70% water. Dehydration, or lack of water, leads to severe functional disorders within the body. All foods contain water; in fruits and vegetables, water can represent up to 80%–95% of their total weight.

Macronutrients

Our body requires a large amount of macronutrients in order to function properly. This group includes proteins, carbohydrates, and lipids.

Proteinscontainmanyessential amino acidsnecessaryforthebody. These amino acids are foundmainly in animal proteins, butalso in certainlegumes.

Carbohydrates are foods rich in carbon hydrates and/or sugars. Cereals, potatoes, bananas, chocolate, and peas are rich in complex carbohydrates.

Lipidsare made up of fats. They are rich in energy and can be of plant origin, such as olive oil, or of animal origin, such as butter.

Micronutrients

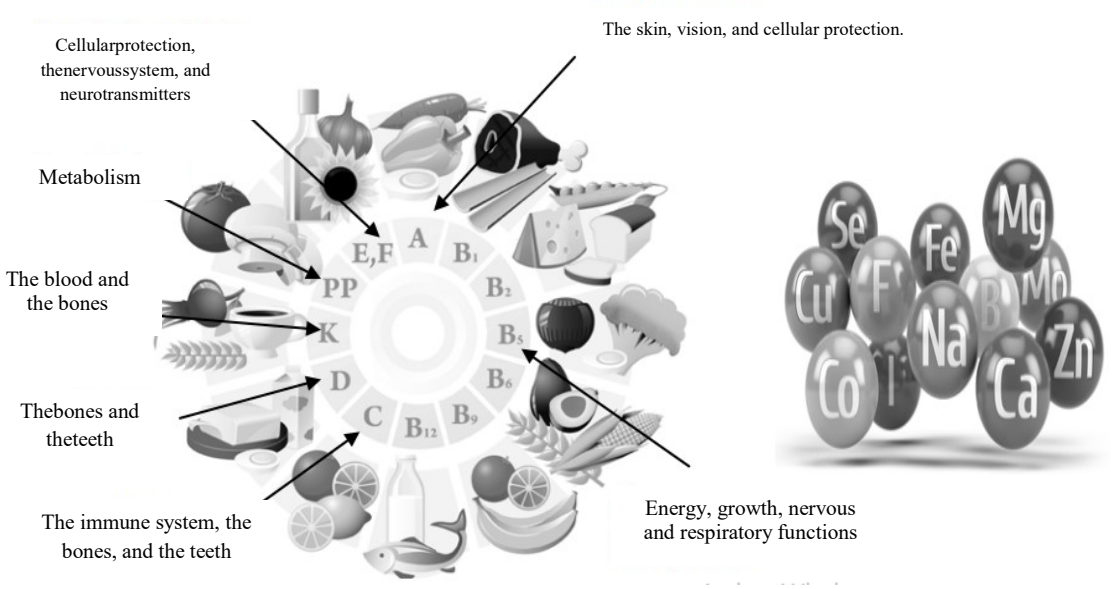
This group includes vitamins, minerals, and trace elements. They do not provide energy and represent about 2% of the total diet. However, they play a crucial role in maintaining health, as they are essential for the proper functioning of the brain, bones, and the body as a whole.

Vitamins are necessary for cellular renewal, toxin elimination, and the prevention of aging. Since the human body cannot synthesize them, they must be obtained from food. A deficiency in vitamins weakens the body's defenses.

All foods contain minerals and trace elements that are vital for cellular life. However, the method of food preparation and cooking is critical to preserving these nutrients.

The most important minerals are sodium (salt), potassium, calcium, iron, magnesium, and phosphorus—all essential for organ function, particularly that of the brain.

The key trace elements include iodine, copper, fluorine, chlorine, zinc, cobalt, selenium, and manganese.



Exercise 1

Look at the pyramid of food types and list two body-building foods, two energy-providing foods, and two functional foods.

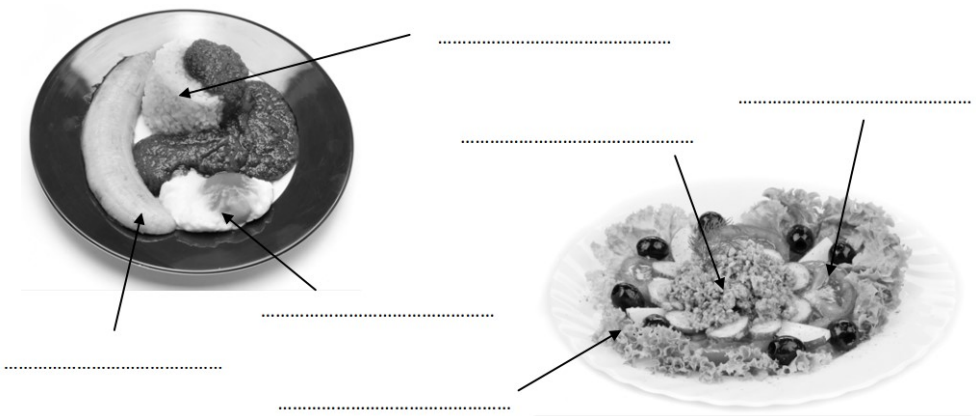
Body-building foods: ……

Energy-providing foods: ……

Functional foods: ……

Exercise 2

To which category of foods do the ingredients of the following dishes belong?



Exercise 3

Examine the nutritional value information on the labels. Identify the components and determine which group of nutrients they belong to.

Lait stérilisé U.H.T. demi-écrémé enrichi en Vitamine D
Ingrédients : *Lait* demi-écrémé, vitamine D

Valeurs nutritionnelles moyennes	Pour 100 ml	Pour un bol de 250 ml
Valeur énergétique :	191 kJ / 45 kcal	475 kJ / 114 kcal
Matières grasses :	1,5 g	3,7 g
dont acides gras saturés :	1,0 g	2,5 g
Glucides :	4,8 g	12,0 g
dont sucres :	4,8 g	12,0 g
Protéines :	3,2 g	8,0 g
Sel :	0,1 g	0,3 g
Vitamine D :	0,8 µg = 15% des AR*	1,9 µg = 37% des AR*
Calcium :	120 mg = 15% des AR*	300 mg = 37% des AR*

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Exercise 4

Record the foods you eat over a period of four days. Is your diet rich, varied, and balanced? Why or why not? What changes could you make to improve your eating habits?

Write down the foods you eat over four days. Is your diet rich, varied, and balanced? Why? What changes could you make to your diet to eat better?

Answer Key:

Exercise 1 – Possible Answers:

- **Body-building foods:** meat, fish, eggs, milk, cheese…
- **Energy-providing foods:** bread, butter, oil, biscuits, pasta…
- **Functional foods:** bananas, tomatoes, pear, orange, carrot…

Exercise 2

- Rice: energy-providing food
- Banana: functional food
- Egg: body-building food
- Salad: functional food
- Tuna: body-building food
- Tomato: functional food

Exercise 3

Chocolate bar label: carbohydrates and proteins are macronutrients, while salt is a micronutrient.

Milk label: carbohydrates and proteins are macronutrients, while salt, vitamin D, and calcium are micronutrients.

Exercise 4

Open-ended answer.

Pw2: Extraction of citrus essential oïl by hydro distillation

I-Introduction

Essential oïls are concentrated liquids containing aromatic (fragrant) and volatile compounds derived from plants or fruits. Their use dates back to antiquity: Akkadian texts from more than four thousand years ago reveal that in Babylon, cypress was burned to stop epidemics.

Today, these oïls are widely used in pharmacology for their therapeutic properties, as well as in cosmetics, perfumery, and the food industry for their aromatic qualities. The amount of essential oïl contained in plants is always small—sometimes very small or even minute.

Several tons of plant material may be required to obtain just one liter of essential oïl, which explains their high cost. However, they are usually diluted before use due to their toxicity at high concentrations; pure essential oïls are often irritating to the skin.

The extraction of these essential oïls therefore represents a major industrial challenge. In this process, water is a solvent of choice for chemists. Indeed, water is inexpensive, non-toxic, and can be used in large quantities in industrial applications. It enables the extraction of most essential oïls through two main techniques: hydro distillation and steam distillation.

II- Experimental procedure

- Peel a citrus fruit, leaving the white part (albedo) on the fruit.
- Cut the zest into small pieces.
- Grind the moistened zest in a mortar.
- Transfer the resulting puree into a 250 mL round-bottom flask and cover it with 100 mL of demineralized water.
- Assemble the distillation apparatus.
- Gently open the tap to allow a steady flow of water through the condenser.
- Turn on the heating mantle and set the thermostat to the maximum position.
- Monitor the boiling process and lower the thermostat when necessary.
- Maintain boiling for about 30 minutes, until approximately 70 mL of distillate is collected.
- In a small beaker, add a spatula of solid NaCl — this step is known as salting out.
- Pour the distillate into a separatory funnel and add 5 mL of cyclohexane.

- Remove the aqueous phase (identify it based on density differences) and collect the organic phase in a stoppered Erlenmeyer flask.

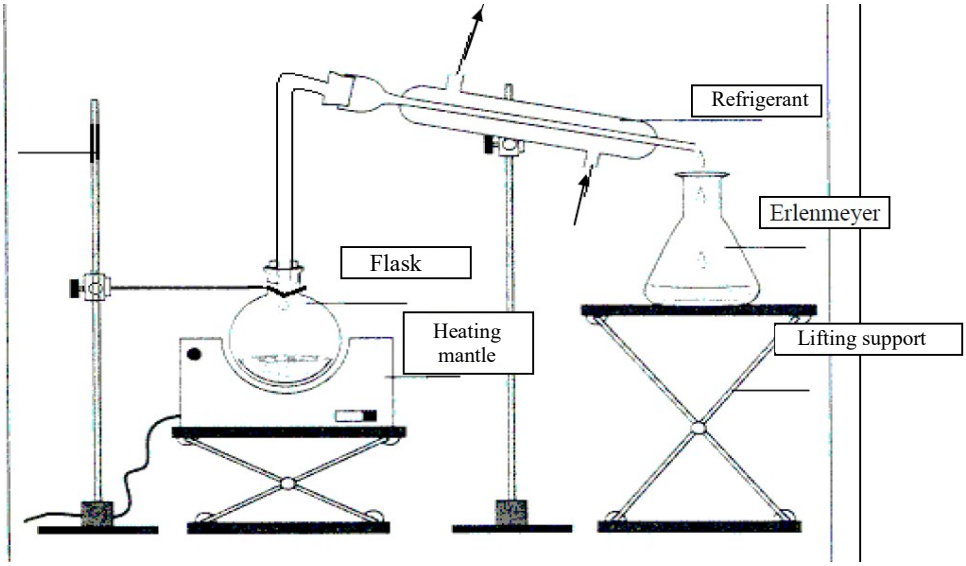

Figure 5: Diagram illustrating the process of hydro distillation.

III. Separation of the Essential Oïl

Separate the essential oïl from the water in the distillate using a separatory funnel: collect the water in an Erlenmeyer flask and the essential oïl in a small vial.

Questions:

1. What is the objective of this practical session?
2. What is the extraction principle of this method?
3. What are the health benefits of citrus essential oïls? Suggest examples of functional foods that could be enriched with citrus essences.

PW 3: dietary supplements introduction

Nine thousand years ago, agriculture brought about the first major changes in human nutrition. New foods and new eating habits emerged. Although dietary supplements are relatively recent, their introduction to the market is closely linked to the health disorders that developed over the centuries.

Indeed, dietary supplements were initially developed to prevent various health problems. Today, their use has expanded to include goals related to well-being, beauty, fitness, vitality, and the delay of aging.

To create a dietary supplement, manufacturers begin with a specific list of ingredients that allows them to produce a pharmaceutical-type formulation, presented in commercial packaging and accompanied by a health or nutritional claim.

Definition of a Dietary Supplement

Dietary supplements are concentrated sources of nutrients (vitamins, minerals, fatty acids, or amino acids) or substances with nutritional or physiological purposes, as well as plants and plant preparations, intended to compensate for deficiencies in a person's regular diet or to help prevent certain diseases.

These supplements may come in various forms, including capsules, lozenges, tablets, pills, powder sachets, liquid ampoules, dropper bottles, and solutions, among others.

The Nutrients May Include:

- **Vitamins and minerals**
- **Plants and plant preparations** (possessing pharmacological properties and intended exclusively for therapeutic use)
- **Substances with nutritional or physiological purposes** (chemically defined substances that have nutritional or physiological properties, excluding vitamins, minerals, and substances with exclusively pharmacological properties)

Additionally, the following ingredients may be used in the manufacture of dietary supplements:

- **Additives, flavorings, and processing aids** authorized for use in human food under the conditions established by regulations.

Why Take Dietary Supplements?

There are three main reasons for taking dietary supplements:

- To improve health and prevent various health problems
- To treat a specific condition
- To make up for certain dietary deficiencies or to maintain an adequate intake of specific nutrients

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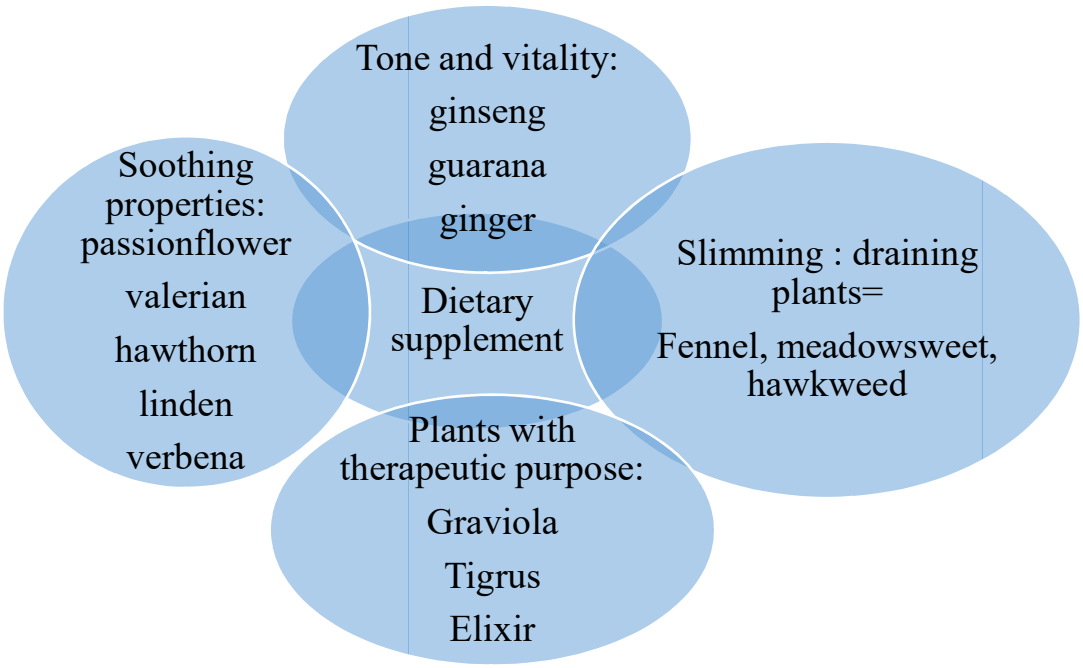

Manufacturing Process of a Dietary Supplement

- **Rigorous selection of ingredients** (vitamins, minerals, plants, and innovative substances) and quality control of each raw material.
- **Blending and production** according to the different dosage forms:
    - Infusion

    - Solid form
    - Semi-liquid form
- **Intermediate quality control** of the mixture is essential.
- **Packaging** of the dietary supplement.
- **Final quality control** of the dietary supplement, followed by systematic quarantine before release for commercialization.
- **Traceability** of each dietary supplement through its batch number and indication of an expiration date.
- **Declaration** to the DGCCRF (French General Directorate for Competition Policy, Consumer Affairs, and Fraud Control).
- **Market release** once the health or nutritional claim is approved.

Graviola

Latin name: *Annona muricata*

Family: Annonaceae

Synonyms: Graviola, soursop, guanabana, guanavana

Parts used: fruit, leaf, seed, bark, root

Various parts of the soursop tree including the bark, leaves, roots, fruit, and seeds have been used for centuries by traditional healers and Indigenous peoples of South America to treat heart disease, asthma, liver problems, and arthritis.

Although only limited scientific evidence has been documented, some companies have invested resources into studying the tree's potential anticancer properties and reported surprising results: the soursop tree appeared to act as a powerful, cancer-fighting agent.

Properties of Graviola (Soursop):

– Anticancer
– Antitumor
– Sedative
– Antibacterial
– Antiparasitic
– Antispasmodic
– Vasodilator

Chemical composition

- **Lactones:**annohexocin, annomuricin A, B, C, and E, annomutacin, annopentocin A, B, and C, muricoreacin, gigantetronemine, murihexocin A and C, javoricin.
- **Isoquinolines:** anonaine, anonine, atherospermine, coreximine.
- **Lipids:** gentisic acid, lignoceric acid, linoleic acid, stearic acid.
- **Leaf acetogenins with anticancer activity:** bullatacin, bullatacinone, muricoreacin, murihexocin C, annomuricinA, annomuricin B, muricatocin A, muricatocin C, muricapentocin.

Action of graviolaacetogenins against cancer

A study conducted at Purdue University in California demonstrated that acetogeninscan selectively inhibit the growth of cancer cells and also suppress the proliferation of tumor cells that are resistant to adriamycin (a chemotherapy drug).

Mechanism of action of acetogenins in cancer cells studies carried out between 1998 and 2000 by McLaughlin, ChihHw, and Chui H.F. revealed that acetogenins inhibit Complex I of the oxidative phosphorylation chain, thereby blocking the formation of ATP, the energy required by cancer cells to activate their P-glycoprotein pump, which helps them remain active.

Acetogenins also inhibit ubiquinone–ubiquinone oxidase, a NADH-dependent enzyme specific to the plasma membrane of cancer cells.

The guanabana (graviola) plant can be used not only for its fruit — which is rich in nutrients and vitamins but also for the medicinal properties of its various parts, especially its leaves, known for their anticancer properties.

PW 04: Sensory and organoleptic analysis of a new functional food product

Introduction

To address nutritional health problems among consumers suffering from metabolic syndrome, a new product has been developed as a functional food. A functional food is defined as a food that provides health benefits beyond basic nutrition, as it contains components that may enhance physical or mental health or reduce the risk of certain diseases or health issues. In contrast, *functional nutrition* is a personalized dietary plan that uses food as medicine, mainly aimed at helping the consumer improve their health and well-being.

Thus, for the development of our functional food product in this practical work (PW), we rely on the seven main categories of foods as the basic components of the diet: cereals and starches, milk and dairy products, meat-eggs-fish, fruits and vegetables, fats, sugars and sweet products, and beverages. These categories provide the seven essential nutrients: carbohydrates, lipids, proteins, vitamins, minerals, fiber, and water.

Problem statement:

Modern diets are abundant and generally safe. However, their excessive sugar and salt content makes them overly rich, leading to real epidemics such as obesity, which in turn causes metabolic syndrome. Foods claiming nutritional or health benefits are multiplying in response to consumer expectations. This market represents significant industrial and commercial stakes. Yet, the key question remains whether some of these foods actually have proven health effects, and whether the general population or specific groups truly benefit from them. This requires defining conditions for validation, communication, and monitoring within a specific regulatory framework. The emergence of the concept of functional foods for optimized nutrition, the establishment of scientific bases to demonstrate functionality, and the development of a rigorous methodology supported by biomarkers are being progressively developed.

Objective of the practical work (pw):

The objective of this TP is to translate consumer needs into functional attributes to be fulfilled. It involves formulating the needs in terms of results to be achieved rather than the means to achieve them.

How to develop a new product in 6 Steps:

1. **Step 1:** Define the consumer's needs or problems.
2. **Step 2:** Gather as much information as possible.
3. **Step 3:** Find the right partners.
4. **Step 4:** Protect the idea.
5. **Step 5:** Set a budget.
6. **Step 6:** Develop a prototype.

Sensory evaluation sheet for the new product

To evaluate a new food product, product testing involves presenting several options to a panel of professional or trainee tasters (classmates) and asking for their opinion on each by assessing selected sensory parameters. This helps identify which product concepts are best received by consumers.

Sensory evaluation focuses on three dimensions of sensory perception:

- **Nature** of the sensation (e.g., salty taste, burning sensation, vanilla aroma, grainy texture),
- **Intensity** (e.g., slightly or very salty), and
- **Hedonic dimension** (i.e., "I like it" or "I don't like it").

Tasting panel

A sensory analysis panel must be treated as a scientific instrument to obtain reliable and valid results. Tests must be conducted under controlled conditions using well-designed experimental plans, verification methods, and statistical analyses. This is the only way sensory analysis can produce consistent and reproducible data.

Sensory (or organoleptic) evaluation is the objective characterization of a food product by a panel of tasters (either expert or naïve) to describe the perceptions generated by the product through the five senses.

Organoleptic qualities refer to all the sensory attributes of a food perceived through sight, touch, smell, hearing, and taste.

Example: A well-presented food (sight), with a pleasant texture (touch), strong aroma (smell), crunchy sound (hearing), and sweet taste (taste).

- **Consumer panels (Pilot panels):** Typically composed of 30–50 untrained participants (students or staff from the faculty). The group should resemble the target consumer population.
- **Expert panels:** Usually consist of 5–15 trained and selected tasters with strong sensory acuity and specialized training.

Organoleptic parameters

These parameters are related to consumption comfort and do not have direct health value. They include:

- Color
- Taste
- Appearance
- Consistency
- Odor

Organoleptic control of a food product is an innovative approach where the panelist acts as a "measuring instrument," quantifying sensory perceptions while minimizing subjectivity.

Consumer or hedonic tests gather consumer opinions about a proposed product. It is a type of survey involving a sufficient number of representative consumers evaluating products that are representative of the target market.

Materials to use

Use plastic or metal trays to serve samples to each taster. Also needed: plastic spoons, forks, and knives, napkins, glass or disposable cups for water and spitting, and large glass pitchers for drinking water.

Instructions for the tasting panel

- Avoid using scented products (soaps, lotions, perfumes) 30 minutes before the session.
- Do not eat, drink, or smoke at least 30 minutes before testing.

- Rinse your mouth with water or eat a small piece of bread after each tasting.
- Rate each parameter on a scale from 0 to 10, based on sensory intensity.
- Serve 30 g of solid food or 15 mL of beverage per sample (ASTM STP 434, 1968).
- Label samples with a random 3-digit code.
- Randomly place samples on trays to minimize bias.
- Evaluate samples using appropriate measurement scales (nominal, ordinal, interval, or ratio), depending on study objectives.

Types of scales:

1. **Ordinal scales:** Numbers represent ranking order. Example: ranking five chicken soup samples by saltiness (1 = saltiest, 5 = least salty).
2. **Nominal scales:** Numbers act as category labels, not numerical values. Example: 1 = fruity, 2 = sweet, 3 = spicy, 4 = hot (for tomato sauce aromas).
3. **Interval scales:** Allow classification based on the magnitude of a characteristic, with equal intervals. Example: not only which soup is saltiest but also *how much* saltier it is.
    - Two types: category scales and linear scales**.**
4. **Ratio scales:** Similar to interval scales but include a *true zero point*. On interval scales, zero is arbitrary and doesn't mean absence of the attribute.

Stastical analysis

The sensory results are analyzed statistically to allow the experimenter to draw conclusions about the population of people or food products based on the sample tasted by these groups.
Statistical tests are used to analyze data obtained from sensory studies. These analyses aim to achieve the following objectives:

Verify hypotheses;
Determine whether there are significant differences between samples, treatments, or populations, and whether these differences depend on other variables or parameters;
Check the consistency of responses provided by expert tasters during both the training phase and the study itself.

Data obtained from nominal and ordinal scales are analyzed using non-parametric statistical tests, while data obtained from interval and ratio scales are analyzed using parametric statistical tests.

Sensory profile

The sensory profile of a product provides consumers or users with precise information about its flavors, aromas, and tactile qualities. It also allows for the comparison of several food products.

The sensory profile of a food product is the description of the perceptions recorded during the tasting of a liquid or solid food. These perceptions involve our five senses: hearing, sight, smell, taste, and touch.

Applying the same statistical analysis method to each tasted product makes it possible to assign a score to each organoleptic parameter. Sensory data can appear as frequencies, rankings, or quantitative numerical data. The form of the data depends on the type of measurement scale used during sensory tests.

Marketing and product commercialization: health claims

Taking into account consumer sensory perceptions is fundamental in developing product policy and marketing strategy.

When choosing a claim (allégation) related to a food product's functionality, it must align with the principles of functional food development. In general, to claim means to highlight an argument to support a statement. Thus, one may claim health benefits for a certain behavior (e.g., physical activity) or a specific food (e.g., fruits and vegetables) within the context of nutrition.

A claim is defined as "any message, statement, or representation that asserts, implies, or suggests that a food possesses particular characteristics, properties, or effects related to its nature, composition, nutritional value, production, or processing method, or any other quality" (Baelde, 2000).

The AFSSA Commissions (French Food Safety Agency) provide opinions on the non-misleading nature of such functional claims.

Today, nutritional claims form a normal basis for identifying a nutritionally healthy food. However, a considerable amount of work remains to be done to provide scientific evidence supporting claims that refer to a reduction in the risk of certain diseases, in line with Hippocrates' famous saying: **"**Let food be the medicine."

Examples of Projects – Master 2 *Functional Foods and Novel Products*

Chickpea flour enriched with chia seed for making bread

Abstract:
This study investigates the potential of chickpea flour enriched with chia seeds for making bread, aiming to improve its nutritional profile and sensory properties. Chickpea flour, a gluten-free alternative, is rich in protein, fiber, and essential minerals, while chia seeds offer significant amounts of omega-3 fatty acids, antioxidants, and dietary fiber. The research focuses on evaluating the effects of chia seed supplementation on the physical, chemical, and sensory characteristics of bread, including texture, color, and taste. Several formulations with varying chia seed concentrations were tested, and the resulting breads were analyzed for their nutritional content, rheological properties, and consumer acceptance. The findings suggest that incorporating chia seeds into chickpea flour-based bread enhances its nutritional value, particularly in terms of healthy fats and fiber, while also improving the texture and overall consumer preference. This work provides a promising approach for developing a more nutritious, gluten-free bread option with added health benefit.
Keywords: Superfood, rich in fiber, chia seeds, bread.

1.Introduction:

Chickpea flour made from grinding hickpeas, is increasingly popular for its nutritional qualities by enriching it with chia seeds we obtain an even more nutritious flour, rich in protein fiber, omega 3 and antioxidants.

This combination offers a healthy alternative for bread making, providing a moist texture and unique flavor **(Crous-Dutton et West, 2015).**

Used as partial or total replacement for wheat flour, this enriched flour may be suitable for people looking for gluten free option or wishing to diversify their diet additionally, the synergy between chickpeas and chia seeds promotes satiety and digestion while providing health benefits, this integration of this flour into bread recipes opens up innovative perspectives for bakers and cooking enthusiasts, combining teste, health and creativity **(Singh, Kaur, et Singh, 2016).**

2. Definition of chia seeds and chickpea flour:

Chia seeds are tiny, edible seeds from the salvia hispanica plant wich is native to central and south Africa, they are rich in nutrients, including omega 3 fatty acids, fiber, protein, and various minerals, they are valued for their health benefits and versatility in cooking.

Figure 1: Chia seeds

Chickpea flour it's made from ground garbanzo beans, belong to the class of hight fiber foods called legumes or pulses, which also includes beans, lentils and green peas.

The health benefits of legume consumption have received rising interest from researchers, and their consumption and production extend worldwide.

Figure 2: Chickpea flour

3.The Advantages of Adding Chia Seed:

Chia seeds, a superfood packed with nutrition, offer numerous benefits when incorporated into bread. Their high fibre content adds bulk and promotes a feeling of fullness. They also contribute to improved texture, acting as a natural binder and moisture retainer **(Rendón-Villalobos *et al.*, 2018).**

- **High in Fibre**: Chia seeds are an

excellent source of fibre, contributing to digestive health and promoting a feeling of fullness.

- **Moisture Retention**: Chia seeds act as natural moisture retainers, keeping the bread moist and preventing it from drying out
- **Omega-3 Fatty Acids:** Chia seeds are rich in omega-3 fatty acids, which are essential for heart health and brain function.
- **Antioxidants:** They are packed with antioxidants, which help protect cells from damage caused by free radicals.

4.The Nutritional Benefits of Chickpea Flour:

Chickpea flour, also known as besan, is a nutrient-rich alternative to wheat flour. It is naturally gluten-free, making it suitable for individuals with celiac disease or gluten sensitivity. It is also a good source of protein, fibre, and essential vitamins and minerals. This combination of benefits makes chickpea flour a valuable addition to a healthy diet **(Ciclitira, 2010).**

- **Rich in Protein**: Chickpea flour is a good source of protein, providing essential building blocks for the body
- **Gluten-Free Alternative:** Chickpea flour offers a naturally gluten-free option for those seeking alternative bread choices.

5. Why use chickpea flour replacing white flour:

Chickpea flour is an interesting alternative to wheat flour to diversify bakery offerings with numerous nutritional benefits, it allows you to meet the requirements of customers looking for authentic and tasty products that can be consumed as part of a balanced diet:

1. Lower blood sugar levels: the fiber and protein in chickpea flour can help regulate blood sugar levels, making it a suitable option for people with diabetes

2. **Gluten free option:** chickpea flour is naturally gluten free making it a suitable alternative for people with celiac disease or gluten intolerance

3. Heart health: The fiber and protein in chickpea flour can help lower cholesterol levels and reduce the risk disease of heart

4. Impoved digestion: Chickpea flour is rich in fiber can aid digestion and pronate a healthy gut.

6. Health Considerations when Using Chickpea Flour and Chia Seeds

6.1. Digestive Issues:

- **Constipation**: Chia seeds are a good source of fiber, which can be

beneficial for digestive health. However, consuming too much fiber too quickly can lead to constipation, bloating, and gas.

- **Difficulty Swallowing:** Dry chia seeds can absorb a significant amount of water, expanding in your esophagus and potentially causing choking or difficulty swallowing. It's crucial to always consume chia seeds with plenty of liquid **(Fond, 2022).**

6.2. Allergic Reactions:

While rare, some people may experience allergic reactions to chia seeds. Symptoms can range from mild skin rashes to more severe reactions like difficulty breathing. If you experience any allergic symptoms after consuming chia seeds, discontinue use and consult a healthcare professional **(Mante, 2019).**

6.3. Interactions with Medications:

Chia seeds can interact with certain medications, particularly blood thinners. The high fiber content in chia seeds can potentially affect the absorption of some medications. It's advisable to consult with your doctor if you're taking any medications and considering adding chia seeds to your diet **(Schepens, 2020).**

6.4. Other Potential Concerns:

- Weight Gain: While chia seeds are low in calories, consuming them in excessive amounts can still contribute to weight gain.
- Prostate Cancer Risk: Some studies have suggested a potential link between high intakes of alpha-linolenic acid (ALA), found in chia seeds, and an increased risk of prostate cancer. However, more research is needed to confirm this association **(Curtay, 2018).**

Materials and protocol of preparation:

In this work we'll make bread with these two functional ingredients:

Chia seeds, and chickpea flour

Equipment:

To prepare a bread here's the equipment you'll need:

- Smoll bowl
- Loaf pan
- Mixing bowl
- Teaspoon

Protocol:

- **The first bread**

Prepare the chia seeds gel: in a small bowl, combine two tablespoons of chia seeds with water and let it sit for about 10 min, until it forms a gel like consistency

Combing dry ingredient: in a large mixing bowl, mix all ingredient (chickpea flour, baking powder, and salt).

Add wet ingredient: add the chia gel,

olive oil

Mix and transfer to pain: mix the batter until smooth, the batter into your prepared loaf pan and spread it evenly.

Bake: bake for 35-40 min or until the top golden brown

Let the bread cool, and enjoy the perfect bread

- **The second bread**

is prepared in the same way as the first, the only difference being that we add chia seeds the functional food.

Finding and discussion:
Result:

Table 1: The result of sensory criteria

Setting	criteria	ordinay bread	bread with chickpea
apparence	smooth	4,4	2,1
	cracked	1,6	0
	granulated	0	3,1
color	opaque white	5	1,1
	brown	1,1	0,3
	yellow	3,9	1,7
sweeb	harmonioustaste	0	2,1
	normaltaste	3,8	4,2
	tasteless	2,2	1,5
odor	odorrless	0	0,4
	flour	4,1	3,1
texture	solid	2,7	2,1
	Crispy	0,7	1,2
	granular	1	4,6

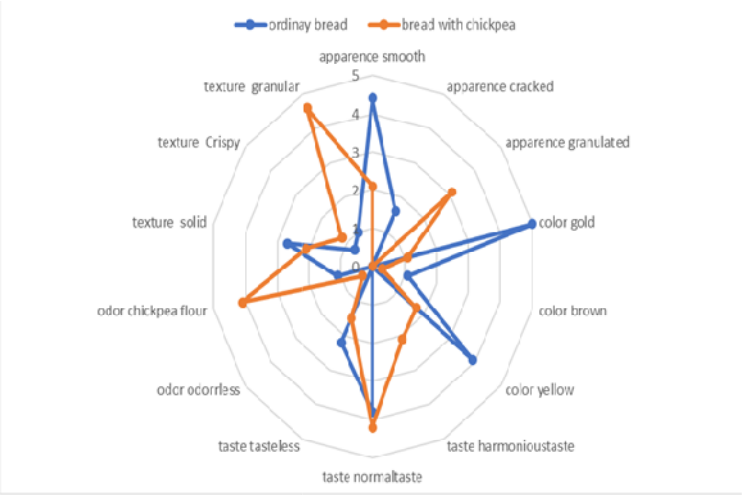

Figure 3: Sensory profile of processed bread

Discussion:

This chart is a radar diagram that compares product -B1-bread with only chickpea flour and -B2-bread with chickpea flour and chia seeds" according to serval sensory criteria, such as color, texture appearance and sweeb.

Color:
B1: appears more visibly White because it comme down to chickpea flour.

B2: the presence of chia seeds tened down the yellow color.

Apparence:
B1: bread with alone chickpea flour appears smoother.

B2: chia seeds are contributed a more granular texture.

Texture:
B1: has a more solid texture.

B2: is a more granular.

Odor:
B1: smell chickpea flour.

B2: smell mild chia seeds.

Sweeb:
B1: is a tasteless

B2: has normal taste

7.Conclusion

This exploration has highlighted the promising potential of chickpea flour enriched with chia seed for making bread. Its nutritional benefits, unique texture, and appealing flavour profile offer a compelling alternative to traditional bread options. Future research could focus on exploring the addition of other superfoods or functional ingredients to enhance the bread's nutritional value and expand its culinary versatility. Further Research Exploring the addition of other superfoods or functional ingredients to enhance the bread's nutritional value. Market Expansion Investigating potential markets and consumer preferences for this novel bread product**.** Product Development Developing new bread recipes and product variations utilizing the chickpea flour and chia seed blend.

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A cake made with rice flour

ABSTRACT

In this work, we discussed a lot of information about rice, we talked about people with celiac disease and the gluten-free food trade, we talked about the properties and benefits of rice, we talked about how to prepare rice flour, and we also talked about how to make a rice flour cake and what ingredients we need for that.

We also discussed the difference between cakes with normal flour and gluten-free flour in a table that includes the results of the sensory test based on several characteristics (aroma, taste, appearance, color and texture) that we did it previously, this work also included an interpretation of the results and finally included a comprehensive summary of everything we have done and completed previously in a conclusion.

Introduction

Food has always been an integral part of human history, closely tied to our existence. Initially, we eat to satisfy our body's needs, but over time, we also seek pleasure in our meals, striving to innovate and diversify our diets. However, what happens when a diet becomes a risk factor for disease?

Celiac disease (CD) is a significant public health issue in many countries. In Algeria, there is limited data on its prevalence, yet it remains a serious condition due to its potential complications, often stemming from non-compliance with a highly restrictive diet **(SAIDAL, 2010)**.

The main symptoms of CD include gastrointestinal discomfort, persistent fatigue, anemia, and weight loss. This chronic autoimmune intestinal disease is triggered by the consumption of gluten. For individuals with celiac disease to maintain their health, there is only one solution: adherence to a lifelong gluten-free diet, which involves eliminating wheat, barley, and rye. Cooking without wheat flour may seem challenging at first, but numerous alternatives, such as rice flour, corn flour, and chickpea flour, can help rediscover the joy of cooking and eating.

However, commercial gluten-free products are often imported, expensive, lack variety, and are frequently criticized for their texture and taste **(BENATALLAH, 2009)**. With the growing demand for gluten-free foods and the search for suitable wheat alternatives, rice flour

produced by milling rice grains has gained popularity. It has become one of the most favored gluten-free flours among consumers.

The aim of this work is to develop nutritious and satisfying biscuits for celiac patients using rice flour.

Figure 3 : white rice.

1. Generalities about rice:

1.1. Characteristics of rice:

- Rich in fiber.
- Source of B-group vitamins.
- Source of manganese and selenium.
- Rich in antioxidants.
- Fights the onset of certain diseases.

1.2. The benefits of rice: Why do we eat it?

- A host of antioxidants.
- Prevents cancer.
- Corrects digestive issues.
- A source of phosphorus and magnesium.
- A reservoir of trace elements.
- A source of group B vitamins.

2. How to make rice flour?

The method involves the milling of rice grains, and consists of the following stages **(CRUZ et *al.*, 2019)**:

2.1. Moistening, filtering, and drying: the grains are weighed using a scale to determine the mass that will be used in the following stages. They are then immersed in water overnight and soaked. They are placed in a colander to drain the excess water. Once done, they should be collected and placed in a sunny place for 20 to 30 minutes, which reduces the water content and makes the next process easier.

2.2. Milling and sifting rice flour: the wet grains obtained after drying in the sun are manually milled using a blender. The milled grains are sifted using a very small plastic sieve. The sieving process is done using an oscillating motion with the hands. The goal of this process is to remove large particles and obtain flour with a uniform grain size, then collect the flour in a clean, dry container.

2.3. Drying the flour: after sifting the flour, spread the flour evenly in a clean, sunny place to reduce its moisture content for 3 days.

Figure 4 : white rice flour.

3. Ingredients:

- 130 grams of rice flour.
- 3 eggs.
- 90 grams of sugar.
- 100 ml of oil.
- 1 tea spoon of vinegar = 5 ml.
- 10 grams of baking powder.
- One bag of vanilla = 6 grams.
- 2 pots of plain yogurt.
- 2 table spoons of starch = 40 grams.
- A pinch of salt = 1 gram.

Figure 5: rice flour cake recipe ingredients.

4. How to prepare rice flour cake:

First, we prepare the mold by greasing it with ghee or butter. Second, we preheat the oven, and then mix all the liquid ingredients and sugar in the mixer, and then we gradually add the dry ingredients in two batches, stirring gently with a hand whisk in one direction. The mixture into the prepared mold and bake the cake for 30 to 40 minutes, depending on your oven. Before removing the cake from the oven, test its doneness by inserting a toothpick into the center; it should come out clean. Once backed, cover the cake to prevent it from drying out.

5. Cake preparation steps:

Figure 4 : grease the mold with butter.

Figure 7 : mix the dry with the liquid ingredients

Figure 5 : mix the dry ingredients

Figure 8 : put the mixture in the mold.

Figure 6 : mix all the liquid ingredients with sugar.

Figure 9 : put the mold in the oven.

Figure 10 : the cake after cooking.

6. Results and discussion:

Table 1: The result of sensory criteria

Parameter	***Criterion***	***A1***	***A2***
Appearance	***Smooth***	*6*	*6,43*
	Gracked	*2,85*	*1,43*
	Granulated	*0,29*	*3,43*
Color	***Opaque white***	*2,36*	*2,71*
	off white	*2,14*	*1,07*
	Biege	*4,53*	*6,36*
Taste	***Tasteless***	*0,86*	*0,29*
	Normal taste	*6,36*	*7,14*
	Harmonious taste	*6,86*	*6,07*
Smell	***Odorless***	*0,71*	*0,29*
	Eggs	*0,64*	*0,43*
	Lemon	*8,04*	*0*
	Rice	*0*	*5,79*
Texture	***Soft***	*6,14*	*6,21*
	Crunchy	*0,43*	*0,5*
	Spongy	*8,21*	*5,5*

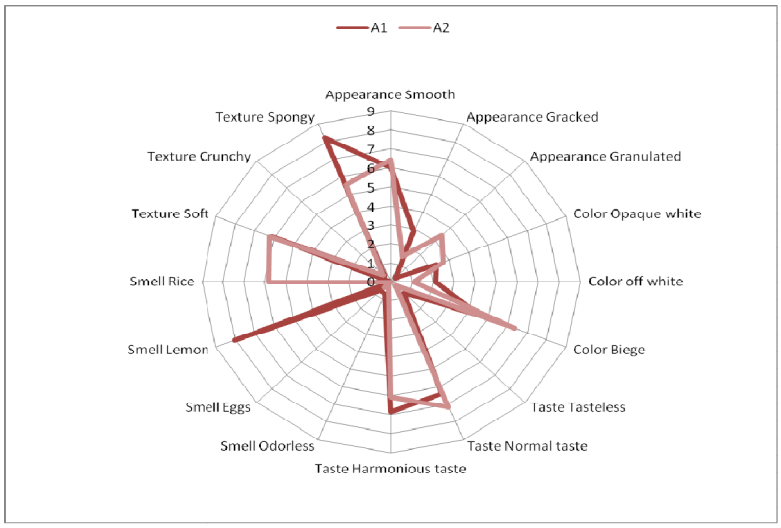

Figure 3: Sensory profile of rice cake

Interpretation of the results:

The graph shows the sensory analysis and comparison between the original cake (A1) and the rice flour cake (A2). This evaluation was based on different criteria (appearance, color, taste, smell and texture) on a scale of 10. After tasting and filling out the sensory evaluation sheets, we got the following results:

The majority of students agreed that A1 had a smooth appearance and a slightly beige color with a harmonious taste, vanilla aroma, and spongy texture. A2 was also soft in appearance and beige in color but had a natural taste, lemon aroma, and soft texture.

Conclusion

Celiac disease is an inflammatory disease of the gastrointestinal tract. The complete and permanent exclusion of gluten from the diet forms the basis of the treatment of this disease. The aim of our work was to create a gluten-free cake based on rice flour.

Therefore, this study enabled us to use artisanal flour made from milled rice grains and prepare gluten-free cakes for patients with celiac disease. The choice of flour was primarily due to the fact that it does not contain gluten, as well as its nutritional value, but above all to the ease of making it ourselves and its low cost.

The sensory analysis carried out on the produced cakes showed that they have good sensory quality (appearance, color, smell, taste and texture). The majority of people who participated in the taste test judged the cake to be between average and good.

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MINT-flavored toast

Degustation: 02/12/2024
Presentation: 09/12/2024

A B S T R A C T S

Today, the world has achieved great developments, including in the food field, by making several food products with the aim of changing and improving them into high-quality foods. In this article, we talked about toast bread, as we improved it with mint to make it more functional, as mint has several benefits, including in the medical field, as it contributes to improving the digestive system.

- **Keywords:** Food, Functional, Medical, digestive system

Introduction:

Toast is sliced bread that has been browned by radiant heat. The browning is the result of a Mallard reaction altering the flavour of the bread and making it crispier in texture. The firm surface is easier to spread toppings on and the warmth can help spreads such as butter reach its melting point. Toasting is a common method of making stale bread more palatable. Bread is commonly toasted using devices specifically designed for such, e.g., a toaster or a toaster oven. Toast may contain more acryl amide, caused by the browning process, which is suspected to be a carcinogen [1] However, claims that acryl amide in burnt food causes cancer have not been proven [2]

What is toast bread?

Toast bread is a food product obtianed through the following stages kneading, fermentation, baking slicing toasting. Nutrionally, toast is a good source of carbohydrates and provides some protein and dietary fibre in addition to a variety of vitamins and minerals.

Definition of mint:

Mint has a long history possibly originating in Europe and the Mediterranean, where it was regarded as the symbol of hospitality, and proliferated from there to most other parts of the world.

It is herbaceous plant belonging to the lamiaceae family, lamiaceae order and a sed herb. It can be added to some foods to give flavour and taste, as it is rich in nutrients and nutritional elements and is a source of antioxidants [3]

Health benefits of mint leaves:

- Poromote brain health
- Digestive health
- Improve respiratory complaints
- Oral care
- Boost immunity & help to ease morning sichnes

Making toast :

Ingredients:

- **3 cups of whole wheat**
- **1 cup warm water**
- **3 tablespoons sugar**
- **3 tablespoons vegetable oil**
- **2 teaspoons instant dry yeast**
- **A tablespoon of salt,**
- **1 cup of mint.**

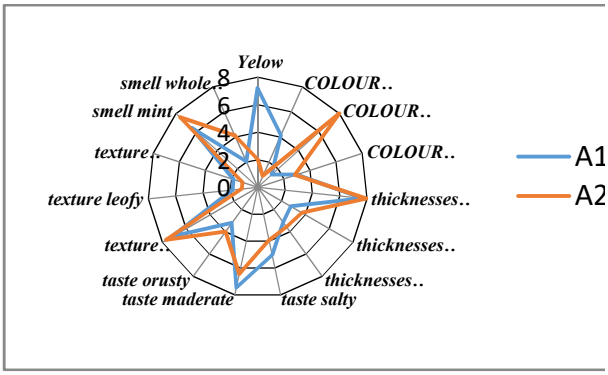
First, in a plate, put the flour, sugar, yeast, salt, and mint, and stir them together, then add the egg, oil, and milk, gradually add water, and knead the dough for about 7 minutes until the dough becomes smooth.

Second: We cover the dough and let it rise for an hour. When it rises, we open the dough into a rectangular shape, then we wrap the rectangular roll and place it in the toast tray. We cover the dough and let it rise again for 1/4 hour, and then we paint the surface of the toast with milk and a Nescafe spoon, and paint the entire dough with a paint brush.

finally: We put the tray in the oven at 200 degrees for 1/4 hour, and when it is cooked and browns on top, we take it out of the oven, cover it, and leave it for 10 minutes until it becomes soft, then we cut the toast.

The table is designed to evaluate taste smell and visual appeal of our new product gathering accurate:

setting	critria	A1	A2
COLOUR	Yellow	7,21	2
	white	4,15	0,89
	Brown	1,38	8
Thicknesses	Thin	2,94	2,84
	Moderate	7,68	7,94
	Rough	2,78	3,73
Taste	Sweet	3,15	3,57
	Salt	5	3,94
	Moderate	7,47	7
Texture	Crusty	3,21	4
	Spongy	7,15	7,8
	Leafy	1,84	1,15
smell	Roosted	1	1,163
	Mint	6	7,6
	whole wheat	2,05	4,105



INTERPRETATION

The graph shows the sensory analysis comparison between plain toast (A1) and mint toast (A2) which were evaluated based on deferent criteria using a10-point scale after tasting and completing the sensory evaluation sheets ,the results showed the following :the majority of students agreed That al had a medium thickness ,slightly beige colour ,harmonious taste and spongy texture .

Similarly, A2 was described as also having a medium thickness, darker colour and a minty taste and smell.

We also say that everyone has their own taste and the majority of them liked our product.

Conclusion

In addition to its delicious taste, mint is rich in many health benefits, such as improving digestion and relieving stress. Therefore, adding mint flavor to toast not only improves the taste, but also contributes to enhancing the nutritional value of the meal and providing additional health benefits.

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Carob-based Madeleines

ABSTRACT

The carob tree is a fruit tree of the legume family, a hardy plant that can be grown in arid regions. Native to the Mediterranean Basin since ancient times, the carob tree has been used for its fruit, the carob, widely used for its medicinal and nutritional benefits. Carob powder is often used as a substitute for cocoa because it has a similar flavour but is lower in fat and caffeine.

Madeleines are small sponge cakes recognized for their distinctive shell shape and delicate flavour. Originating in France, they are a popular food all over the world. The success of making madeleines lies in archieving a precise balance of ingredients and techniques.This study explores the scientific process of creating healthy madeleines with carob powder, including the key factors that influence their texture and flavour, with a focus on their scientific and culinary principles. The methodology includes ingredient preparation, mixing techniques and baking criteria. A statistical analysis was conducted based on the ratings of taste, texture and appearance ratings collected from a group of testers on carob madeleines.

Keywords: carob, carob powder, madeleine, carob madeleine.

INTRODUCTION

The scientific name of carob tree, *Ceratonia siliqua* L., derives from the Greek word “Kera,” which relates to the keratomorphic shape of the fruit, and the Latin word siliqua, which refers to the pods’ hardness and shape. World production of carob is estimated at 160,000 tons per year (Goulas, Stylos, Chatziathanasiadou, Mavromoustakos, & Tzakos, 2016). Spain produces the largest quantities, followed by Italy, Portugal, Morocco, Turkey, Greece, Cyprus, and Lebanon (Food and Agriculture Organization of the United Nations).

The madeleine industry occupies a significant place in the food industry in Algeria (Nhouchi *et al.,* 2018). This product, intended mainly for infant and elderly consumption, is becoming increasingly important.Today's consumer is looking for the safety of bakery products not only with a fresh and pleasant taste but also with health benefits (Nhouchi *et al.,* 2018). This change in consumer perspective has encouraged the food industry to apply modern manufacturing technologies to the enrichment of biscuits (Ansari and Kumar, 2012).

Over the years, several studies have been reported to improve the nutritional value of madeleines by incorporating legumes and oilseeds such as beans, barley and corn, carob (Serrem, 2010).The aim of this work was to substitute a certain amount of wheat flour (50%) with carob flour then in order to evaluate their quality. Our objective lies in improving the

nutritional and sensory quality of enriched and treated madeleines, the richness of carob flours in natural sugars, it replaces commercialized white sugar (iced or crystallized)

METHODS

Total time: ~30 minutes

Preparation: 15 minutes

Cooking: 10-12 minutes

Resting: 5 minutes

Fig 1: Steps in the Preparation of Carob-Enriched Madeleines:

Fig 2: Final Appearance of Carob-Based Madeleines

Making madeleines with carob powder is an innovative approach to baking, combining healthy ingredients with classic techniques. The process begins with mixing 3 eggs and carob powder (100 g), which acts as a coloring and flavoring agent while providing antioxidants and imparting a unique flavor (sweetness). To this mixture, a liquid phase composed of 1/2 cup of vegetable oil and 1 cup of milk is added, which provides moisture and a tender texture to the madeleines, and a tablespoon of white vinegar, the latter reacting with the baking powder to produce the carbon dioxide needed to improve the texture and rise of the madeleines. Adding a pinch of salt enhances the flavors, and the oat flour (150 g), rich in fiber and low in gluten, is gradually incorporated to ensure a homogeneous consistency, essential for uniform baking,

Adding pieces of dried black raisins, rich in a special flavour mixed with sweetness and acidity, to increase the nutritional value and taste.

Once the dough is distributed in paper cases and placed in molds, baking at 180 °C for 10 to 12 minutes produces brown madeleines, soft on the inside and slightly crispy on the outside. This recipe illustrates the balance between nutrition and gastronomy by introducing alternative ingredients into a classic setting Carob Powder Madeleines.

RESULTS AND DISCUSSION

Table 1: Sensory Evaluation Statistics: Comparison of Classic and Carob-Enriched Madeleines

Tests	Sensation felt	White product	Elaborate produit
Taste	Lightly sweet	5,37	4,79
	Moderately sweet	5,89	5,72
	Very sweet	3,17	3,06
Texture	Soft	6,55	5,82
	Dry	6,1	5,62
	Grainy	2,1	2,24
Aroma	Vanilla	8,13	4.20
	Carob	0,8	9,03
Color	Light	8,86	1,1
	Dark	0,55	8,93

We prepared two types of madeleines: the first is a classic white madeleine, and the second is a carob-based madeleine, rich and healthy. After distributing them to our colleagues for tasting, the statistics revealed interesting differences. In terms of taste, the white madeleine received higher scores for light sweetness (5.37 vs. 4.79) and moderate sweetness (5.89 vs. 5.72), while both products were nearly equal in intense sweetness (3.17 vs. 3.06). Regarding texture, the white madeleine was found to be softer (6.55 vs. 5.82) and slightly less dry (6.1 vs. 5.62). However, the carob madeleine stood out for its natural aroma of carob (9.06 vs. 8.13) the white Madeleine stood out for its natural aroma of vanilla (1.79 vs. 2.14). Finally, in terms of color, the white madeleine was preferred for its light appearance (8.86 vs. 1.1), while the carob madeleine excelled in its dark color (8.93 vs. 0.55). These results highlight varied preferences based on taste, texture, and visual appeal.

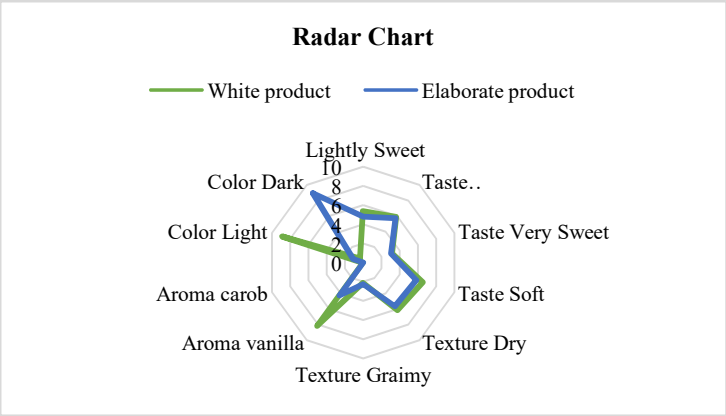

Fig3: *Radar Chart Analysis: Sensory Attributes of Carob-Enriched vs. Classic Madeleines*

In this radar chart, the regular white madeleine (represented by the red color) is compared to the carob madeleine (represented by the green color) across several criteria. The regular white madeleine performs better in areas such as light and moderate sweetness, where it received higher scores than the carob madeleine. It also excels in texture, being softer, and in the light color rating. On the other hand, the carob madeleine stands out in other areas, such as its natural aroma and dark color, reflecting its healthy and rich carob ingredients. While there are differences between the two products in some aspects, each appeal to different consumer preferences. Based on this analysis, the carob madeleine could be improved in areas like texture and sweetness balance, while the white madeleine could benefit from enhancing its aroma to combine the strengths of both products.

CONCLUSIONS

In conclusion, natural substances are increasingly occupying a prominent place in the food industry. The carob tree, a natural source from which maximum benefit must be taken to improve the food industry, the choice of this raw material is due on the one hand to its nutritional richness, especially in proteins, and on the other hand to its availability and low cost.

The preparation of carob madeleines is a creative and healthy variation of the classic French pastry. Carob, with its naturally sweet and slightly nutty flavor, not only enhances the taste, but also offers nutritional benefits, such as being rich in fiber and antioxidants and the healthy alternative to industrial cocoa is the ideal solution for those looking to eat healthy and take care of their health. By incorporating carob into madeleines, we combine tradition and innovation, creating a delicious treat that meets modern dietary preferences while preserving the charm of this beloved dessert.

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PEANUT BUTTER WITH FENNEL SEEDS

ABSTRACT

This study addresses the production of peanut butter, a product that is still underutilized in the Algerian market. Our experience shows the nutritional benefits of this product.

In this work, a formula for peanut butter was chosen that consists exclusively of pure natural ingredients (fennel seed powder).

The results of the sensory analysis, compared to two products of original peanut butter and peanut butter fortified with fennel seeds, show that the fortified peanut butter is the most appreciated by consumers.

Introduction

Peanuts are consumed worldwide due to their high nutritional value and their pleasant or unique flavor after roasting or boiling. Because of their high nutrient content, peanuts have been used to combat malnutrition in most developing countries. Peanut butter is one of the most sought-after peanut products that was created in the late 18th century as a protein substitute for people with poor teeth.

The commercial production of peanut butter has developed worldwide, and the product is now ubiquitous and consumed as part of the staple diet **(1).** Aromatic plants are promising and constitute a great source of antioxidants and natural antibacterials for the agri-food industry. Fennel is one of the most appreciated traditional and medicinal plants. It belongs to the Apiaceae family, formerly called Umbelliferae. Fennel is mainly cultivated for its seeds, which are the most exploited part. These fennel seeds are used to flavor food products such as pickles, breads, pastries, and cheeses. **(2).**

I. Origin and history

I.1. Peanut butter

The origin and history of peanut butter are fascinating and show the evolution of this popular food. Peanuts, from which the butter is derived, have roots in South America, where they were cultivated by ancient civilizations, such as the Incas. They were introduced to Africa and North America in the 17th century through trade

Peanut butter as we know it today was popularized in the 19th century. In 1884, a

Canadian physician, Marcellus Gilmore Edson, patented a process for producing a paste made from peanuts, which was one of the earliest versions of this product. Later, in the 1890s, another inventor, George Washington Carver, developed methods for cultivating and processing peanuts, contributing to their growing popularity

By the early 20th century, peanut butter became a staple food in the United States, especially during World War I, due to its nutritional value and affordability. Today, it is consumed worldwide, appreciated for its unique flavor and nutritional benefits, and there are many variations, ranging from creamy to crunchy. (3).

(Original picture)

I.2. Fennel seeds

Fennel seeds, derived from the plant Foeniculum vulgar, have a rich origin and a history of traditional use. They are native to the Mediterranean regions, where they have been cultivated since ancient times. In ancient cultures, fennel seeds were used not only as a spice but also for their medicinal properties. They were often employed to treat digestive issues such as bloating and colic. Additionally, in some traditions, fennel seeds were considered a remedy to improve lactation in nursing mothers.

(Original picture)

This traditional use highlights the significance of fennel seeds in both culinary and folk medicine practices, showcasing their value throughout history**. (4).**

II. Making and preparation

II.1. Ingredients needed

- **Peanut butter:** Use unsalted peanuts for better control over the flavor.
- **Fennel seeds:** Using it finely ground.

II.2. Preparation process

- **Roasting the peanuts:** Preheat the oven to 180 degrees Celsius (350 degrees Fahrenheit).We roast 1 kg of shelled peanuts in a pan over low heat and stir them well so they don't burn until they acquire a golden color.
- **Blending:** We put the mixture directly into the electric blender until we achieve a smooth, creamy consistency.

Next, we gradually add 250 g of fennel seed powder until the mixture is blended, and thus we have our product.

To prepare peanuts butter with fennel seeds, we start by gathering the ingredients and then follow these steps:

(Original pictures)

III. Nutritional Profile of Peanut Butter

One tablespoon of peanut butter (16g) provides:

- 97 kcal / 402 kJ.
- 3.6g of protein.
- 8.3g of fat.
- 2.0g of saturated fat.
- 2.1g of carbohydrates.
- 1.1g of sugars.
- 1.1g of fiber.

Many brands add ingredients such as oil, sugar, xylitol, and salt, which alter the nutritional profile. For example, products marketed as "reduced-fat" may contain added sugar to enhance flavor **(5).**

IV. Health Benefits of Peanut Butter

IV.1. Rich in Nutrients

Peanuts are an excellent source of nutrients, providing various minerals such as magnesium, iron, zinc, and copper. They also contain vitamins, including B vitamins and vitamin E.

IV.2. Balanced Energy Source

Peanuts offer a good balance of protein and carbohydrates, with a slightly higher proportion of energy coming from fats. As a result, peanut butter is calorie-dense.

IV.3. Healthy Fats

Peanut butter is rich in fats, especially oleic acid, a beneficial monounsaturated fat also found in olive oil. Oleic acid is associated with several health benefits, including improved insulin sensitivity. Although peanuts contain some saturated fats, the majority of their fats are monounsaturated, with a good balance of polyunsaturated and saturated fats. One tablespoon of peanut butter provides about 10% of the recommended daily intake of saturated fats for an adult.

IV.4. Concentrated Energy Source

Peanuts provide a high amount of energy in small portions, making them useful for individuals with limited appetite or those suffering from malnutrition. Their high fat content, with 9 kcal per gram, makes them more calorie-dense than milk, soy, and cereals.

IV.5. Source of Plant-Based Proteins

Peanuts are a good source of plant-based proteins, although they lack certain essential amino acids like lysine and methionine. In a balanced plant-based diet, they are valuable, as their proteins are as digestible as those from animal sources.

IV.6. Source of Protective Plant Compounds

Peanut butter is rich in antioxidant plant compounds such as p-coumaric acid and resveratrol, which may reduce the risk of heart disease and arthritis, as observed in animal studies.

IV.7. Source of Fiber

Peanut butter is also a good source of fiber, providing about 1.3g per tablespoon when made from peanuts with the skin. Fiber promotes gut health and helps with appetite management.

IV.8. Low Glycemic Value

Peanuts have a low glycemic value, meaning they do not cause a sharp rise in blood glucose levels. When added to high-GI foods, they help stabilize blood sugar levels.

IV.9. Source of Coenzyme Q10

Peanuts and their skins are rich in biologically active components, including coenzyme Q10. This essential compound may support the skin, brain, and lungs while protecting the heart from oxygen deprivation, which can occur due to coronary heart disease.

IV.10. Rich in Plant Stanols and Sterols

Peanuts and peanut butter are rich in plant compounds called stanols and sterols, which inhibit the absorption of dietary cholesterol. These compounds are believed to help reduce the risk of heart disease **(5).**

V. Nutritional Values of Fennel Seeds

For 100g of fennel seeds (though typical portions consumed are much smaller), here are the main nutritional values:

- Calories: 345 kcal.
- Fiber: 39g.
- Protein: 15g.
- Fat: 14.9g.
- Calcium: 1196 mg (about 120% of the Recommended Daily Intake - RDI).
- Iron: 18.5 mg (about 130% of the RDI).
- Magnesium: 385 mg.
- Vitamin C: 21 mg.

In small amounts, fennel seeds remain a concentrated source of minerals like calcium, iron, and magnesium, essential for bone health, blood circulation, and muscle function. **(6).**

VI. Health Benefits of Fennel Seeds

VI.1. Aids Digestion

Fennel seeds are well-known for their digestive properties. They contain active compounds that stimulate the production of gastric juices, helping to relieve bloating, gas, and indigestion.

Chewing a few fennel seeds or drinking them as a tea after a heavy meal can promote easier digestion.

VI.2. Source of Antioxidants

Rich in antioxidants such as quercetin and anethole, fennel seeds help neutralize free radicals in the body. This can reduce oxidative stress, slow down cellular aging, and lower the risk of chronic diseases.

VI.3. Immune System Support

Fennel seeds contain vitamin C, which is known for boosting the immune system. By increasing vitamin C intake, they help strengthen the body's natural defenses, especially during cold seasons.

VI.4. Hormonal Regulation

Anethole, a compound found in fennel seeds, has estrogen-like effects that may help regulate hormones in women. It is often used to alleviate menstrual-related symptoms such as pain and cramps.

VI.5. Natural Antimicrobial

Fennel seeds have natural antimicrobial properties that help fight bacteria and yeast. They are commonly used in herbal teas to relieve minor respiratory or oral infections**.(6).**

VII. Culinary uses

Peanut butter made from fennel seeds is a versatile ingredient that can be used in a wide range of sweet and savory recipes:

VII.1_Sweet recipes

On bread: spread on slices of bread with a layer of jam on top, just like butter.

In pastries: To add a unique flavor to brownies, cupcakes, muffins, and more.

Smoothies: Add a spoonful of peanut butter to a banana and milk smoothie for a rich and creamy flavor.

Cookies and brownies: Incorporate it into cookie, brownie, or cake recipes for a unique flavor.

Dessert sauce: Mix it with a bit of milk or almond milk and sugar to create a sauce to drizzle over ice cream or fruit. **(7).**

VIII.2_Savory recipes

Noodles or Pasta: Make a sauce by mixing peanut butter with a bit of soy sauce, grated ginger, and vinegar to accompany Asian-style noodles or pasta.

Sandwiches: Pair it with grilled vegetables, apple slices, or even chicken for delicious sandwiches.

In cold sauces: Like Gado-Gado sauce, an Indonesian vegetable salad accompanied by a peanut butter dressing.

In hot sauces: Like Satay sauce, a spiced sauce served with chicken or shrimp skewers.
In stewed sauces: As the base for the aromatic Mafé chicken sauce. **(8).**

Conclusion

Peanut butter is rich in protein, healthy fats, and various nutrients such as vitamin E, magnesium, and potassium. When combined with fennel seeds, which are known for their digestive properties and slightly sweet, anise-like flavor, this combination becomes not only delicious but also beneficial for health.

Fennel seeds add antioxidants and fiber, which can aid digestion and regulate metabolism. Additionally, they contain anti-inflammatory compounds that can contribute to overall health. By incorporating peanut butter with fennel seeds into your diet, you can enjoy a tasty snack that supports both your physical well-being and digestive health.

In summary, peanut butter with fennel seeds is an excellent option for those looking to diversify their diet while benefiting from the nutritional properties of these two ingredients. Whether spread on toast, blended into smoothies, or used as an ingredient in recipes, this combination provides a delicious way to enhance your dietary regimen.

Note

It's important to consider potential allergies when consuming peanut butter and fennel seeds. Peanuts are one of the most common food allergens, and an allergy to them can lead to severe reactions such as difficulty breathing or facial swelling. Therefore, individuals with a history of peanut allergies should avoid consuming them altogether.

On the other hand, fennel seeds are less commonly associated with allergies, but some individuals may still experience allergic reactions to them. If you have any type of food allergy, it's best to consult with a healthcare professional before including these ingredients in your diet.

In summary, you should be cautious and check for any allergies before incorporating peanut butter and fennel seeds into your diet.

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Potential of Pomegranate Seed Madeleines in Disease Prevention and Health Improvement

ABSTRACT

This article presents an in-depth analysis of an innovative new product: the "Pomegranate Seed-Enriched Madeleine." Developed as an enhanced version of the traditional recipe, this new variant aims to provide additional nutritional benefits thanks to the antioxidants and vitamins found in pomegranate seeds. The study explores sensory characteristics and consumer preferences for this enriched version compared to the classic Madeleine.

Sensory panels were conducted to evaluate taste, texture, and appearance, while a statistical analysis compares the two versions across these criteria. Results show growing consumer interest in products enriched with superfoods, though some differences in taste and texture perception were noted. The enriched Madeleine scores higher in terms of nutritional value and originality, but opinions are divided regarding the specific taste of pomegranate seeds. The article concludes with insights on the opportunities and challenges associated with introducing this enriched version into the pastry market.

Introduction

Nutrition plays a central role in our health and well-being. Today, research increasingly highlights the importance of functional foods, products that go beyond basic nutrition to offer additional benefits, such as disease prevention and improved quality of life. These foods, enriched with specific nutrients or designed for particular goals, are at the heart of many innovations in the food industry. In this context, creating new products that meet modern nutritional needs and consumer expectations has become essential. In this context, the use of pomegranate seeds in food opens up new perspectives for creating innovative products that combine unique flavors and health benefits, addressing modern nutritional needs and consumer expectations.

With a growing demand for natural and health-beneficial foods, pomegranate seeds are emerging as an ideal ingredient for innovation. they can transform a simple madeleine into a delightful and nutritious experience. This fusion aims to meet the expectations of health-conscious consumers, while offering a touch of exoticism and vitality.

History of pomegranate

The pomegranate originates in the Middle East, with findings such as fossilized leaves, branches and seeds dating back to the early Bronze Age (3500–2000 BC). Scientists have placed it in the first five positions in the list of the oldest cultivated fruits, along with the olive, grape, date palm and fig, while references of pomegranate exist in the Koran and the Bible. In many religions and cultures, pomegranate is thought to be an auspicious symbol, mostly of life, luck, abundance and fertility. The process of the domestication of pomegranate took place during the prehistoric times, when traders, sailors and missionaries are said to have been responsible for the introduction of pomegranate to the Mediterranean region, Mexico and California. Its spread through Eurasia and America demonstrates the versatility of the plant as far as climatic and soil conditions are concerned, and this is actually the reason for the fruit's current morphological conditions.

Pomegranate is the well-established fruit of a shrub (***Punicagranatum L***.) that is particularly cultivated in west Asia and in the region around the Mediterranean, as well as other parts of the world, including America, where the climate is suitable for its growth. The shrub normally grows up to 5 m, but in some cases, it may reach a morphology of a tree that is as tall as 10 m, except for dwarf cultivars that grow up to 1–2 m. Climates that simulate that of Mediterranean (with high sunlight-exposed mild winters and dry summers), seem to be ideal for the growth of pomegranate. Most varieties are deciduous, although there have been reports of evergreen and conditionally deciduous pomegranates, depending on the altitude and temperature of the zone. The fruit is categorized as a fleshy berry. Its shape is nearly round, with a diameter up to 10 cm, and there is a crown-shaped calyx at the top. Inside the leathery exocarp is a fleshy mesocarp, organized in chambers that are separated by membranes. The arils contain the edible portion of the fruit. The exocarp, namely the pomegranate peel, comprises around 50% of the whole fruit, while the edible part consists of 10% seeds and 40% arils. The whole pomegranate and its juice have an intense color for which selected bioactive compounds are responsible, especially anthocyanins. Therefore, the variation in color amongst different cultivars is mainly due to the different concentration of these compounds.

There are many different cultivars of pomegranate (more than 500) spread all over the world. However, the type of cultivars that have prevailed in certain regions reflects the preferences and taste of the local populations, e.g., nonacidic cultivars are favored in India.

The origin of the current cultivars is covered by a shroud of doubt because most of them are derivatives of mutations with no recordings of their origin. Exemptions are some cultivars that are the result of deliberate breeding.

In general, the same basic pomegranate fruit is known by different names in different regions, and this is mainly due to the fact that husk and aril color can markedly vary when grown in different regions. These differences mainly affect fruit size, husk color (ranging from yellow to purple, with pink and red most common), aril color (ranging from white to red).

Table I: seed hardness, maturity, juice content, acidity, sweetness and astringency asit shows in the below.

Country	**Variety**
China	Dabaitian, Heyinruanzi, Tongpi, Bopi
Egypt	Arabi, Manfaloty, Nab ElGamal, Wardy
Georgia	Pirosmani, Rubin, Shirvani, Slunar, Vedzisuri, ImeretisSauketeso
Greece	Hermione, Persephone, Porphirogeneti
India	Ganesh, Mridula, Bhagwa, Ruby, Alandi
Iran	Malas-e-Saveh, Rabab-e-Neyriz, Malas-e-Yazdi, SisheKape-Ferdos, Naderi-e-Budrood
Italy	Dente di Cavallo, Neirana, Profeta, A dente Molfetta, EcotipoTuri, Maddaloni Dolce, GiardinoChiuso Dolce
Malta	Blance, Dulce Colourada, Cagin
Morocco	Gjebali, Djeibi, Grenade Jaune, Grenade rouge, Bzou, Sefri, Chelfi
Spain	Mollar de Elche, Agri de albatera, Valenciana
Tunisia	Gabsi, Tounsi, Zehri, Mezzi, Jebali, Garoussi, Kalaii, Zaghouani
Turkey	Cekirdksiz, Ernar, Fellahyemez, Hatay, Akanar, Hicaznar, Janarnar
USA	Wonderful, Early Foothill, Granada, Spanish sweet, Ruby red

(PANAGIOTIS KANDYLIS ET EVANGELOS KOKKINOMAGOULOS, 2020).

Benefits of pomegranates (seeds)

- Heart health benefits
- Anti-inflammatory properties
- Anti-cancer phytonutrients
- Urinary health supportDigestive health benefits
- Elevated endurance

- A boast in antimicrobial properties that fight oral germs that cause gum disease and bad breath **(CHAVIL**, **2020).**

Table II : The physicochemical properties of pomegranate seeds

Parameter (%)	Pomegranates seeds
pH	5,85
Moisture	3,95
Protein	18,80
Crude oil	19,20
Total ash	1,70
Crude fiber	20,00
TTA	92,45

ZAINEB, BEHZAD, et HOSSEIN, (2018).

Experimental part

Materials and methods

Ingredients

- Sugar
- Eggs
- Oil
- Pomegranates seed powder
- Salt
- Vanilla extract
- Flour
- Chemical yeast
- Yogurt
- Chocolate pipette
- A spoon of vinegar

Materials

- Drummer
- Spoon
- Cup
- Electric oven
- Whip
- Spatula
- bowl

Methods

Preparation of pomegranate seed powder

We peel the pomegranate, crush it, filter the seeds and dry them in the sun for a week until it is completely dry. Then we grind it until we get a very fine powder.

Preparation of madeleine

We mix 4 eggs with a 240 ml cup of sugar and mix well, then add a pinch of salt, a pot of yogurt and a tablespoon of vinegar.

Then we add a teaspoon of vanilla perfume a 240 ml cup of oil and 3 cups of the same capacity of flour and 2 chemical yeast with continuous mixing until we get a homogeneous and heavy mixture, then cover the mixture with plastic bag and leave it to ferment for 30min in the refrigerator. After that prepare the molds and put a tablespoon of the mixture in each mold. Then decorate it with chocolate chips and put it in the oven for 20/30 min and cook at 160 C°.

We repeat the same steps to prepare the madeleine enriched, by adding 120 ml of pomegranate seed powder without adding any colorings or flavorings

Final product labels «pomegranate heart cake»

As a part of marketing pomegranate heart cake:

Nutritional claims:

- ✓ Rich in antioxidants
- ✓ Source of fiber
- ✓ Gluten free
- ✓ Without coloring and without flavors

Slogan: The little pleasure that is good for your health

Zone of valorization: The delicious and unique taste of these madeleines

Sensory evaluation sheet:

Sensory evaluation sheet for madeleine enriched with pomegranate seed

Name & family name: **Date:**

Age: **Gender:**

The madeleine, this small masterpiece of French pastry, is often associated with nostalgic memories. By adding pomegranate seeds to this iconic recipe, we pave the way for a sublime reinterpretation of this classic. This fusion of the airy texture of the madeleine and the tangy crunch of the pomegranate seeds creates a perfect harmony, both visually and in taste.

Discover this innovative creation that redefines the boundaries of flavor and invites you to a tasting experience filled with sophistication.

We have two distinct products: the classic madeleine (C1) and the madeleine enriched with pomegranate seeds (C2). A comparison will be made between these two versions, highlighting their sensory qualities and nutritional benefits.

Dear tasters:

Settings	Criteria	Note
Color	Gold	
	Yellow	
	Brown	
Appearance	Swell	
	Perforated	
	Unfermented	
Taste	Sweet	
	Vanilla	
	Tasteless	
Touch	Spongy	
	Hard	
	Pasty	
Smell	Vanilla	
	Eggs	
	Odorless	

Settings	Criteria	Note
Color	Gold	
	Yellow	
	Brown	
Appearance	Swell	
	Perforated	
	Unfermented	
Taste	Sweet	
	Pomegranate	
	Tasteless	
Touch	Spongy	
	Hard	
	Pasty	
Smell	Pomegranate	
	Eggs	
	Odorless	

This table is created to assess the taste, smell, and visual qualities of our new product, collecting precise and constructive feedback:

Individuals will taste the new product and provide ratings out of 10 for each category, contributing valuable insights for its development.

(IF YOU ARE ALLERGIC TO POMEGRANATE, IT IS NOT RECOMMENDED TO TAKE THIS PRODUCT)

Original Madeleine **pomegranate heart cake**

Satisfaction index for pomegranate heart cake: 😐 ☺️ 😊 😁 😍

Personnel teste for pomegranate heart cake : ……/10

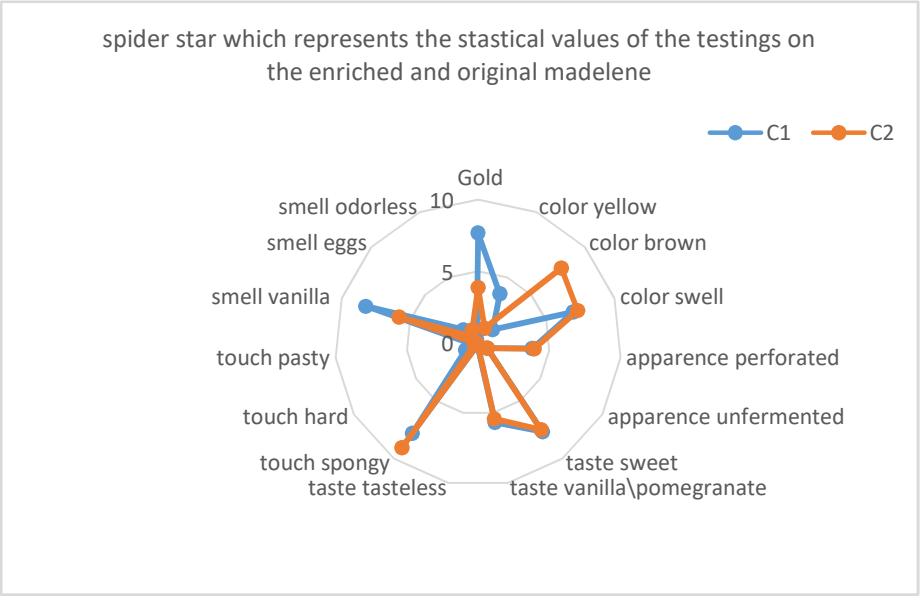
To conclude the tasting experience, participants are encouraged to share their overall impressions and any lingering flavors they detected, providing insights into the product's complexity and depth.

Feedback :

……

Sensory profil

settings	criteria	C1	C2
Color	Gold	**7,68**	**3,87**
	Yellow	**3,75**	**1,12**
	Brown	**1,37**	**7,81**
Appearance	Swell	**7**	**7,31**
	Perforated	**3,81**	**3,93**
	Unfermented	**0,75**	**0,75**
Taste	Sweet	**7,68**	**7,5**
	Vanilla\pomegranate	**5,68**	**5,43**
	Tasteless	**0,18**	**0,12**
Touch	Spongy	**7,81**	**9,06**
	Hard	**1**	**0,31**
	Pasty	**0,56**	**0,12**
Smell	Vanilla	**8,25**	**5,81**
	Eggs	**1,37**	**0,68**
	Odorless	**0,25**	**1**



Graph Analysis: Comparison between original and enriched madeleine

Understanding the graph:

The graph presented seems to be a sensory analysis tool comparing an "original" madeleine and an "enriched" madeleine. The different sensory criteria (color, appearance, taste, touch, smell) were evaluated on a numerical scale, thus making it possible to visualize the differences between the two products

Impact of pomegranate:

The addition of pomegranate seeds appears to have a significant impact on the attributes “color”, “appearance” and “taste”. The scores given to C2 (enriched madeleine) are generally higher for these attributes, suggesting that consumers appreciate more the color and taste provided by the pomegranate.

Texture perception:

The attributes related to texture (spongy, hard, pastry) appear less differentiated between the two products. This suggests that the addition of pomegranate seeds did not significantly modify the perceived texture of the madeleines

Odor:

The attribute "odor" seems to be more complex to interpret. The scores assigned to C2 are higher for the vanilla odor, but lower for the egg odor. This could indicate an interaction between the aromas of the pomegranate and those of the original madeleine.

Conclusion of the statistical analysis:

Sensory analysis showed that the addition of pomegranate seeds to the madeleines significantly improved their visual appeal, particularly thanks to a more intense color and a more gourmet appearance. Taste scores were also higher for the enriched madeleines, suggesting that the contribution of fruity aromas was appreciated by tasters. However, some consumers found the pomegranate aroma too pronounced, which could limit the overall appeal of the product. In terms of texture, no significant difference was observed between the two products.

These results suggest that the addition of pomegranate seeds is a promising avenue for developing new, more original and more attractive madeleine recipes for consumers. Nevertheless, it would be interesting to study the impact of different proportions of pomegranate seeds in order to optimize the compromise between taste contribution and general acceptability of the product.

Conclusion

In conclusion, incorporating pomegranate seeds into a product like the enhanced madeleine opens up exciting possibilities for modern pastry. Rich in antioxidants, vitamins, and fiber, pomegranate seeds not only bring nutritional benefits but also add a burst of color and freshness, meeting the needs of consumers who seek products that are both healthy and flavorful. This approach highlights the potential of natural ingredients to reinvent traditional recipes, allowing artisans to offer enriched products that combine taste and wellness. The enhanced madeleine with pomegranate seeds could appeal to a health-conscious audience looking for originality in their food choices, while adding an innovative dimension to the world of pastry.

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Conclusions

Functional foods represent one of the most dynamic fields of innovation in nutrition and public health. Their importance lies in their ability to exert beneficial effects on health beyond basic nutrition. These foods—whether naturally rich in bioactive compounds or intentionally fortified—play a key role in preventing chronic diseases and promoting both physical and mental well-being.

The categories of functional foods are diverse: probiotics and prebiotics that support gut health, antioxidants that combat oxidative stress, dietary fibers that regulate blood sugar and cholesterol levels, and essential fatty acids that contribute to cardiovascular health. More recently, functional foods derived from aromatic and medicinal plants have gained attention for their high content of natural bioactive compounds such as polyphenols, flavonoids, and essential oils, which provide powerful anti-inflammatory, antimicrobial, and antioxidant properties.

The positioning of functional foods in the market depends on scientific credibility, consumer trust, and the transparency of nutrition and health claims. These claims are now tightly regulated and must be supported by robust scientific evidence demonstrating the product's beneficial effects. Such rigor is essential to ensure consumer safety and prevent misleading marketing practices.

In the context of the rising prevalence of metabolic syndrome—which encompasses obesity, diabetes, hypertension, and lipid disorders—functional foods offer a valuable complementary approach to medical treatment. When consumed regularly as part of a balanced diet, they can help regulate metabolism, lower cholesterol, improve insulin sensitivity, and reduce cardiovascular risk factors.

Recent trends indicate that the most commonly consumed functional ingredients are caffeine (55%), electrolytes (30%), and antioxidants (28%), all of which are widely present in everyday foods and beverages. Emerging ingredients such as prebiotics (15%), melatonin (11%), and adaptogens (7%) are increasingly used in products targeting specific health outcomes, including mental well-being, stress resistance, and sleep regulation (Mintel-Kantar, 2022).

When access to such foods is limited, or when they are not consumed in sufficient quantities to produce measurable benefits, dietary supplements can provide a practical alternative, ensuring the required intake of key bioactive compounds in a cost-effective manner.

The impact of functional foods on health can be assessed through oxidative stress balance, an indicator of the equilibrium between free radicals and antioxidants in the body. A diet rich in natural antioxidants—fruits, vegetables, virgin oils, and legumes—combined with healthy lifestyle habits, helps reduce inflammation, strengthen the immune system, and protect cells from oxidative damage.

Beyond technological innovation, one of the main challenges remains nutrition education and public awareness. Encouraging people to adopt sustainable dietary habits is essential: consuming whole grains and legumes, including raw vegetables in each meal, limiting animal products and ultra-processed foods, and favoring biodiversity in plant-based diets. The traditional cereal–legume combination should once again serve as the foundation of a healthy, affordable, and environmentally friendly diet.

Ultimately, functional foods and newly developed products emerging from agronomic and biotechnological research embody the convergence of science, health, and sustainability**.** By embracing the principle that **"***food should be our medicine*," they pave the way toward preventive nutrition—tailored to individual needs and respectful of our environment—thus promoting the health of both humanity and the planet.

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