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# THESIS

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THEME

# Assessment of Food Additives in Selected Food Products from El Oued Region: Comparative with International Regulatory Standards and Recent Toxicological Evidence

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Thanks be to **Allah**, for the gift of life and knowledge

To our families, for their love and constant support.

To my professors, for their guidance and wisdom

To my friends, for their encouragement

To the difficult days

This work is dedicated to you

# TABLES OF CONTENTS

***CHAPTER II***

***Toxicological Evidence and Health Risks of Food Additives***



**PRACTICAL SECTION**

# ACKNOWLEDGMENT

*I am grateful to **Allah** for the opportunity and ability to complete this master thesis.*

*With deep love and heartfelt gratitude, and with hearts filled with joy after a long journey of effort, we dedicate the fruit of our work:*

*To those who, after God, had the greatest influence in every step we took… to those who stayed up nights for our comfort and carried the burdens of the path on our behalf…*

*To those whose prayers accompanied us at every moment, giving us strength whenever we felt weak…*

*Our beloved mothers and fathers, you are the light that illuminated our path and the support that never falters. May God reward you abundantly and keep you for us.*

*To our brothers and sisters, who were our support and strength, sharing with us the moments of hardship before joy.*

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*And to ourselves…*

*We who were patient and persevered, who faced exhaustion in silence, and held onto hope despite every difficulty… until we arrived.*

*We dedicate this humble work, which carries within its lines our effort and within its words a dream fulfilled. We ask God to make it the beginning of a path full of success and achievement.*

# Summary

This study aims to conduct a systematic and comparative assessment of authorized food additives in a sample of the most widely consumed food products in the El Oued region (Algeria).

The adopted methodology relies on an analytical approach that compares the extracted data with the Algerian national legislation and international standards endorsed by the Codex Alimentarius, the European Food Safety Authority (EFSA), and the Joint FAO/WHO Expert Committee on Food Additives (JECFA), while integrating the latest scientific evidence in the fields of food toxicology and nutritional epidemiology.

The research employed a descriptive, analytical, cross-sectional design encompassing 46 leading food products in the local market, categorized into five main groups: beverages, dairy products, sweets, preserved foods, and snacks. Additive data were accurately extracted and coded according to the International Numbering System (INS/E-numbers), and then classified technologically and functionally to identify patterns of high-concern additives.

The study yieldedquantitative and statistical results, recording 151 food additive entries covering 60 distinct codes and technological terms, with an overall mean of $3.35 \pm 2.64$ additives per product. Statistical analyses demonstrated a highly significant variance in the distribution of additive counts across the different food categories ( $p = 0.003$), with the beverage category recording the highest mean at $5.40 \pm 1.58$ additives per product. Furthermore, the Chi-square test revealed a strong and statistically significant association between the food category type and the probability of containing high-concern additives, with prevalence rates reaching 80% in beverages, 70% in dairy products, and 66.7% in chips and crackers. The study accurately identified recurrent patterns of preservatives (such as benzoates and sorbates) in children's juices, synthetic azo dyes in sweets, emulsifying phosphate salts in processed cheeses, and artificial sweeteners such as aspartame and sucralose.

The significance and applied value of these results lie in providing the first structural survey that identifies hotspots of chemical accumulation in the food environment of the El Oued region, highlighting the importance of transitioning from evaluating additives individually to studying the "cocktail effect" or combined exposure to multiple compounds through the daily diet. The scientific and practical value of the outputs is manifested in providing a rigorous, forward-looking guiding framework that enables regulatory and health authorities to improve inspection efficiency, and to allocate and direct laboratory testing resources towards priority products for advanced quantitative analysis (such as HPLC-MS techniques). Moreover, these findings contribute to the formulation of national preventive and educational policies precisely targeted at protecting vulnerable groups, particularly children and patients suffering from toxicological, renal, or metabolic disorders in desert environments characterized by specific climatic and consumption patterns.

Results reveal significant additive accumulation patterns, urging cumulative risk evaluation and stronger regulatory oversight for vulnerable populations.



**Keywords:** Food additives, Toxicological assessment, Food labeling, Food legislation, Cumulative exposure, Risk assessment.

## SUMMARY IN ARABIC (مُلخص)


تهدف هذه الدراسة إلى إجراء تقييم منهجي ومقارن للمضافات الغذائية المصرح بها في عينة من المنتجات الغذائية الأكثر استهلاكاً في ولاية الوادي (الجزائر).

تستند المنهجية المعتمدة إلى مقاربة تحليلية تقارن البيانات المستخلصة بالتشريع الوطني الجزائري والمعايير الدولية المعتمدة من قِبل هيئة الدستور الغذائي(Codex Alimentarius) ، والهيئة الأوروبية لسلامة الأغذية(EFSA) ، ولجنة الخبراء المشتركة(JECFA) ، مع دمج أحدث الأدلة العلمية في مجالي علم السموم الغذائي والوبائيات التغذوية .

اعتمد البحث تصميماً وصفياً تحليلياً مقطعياً شمل 46 منتجاً غذائياً من المنتجات الرائدة في السوق المحلية ، جرى تصنيفها إلى خمس فئات رئيسية هي: المشروبات، منتجات الألبان، الحلويات، الأغذية المحفوظة، والوجبات الخفيفة .وتم استخراج وتشفير بيانات المضافات بدقة وفق نظام الترميز الدولي(INS/E-numbers) ، وتصنيفها تكنولوجياً ووظيفياً لتحديد أنماط المضافات ذات الاهتمام الصحي المرتفع .

وقد أسفرت الدراسة عن نتائج كمية وإحصائية ؛ حيث جرى رصد 151 إدخالاً للمضافات الغذائية تغطي 60 رمزاً ومصطلحاً مستقلاً ، بمعدل إجمالي بلغ $3.35 \pm 2.64$ مضافاً لكل منتج .وأثبتت التحليلات الإحصائية وجود تباين جوهري ذي دلالة إحصائية عالية في توزيع أعداد المضافات بين الفئات الغذائية المختلفة ($p = 0.003$) ، حيث سجلت فئة المشروبات المعدل الأعلى بـ $5.40 \pm 1.58$ مضافاً لكل منتج .كما كشف اختبار كاي تربيع عن ارتباط وثيق ودال إحصائياً بين نوع الفئة الغذائية واحتمالية احتوائها على مضافات ذات اهتمام صحي مرتفع ، بنسب انتشار بلغت 80% في المشروبات، و70% في منتجات الألبان، و66.7% في فئة المقرمشات والرقائق .وحددت الدراسة بدقة الأنماط المتكررة للمواد الحافظة (كالبنزوات والسوربات) في عصائر الأطفال، والأصباغ الصناعية الآزوية في السكاكر، وأملاح الفوسفات المستحلبة في الأجبان المطبوخة، والمحليات الاصلاحية كالأسبارتام والسكرالوز .

تكمن أهمية هذه النتائج وقيمتها التطبيقية في تقديم أول مسح هيكلي يحدد بؤر التراكم الكيميائي في البيئة الغذائية لولاية الوادي، مبرزةً أهمية الانتقال من تقييم المضافات بشكل منفرد إلى دراسة "أثر الكوكتيل" أو التعرض المشترك لعدة مركبات عبر النظام الغذائي اليومي .وتتجلى القيمة العلمية والعملية للمخرجات في توفير إطار توجيهي واستشرافي محكم يتيح للجهات الرقابية والصحية (كملحقات مديريات التجارة والصحة) تحسين كفاءة التفتيش، وتخصيص موارد الفحص المخبري وتوجيهها نحو المنتجات ذات الأولوية لإجراء التحاليل الكمية المتقدمة) كتقنية .(HPLC-MS علاوة على ذلك، تسهم هذه النتائج في صياغة سياسات وقائية وطنية وتوعوية موجهة بدقة لحماية الفئات الهشة، لاسيما الأطفال والمرضى المصابين باعتلالات سمية أو كلوية أو أيضية في البيئات الصحراوية ذات الخصوصية المناخية والاستهلاكية .

كشفت النتائج عن أنماط تراكم ملحوظة للمضافات، مما يستوجب تقييم المخاطر التراكمية وتعزيز الرقابة التنظيمية لحماية الفئات الهشة.



**الكلمات المفتاحية :**المضافات الغذائية، التقييم السمي، الوسم الغذائي، التشريعات الغذائية، التعرض التراكمي، تقييم المخاطر.

# SUMMARY IN FRENCH (RESUME)

Cette étude vise à mener une évaluation systématique et comparative des additifs alimentaires autorisés dans un échantillon des produits alimentaires les plus consommés dans la région d'El Oued (Algérie).

La méthodologie adoptée repose sur une approche analytique comparant les données extraites à la législation nationale algérienne et aux normes internationales approuvées par le Codex Alimentarius, l'Autorité européenne de sécurité des aliments (EFSA) et le Comité mixte d'experts FAO/OMS sur les additifs alimentaires (JECFA), tout en intégrant les preuves scientifiques les plus récentes dans les domaines de la toxicologie alimentaire et de l'épidémiologie nutritionnelle.

La recherche a adopté un plan transversal descriptif et analytique portant sur 46 produits alimentaires phares du marché local, classés en cinq catégories principales : les boissons, les produits laitiers, les confiseries, les aliments conservés et les snacks. Les données relatives aux additifs ont été extraites et codées avec précision selon le système international de numérotation (INS/E-numbers), puis classées sur le plan technologique et fonctionnel afin d'identifier les profils d'additifs suscitant une préoccupation sanitaire élevée.

L'étude a abouti à des résultats quantitatifs et statistiques; 151 entrées d'additifs alimentaires ont été recensées, couvrant 60 codes et termes technologiques distincts, avec une moyenne globale de $3.35 \pm 2.64$ additifs par produit. Les analyses statistiques ont démontré une variance hautement significative dans la distribution du nombre d'additifs entre les différentes catégories alimentaires ($p = 0.003$), la catégorie des boissons enregistrant la moyenne la plus élevée avec $5.40 \pm 1.58$ additifs par produit. De plus, le test du Chi-carré a révélé une association forte et statistiquement significative entre le type de catégorie alimentaire et la probabilité de contenir des additifs à préoccupation élevée, avec des taux de prévalence atteignant 80 % dans les boissons, 70 % dans les produits laitiers et 66.7 % dans la catégorie des chips et craquelins. L'étude a identifié avec précision les schémas récurrents de conservateurs (tels que les benzoates et les sorbates) dans les jus pour enfants, de colorants azoïques synthétiques dans les confiseries, de sels de phosphate émulsifiants dans les fromages fondus, et d'édulcorants artificiels tels que l'aspartame et le sucralose.

L'importance et la valeur appliquée de ces résultats résident dans la présentation de la première enquête structurelle identifiant les points d'accumulation chimique dans l'environnement alimentaire de la région d'El Oued, soulignant ainsi l'importance de passer d'une évaluation individuelle des additifs à l'étude de « l'effet cocktail » ou de l'exposition combinée à de multiples composés via le régime alimentaire quotidien. La valeur scientifique et pratique des résultats se manifeste par la fourniture d'un cadre d'orientation prospectif et rigoureux permettant aux autorités réglementaires et sanitaires d'améliorer l'efficacité des inspections et d'allouer les ressources d'analyse en laboratoire vers les produits prioritaires pour des analyses quantitatives avancées (telles que la technique HPLC-MS). En outre, ces résultats contribuent à l'élaboration de politiques préventives et éducatives nationales ciblant précisément la protection des groupes vulnérables, en particulier les enfants et les patients souffrant de troubles toxicologiques, rénaux ou métaboliques dans des environnements désertiques aux caractéristiques climatiques et de consommation spécifiques.

Les résultats révèlent des schémas d'accumulation significatifs d'additifs, appelant à une évaluation des risques cumulatifs et à un renforcement du contrôle réglementaire pour les populations vulnérables.

**Mots-clés :** Additifs alimentaires, Évaluation toxicologique, Étiquetage alimentaire, Législation alimentaire, Exposition cumulative, Évaluation des risques.

# NOMENCLATURE

***Symbol:***

**G** gram

**Kg** kilogram

**Mg** milligram

**mg/kg** milligrams per kilogram

**%** percent

**Kcal** kilocalorie (non-SI, accepted)

**°C** Degrees Celsius

**$p < 0.05$** Statistical significance threshold

***Abbreviations:***

**ADI** Acceptable Daily Intake

**EFSA** European Food Safety Authority

**JECFA** Joint FAO/WHO Expert Committee on Food Additives

**FAO** Food and Agriculture Organization

**WHO** World Health Organization

**FDA** Food and Drug Administration (US)

**IARC** International Agency for Research on Cancer

**USDA** United States Department of Agriculture

**EU** European Union

**EC** European Commission

**UK** United Kingdom

**INS** International Numbering System

**SIN / E-number** Système International de Numérotation / European additive code

**GSFA** General Standard for Food Additives

**GRAS** Generally Recognized as Safe

**GMP** Good Manufacturing Practice

**NCD** Noncommunicable Disease

**CVD** Cardiovascular Disease

**UHT** Ultra-High Temperatu

**NOAEL** No-Observed-Adverse-Effect Level

**LOAEL** Lowest-Observed-Adverse-Effect Level

**BMD** Benchmark Dose

**BMDL** Benchmark Dose Lower Confidence Bound

**DNA** Deoxyribonucleic Acid

**SD** Standard Deviation

**ANOVA** Analysis of Variance

**HPLC** High-Performance Liquid Chromatography

**EDTA** Ethylenediaminetetraacetic acid

**FCF** Fast Green FCF / FD&C Green No. 3

**E101** Riboflavin

**E101(ii)** Riboflavin-5'-phosphate

**E102** Tartrazine

**E104** Quinoline Yellow

**E110** Sunset Yellow FCF

**E122** Carmoisine (Azorubine)

**E124** Ponceau 4R

**E129** Allura Red AC

**E133** Brilliant Blue FCF

**E140** Chlorophylls and chlorophyllins

**E141** Copper complexes of chlorophylls

**E142** Green S

**E144** Fast Red E

**E145** Fast Blue B

**E150a** Plain caramel

**E150d** Sulphite ammonia caramel

**E152** Black 7984

**E160a** Carotenes

**E160a(ii)** Beta-carotene

**E160b** Annatto, bixin, norbixin

**E160c** Paprika extract

**E170** Calcium carbonate

**E171** Titanium dioxide

**E202** Potassium sorbate

**E211** Sodium benzoate

**E262** Sodium acetates

**E290** Carbon dioxide

**E296** Malic acid

**E300** Ascorbic acid (Vitamin C)

**E322** Lecithins

**E330** Citric acid

**E331** Sodium citrates

**E338** Phosphoric acid

**E339** Sodium phosphates

**E385** Calcium disodium EDTA

**E407** Carrageenan

**E414** Acacia gum (Gum Arabic)

**E415** Xanthan gum

**E444** Sucrose acetate isobutyrate

**E445** Glycerol esters of wood rosins

**E450** Diphosphates

**E452** Polyphosphates

**E460** Microcrystalline cellulose

**E460(i)** Microcrystalline cellulose

**E461** Methyl cellulose

**E466** Carboxymethyl cellulose (CMC)

**E468** Crosslinked carboxymethyl cellulose

**E471** Mono- and diglycerides of fatty acids

**E476** Polyglycerol polyricinoleate (PGPR)

**E500** Sodium carbonates

**E504** Magnesium carbonates

**E551** Silicon dioxide

**E621** Monosodium glutamate (MSG)

**E627** Disodium guanylate

**E631** Disodium inosinate

**E635** Disodium ribonucleotides

**E900a** Dimethyl polysiloxane

**E951** Aspartame

**E955** Sucralose

**E1400** Dextrin

**E1412** Distarch phosphate

**E1420** Acetylated starch

**E1422** Acetylated distarch adipate

**E1442** Hydroxypropyl distarch phosphate

**E1450** Starch sodium octenyl succinate

**E1520** Propylene glycol

# LIST OF FIGURES

# LIST OF TABLES

# General Introduction

Food additives are now central to modern food systems, where industrial processing and long-distance distribution have increased reliance on convenient, shelf-stable products worldwide, particularly in hot and semi-arid regions such as North Africa. In these contexts, additives help ensure microbiological safety, stability, sensory quality, and year-round availability of foods and beverages, but their growing use in ultra-processed products has intensified concern about cumulative exposure, nutritional quality, and potential health impacts (Codex Alimentarius Commission, 1995–2025; Carocho et al., 2015; WHO, 2023c). Rather than treating all additives as inherently harmful or harmless, contemporary food safety and public-health perspectives emphasize the need to interpret additives through their technological role, toxicological evaluation, and regulatory conditions of use (Codex Alimentarius Commission, 1995; EFSA Scientific Committee, 2017; WHO, 2023c).

Regulatory frameworks at international and national levels converge on a common definition of food additives as substances not normally consumed as foods by themselves, intentionally added for technological purposes during manufacture, processing, packaging, or storage, and expected to become components of the food or otherwise affect its characteristics (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008). The Codex Alimentarius General Standard for Food Additives (GSFA), JECFA evaluations, the EU system under Regulation (EC) No. 1333/2008, and the United States FDA model all rely on positive lists or authorization systems, explicit technological justification, and conditions of use linked to specific food categories, while also requiring that additives do not mislead consumers (Codex Alimentarius Commission, 1989, 1995; European Commission, n.d.; Joint FAO/WHO Expert Committee on Food Additives, 2026; U.S. Food and Drug Administration, 2023). In Algeria, Executive Decree No. 12-214 operationalizes these principles by defining food additives, acceptable daily intake (ADI), maximum concentrations, halal considerations, and detailed annexes linking authorized additives to food categories and maximum permitted levels, together with labelling obligations for additive names, functional classes, and certain sweeteners (Journal Officiel de la République Algérienne, 2012; USDA Foreign Agricultural Service, 2022). Codex INS and European "E-number" coding systems further facilitate standardized identification of additives on labels and enable comparison with national and international lists (Codex Alimentarius Commission, 1989, 1995; FAO/WHO Codex Alimentarius Commission, n.d.).

Toxicological assessment builds on concepts such as the ADI, NOAEL, benchmark-dose modelling, and margins of exposure, which require both hazard characterization and exposure estimation (EFSA Scientific Committee, 2017; WHO, 2023c). Regulatory decisions evolve as

new evidence emerges, as illustrated by EFSA's conclusion that titanium dioxide (E171) could no longer be considered safe as a food additive due to unresolved genotoxicity concerns, leading to its withdrawal from the EU market (EFSA Panel on Food Additives and Flavourings, 2021; European Food Safety Authority, 2021). Artificial sweeteners and other controversial additives highlight the distinction between hazard and risk: IARC classified aspartame as possibly carcinogenic, whereas JECFA maintained its ADI, and EFSA has confirmed the existing ADI for sucralose while calling for caution regarding certain impurities (Debras et al., 2022; International Agency for Research on Cancer, 2023; JECFA, 1990–1991, 2023; European Food Safety Authority, 2026). Recent epidemiological and experimental work has also focused on preservatives (e.g., sodium benzoate, potassium sorbate), synthetic colours requiring warning labels in the EU (E102, E110, E122, E129), emulsifiers and cellulose derivatives (e.g., E466, E407, E471), phosphate additives, and non-nutritive sweeteners, as well as on mixtures of these additives and their possible interactions with the gut microbiota and chronic-disease risk (Chassaing et al., 2015; Debras et al., 2022; Naimi et al., 2021; Payen de la Garanderie et al., 2025; Ritz et al., 2012; Sellem et al., 2023, 2024; Suez et al., 2022). These findings justify prioritizing certain additive groups and combinations for surveillance and exposure assessment, while still recognizing that observational associations and in vitro data do not by themselves prove product-level causality (EFSA Scientific Committee, 2017; WHO, 2023c).

In Algeria, this scientific and regulatory background must be interpreted within a broader epidemiological transition in which noncommunicable diseases such as hypertension, diabetes, cardiovascular disease, and cancer contribute substantially to the morbidity and mortality burden, while infectious and parasitic diseases remain important (Benikhlef et al., 2021; Moussouni et al., 2022; WHO, 2024). The El Oued Wilaya, a Saharan region with a hot, arid climate and commercial concentration in large retail centres, illustrates how environmental and socioeconomic conditions can favour increased consumption of packaged, shelf-stable foods and beverages (Benikhlef et al., 2021; Moussouni et al., 2022). In such settings, children and adolescents are particularly vulnerable because of higher exposure per kilogram body weight, targeted marketing of highly coloured and sweet products, and patterns of frequent consumption of soft drinks, flavoured yoghurts, confectionery, and snacks (Food Standards Agency, 2025; WHO, 2023c; Zouaoui et al., 2024). Other priority groups include pregnant women, individuals with hypertension or cardiovascular disease, people with diabetes, and patients with chronic kidney disease, for whom certain additive groups—such as phosphate additives, high-salt fla-

vour enhancers, stimulants in energy drinks, and repeated exposure to preservatives—may require special caution (Calvo et al., 2023; European Food Safety Authority, 2015; Mandato et al., 2025; Ritz et al., 2012).

Despite the existence of detailed Algerian and international regulatory texts, systematic, region-specific data on food-additive patterns in Algerian retail markets remain scarce. In El Oued in particular, there has been little structured assessment of how many additives are present in the top-selling products, which additive groups predominate in key categories such as beverages, dairy, sweets, preserved foods, and snacks, how often high-priority additives (e.g., warning-label colours, aspartame, sucralose, phosphate emulsifying salts, certain emulsifiers, E202/E211 combinations, caffeine) appear, and whether labelling practices support or hinder transparent screening (Codex Alimentarius Commission, 1995; Journal Officiel de la République Algérienne, 2012; Zouaoui et al., 2024). Label-based assessment is a practical tool to address this gap because product labels provide the first layer of information available to consumers, health professionals, and inspectors, and allow identification and coding of declared additives, functional classes, and high-concern patterns without requiring immediate laboratory analysis (Codex Alimentarius Commission, 1985, 1995; FAO/WHO Codex Alimentarius Commission, n.d.; WHO, 2023c). However, since labels do not disclose concentrations or actual intake, such assessments must be framed as screening exercises that can prioritize products and additive groups for future analytical measurement and exposure modelling, not as proof of ADI exceedance or legal non-compliance (EFSA Scientific Committee, 2017; Journal Officiel de la République Algérienne, 2012; WHO, 2023c).

Building on this theoretical and public-health context, the present thesis was designed as a descriptive-analytical, cross-sectional, label-based investigation of food additives in top-selling products marketed in El Oued Wilaya. Products were purposively selected from the largest commercial centre using managerial information on best-selling items and then grouped into five categories—canned and packaged sweets, canned and preserved foods, dairy products, soft drinks/energy drinks/juices, and chips/crackers—to reflect major contributors to local packaged-food consumption (Moussouni et al., 2022; Zouaoui et al., 2024). For each product, label information was systematically collected and standardized, including declared additives, E-numbers or INS/SIN codes, and functional classes, and then interpreted with reference to Codex, JECFA, EFSA, EU, FDA, and Algerian regulatory lists (Codex Alimentarius Commission, 1989, 1995–2025; European Parliament and Council, 2008; Joint FAO/WHO Expert Committee on Food Additives, 2026; Journal Officiel de la République Algérienne, 2012; U.S. Food

and Drug Administration, 2023). A high-concern category was defined to flag products containing additives or ingredient groups of particular toxicological or regulatory interest, including EU warning-label colours (E102, E110, E122, E129), aspartame (E951) and sucralose (E955), phosphate additives and phosphoric acid, selected emulsifiers and cellulose derivatives, stimulant-containing energy drinks, and preservative combinations involving E202 and E211 in child-relevant beverages, based on recent toxicological and epidemiological evidence (Debras et al., 2022; European Food Safety Authority, 2015, 2021, 2026; Mandato et al., 2025; Payen de la Garanderie et al., 2025; Ritz et al., 2012; Sellem et al., 2023, 2024; Zouaoui et al., 2024).

The findings show that in this sample of 46 top-selling products, beverages, processed dairy products, and chips/crackers carry the highest additive burden and the highest prevalence of at least one high-concern additive, particularly in soft drinks, energy drinks, fruit drinks, flavoured yoghurts, processed cheeses, and highly seasoned snacks (European Food Safety Authority, 2015; Mandato et al., 2025; Ritz et al., 2012; Sellem et al., 2023; Zouaoui et al., 2024). Key screening signals include the recurrent use of sodium benzoate and potassium sorbate in beverages consumed by children, the presence of EU warning-label synthetic colours in sweets, yoghurts, beverages, and chips, the use of phosphate salts in processed cheeses and phosphoric acid in energy drinks, and the combination of multiple emulsifiers and stabilizers in dairy and beverage matrices, all within a broader food environment already challenged by NCD burdens and climatic constraints in El Oued (Benikhlef et al., 2021; Calvo et al., 2023; Moussouni et al., 2022; Ritz et al., 2012; Sellem et al., 2023; Zouaoui et al., 2024). At the same time, the study deliberately avoids inferring ADI exceedance or legal non-compliance from label presence alone, and it does not claim that specific products cause particular diseases; instead, it positions the results as a structured screening contribution to future laboratory and exposure work (EFSA Scientific Committee, 2017; Journal Officiel de la République Algérienne, 2012; WHO, 2023).

In this framework, the main objective of the thesis is to conduct a label-based cross-sectional assessment of declared food additives in selected top-selling food and beverage products marketed in El Oued Wilaya, to characterize additive profiles and patterns of high-concern additives, and to compare these findings with Algerian legislation and major international regulatory and toxicological references. The research problem addressed by the thesis can be summarized as follows: in a Saharan region with growing consumption of packaged and ultra-processed foods, a substantial burden of noncommunicable diseases, and vulnerable groups such

as children, pregnant women, and patients with cardiometabolic or renal conditions, there is a lack of systematic, label-based surveillance of food additives in top-selling products; this limits the ability of health authorities and researchers to identify additive patterns, mixture profiles, and high-priority products for further investigation in light of Algerian and international standards and recent toxicological evidence. We have answered the problem presented in the following thesis, which we divided into:

A theoretical section divided into two chapters:

1- Chapter One: Food Additives: Concepts, Classification, Regulatory Framework, and International Standards

2- Chapter Two: Toxicological Evidence and Health Risks of Food Additives

And an applied section that consisted of a label-based, descriptive-analytical, cross-sectional assessment of declared food additives in 46 selected top-selling food and beverage products from El Oued Wilaya, including classification of additives, identification of high-concern additives, and comparison with Algerian legislation and major international regulatory and toxicological references

# THEORETICAL SECTION

# CHAPTER I

***Food Additives: Concepts, Classification, Regulatory Framework, and International Standards***

## 1.1. Introduction

Food additives occupy a central position in modern food technology because they help preserve, stabilize, colour, sweeten, emulsify, texturize, and standardize foods produced at industrial scale. Their use must be understood through technological need, toxicological evaluation, and regulatory limits rather than through a simplistic view that treats all additives as either dangerous or harmless (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008).

This chapter provides the conceptual basis required to interpret additive declarations in commercial foods. It focuses on definitions, classification systems, technological functions, safety-assessment concepts, labelling requirements, and major regulatory frameworks relevant to preservatives, colourants, emulsifiers, stabilizers, acidity regulators, sweeteners, flavour enhancers, phosphate additives, and stimulant-containing formulations (Codex Alimentarius Commission, 1989; Joint FAO/WHO Expert Committee on Food Additives, 2026).

The expansion of packaged and ultra-processed foods has increased the importance of food additives as technological tools for preservation, standardization, texture, colour, sweetness, and processing stability. This issue is especially relevant in hot and semi-arid environments, where shelf-stable foods may occupy an important place in the retail food supply. International standards emphasize that additives must be identified, technologically justified, and uQWsed under defined conditions rather than treated as inherently safe or inherently harmful (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008).

A theoretical review of food additives should therefore support a balanced understanding of label-based screening and exposure assessment. Additive burden is understood as a screening indicator of formulation complexity, not as direct proof of toxicity. Products containing warning-label colours, sweeteners, preservatives, phosphates, emulsifiers, or stimulant-associated ingredients deserve closer surveillance because their interpretation depends on additive identity, permitted use, concentration, consumption frequency, and vulnerable-population exposure (Joint FAO/WHO Expert Committee on Food Additives, 2026; World Health Organization, 2023a).

The chapter also links international and national frameworks. Codex and JECFA provide global terminology and toxicological evaluation, EFSA/EU and FDA offer influential comparative models, and Algerian regulation provides the local legal basis for products marketed in

Algeria. This combined approach supports regulatory interpretation while maintaining the necessary caution that label presence alone cannot establish ADI exceedance or legal non-compliance (Codex Alimentarius Commission, 1995; World Health Organization, 2023c).

### 1.2. Definitions and fundamental concepts:

A food additive is generally defined as a substance not normally consumed as a food by itself and not normally used as a characteristic ingredient of food, whether or not it has nutritive value, that is intentionally added for a technological purpose during manufacture, processing, preparation, treatment, packaging, transport, or storage and that becomes, or may reasonably be expected to become, a component of the food or otherwise affect its characteristics. This definition is used by Codex and is closely reflected in European Union legislation; it excludes contaminants and substances added primarily for nutritional purposes unless their role is technological. (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008).

The key element common to major regulatory definitions is intentional technological function. A substance is treated as an additive because it is deliberately used to achieve preservation, colouring, sweetening, emulsification, stabilization, acidity control, antioxidant protection, flavour enhancement, textural modification, or another recognized technological effect. This criterion separates additives from accidental contaminants, pesticide residues, natural toxicants, and processing residues, although all of these may be relevant to broader food-safety assessment. (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008; World Health Organization, 2023c).

The European Union framework embeds the additive definition within a positive-list system. Regulation (EC) No. 1333/2008 requires that a food additive be safe at the proposed level of use, technologically justified, not misleading to the consumer, and authorized for specified foods and conditions of use. The regulation also defines functional classes according to the technological role exerted in the foodstuff, which is important when interpreting label terms such as preservative, antioxidant, colour, emulsifier, stabilizer, acidity regulator, sweetener, and thickener. (European Parliament and Council, 2008).

The United States framework uses a different legal architecture. Under the Federal Food, Drug, and Cosmetic Act, an intentionally added substance is generally a food additive requiring premarket approval unless it is generally recognized, among qualified experts, as safe under the conditions of its intended use or is otherwise excluded from the food-additive definition. GRAS status may be based on scientific procedures or, for substances used before 1958, on common

use in food; therefore, GRAS is an intended-use safety concept rather than a universal declaration that a substance is safe in all products or concentrations. (U.S. Food and Drug Administration, 2024).

In Algeria, Executive Decree No. 12-214 of 15 May 2012 provides the additive-specific legal foundation for foods intended for human consumption. It defines food additive, halal food additive, indirect addition, acceptable daily intake, maximum concentration, good manufacturing practice, and contaminant, and it links authorized additives with food categories and maximum permitted levels through annexes. This national framework is essential for legal interpretation, while Codex, JECFA, EU, and FDA sources remain useful scientific and comparative references. (Journal Officiel de la République Algérienne, 2012).

The acceptable daily intake (ADI) is a central toxicological concept. WHO describes the ADI as an estimate of the amount of an additive in food or drinking water that can be consumed daily over a lifetime without adverse health effects. It is generally expressed in mg/kg body weight/day and is derived from toxicological evidence using a point of departure and uncertainty factors. The ADI is not a maximum concentration in a finished food and should not be interpreted as a boundary between safety and toxicity for a single meal. (World Health Organization, 2023c).

Toxicological points of departure include the no-observed-adverse-effect level (NOAEL), the lowest-observed-adverse-effect level (LOAEL), and benchmark-dose values such as the BMDL. The NOAEL identifies the highest tested dose without observed adverse effects in a particular study, whereas the LOAEL identifies the lowest tested dose at which adverse effects are observed. EFSA considers benchmark-dose modelling a more advanced approach than relying only on NOAEL values because it uses more dose-response information and can quantify uncertainty around the reference point. (EFSA Scientific Committee, 2017).

The margin of safety or margin of exposure compares estimated human exposure with a toxicological reference point. Its interpretation requires quantitative exposure information, including additive concentration, portion size, consumption frequency, body weight, and vulnerable-population status. For this reason, a label-based assessment can identify declared additives and regulatory screening priorities, but it cannot demonstrate ADI exceedance or legal noncompliance without analytical measurement and exposure modelling. (EFSA Scientific Committee, 2017; World Health Organization, 2023c).

The carry-over principle explains why an additive may be present in a finished food because it was used in one of its ingredients or because it entered during processing. Regulatory interpretation depends on whether the additive continues to exert a technological function in the final food, whether the relevant legislation allows such carry-over, and whether labelling obligations are triggered. This concept is particularly important in complex processed foods where compound ingredients, premixes, flavourings, and stabilizing systems may introduce additives indirectly. (Codex Alimentarius Commission, 1995 ; European Parliament and Council, 2008; Journal Officiel de la République Algérienne, 2012).

Technological justification is both a regulatory and ethical concept. An additive should be used only when it serves a legitimate technological purpose, when the effect cannot reasonably be achieved by other practicable means, and when its use does not mislead consumers about freshness, composition, quality, nutritional value, or the nature of the food. This principle is central to modern additive regulation because safety assessment alone is not sufficient; the additive must also be necessary and transparent in its intended food application. (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008).

Finally, the absence or presence of an additive declaration on a label must be interpreted scientifically. A label can identify the declared additive name, E-number or INS/SIN code, and sometimes the functional class, but it usually does not disclose the concentration, actual intake, exposure by age group, degradation products, impurities, or possible combined exposure from other foods. Consequently, definitions and fundamental concepts should be used to support careful screening, not unsupported claims of toxicity, ADI exceedance, or non-compliance. (World Health Organization, 2023c; EFSA Panel on Food Additives and Flavourings, 2021).

**Table 1.** Fundamental concepts used in food-additive assessment.

| Concept | Meaning | Importance | Reference(s) |
|---|---|---|---|
| **Food additive** | Substance intentionally added to food for a technological purpose and expected to become, or affect, a component of the food. | Defines the scope of additive regulation and label-based screening. | Codex Alimentarius Commission (1995); European Parliament and Council (2008). |
| **Functional class** | Category based on the technological function exerted by the additive in the food. | Allows additives to be interpreted by role, such as preservative, colour, emulsifier, stabilizer, or sweetener. | European Parliament and Council (2008). |
| **ADI** | Estimated daily intake over a lifetime without appreciable adverse health effects, usually expressed in mg/kg body weight/day. | Supports long-term exposure assessment but requires concentration and consumption data. | World Health Organization (2023c). |
| **NOAEL/LOAEL** | Experimental dose levels without observed adverse effects or with the lowest observed adverse effects. | Traditional toxicological points of departure for deriving health-based guidance values. | EFSA Scientific Committee (2017). |
| **BMD/BMDL** | Modelled benchmark dose and its lower confidence bound derived from dose-response data. | Provides a more informative reference point when suitable dose-response data are available. | EFSA Scientific Committee (2017). |
| **GRAS** | U.S. recognition that a substance is safe under intended conditions of use based on qualified expert consensus. | Not identical to EU or Algerian authorization; depends on intended use and evidence basis. | U.S. Food and Drug Administration (2024). |
| **Carry-over** | Presence of an additive in a finished food because it was introduced through an ingredient or processing route. | Explains why additive interpretation may be complex in compound foods. | Codex Alimentarius Commission (1995); European Parliament and Council (2008). |
| **Technological justification** | Requirement that additive use be necessary, beneficial, and non-misleading. | Links safety assessment with consumer protection and transparent formulation. | Codex Alimentarius Commission (1995); European Parliament and Council (2008). |

| | | | |
|---|---|---|---|
| **Margin of exposure/safety** | Comparison between human exposure estimates and toxicological reference points. | Cannot be evaluated from label presence alone; requires analytical and dietary-exposure data. | EFSA Scientific Committee (2017); World Health Organization (2023c). |

## 1.3. Historical evolution of food additives

### 1.3.1. Ancient and Traditional Preservation Methods

The earliest food additives were not synthetic chemicals but traditional materials and processes used to improve preservation and palatability. Salt, vinegar, smoke, fermentation, sugar, drying, herbs, and spices modified water activity, pH, microbial ecology, and sensory properties. These practices were developed empirically long before the emergence of analytical chemistry or formal toxicology (Carocho et al., 2015; Codex Alimentarius Commission, 1995).

Traditional preservation demonstrates that the technological purpose of additives is legitimate in principle. Foods deteriorate through microbial growth, enzymatic activity, oxidation, and physical instability. Substances capable of slowing these processes can improve food safety and reduce waste when used appropriately. The historical lesson is therefore not that additives are new or unnecessary, but that their modern use requires clear identity, purity, dose control, and oversight (Carocho et al., 2015; Codex Alimentarius Commission, 1995).

### 1.3.2. Industrial Revolution and the Emergence of Synthetic Additives

The industrial period changed the scale of additive use. Urbanization, centralized production, long-distance transport, and mass retailing increased the need for stable, standardized products. Synthetic colours, chemical preservatives, emulsifiers, leavening agents, stabilizers, and flavour systems became increasingly common because they allowed manufacturers to produce consistent foods under industrial conditions (Carocho et al., 2015; Codex Alimentarius Commission, 1995).

This period also revealed the risks of unregulated food chemistry. Some substances were used to mask spoilage, imitate quality, or improve appearance at the expense of consumer safety. Historical examples of adulteration contributed to the emergence of food laws, analytical control, official standards, and the principle that food additives must be evaluated before widespread use (Carocho et al., 2015; Codex Alimentarius Commission, 1995).

### 1.3.3. Modern Regulatory Era

The modern regulatory era is characterized by positive lists, specifications, toxicological evaluation, food-category restrictions, maximum permitted levels, and periodic re-evaluation. International scientific bodies such as JECFA and regulatory authorities such as EFSA and FDA

evaluate additives using hazard identification, dose-response assessment, exposure assessment, and risk characterization (Carocho et al., 2015; Codex Alimentarius Commission, 1995).

The modern era also shows that regulatory decisions evolve. Titanium dioxide E171 is a prominent example: EFSA concluded in 2021 that it could no longer be considered safe as a food additive because a concern for genotoxicity could not be ruled out (European Food Safety Authority, 2021). Similarly, recent evaluations of aspartame show the distinction between hazard classification and risk assessment, with IARC classifying aspartame as possibly carcinogenic while JECFA reaffirmed the existing ADI (World Health Organization, 2023b).

## 1.4. Classification of Food Additives

### 1.4.1. Classification by Technological Function

Functional classification is the most useful system for food science and regulatory interpretation because it explains why an additive is used. Codex class names include acidity regulators, anticaking agents, antioxidants, carbonating agents, colours, emulsifiers, emulsifying salts, flavour enhancers, preservatives, raising agents, stabilizers, sweeteners, and thickeners (Codex Alimentarius Commission, 1989).

This functional approach is directly useful for general label interpretation because commercial products rarely contain isolated additives. A beverage may combine acidity regulators, colours, preservatives, stabilizers, sweeteners, and carbonating agents. A processed cheese may contain emulsifying salts and stabilizers. A snack may contain colours, anticaking agents, acidity regulators, and flavour enhancers. The role of the theoretical section is to explain these categories before any regulatory or exposure interpretation is attempted (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008).

Functional classification is also helpful because the same chemical can appear in more than one interpretive context. Citric acid may function as an acidity regulator, antioxidant synergist, flavour-related acidulant, or preservative-supporting ingredient depending on the product matrix. Phosphates may act as emulsifying salts in processed cheese, acidity regulators in beverages, or moisture-retention agents in processed foods. Therefore, the functional class reported on labels should be interpreted with attention to the food matrix (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008).

In label-based assessment, coding systems reduce ambiguity but do not remove the need for scientific judgement. A declaration such as E211 identifies sodium benzoate, while E202 identifies potassium sorbate; however, the toxicological question depends on concentration, co-

occurring acids, storage conditions, consumption frequency, and the age or health status of consumers. The same logic applies to sweeteners, colours, cellulose derivatives, phosphates, and emulsifiers (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008).

The distinction between E-number and INS notation is particularly important in multilingual markets, including North African contexts where labels may combine Arabic, French, English, E-numbers, INS/SIN codes, or common names. Standardizing declarations into a single notation is therefore a methodological necessity, not merely a formatting preference. It allows product labels to be compared with Codex, EU, and Algerian lists and reduces the risk of double-counting the same additive under different names (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008).

Classification by origin should be used cautiously in academic writing. Natural colours, plant extracts, mineral salts, fermentation products, and synthetic compounds all require toxicological evaluation. A natural substance may contain allergens or biologically active constituents, and a synthetic substance may be highly characterized and safe under defined use conditions. This principle prevents the theoretical section from reproducing marketing language and keeps the analysis aligned with toxicological reasoning (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008).

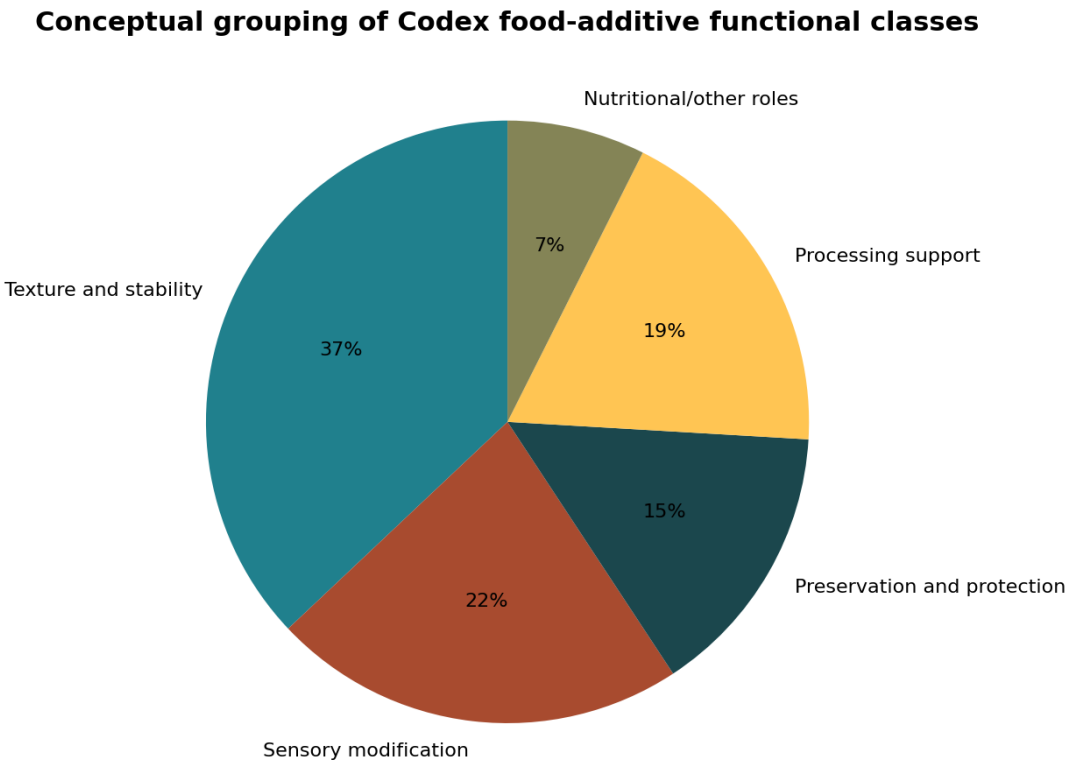


**Figure 1.** Conceptual grouping of Codex food-additive functional classes.

### 1.4.2. Classification by Origin Natural and Synthetic Additives

Additives may be natural, nature-identical, synthetic, mineral, microbial, or chemically modified derivatives of natural substances. However, origin is not a reliable indicator of safety. A natural extract may contain potent biologically active compounds, while a synthetic additive may be safe at regulated levels if its identity, purity, and exposure are well controlled (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008).

The distinction between natural and synthetic additives is often important for consumer perception but less decisive for toxicological assessment. Safety depends on dose, exposure duration, metabolic fate, impurities, matrix effects, vulnerable populations, and the strength of toxicological evidence. Regulatory science therefore evaluates substances by identity and use conditions rather than by marketing claims of naturalness (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008).

### 1.4.3. The E-Number and INS Coding System

The International Numbering System provides a harmonized way of identifying food additives and reducing ambiguity in labels and regulations. In the European context, E-numbers indicate additives authorized for permitted uses, while INS numbers provide a broader Codex identification system. Codex emphasizes that inclusion in the INS does not itself imply approval for all uses or in all jurisdictions (Codex Alimentarius Commission, 1989).

This distinction is essential for label-based assessment. A code identifies the substance, but regulatory interpretation also requires the food category, functional role, maximum permitted level, national authorization, and actual concentration. For example, colors, benzoates, sorbates, phosphates, cellulose derivatives, sweeteners, and acidity regulators cannot be judged solely by their code; they must be interpreted in context (Codex Alimentarius Commission, 1995; European Parliament and Council, 2008).

## 1.5. Technological Functions and Importance of Food Additives

### 1.5.1. Food Preservation and Safety

Preservatives inhibit microbial growth and help extend shelf-life, particularly in acidic foods, beverages, sauces, dairy products, and fruit-based products. Potassium sorbate and sodium benzoate are widely used examples. Their technological value is clear, yet exposure assessment remains important because repeated consumption across multiple foods can contribute to cumulative intake, especially among children and adolescents (World Health Organization, 2023c).

Antioxidants serve a different preservative role by slowing oxidative deterioration. Oxidation affects fats, colors, flavors, and some vitamins. Ascorbic acid, tocopherols, and other antioxidants can therefore protect sensory and nutritional quality. The safety significance of an antioxidant depends on identity, concentration, purity, and the food matrix (Carocho et al., 2015; European Parliament and Council, 2008).

### 1.5.2. Improvement of Sensory Properties

Colourants, sweeteners, flavour enhancers, acids, and flavour systems are used to create or maintain sensory appeal. Colours may restore appearance after processing or create an expected product identity. Sweeteners such as aspartame and sucralose provide sweetness with little caloric contribution, while flavour enhancers such as glutamates and ribonucleotide salts intensify savoury taste (Carocho et al., 2015; European Parliament and Council, 2008).

Sensory additives require careful discussion because they may influence food choice, especially among children. Some synthetic colours have specific warning-label requirements in the European Union, and non-sugar sweeteners have been discussed in relation to long-term dietary outcomes and cancer-risk research (Debras et al., 2022; European Parliament and Council, 2008; World Health Organization, 2023a).

### 1.5.3. Texture, Stability, and Processing Optimization

Emulsifiers, stabilizers, thickeners, modified starches, carrageenan, gums, and cellulose derivatives are used to maintain uniform texture and prevent separation. These additives are especially important in dairy products, sauces, beverages, creams, processed cheeses, confectionery, and bakery products. Their technological role may be indispensable for certain industrial formulations (Carocho et al., 2015; European Parliament and Council, 2008).

Recent toxicological and epidemiological interest in emulsifiers does not mean that all texture agents are harmful. Rather, it indicates that some emulsifier groups require refined exposure assessment because experimental models show effects on microbiota and intestinal inflammation, and cohort studies have reported associations with cardiovascular disease, cancer, or diabetes for selected groups (Chassaing et al., 2015; Payen de la Garanderie et al., 2025; Sellem et al., 2023, 2024).

### 1.5.4. Nutritional Enhancement

Some substances are added primarily to improve nutritional quality, such as vitamins, minerals, amino acids, and fortification agents. These are not always classified as food additives in the

strict regulatory sense when the primary purpose is nutritional rather than technological. However, label interpretation may encounter both technological additives and nutrient additions in the same product (Carocho et al., 2015; European Parliament and Council, 2008).

The distinction is particularly relevant for energy drinks and fortified beverages, where vitamins, caffeine, taurine, acidity regulators, sweeteners, and preservatives may appear together. Caffeine and taurine are not conventional E-number additives, but they are toxicologically relevant ingredients when discussing stimulant formulations and vulnerable consumers (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; Mandato et al., 2025).

The preservative function is especially relevant to beverages, fruit drinks, sauces, confectionery fillings, and some dairy-related products because acidic and sugar-containing matrices can support microbial or yeast spoilage if formulation is not properly controlled. Benzoates and sorbates are often used because they are effective under acidic conditions, but their presence in multiple beverages can create repeated exposure patterns. Dietary exposure assessment illustrates the value of moving beyond label presence toward measured concentrations and intake scenarios (World Health Organization, 2023c).

Sensory additives raise a different public-health question. Colours, sweeteners, flavour enhancers, and acids may not primarily protect the consumer from microbiological spoilage; they make products more attractive, recognizable, palatable, or brand-consistent. This is legitimate when transparent and properly regulated, but it becomes important for preventive nutrition when highly coloured or intensely sweet products are marketed to children. The EU warning-label approach for selected colours reflects this risk-communication dimension rather than a universal ban (European Parliament and Council, 2008).

Texture agents have become central to modern formulation because consumers expect a stable mouthfeel, a uniform appearance, and resistance to phase separation during storage. Emulsifiers, gums, cellulose derivatives, carrageenan, modified starches, and phosphates can produce these characteristics in dairy desserts, processed cheeses, sauces, beverages, and snack coatings. Recent experimental studies demonstrate that some emulsifiers can directly affect human-derived microbiota systems and inflammatory pathways, which justifies continued attention to exposure levels and additive combinations (Naimi et al., 2021; Viennois, Chassaing, et al., 2017).

Phosphate additives deserve specific technological discussion because they are highly effective in processed foods. In processed cheese, they help solubilize casein, promote emulsification, improve meltability, and stabilize texture. In beverages and other processed products,

phosphoric acid or phosphate salts may contribute to acidity, flavour profile, or processing stability. Their technological usefulness must be weighed against emerging concerns regarding highly absorbable inorganic phosphate in populations with kidney or cardiovascular vulnerability (Calvo et al., 2023; Ritz et al., 2012).

Fortification and stimulant-associated formulation also require distinction. Vitamins may be added for nutritional purposes, whereas caffeine, taurine, sweeteners, acidity regulators, colours, and preservatives may create the functional profile of energy drinks and similar beverages. Toxicological discussion should therefore not treat all labelled compounds as E-number additives, but it should still include non-additive ingredients when they materially influence risk communication, especially for adolescents, pregnant women, and cardiovascularly vulnerable consumers (Carocho et al., 2015; European Parliament and Council, 2008).

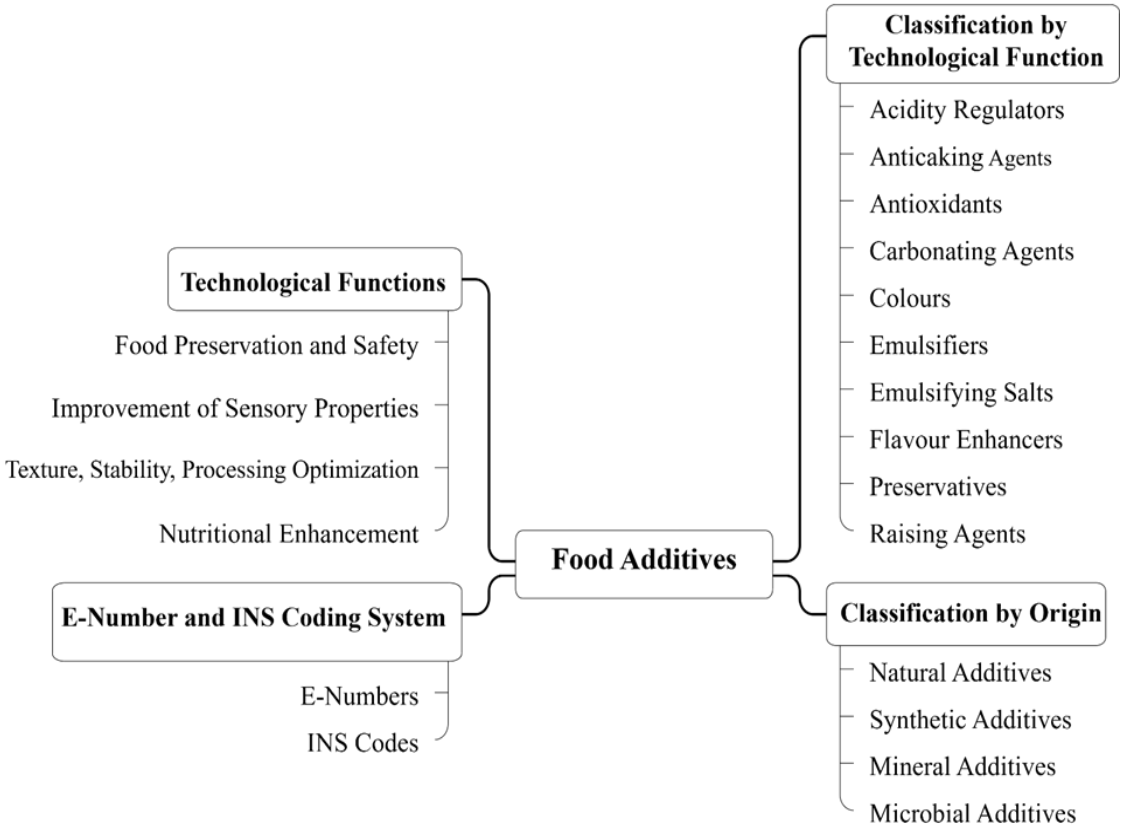


**Figure 2.** Classification and technological functions of food additives (Said et al.,2026).

## 1.6. International Regulatory Framework for Food Additives

### 1.6.1. Joint FAO/WHO Expert Committee on Food Additives

JECFA provides independent scientific evaluations of food additives, contaminants, naturally occurring toxicants, and veterinary drug residues. For additives, JECFA evaluates toxicological data, estimates safe intake values when possible, establishes specifications, and provides advice

that supports Codex standards. Its evaluations are central to international risk assessment because they combine hazard data with exposure considerations (Joint FAO/WHO Expert Committee on Food Additives, 2026; World Health Organization, 2023c).

The JECFA approach is important because it clarifies the difference between hazard and risk. A substance may show a hazard under certain experimental conditions, but consumer risk depends on exposure level, duration, and population susceptibility. This distinction is especially important when interpreting debated additives such as aspartame, which was classified by IARC as a possible carcinogenic hazard while JECFA maintained its ADI after risk assessment (World Health Organization, 2023b).

### 1.6.2. Codex Alimentarius and the General Standard for Food Additives

Codex develops international food standards intended to protect consumer health and facilitate fair trade. The General Standard for Food Additives organizes permitted uses by food category and technological function and is regularly updated (Codex Alimentarius Commission, 1995). Codex standards are not automatically national law, but they strongly influence national legislation and international trade requirements (Codex Alimentarius Commission, 1995; FAO/WHO Codex Alimentarius Commission, n.d.).

For label-based research, Codex also provides the conceptual basis for functional names and INS codes. The combination of a food category, additive identity, function, and maximum use level is more informative than additive name alone. This is why a later analytical assessment should avoid declaring non-compliance from labels unless measured concentrations can be compared with relevant food-category limits (Codex Alimentarius Commission, 1995; FAO/WHO Codex Alimentarius Commission, n.d.).

### 1.6.3. European Union Regulatory Framework

The European Union uses a positive-list system under Regulation (EC) No. 1333/2008. Additives must be authorized before use, and authorization depends on safety, technological need, and absence of consumer deception (European Commission, n.d.; European Parliament and Council, 2008). The regulation also defines functional classes and contains provisions on labelling, including special requirements for foods containing certain colours (European Commission, n.d.; European Parliament and Council, 2008).

The EU framework is particularly influential because EFSA performs scientific risk assessments and re-evaluations using updated guidance. The withdrawal of food-additive titanium dioxide from the EU market after EFSA's 2021 assessment illustrates how regulatory positions may change when new evidence or uncertainty becomes significant (European Food Safety Authority, 2021).

### 1.6.4. United States FDA Regulatory Approach

The FDA system distinguishes approved food additives from substances that are generally recognized as safe under their conditions of intended use. A GRAS conclusion can be based on scientific procedures or common use in food before 1958, but it still depends on qualified expert recognition and defined use conditions (U.S. Food and Drug Administration, 2024).

For comparative academic work, the FDA framework is useful but should not be treated as identical to Codex, EU, or Algerian systems. Differences may exist in terminology, authorization pathways, colour certification, labelling, and food-category limits. A rigorous scientific

review should therefore state the framework being used whenever regulatory status is discussed (U.S. Food and Drug Administration, 2024).

### 1.6.5. Algerian National Regulatory Framework

Algeria regulates food additives through a national framework that combines consumer protection, food-safety control, authorized-use lists, maximum permitted levels, and labelling obligations. The central legal reference for food additives is Executive Decree No. 12-214 of 15 May 2012, published in the Official Journal of the Algerian Republic, which establishes the conditions and modalities for using additives in foods intended for human consumption (Journal Officiel de la République Algérienne, 2012). This decree defines key terms such as food additive, halal food additive, indirect addition, acceptable daily intake, maximum concentration, good manufacturing practice, and contaminant; it also excludes additives used in animal feed and clarifies that contaminants and pesticide residues must not be considered food additives (Journal Officiel de la République Algérienne, 2012; USDA Foreign Agricultural Service, 2022).

The Algerian framework is based on a positive-list logic. Only additives listed in Annex I may be used, and their use must comply with the food categories and conditions specified in the decree, particularly Annex II for food categories and Annex III for authorized uses and maximum levels (Journal Officiel de la République Algérienne, 2012). Maximum levels are interpreted for the finished food as consumed, and where no numerical maximum is specified, the principle of good manufacturing practice applies. The decree also requires additives to comply with relevant identity and purity specifications, whether established in Algerian standards or in recognized international standards (Journal Officiel de la République Algérienne, 2012; USDA Foreign Agricultural Service, 2022).

From a regulatory-science perspective, the Algerian system is not limited to chemical authorization. It also requires technological justification and consumer protection: additive use should preserve nutritional quality, support special dietary needs where relevant, improve preservation or stability, or enhance organoleptic properties without misleading the consumer or concealing poor product quality (Journal Officiel de la République Algérienne, 2012). In addition, the decree provides specific labelling requirements for additives, including the additive name or SIN/INS code, functional class, maximum quantity, good manufacturing practice indication where applicable, and warnings for certain sweeteners such as polyols and aspartame (Journal Officiel de la République Algérienne, 2012; USDA Foreign Agricultural Service, 2022).

For academic interpretation, Algerian regulation should be treated as the primary legal reference for foods marketed in Algeria. International standards remain scientifically useful, but they do not replace national law. JECFA provides independent toxicological evaluation and health-based guidance values such as ADIs, while the Codex General Standard for Food Additives provides internationally harmonized terminology, food categories, INS numbers, functional classes, and additive provisions adopted by the Codex Alimentarius Commission (Codex Alimentarius Commission, 1995; World Health Organization, 2023c). These references are valuable for screening and comparison, especially when national texts require interpretation in light of international specifications (Journal Officiel de la République Algérienne, 2012; USDA Foreign Agricultural Service, 2022).

The European Union and United States frameworks may also be used as comparative references, but their legal status differs from the Algerian framework. The EU model is based on authorized lists, food-category conditions, labelling provisions, and scientific re-evaluation, whereas the FDA model distinguishes approved food additives from substances that are generally recognized as safe under their intended conditions of use (European Parliament and Council, 2008; U.S. Food and Drug Administration, 2023). These systems help contextualize controversial additives and regulatory trends, but they should not be used to declare Algerian non-compliance unless the relevant Algerian legal provisions and analytical evidence support such a conclusion (Journal Officiel de la République Algérienne, 2012; USDA Foreign Agricultural Service, 2022).

Consequently, a label-based assessment should use the Algerian framework as a national screening reference while clearly recognizing its methodological limits. Product labels can identify declared additive names, E-numbers or INS/SIN codes, functional classes, and warning-relevant ingredients, but they do not provide concentrations or actual dietary exposure. Claims of maximum-level exceedance, ADI exceedance, or legal non-compliance therefore require laboratory quantification and dietary exposure assessment, in addition to comparison with the most recent official Algerian texts and, where appropriate, Codex/JECFA, EU, and FDA references (Journal Officiel de la République Algérienne, 2012; USDA Foreign Agricultural Service, 2022).

**Table 2.** Comparative regulatory frameworks relevant to food-additive assessment.

| Framework | Main role | Use in scientific interpretation | Reference(s) |
|---|---|---|---|
| **JECFA** | Independent scientific risk assessment, toxicological evaluation, ADIs, and additive specifications. | International toxicological benchmark for interpreting ADIs, safety concepts, and risk-assessment terminology. | World Health Organization (2023c); Joint FAO/WHO Expert Committee on Food Additives (n.d.). |
| **Codex GSFA** | International food-category provisions, INS numbers, functional classes, and additive-use conditions. | Standardized reference for terminology, additive classification, food categories, and international comparison. | Codex Alimentarius Commission (1995); FAO/WHO Codex Alimentarius Commission (n.d.). |
| **EFSA/EU** | Positive lists, conditions of use, labelling provisions, scientific opinions, and re-evaluation of authorized additives. | High-value comparator for controversial additives, warning-label colours, re-evaluation practice, and EU market rules. | European Parliament and Council (2008); European Commission (n.d.). |
| **FDA** | Premarket food-additive approval unless the substance is GRAS under intended conditions of use. | Alternative regulatory model for understanding GRAS, intended-use safety, and U.S. food-ingredient assessment. | U.S. Food and Drug Administration (2023). |
| **Algeria** | National authorization, food categories, maximum permitted levels, halal requirement, identity/purity specifications, and additive labelling. | Primary legal framework for foods marketed in Algeria; supports screening but requires laboratory data for non-compliance claims. | Journal Officiel de la République Algérienne (2012); USDA Foreign Agricultural Service (2022). |

## 1.7. Food Labeling Standards and Label-Based Assessment Methodology

### 1.7.1. International Labeling Requirements for Food Additives

Food labelling is a central element of consumer protection and regulatory transparency. Codex states that prepackaged foods should not be presented in a false, misleading, or deceptive manner and requires ingredient lists for most prepackaged foods. It also indicates that additive declarations should include functional class names together with specific names or recognized numerical identifiers where required by national legislation (Codex Alimentarius Commission, 1985).

Good labelling allows consumers, regulators, and researchers to identify additives and understand their technological function. Poor labelling, vague terminology, illegible text, missing functional classes, or inconsistent code systems can weaken risk communication and complicate surveillance. This is particularly important when products contain additives of special interest such as warning colours, preservatives, high-intensity sweeteners, phosphates, or caffeine-containing formulations (Codex Alimentarius Commission, 1995; World Health Organization, 2023c).

### 1.7.2. Justification of Label-Based Assessment Methodology

Label-based assessment is an accepted first step in food-additive surveillance because it is feasible, reproducible, and directly related to information available to consumers. It can identify product categories with complex additive profiles, reveal labelling weaknesses, and prioritize samples for laboratory testing. It is especially appropriate for descriptive regulatory screening when the objective is descriptive and regulatory screening rather than full dietary risk assessment (Codex Alimentarius Commission, 1995; World Health Organization, 2023c).

The limitations must be explicit. Labels identify declared presence, not concentration. They cannot detect undeclared additives, degradation products, contaminants, impurities, or batch variability. They also cannot establish ADI exceedance without information on additive concentration and consumption frequency. Therefore, label-based findings should be interpreted as screening evidence and as a basis for further laboratory and exposure-assessment studies (Codex Alimentarius Commission, 1995; World Health Organization, 2023c).

Food labels are not laboratory reports, but they are the first official information layer available to consumers, inspectors, researchers, and healthcare educators. A well-constructed label supports informed choice and allows preliminary screening of additive complexity. In contrast, incomplete or ambiguous labels reduce transparency and make it difficult to compare products with international and national requirements (Codex Alimentarius Commission, 1995; World Health Organization, 2023c).

The scientific value of label-based assessment is strongest when the research question is descriptive, comparative, and regulatory-screening oriented. Such studies can identify products containing warning-label colours, preservatives, sweeteners, phosphates, emulsifiers, or stimulant ingredients and can rank categories according to declared additive complexity. This information helps prioritize limited laboratory resources toward products of greatest public-health or regulatory relevance (Codex Alimentarius Commission, 1995; World Health Organization, 2023c).

Label-based assessment is also useful in regions where formal food-composition databases may be incomplete or where market products change rapidly. Researchers can create a snapshot of the retail food environment, identify recurring additives, and document labelling practices. These data are especially valuable when linked to future analytical chemistry, dietary-intake surveys, and vulnerability-based exposure modelling (Codex Alimentarius Commission, 1995; World Health Organization, 2023c).

The method has unavoidable limitations. Labels may contain transcription errors, OCR difficulties, translation variation, inconsistent naming, missing E-numbers, or incomplete functional class declarations. They also cannot reveal degradation products such as benzene formed under particular beverage-storage conditions, nor can they identify undeclared substances. Therefore, label-based conclusions should be phrased as screening findings, not as proof of exposure magnitude or legal violation (Codex Alimentarius Commission, 1995; World Health Organization, 2023c).

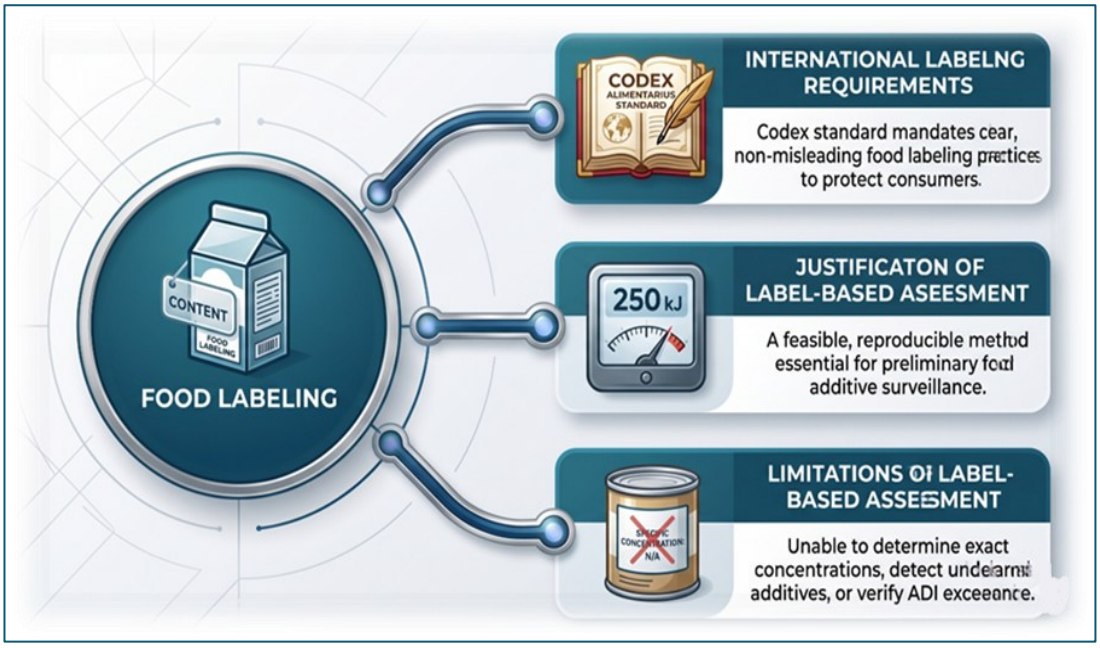


**Figure 3.** Unveiling the Dimensions of Food Labeling(Said et al.,2026).

### 1.8. Food Additive Exposure and Vulnerable Populations

Exposure to food additives depends on concentration, consumption frequency, portion size, body weight, and the number of products containing the same additive or related additive groups. Vulnerability may be higher in children, pregnant women, individuals with chronic kidney disease, consumers with cardiovascular disease, and people with metabolic disorders. These groups require special attention because their intake per kilogram body weight, physiological reserve, or sensitivity to specific ingredients may differ from that of healthy adults (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; World Health Organization, 2023c).

Children and adolescents are often exposed through sweetened beverages, confectionery, snacks, flavoured dairy products, and coloured foods. Pregnant women require careful guidance regarding caffeine-containing products and highly processed diets. Individuals with kidney disease or cardiovascular vulnerability may require attention to phosphate additives, sodium-rich

products, and stimulant beverages. These considerations justify a preventive approach, but they do not support claims of direct causality from label data alone (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; World Health Organization, 2023c).

The public-health context in Algeria reinforces the need for balanced interpretation. WHO country data indicate that noncommunicable diseases account for a large share of mortality in Algeria (World Health Organization, 2024), and IARC data identify important cancer burdens, including breast cancer among women and lung cancer among men (International Agency for Research on Cancer, 2022). Food additives should be viewed as one component of the broader food environment, alongside sugar, salt, saturated fat, product marketing, affordability, and access to fresh foods (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; World Health Organization, 2023c).

Children represent a priority group because their intake per kilogram body weight may be higher than that of adults for sweet drinks, snacks, confectionery, and flavoured dairy products. They may also be more sensitive to products designed around colour, sweetness, novelty, and brand appeal. This does not mean that all colourful products are toxic; it means that additive-rich child-oriented foods should receive greater attention in labelling and surveillance (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; World Health Organization, 2023c).

Pregnant women require a different form of caution. The main concerns are not limited to conventional additives but include caffeine-containing beverages, highly processed diets, excessive sugar intake, and possible micronutrient imbalance. EFSA's caffeine opinion and subsequent reviews on energy drinks support careful guidance for pregnant women and adolescents because stimulant effects, sleep disturbance, and cardiovascular responses depend on dose and individual sensitivity (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; Mandato et al., 2025).

Individuals with hypertension, diabetes, cardiovascular disease, or chronic kidney disease may be more vulnerable to the broader processed-food matrix in which additives are embedded. Sodium load, sugar content, saturated fat, phosphate additives, stimulant ingredients, and high-intensity palatability can act together. For kidney disease specifically, phosphate additives are important because inorganic phosphate is often highly bioavailable and may be difficult for susceptible patients to control (Calvo et al., 2023; St-Jules et al., 2017).

Population vulnerability should be discussed without deterministic claims. Regional or national disease patterns may justify preventive food-environment surveillance, but additive

declarations alone cannot explain the occurrence of chronic or infectious diseases. Label-based information can only identify substances and categories that may require more detailed exposure assessment, laboratory verification, and proportionate risk communication (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; World Health Organization, 2023c).

This balanced approach protects the scientific review from alarmism while preserving public-health relevance. It recognizes that additives are one component of a larger risk environment that includes nutrition transition, affordability, product marketing, climate, storage conditions, dietary habits, and healthcare access. Such framing is scientifically stronger than attempting to attribute complex disease burdens to additive labels alone (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; World Health Organization, 2023c)

**Table 2.** Editable source-informed matrix linking food-category exposure with vulnerable population priorities.

| Product category | Children | Pregnant women | Hypertension /CV risk | Diabetes | Kidney vulnerability | Reference(s) |
|---|---|---|---|---|---|---|
| **Beverages** | **X** | **X** | **X** | **X** | | EFSA Panel on Dietetic Products, Nutrition and Allergies (2015); World Health Organization (2023a) |
| **Flavoured dairy** | **X** | | | **X** | | World Health Organization (2023a); Conz et al. (2023) |
| **Sweets** | **X** | | | **X** | | McCann et al. (2007); European Parliament and Council (2008) |
| **Chips and crackers** | **X** | | **X** | **X** | | Tan et al. (2024); Cordova et al. (2023) |
| **Preserved foods + processed cheese** | | | **X** | X | **X** | Calvo et al. (2023); St-Jules et al. (2017) |

# CHAPTER II

*Toxicological Evidence and Health Risks of Food Additives*

## 2.1. Introduction

The toxicological evaluation of food additives is based on the principle that risk depends on both hazard and exposure. Many additives are safe when used within authorized limits and consumed at ordinary levels, but some additive groups remain under scientific discussion because of new toxicological evidence, epidemiological associations, or changing exposure patterns. The purpose of this chapter is to review the main health-risk evidence relevant to common additive groups in processed foods (EFSA Scientific Committee, 2017; World Health Organization, 2023c).

A balanced approach is essential. The presence of an additive on a label does not prove harm, and the absence of measured concentration prevents assessment of ADI exceedance. At the same time, repeated exposure to mixtures of additives in ultra-processed foods may deserve attention, particularly among vulnerable groups. The theoretical review therefore distinguishes established evidence, regulatory concern, suggestive epidemiology, experimental mechanisms, and hypotheses requiring further research (EFSA Scientific Committee, 2017; World Health Organization, 2023c).

The toxicological chapter should be read as an evidence hierarchy rather than as a catalogue of dangers. At the strongest level are established toxicological endpoints that lead to regulatory restriction or prohibition. At an intermediate level are authoritative evaluations showing uncertainty or specific risk-management conditions. At a more exploratory level are observational associations, mechanistic experiments, and mixture hypotheses that require confirmation through exposure assessment and controlled studies (EFSA Scientific Committee, 2017; World Health Organization, 2023c).

This hierarchy matters because many additive controversies arise from confusion between hazard identification and risk assessment. A hazard classification indicates that a substance can cause harm under certain conditions, whereas risk assessment asks whether real-world exposure is sufficient to create concern in a defined population. The aspartame case illustrates this distinction because IARC and JECFA issued different but not necessarily contradictory evaluations: one addressed carcinogenic hazard classification, whereas the other evaluated exposure-based risk and retained the ADI (World Health Organization, 2023b).

A second interpretive challenge is that additive exposure often occurs through ultra-processed products. These products may contain additives, but they may also be high in free sugars, salt, refined starches, fats, and flavour systems while being low in fibre or protective nutrients. Large epidemiological studies have associated higher ultra-processed food consumption with cancer, cardiometabolic

outcomes, multimorbidity, and mortality, but additive-specific causality remains difficult to isolate (Cordova et al., 2023; Kliemann et al., 2022; Lo et al., 2024; Tan et al., 2024).

## 2.2. General Mechanisms of Food Additive Toxicity

### 2.2.1. Disruption of Gut Microbiota and Intestinal Barrier Function

The gastrointestinal tract is a primary interface between food additives and the organism. Some additives may remain largely within the gut lumen, where they can affect mucus, microbial ecology, viscosity, or local immune signalling. Experimental research has shown that certain emulsifiers can alter gut microbiota and promote low-grade inflammation in animal models (Chassaing et al., 2015).

These mechanisms are relevant to stabilizers, emulsifiers, thickeners, and cellulose derivatives, but animal findings should not be translated into direct human disease claims without caution. Human effects depend on exposure level, duration, background diet, microbiota composition, and host susceptibility. Recent cohort studies nonetheless make the gut-microbiota hypothesis important for interpreting additive mixtures in processed foods (Payen de la Garanderie et al., 2025; Sellem et al., 2023).

Mechanistic toxicology begins with toxicokinetics: absorption, distribution, metabolism, and excretion. Some additives are absorbed and metabolized systemically, while others act mainly within the intestinal lumen or are modified by gut microorganisms. This distinction affects the interpretation of sweeteners, emulsifiers, preservatives, phosphates, and colourants because each group has different bioavailability and biological targets (Chassaing et al., 2015; Naimi et al., 2021; Viennois, Chassaing, et al., 2017).

The gut microbiota is a major emerging pathway because it participates in digestion, immune regulation, barrier integrity, bile acid metabolism, and short-chain fatty acid production. Experimental research indicates that some emulsifiers can modify microbial composition, promote inflammatory gene expression, or alter host–microbe interactions under specific models (Chassaing et al., 2015; Naimi et al., 2021; Viennois, Chassaing, et al., 2017). These findings make emulsifier-rich foods scientifically relevant even though direct human disease claims require caution (Chassaing et al., 2015; Naimi et al., 2021; Viennois, Chassaing, et al., 2017).

Non-nutritive sweeteners add another mechanistic dimension. Human and review evidence suggests that responses may vary by sweetener type and individual microbiome characteristics, and some studies have reported microbiome-mediated changes in glucose tolerance for selected sweeteners

(Conz et al., 2023; Richardson & Frese, 2022; Suez et al., 2022). This does not support a simple statement that all sweeteners cause diabetes, but it supports careful discussion of long-term exposure patterns (Chassaing et al., 2015; Naimi et al., 2021; Viennois, Chassaing, et al., 2017).

Oxidative stress and genotoxicity remain central to regulatory toxicology because they can influence cancer-risk evaluation. The titanium dioxide case demonstrates how unresolved genotoxic concern can shift regulatory decisions even without direct epidemiological proof for consumer products (European Food Safety Authority Panel on Food Additives and Flavourings, 2021). Similar caution is applied when additive impurities or reaction products raise mechanistic concerns (Chassaing et al., 2015; Naimi et al., 2021; Viennois, Chassaing, et al., 2017).

Inflammation is the conceptual bridge linking several mechanisms. Dietary emulsifiers, ultra-processed food matrices, high sodium, high sugar, low fibre, and repeated exposure to palatable products may interact through gut barrier changes, immune activation, metabolic dysregulation, and the gut-liver axis. However, these are hypotheses with variable strength across additive classes, and scientific interpretation should not convert them into universal claims about all additives (Chassaing et al., 2015; Naimi et al., 2021; Viennois, Chassaing, et al., 2017).

### 2.2.2. Oxidative Stress and Genotoxicity

Oxidative stress occurs when reactive oxygen or nitrogen species exceed the capacity of antioxidant defences. Some additives or additive-related impurities may induce oxidative stress under experimental conditions, but toxicological relevance depends on dose and bioavailability. Genotoxicity is more serious because DNA damage can be relevant to carcinogenic risk assessment (EFSA Panel on Food Additives and Flavourings, 2021; EFSA Scientific Committee, 2017).

Titanium dioxide illustrates the regulatory importance of unresolved genotoxicity. EFSA concluded that E171 could no longer be considered safe as a food additive because a concern for genotoxicity could not be ruled out (European Food Safety Authority, 2021). This case demonstrates how uncertainty can lead to regulatory restriction even when direct human disease causality is not established (EFSA Panel on Food Additives and Flavourings, 2021; EFSA Scientific Committee, 2017).

### 2.2.3. Endocrine and Metabolic Interference

Some additives have been investigated for possible effects on glucose homeostasis, appetite regulation, taste preference, insulin response, or metabolic signalling. Non-sugar sweeteners are a prominent example because they are intended to provide sweetness without sugar calories, yet long-term population studies have raised questions about their relationship with weight control, diabetes, and cardiometabolic risk (Conz et al., 2023; Richardson & Frese, 2022; Suez et al., 2022).

WHO issued guidance indicating that non-sugar sweeteners should not be used as a long-term strategy for weight control or reducing noncommunicable disease risk in the general population (World Health Organization, 2023a). This recommendation does not mean that every sweetener is acutely toxic; rather, it highlights uncertainty about long-term health outcomes and the need to consider dietary patterns (Conz et al., 2023; Richardson & Frese, 2022; Suez et al., 2022).

### 2.2.4. Chronic Inflammation and Immune Dysregulation

Low-grade inflammation is a plausible bridge between diet, gut barrier function, metabolic disease, and some chronic outcomes. Emulsifiers, ultra-processed food matrices, high sugar, high salt, and low dietary fibre may interact in ways that affect inflammatory signalling. Evidence for individual additives varies considerably, and it is important not to overgeneralize from one additive group to all additives (Chassaing et al., 2015; Naimi et al., 2021).

Mechanistic studies are most useful when they are interpreted with epidemiological and exposure data. For example, experimental work on emulsifiers supports biological plausibility, while prospective cohort studies have begun to examine associations between specific emulsifier intakes and disease outcomes (Sellem et al., 2023, 2024; Viennois et al., 2017).

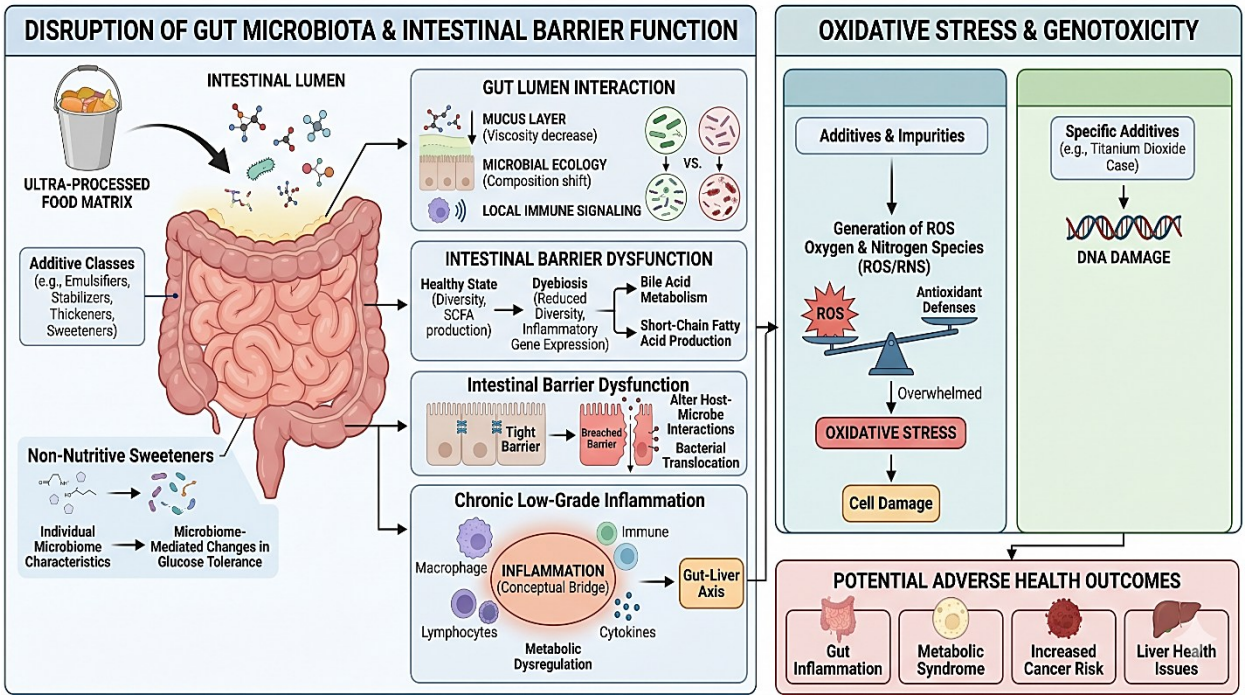


**Figure 4.** General mechanisms of food additive toxicity

## 2.3. Food Additives and Cancer Risk

### 2.3.1. Artificial Sweeteners and Cancer

Artificial sweeteners have received renewed attention because of epidemiological findings and international evaluations. Debras et al. (2022) reported associations between artificial sweetener intake, especially aspartame and acesulfame-K, and cancer risk in the NutriNet-Santé cohort. Such studies are important because they evaluate real dietary patterns, but they remain observational and cannot alone prove causality (Debras et al., 2022; World Health Organization, 2023b).

Aspartame is a useful example of evidence hierarchy. IARC classified it as possibly carcinogenic to humans, whereas JECFA reaffirmed the ADI of 0–40 mg/kg body weight per day and stated that available evidence did not justify changing the ADI (World Health Organization, 2023b). Therefore, theoretical discussion should present aspartame as a substance requiring cautious risk communication, not as a substance proven to cause cancer at permitted exposure levels (Debras et al., 2022; World Health Organization, 2023b).

### 2.3.2. Preservatives and Cancer

Preservatives include diverse substances with different mechanisms and risk profiles. Benzoates and sorbates are widely used in acidic beverages and foods, while nitrites and nitrates are used

primarily in processed meats. Nitrite-related formation of N-nitroso compounds is a long-standing cancer-related issue and has been reviewed by IARC (International Agency for Research on Cancer, 2010).

Benzoate-containing beverages require a different discussion. Under specific conditions involving ascorbic acid, metal catalysts, heat, and light, benzene formation may occur, which supports good manufacturing control and surveillance. This does not mean that every product containing sodium benzoate is carcinogenic; it means that formulation and storage conditions are relevant to safety assurance (International Agency for Research on Cancer, 2010; World Health Organization, 2023c).

### 2.3.3. Food Colourants and Cancer

Food colourants are heterogeneous. Some colours have long histories of regulated use, while others have been restricted, re-evaluated, or removed from certain jurisdictions. Synthetic azo dyes are more often discussed in relation to child behaviour and hypersensitivity-type reactions than to proven human carcinogenicity at permitted levels (European Parliament and Council, 2008; McCann et al., 2007).

The correct theoretical approach is to distinguish legal authorization, warning-label requirements, and toxicological evidence. Selected colours such as tartrazine, sunset yellow, carmoisine, and allura red have special labelling relevance in the EU because of possible effects on activity and attention in children (European Parliament and Council, 2008; McCann et al., 2007).

### 2.3.4. Emulsifiers and Cancer

Emulsifiers have become a major research topic because they may interact with gut barrier function and microbiota. In animal models, emulsifier-induced low-grade inflammation has promoted colon carcinogenesis under susceptible conditions (Viennois et al., 2017). These findings provide biological plausibility but do not directly prove equivalent effects in consumers (Sellem et al., 2024; Viennois, Merlin, et al., 2017).

Human cohort evidence has also emerged. Sellem et al. (2024) reported associations between higher intakes of certain emulsifier groups and cancer risk in the NutriNet-Santé cohort. Such data justify continued evaluation of emulsifiers in processed foods, especially when products contain multiple texture agents, but causality and product-specific risk require further investigation (Sellem et al., 2024; Viennois, Merlin, et al., 2017).

### 2.3.5. Ultra-Processed Foods and the Additive Hypothesis

Many additive exposures occur in ultra-processed foods, which also tend to contain high sugar, salt, refined starches, fats, flavourings, and low levels of protective dietary components. This makes causal attribution difficult. Additives may be markers of industrial processing, contributors to texture and palatability, or independent exposures depending on the additive and the product (Cordova et al., 2023; Kliemann et al., 2022; Lo et al., 2024).

The additive hypothesis should therefore be treated as one component of the ultra-processed food problem. A rigorous scientific review should discuss additives alongside nutritional quality and food environment, rather than attributing chronic diseases to additives alone (Cordova et al., 2023; Kliemann et al., 2022; Lo et al., 2024).

Cancer-related interpretation requires particular restraint because cancer is multifactorial and develops through long latency. Genetics, infection, smoking, occupational exposure, reproductive factors, obesity, alcohol, diet quality, and healthcare access all influence cancer risk. Food additives may enter the discussion through specific substances, reaction products, or ultra-processed dietary patterns, but they should not be presented as isolated explanations for local cancer burden (Cordova et al., 2023; Kliemann et al., 2022; Lo et al., 2024).

Artificial sweeteners are a useful example of evidence complexity. Debras et al. (2022) reported associations between artificial sweetener intake and cancer risk in a large cohort, while WHO/JECFA evaluations emphasized that exposure-based ADI conclusions remain distinct from hazard classification (World Health Organization, 2023b). The appropriate thesis language is therefore cautious: sweetener-containing products may deserve surveillance and consumption moderation, especially among frequent users, but labels alone cannot demonstrate cancer risk (Cordova et al., 2023; Kliemann et al., 2022; Lo et al., 2024).

Nitrites and nitrates have a stronger historical link to cancer discussion because of N-nitroso compound formation under certain conditions and their relevance to processed meats. Although the food categories may not focus primarily on cured meats, the theoretical section should include this example because it illustrates the principle that technological necessity and toxicological concern can coexist. It also clarifies why regulatory controls, maximum levels, and manufacturing conditions are essential (Cordova et al., 2023; Kliemann et al., 2022; Lo et al., 2024).

Benzoates and sorbates are not evaluated in the same way as nitrites. Their concern in beverages is more often related to cumulative intake, child exposure, and potential benzene formation under

specific formulation and storage conditions. Thus, the theoretical chapter should avoid describing sodium benzoate as a direct carcinogen in labelled beverages; instead, it should identify the conditions under which surveillance becomes relevant (Cordova et al., 2023; Kliemann et al., 2022; Lo et al., 2024).

The ultra-processed food literature provides broader context. Reviews and cohort studies suggest associations between high ultra-processed food intake and cancer risk, but the mechanisms may include nutrient profile, contaminants, packaging migrants, dietary displacement, palatability, and additives together (Kliemann et al., 2022; Lo et al., 2024). This supports a screening framework's category-based surveillance approach while preventing over-attribution to a single additive (Cordova et al., 2023; Kliemann et al., 2022; Lo et al., 2024).

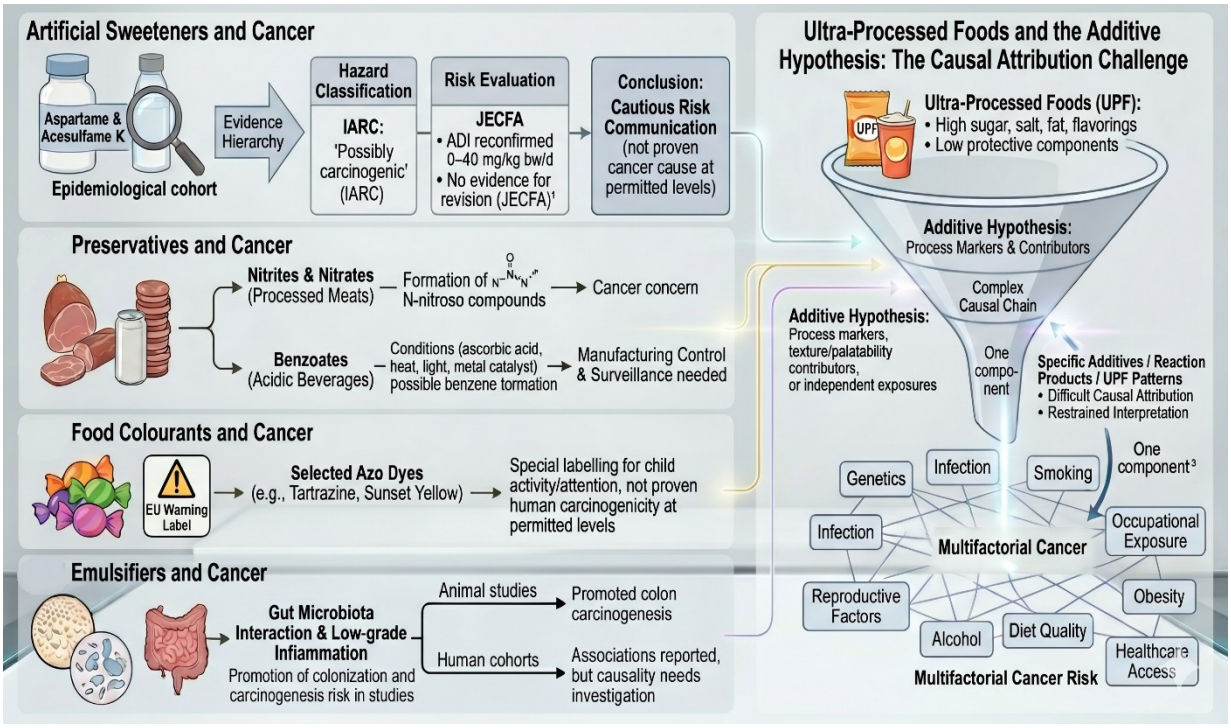


**Figure 5.** Food additives and cancer risk

### 2.4. Food Additives and Type 2 Diabetes Mellitus

Type 2 diabetes is a multifactorial condition influenced by genetics, adiposity, dietary patterns, physical activity, socioeconomic factors, and metabolic health. Additives may be relevant when they appear in products that are high in sugar, salt, refined carbohydrates, or energy density, or when they affect gut microbiota, taste preference, or metabolic signalling (Payen de la Garanderie et al., 2025; Tan et al., 2024).

Recent studies have examined additive mixtures rather than isolated substances. Payen de la Garanderie et al. (2025) reported that certain food-additive mixtures were associated with higher type 2 diabetes incidence, including mixtures containing modified starches, gums, carrageenan, phosphates, sorbates, citric acid, phosphoric acid, caramel colour, sweeteners, and other additives. This supports mixture-oriented research but does not prove causation for individual products (Payen de la Garanderie et al., 2025; Tan et al., 2024).

Preservatives have also been evaluated through dietary exposure approaches that combine occurrence data, measured concentrations, consumption scenarios, and high-percentile intake estimates. Such work illustrates why label declarations alone are insufficient for risk characterization and why preservative assessment should integrate concentration data with age-specific intake patterns (Payen de la Garanderie et al., 2025; Tan et al., 2024).

For type 2 diabetes and cardiometabolic disease, additive interpretation should be integrated with diet quality. Sweetened beverages, snack foods, processed cheeses, and flavoured dairy products may combine additives with free sugars, sodium, saturated fat, refined carbohydrates, or stimulant ingredients. Consequently, additive-rich products may be important not only because of additive toxicology but also because they indicate highly processed dietary patterns (Payen de la Garanderie et al., 2025; Tan et al., 2024).

Recent population studies strengthen the rationale for surveillance. Ultra-processed food consumption has been associated with cardiovascular events and cardiometabolic multimorbidity in large prospective and meta-analytic work, although residual confounding and product heterogeneity remain important limitations (Cordova et al., 2023; Tan et al., 2024). Scientific interpretation should use this evidence to support preventive attention to additive-dense categories, not to claim that additives alone cause diabetes or heart disease (Payen de la Garanderie et al., 2025; Tan et al., 2024).

Food-additive mixture research is particularly relevant to diabetes because it reflects how consumers actually encounter additives. Payen de la Garanderie et al. (2025) reported associations between certain additive mixtures and type 2 diabetes incidence, including mixtures containing modified starches, gums, carrageenan, phosphates, sorbates, citric acid, phosphoric acid, caramel colour, and sweeteners. This evidence aligns conceptually with label-based screening of complex beverages, dairy products, and snack foods (Payen de la Garanderie et al., 2025; Tan et al., 2024).

Phosphate additives provide a more specific route from processed foods to kidney and cardiovascular vulnerability. Inorganic phosphate added during processing can be highly absorbable, and

patients with chronic kidney disease may have limited ability to maintain phosphate balance. Reviews therefore recommend attention to phosphate additives and improved labelling to help vulnerable patients reduce exposure (Calvo et al., 2023; Ritz et al., 2012; St-Jules et al., 2017).

The liver-related interpretation should emphasize the gut-liver axis. Additives that alter the gut environment could theoretically influence hepatic inflammation or metabolic signalling, while sweeteners and ultra-processed dietary patterns may relate to glucose and lipid metabolism. Still, current evidence does not support assigning liver disease risk to a labelled additive without exposure and clinical data. This distinction is important for maintaining academic credibility (Payen de la Garanderie et al., 2025; Tan et al., 2024).

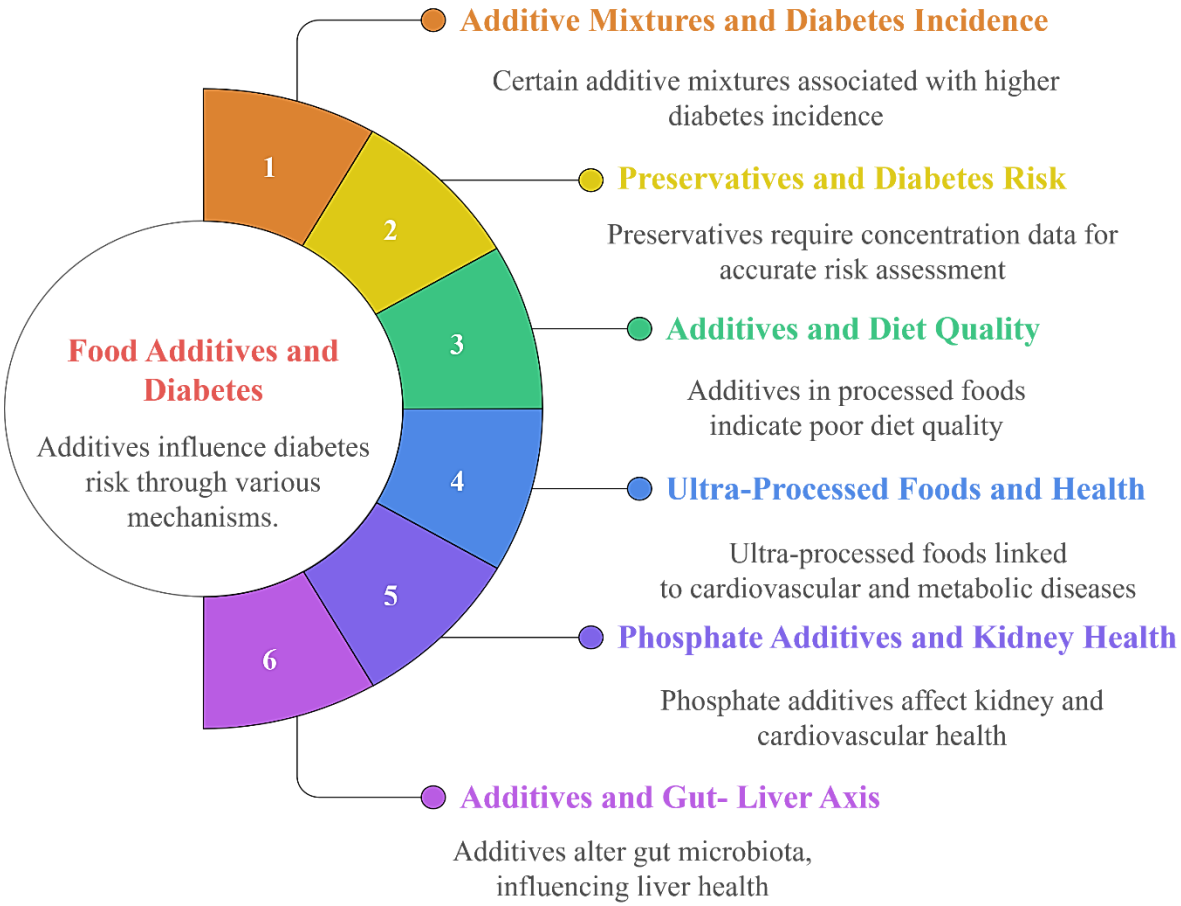


**Figure 6.** Unveiling the multifaceted impact of food additives on diabetes

### 2.5. Food Additives and Liver Disease

The liver is a central organ for xenobiotic metabolism, bile acid signalling, inflammatory responses, and nutrient processing. Food additives may affect the liver directly through absorbed compounds or indirectly through gut-liver axis mechanisms. However, evidence varies substantially among additive

groups, and liver disease should not be attributed to additives without strong exposure and clinical data (Chassaing et al., 2015; Suez et al., 2022).

Sweeteners, emulsifiers, preservatives, colourants, and ultra-processed dietary patterns have all been discussed in relation to metabolic dysfunction and liver health. The most scientifically cautious position is that some additive groups may contribute to biological pathways relevant to liver stress when embedded in poor-quality diets, but direct human evidence remains incomplete (Chassaing et al., 2015; Suez et al., 2022).

Research on sucralose has expanded partly because of concerns about sucralose-6-acetate and related toxicological screening findings (Schiffman et al., 2023). This evidence should be interpreted as emerging and mechanistic rather than as a basis for immediate product-level disease claims. It supports continued surveillance, impurity control, and updated risk assessment when necessary (Chassaing et al., 2015; Suez et al., 2022).

### 2.6. Food Additives and Kidney Disease

Kidney disease is especially relevant to additives that affect mineral load, electrolyte balance, or compounds requiring renal excretion. Phosphate additives deserve particular attention because inorganic phosphate added to foods is often more readily absorbable than naturally occurring organic phosphorus. Ritz et al. (2012) argued that phosphate additives may represent a health concern, especially for individuals with chronic kidney disease and cardiovascular vulnerability (Calvo et al., 2023; Ritz et al., 2012; St-Jules et al., 2017).

Phosphates are technologically useful in processed cheeses, processed meats, bakery products, and cola-type or acidified beverages. Their presence does not prove excessive intake, but it should prompt consideration of vulnerable consumers. Laboratory quantification and dietary exposure assessment are necessary before any conclusion about risk can be made (Calvo et al., 2023; Ritz et al., 2012; St-Jules et al., 2017).

Other additives may be relevant to kidney health under specific conditions, but evidence is often less direct. The appropriate scientifically cautious conclusion is that kidney-vulnerable populations justify special attention to phosphate-containing products and high-sodium processed foods, while avoiding unsupported generalizations about all additives (Calvo et al., 2023; Ritz et al., 2012; St-Jules et al., 2017).

## 2.7. Food Additives and Neurobehavioral Effects in Children

Neurobehavioral concerns are most developed for selected synthetic colours, sodium benzoate in mixture studies, and caffeine-containing products. The Southampton study reported increased hyperactivity-type behaviours in children exposed to mixtures of certain colours and sodium benzoate, contributing to EU warning-label requirements for selected colours (European Parliament and Council, 2008; McCann et al., 2007).

These findings do not mean that every child will show behavioural effects after consuming a coloured food. They indicate that susceptible children may be affected by certain mixtures and that warning information is justified. In food-safety interpretation, synthetic colours such as E102, E110, E122, and E129 should therefore be treated as child-relevant screening priorities (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; McCann et al., 2007).

Caffeine represents a different neurobehavioral concern. EFSA concluded that defined caffeine intakes are not of safety concern for healthy adults, but children, adolescents, pregnant women, and individuals with cardiovascular or anxiety-related vulnerabilities require more careful guidance (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015). Energy drinks therefore belong in the theoretical discussion even when caffeine is not classified as a conventional E-number additive (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; McCann et al., 2007).

Child-health concerns combine toxicology, behaviour, marketing, and exposure frequency. Synthetic colours and sodium benzoate are historically important because the Southampton trial examined mixtures and contributed to EU labelling requirements for selected colours (McCann et al., 2007; European Parliament and Council, 2008). The main public-health implication is not that all children will develop hyperactivity, but that child-oriented products containing these colours should be treated as higher-priority for risk communication (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; McCann et al., 2007).

Energy drinks and caffeine-containing beverages present a separate child and adolescent issue. Caffeine can affect sleep, heart rate, blood pressure, anxiety, and stimulant tolerance depending on dose and individual susceptibility. EFSA's caffeine opinion and more recent reviews support caution for adolescents, pregnant women, and individuals with cardiovascular vulnerability (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; Mandato et al., 2025).

Sweeteners and intense flavours may also influence taste preference and dietary substitution. Even when a sweetener remains authorized, products designed around high sweetness may reinforce

preference for sweet foods and beverages. WHO guidance on non-sugar sweeteners therefore supports caution when these ingredients are used as a long-term strategy for population-level prevention of obesity or noncommunicable disease (World Health Organization, 2023a).

In food-safety interpretation, child-relevant risk should be presented as a prioritization category. Products that are brightly coloured, intensely sweet, snack-like, or marketed in a playful form may be more likely to be consumed repeatedly by children. This justifies careful labelling review, parental guidance, and possible market surveillance, while avoiding unsupported statements about individual diagnosis or causation (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2015; McCann et al., 2007).

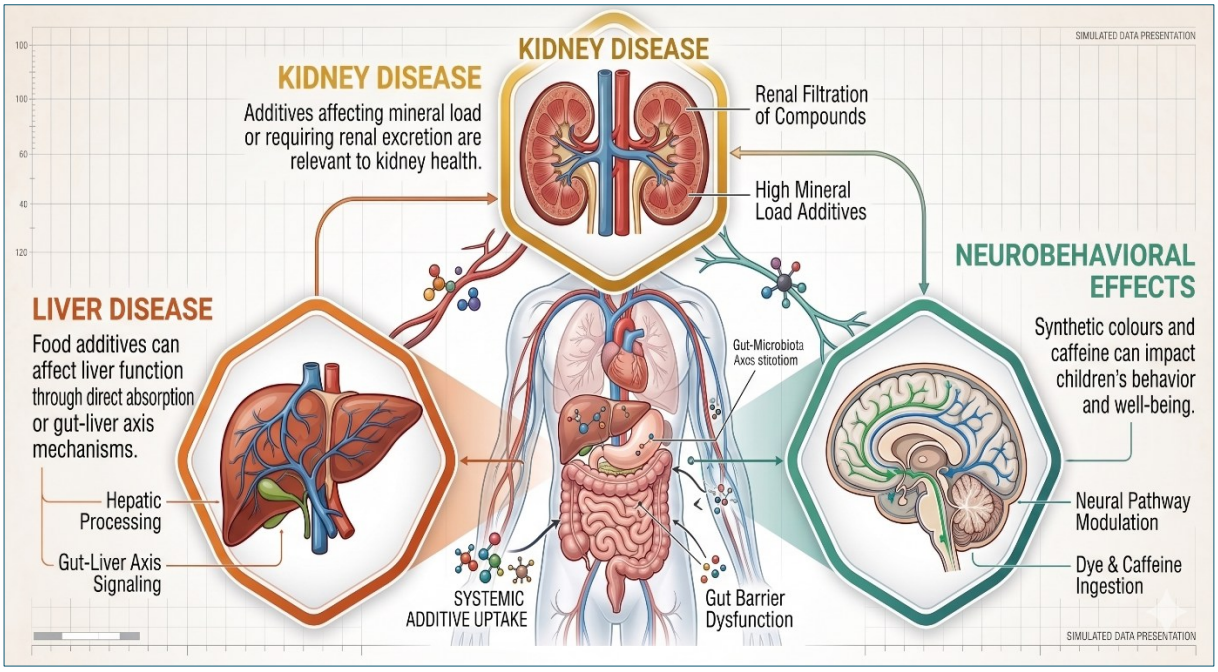


**Figure 7.** Food Additive Health Impacts

### 2.8. Controversial and Banned Food Additives: Regulatory Case Studies

Controversial additives are useful case studies because they show how regulatory science evolves. Titanium dioxide E171 is the clearest recent example in Europe. EFSA concluded that it could no longer be considered safe as a food additive because genotoxicity concerns could not be excluded, leading to major regulatory consequences (European Food Safety Authority, 2021).

Azo dyes illustrate a different regulatory pattern. They are not universally banned, but some require specific warnings in the European Union because of possible effects on children's activity and attention. This distinction is important: a warning-label colour may be legally authorized under conditions while still being a public-health priority for child-focused risk communication (EFSA Panel on Food Additives and Flavourings, 2021; World Health Organization, 2023b).

Sweeteners such as aspartame and sucralose demonstrate another kind of controversy. Aspartame has a recent IARC hazard classification but a reaffirmed JECFA ADI, while sucralose remains authorized in many jurisdictions but is the subject of ongoing toxicological discussion regarding impurities and mechanistic evidence (Schiffman et al., 2023; World Health Organization, 2023b). A rigorous scientific review should present these controversies as evolving evidence, not as absolute proof of harm (EFSA Panel on Food Additives and Flavourings, 2021; World Health Organization, 2023b).

Potassium bromate and nitrite/nitrate preservatives are often discussed in regulatory science because they show how technological usefulness can conflict with toxicological concern. Potassium bromate is restricted or banned in many jurisdictions due to carcinogenicity concerns, while nitrites and nitrates remain controlled because they inhibit dangerous pathogens in cured meats but can contribute to N-nitroso compound formation under certain conditions (International Agency for Research on Cancer, 2010).

**Table 2.** Examples of additive groups requiring careful regulatory interpretation.

| Additive or group | Main issue | Interpretive caution | Reference (s) |
|---|---|---|---|
| **E171 titanium dioxide** | Unresolved genotoxicity concern in EFSA assessment. | Do not generalize this conclusion to unrelated colourants. | EFSA Panel on Food Additives and Flavourings (2021) |
| **Azo colours** | EU warning relevance for children's activity and attention. | Authorized use and warning status must be distinguished. | McCann et al. (2007); European Parliament and Council (2008) |
| **Aspartame** | IARC hazard classification and JECFA ADI reaffirmation. | Hazard classification is not the same as exposure-based risk. | World Health Organization (2023b) |
| **Sucralose** | Emerging impurity and mechanistic discussions. | Requires updated evidence review, not unsupported disease claims. | Schiffman et al. (2023) |
| **Benzoates/sorbates** | Cumulative exposure concern in frequently consumed products. | ADI assessment needs concentration and intake data. | World Health Organization (2023c); Codex Alimentarius Commission (1995) |
| **Phosphates** | Kidney and cardiovascular vulnerability concerns. | Most relevant to susceptible consumers and high cumulative intake. | Calvo et al. (2023); Ritz et al. (2012) |

### 2.9. Cumulative and Combined Exposure: The Cocktail Effect

Food-additive risk assessment traditionally evaluates substances individually. This approach is necessary because each additive has a specific identity, specification, toxicokinetic profile, and toxicological database. However, consumers are exposed to products and diets, not isolated substances. A single processed food may contain several additives, and a daily diet may include repeated exposure to the same additive across multiple products (Payen de la Garanderie et al., 2025; Sellem et al., 2023, 2024).

The cocktail-effect concept refers to the possibility that multiple additives or additive groups may act through shared or interacting biological pathways. Potential pathways include gut microbiota alteration, low-grade inflammation, taste preference, phosphate burden, stimulant effects, or metabolic signalling. Evidence for mixture effects remains incomplete, but recent prospective work on additive mixtures and type 2 diabetes supports the need for mixture-oriented research (Payen de la Garanderie et al., 2025).

The appropriate conclusion for a Master's thesis is cautious but practical. Label-based assessments can identify products and categories containing additive mixtures, but they cannot quantify cumulative exposure alone. The next step should be laboratory measurement of priority additives, dietary intake surveys, exposure modelling by age and vulnerability group, and comparison with Codex, JECFA, EFSA/EU, FDA, and Algerian reference values. This framework preserves scientific rigor while supporting preventive food-safety surveillance (Payen de la Garanderie et al., 2025; Sellem et al., 2023, 2024).

Controversial additives should be used pedagogically to illustrate how regulatory conclusions evolve. Titanium dioxide demonstrates uncertainty-driven restriction; aspartame demonstrates the difference between hazard classification and exposure-based ADI conclusions; azo colours demonstrate warning-label risk communication; phosphates demonstrate vulnerability-specific concern; and benzoate/sorbate preservatives demonstrate the need for exposure and formulation context (Payen de la Garanderie et al., 2025; Sellem et al., 2023, 2024).

The cocktail-effect concept does not imply that every combination of additives is dangerous. It means that consumers encounter additive patterns, not isolated compounds, and that regulatory assessment based only on individual additives may not fully capture repeated exposure to functional combinations. Products that combine colours, preservatives, sweeteners, acidity regulators, emulsifiers, phosphates, and stimulant ingredients may therefore deserve special attention in screening studies (Payen de la Garanderie et al., 2025; Sellem et al., 2023, 2024).

Recent epidemiological work on emulsifiers and additive mixtures supports this direction. Studies have reported associations between selected emulsifier intakes and cardiovascular disease or cancer, and between additive-mixture patterns and type 2 diabetes (Payen de la Garanderie et al., 2025; Sellem et al., 2023, 2024). These findings are not final proof of causality, but they strengthen the scientific justification for recording additive mixtures rather than only counting individual additives (Payen de la Garanderie et al., 2025; Sellem et al., 2023, 2024).

Mixture-oriented thinking is especially useful for food-control planning. If resources are limited, authorities can prioritize laboratory testing for products that combine multiple additives of special interest, products consumed by children, products with ambiguous labels, and categories with high consumption frequency. Such prioritization converts theoretical toxicology into practical surveillance without overstating what label data can prove (Payen de la Garanderie et al., 2025; Sellem et al., 2023, 2024).

The final conceptual message is that additive assessment should move through stages: label identification, standardized coding, functional classification, toxicological screening, laboratory quantification, dietary exposure estimation, and regulatory comparison. The present theoretical framework supports exactly this staged model and explains why screening can identify priorities while recommending further analytical verification (Payen de la Garanderie et al., 2025; Sellem et al., 2023, 2024)

**Table 5.** From theoretical concepts to regulatory risk assessment.

| Step | Purpose | Expected output | Reference(s) |
|---|---|---|---|
| **Additive identification** | Define additive identity, specifications, functional class, and intended technological role. | Standardized identity and function profile. | Codex Alimentarius Commission (1995); European Parliament and Council (2008) |
| **Hazard characterization** | Evaluate toxicological endpoints, dose-response data, points of departure, and uncertainty. | Health-based guidance value or reference point. | EFSA Scientific Committee (2017); World Health Organization (2023c) |
| **Exposure assessment** | Estimate intake using concentration, portion size, consumption frequency, body weight, and population group. | Estimated exposure in mg/kg body weight/day. | World Health Organization (2023c) |
| **Risk characterization** | Compare estimated exposure with ADI, margin of exposure, or another relevant toxicological benchmark. | Evidence-based interpretation of risk and uncertainty. | EFSA Scientific Committee (2017); World Health Organization (2023c) |
| **Regulatory interpretation** | Compare authorized uses, food categories, conditions of use, and | Regulatory conclusion proportional to available evidence. | Codex Alimentarius Commission (1995); European Parliament and Council (2008) |

| | | | |
|---|---|---|---|
| | maximum permitted levels across applicable frameworks. | | |
| **Risk communication** | Translate conclusions into clear, non-alarmist information for consumers, professionals, and regulators. | Proportionate communication of benefits, uncertainties, and precautions. | World Health Organization (2023c) |

# PRACTICAL SECTION

# Materials and Methods

### 1.1. Study Area El-Oued Wilaya, Algeria

We conducted our applied investigation in El-Oued Wilaya, Algeria, a Saharan region where climatic aridity, high summer temperatures, commercial concentration, and reliance on packaged shelf-stable products make food-label surveillance particularly relevant.

We considered the regional disease context when framing our food-safety question. Algeria faces a substantial burden of noncommunicable diseases, including hypertension, diabetes, cardiovascular disease, and cancer, while communicable, maternal, nutritional, intestinal, respiratory, skin, parasitic, and emerging conditions remain relevant to health services (Benikhlef et al., 2021; Moussouni et al., 2022; World Health Organization, 2024). We therefore approached additives as one component of a wider food-environment risk profile rather than as isolated causes of disease.

We paid particular attention to products consumed by children and adolescents because exposure per kilogram body weight may be higher in these groups and because several additives identified in our dataset are linked to warning-label, stimulant, preservative, sweetener, or emulsifier discussions in recent toxicological and regulatory literature (European Food Safety Authority, 2015; Food Standards Agency, 2025; Sellem et al., 2023, 2024).

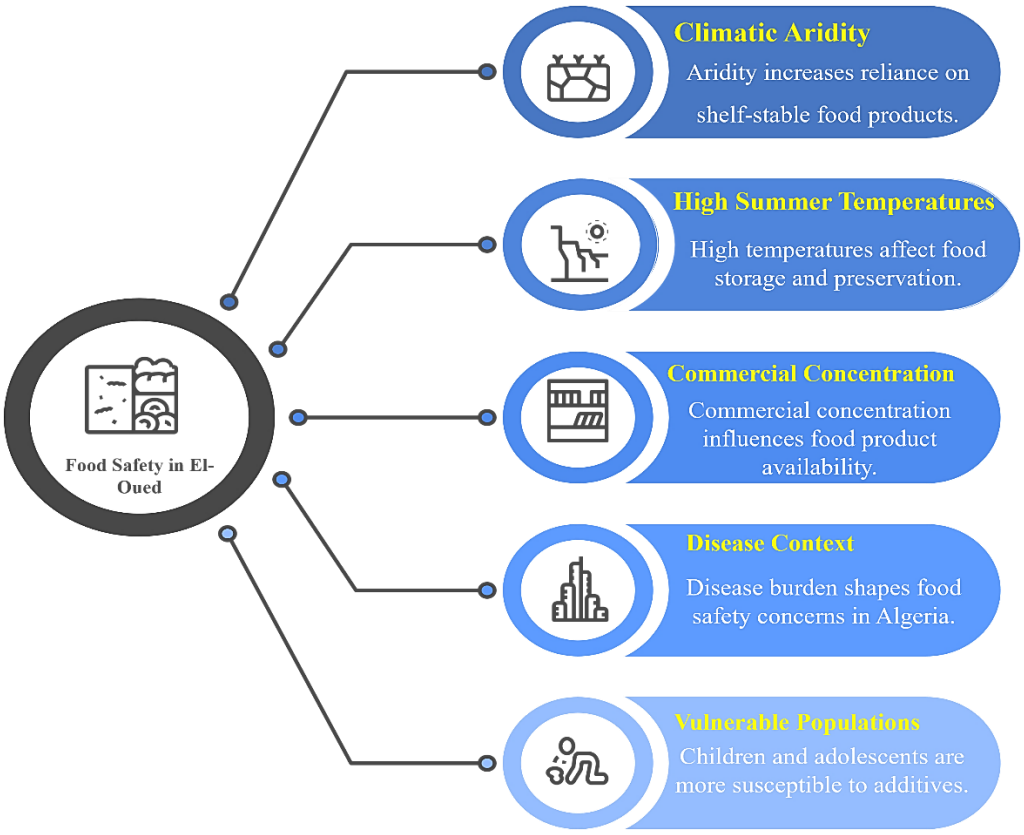


**Figure 8.** Unveiling Food Safety Dimensions in El-Oued

### 1.2. Study Design

We designed the practical work as a descriptive-analytical, cross-sectional, label-based assessment of declared food additives in commercially available products. We used each packaged product as the unit of observation. We did not perform laboratory quantification in this phase; instead, we extracted and standardized label information to identify additive patterns, high-concern screening signals, and categories requiring analytical verification.

We used a label-based design because labels represent the first information layer available to consumers, inspectors, clinicians, toxicologists, and researchers. At the same time, we explicitly recognized that label presence does not equal exposure dose. We therefore avoided claiming that any product exceeded an ADI, EFSA threshold, Codex maximum level, or Algerian legal limit unless concentration data were available.

### 1.3. Sampling Strategy and Product Selection

We selected products from Ben Sassi commercial center, which we treated in our field framework as the largest commercial center in El-Oued Wilaya and a major supplier for the local population. We used the store manager's list of top-selling products to prioritize foods and beverages with realistic consumption relevance. We classified the selected items into five categories: canned and packaged sweets, canned and preserved foods, dairy products, soft drinks/energy drinks/juices, and chips/crackers.

We included packaged products with identifiable product names, label images, ingredient lists, nutritional information, or additive declarations. We excluded unpackaged foods, duplicate product presentations, and non-food items. We assigned a unique product code to each item: SWT for sweets, CPF for canned/preserved foods, DRY for dairy products, BEV for beverages, and CHP for chips/crackers.

### 1.4. Data Collection and Beverage Dataset Integration

We collected all necessary information directly from the printed labels and packaging labels of the selected food products. For each product, we carefully examined the information displayed on the package, including the ingredient list, declared nutritional value, food additives, preservatives, E-numbers or SIN/INS codes when available, and any additional labeling details relevant to toxicological and regulatory interpretation.

For each product, we extracted the following variables: product name, brand or commercial designation, product category, country of origin when declared, ingredient list, nutritional composition, declared additives and preservatives, E-number or SIN/INS code, functional class of each additive, and any label information relevant to child consumption or potential toxicological concern. We then organized these data into structured analytical tables and standardized additive declarations to E-number or INS/SIN notation whenever possible.

This label-based approach allowed us to assess the additive profile of each product using the information available to consumers and regulatory inspectors at the point of purchase. When label wording was unclear, incomplete, or presented in different formats, we interpreted the information cautiously and retained the original label meaning as closely as possible. We did not assume the presence or concentration of any additive unless it was explicitly declared on the product packaging.

### 1.5. Additive Classification and Regulatory Screening

We classified additives according to the Codex INS system, Codex GSFA, EU Regulation 1333/2008, JECFA evaluations, EFSA opinions, and Algerian permitted-additive lists (Codex Alimentarius Commission, 1989/2015, 1995/2025; European Parliament and Council, 2008; Ministère du Commerce, Algérie, n.d.). We assigned functional classes such as colour, preservative, acidity regulator, antioxidant, emulsifier, stabilizer, thickener, flavour enhancer, sweetener, anticaking agent, carbonating agent, and stimulant ingredient.

We defined a product as containing at least one high-concern additive when it included additives or ingredient groups with special toxicological or regulatory relevance. This included EU warning-label colours such as E102, E110, E122, and E129; aspartame E951; sucralose E955 in the context of recent impurity-related debate; phosphate additives and phosphoric acid; cellulose derivatives and selected emulsifiers; caffeine/taurine-containing energy-drink formulations; and preservative combinations involving E202 and E211 in child-relevant beverages. We used this variable for screening and prioritization, not as a declaration of illegality or proven harm.

### 1.6. Statistical Study

We calculated frequencies, percentages, means, standard deviations, and ranges for product distribution, additive counts, additive classes, and high-concern additive prevalence. Because the revised

beverage dataset made all products analyzable, our final statistical dataset included all 46 products. We used Pearson's chi-square test to examine the association between product category and the presence of at least one high-concern additive. We used the Kruskal-Wallis test to compare additive-count distributions across the five categories because the counts were discrete and not normally distributed. We set statistical significance at $p < 0.05$.

Our final inferential results were $\chi^2(4) = 13.07$, $p = 0.011$ for the chi-square test and $H = 15.78$, $p = 0.003$ for the Kruskal-Wallis test. We interpreted these results as category-level screening evidence because the sample was purposively selected from top-selling products and not randomly drawn from the entire Algerian market.

# RESULTS

We conducted a label-based cross-sectional assessment of food additives in 46 selected top-selling food and beverage products marketed in El Oued Wilaya. The final dataset included five product categories: canned and packaged sweets, canned and preserved foods, dairy products, soft drinks, energy drinks and juices, and chips and crackers. Our analysis identified 151 declared additive entries, corresponding to 47 distinct additive or stimulant-related codes/terms. These findings demonstrate that additive use is widespread across the sampled products, but its intensity and toxicological relevance vary considerably according to product category and formulation type.

The soft drinks, energy drinks, and juices category emerged as one of the most important contributors to additive exposure in the sample, both in terms of mean additive count and prevalence of additives or ingredients requiring toxicological attention. Products such as Farha pineapple-flavoured soft drink and Zaim fruit-flavoured soft drink contained synthetic colourants and preservative systems, while Izem and TNT energy drinks contained stimulant-based formulations involving caffeine and related functional ingredients. Bifa Daily Cocktail 1 and 2, Ramy orange fruit drink, Rouiba pineapple fruit drink, and Tazej lemon-orange fruit drink also illustrated the importance of evaluating fruit drinks not only as sources of sugar, but also as vehicles of acidity regulators, preservatives, stabilizers, emulsifiers, and other technological additives.

Our results showed that the presence of at least one high-concern additive differed significantly across product categories. Soft drinks, energy drinks, and juices presented the highest proportion of products containing additives or stimulant-related ingredients of toxicological or regulatory concern, followed by dairy products and chips/crackers. The statistical analysis confirmed a significant association between product category and high-concern additive presence, as well as a significant difference in additive-count distribution between categories. These findings support the conclusion that food-additive surveillance should be category-specific, with particular priority given to beverages, child-oriented sweets, flavoured dairy products, processed cheeses, stock cubes, and highly seasoned snacks.

From a toxicological perspective, the most relevant additive groups identified in this study were synthetic colourants, preservatives such as potassium sorbate and sodium benzoate, phosphate additives, artificial sweeteners, flavour enhancers, emulsifiers, stabilizers, and stimulant ingredients in energy drinks. The presence of these additives does not automatically indicate that the products are

unsafe or non-compliant. However, their repeated occurrence in commonly consumed products, especially those consumed by children and adolescents, supports the need for exposure assessment, clearer labeling, and targeted laboratory analysis. This is particularly important because label information alone does not provide additive concentrations and therefore cannot determine whether acceptable daily intakes or maximum permitted levels are exceeded.

We did not claim direct causality between additive exposure and disease in El Oued, and we did not claim legal non-compliance without concentration data. However, our results provide a strong evidence-based basis for targeted label inspection, laboratory verification, consumer education, and future exposure modelling. They also highlight the need for coordinated action by local and national authorities to monitor high-priority product categories, update regulatory lists in line with international scientific evaluations, and protect vulnerable populations, particularly children, pregnant women, and individuals with hypertension, diabetes, kidney disease, cardiovascular disease, or other chronic conditions.

# RECOMMENDATIONS

We recommend that consumers reduce frequent consumption of highly processed foods and beverages that combine several additives with high sugar, salt, caffeine, synthetic colourants, artificial sweeteners, or flavour enhancers. The main products requiring caution are soft drinks and energy drinks, coloured confectionery, flavoured dairy products, processed cheeses, stock cubes, and highly seasoned chips or crackers. Occasional consumption does not necessarily indicate immediate risk, but repeated intake may increase cumulative exposure to additives of toxicological or regulatory concern.

At the provincial level, we recommend that the Directorate of Health of El Oued, in coordination with the Directorate of Trade and Industry, strengthen routine market surveillance of packaged foods and beverages, particularly products consumed by children and adolescents. Priority actions should include systematic label inspection, verification of additive declarations, control of misleading nutritional or health claims, sampling of high-priority products for laboratory analysis, and public-awareness campaigns on excessive consumption of coloured sweets, energy drinks, soft drinks, processed cheeses, stock cubes, and salty snacks.

At the national level, we recommend that the Ministry of Trade and Industry and the Ministry of Health regularly update national lists of authorized food ingredients, additives, preservatives, colourants, sweeteners, emulsifiers, flavour enhancers, and processing aids according to the most recent evaluations and releases from major international bodies. These should include Codex Alimentarius, FAO/WHO JECFA, WHO, EFSA, the European Union regulatory framework, FDA, IARC, and other recognized scientific and regulatory authorities. National updates should also consider recent peer-reviewed toxicology, epidemiology, and food-safety research, especially on controversial additives, cumulative exposure, children's vulnerability, energy drinks, artificial sweeteners, preservatives, phosphates, and emulsifiers.

Overall, we recommend that consumers prioritize careful label reading and choose products with shorter ingredient lists, fewer additives, lower sugar, lower salt, and no synthetic colourants whenever possible. Particular attention should be given to labels containing E102, E110, E122, E129, E202, E211, E338, E339, E450, E452, E466, E471, E621, E635, E951, E955, caffeine, or taurine. The most effective preventive strategy is to reduce routine dependence on ultra-processed foods and replace them with water, fresh fruit, plain dairy products, legumes, vegetables, cereals, and home-prepared meals

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# ANNEXES

## Annex A. Statistical Output

| Test | Variables | Statistic | Df | p-value | Interpretation |
|---|---|---|---|---|---|
| **Pearson chi-square** | Category × high-concern additive presence | $\chi^2 = 13.07$ | 4 | 0.011 | Significant at $p < 0.05$ |
| **Kruskal-Wallis** | Category × additive count | $H = 15.78$ | 4 | 0.003 | Significant at $p < 0.05$ |

## Annex B. Regulatory Comparison Checklist

| Question | Use |
|---|---|
| **Did we identify the additive name and code?** | Verify label clarity and standardize E-number/SIN. |
| **Did we identify the functional class?** | Confirm technological purpose. |
| **Is the additive permitted in the relevant food category?** | Compare with Algerian, Codex, and EU category lists. |
| **Does the additive have an ADI?** | Use only with concentration and intake data. |
| **Does the product target children or adolescents?** | Prioritize lower-body-weight exposure modelling. |
| **Does the product contain caffeine or stimulant ingredients?** | Prioritize adolescent, pregnancy, hypertension, and arrhythmia caution. |
| **Does the label lack concentration data?** | Avoid claiming threshold exceedance without laboratory analysis. |