IOSR Journal of Business and Management (IOSR-JBM)
e-ISSN:2278-487X, p-ISSN: 2319-7668. Volume 27, Issue 9. Ser. 2 (September. 2025), PP 72-80
www.iosrjournals.org

Application Of Sugar And Sodium Reduction Technologies In Processed Foods: Review Of Feasible Strategies And Their Technological Effects

João Guilherme Sodré De Souza[1], Miguel Vitor Lima Costa[2], Pedro Henrique Arruda Chaves[3], Marjorie Kelly Lindoso Pereira[4], Mirella Teles Oliveira[5], Matheus Filipe Leitão Oliveira[6], Jeiza Freitas Pinheiro[7], Adriana Silva Caldas[8], Arlan Silva Freitas[9]
(Federal Institute Of Education, Science And Technology Of Maranhão, Brazil)
(Departament Of Chemistry, Federal Institute Of Education, Science And Technology Of Maranhão, Brazil)

Abstract:
This article provides an integrative review of technological strategies for reducing sodium and sugars in processed foods, examining their effects on public health and sensory acceptance. Evidence indicates that excessive consumption of these components is linked to non-communicable diseases such as hypertension, diabetes, and obesity. The strategies discussed include physical modifications of salt, substitution with potassium chloride, gradual sugar reduction, and the use of flavor enhancers. The conclusion highlights that combining technological innovations, public policies, and nutritional education is crucial for fostering healthier habits.
Background: *The growing incidence of non-communicable chronic diseases (NCDs), such as hypertension, type 2 diabetes, and obesity, is a major global public health challenge. These conditions are strongly associated with unbalanced dietary patterns, particularly the excessive consumption of sodium and added sugars, common in processed and convenience foods. In Brazil, sodium and sugar intake exceeds the limits recommended by the World Health Organization (WHO), contributing to increased blood pressure and higher rates of cardiovascular diseases. High sodium consumption is directly linked to systemic arterial hypertension, while excessive sugar intake is strongly associated with obesity and type 2 diabetes. Given this context, the development of effective technological and regulatory strategies to reduce sodium and sugar in processed foods is urgent. Food technology innovations, combined with public health policies and nutritional education, present promising alternatives for healthier eating habits.*
Materials and Methods*: This review was based on a systematic literature search in scientific databases such as SciELO, PubMed, Scopus, Web of Science, and Google Scholar. Keywords used included "sodium reduction in foods", "sugar reduction in foods", "non-communicable diseases," "diabetes," "hypertension," and "cardiovascular diseases," both in Portuguese and English. Publications from 2010 to July 2025 were considered, including clinical studies, theoretical reviews, experimental investigations, and population modeling. Duplicate records, studies with low methodological quality, or without full-text availability were excluded.*
Results: *The studies reviewed confirm that reducing sodium and sugars in processed foods is technologically feasible but faces sensory, cultural, and industrial challenges.*
Conclusion: *Reducing sodium and sugars in processed foods is an essential public health strategy to combat chronic diseases such as hypertension, diabetes, and obesity. Technological approaches like salt modification, partial substitution with potassium chloride, and gradual sugar reduction, combined with educational and regulatory policies, can promote healthier eating habits. Collaboration among industry, government, and society is fundamental to overcoming technological and cultural barriers, ensuring consumer acceptance, and improving population health.*
Key Words: *Sodium reduction; Sugar reduction; Processed foods; Public health; Food technology.*

Date of Submission: 27-08-2025 Date of Acceptance: 07-09-2025

I. Introduction

Non-communicable diseases (NCDs), including hypertension, type 2 diabetes, and obesity, represent one of the greatest global public health challenges. These conditions are strongly associated with dietary imbalances, particularly excessive sodium and added sugar intake from ultra-processed foods. In Brazil, consumption of these components exceeds World Health Organization (WHO) recommendations, directly contributing to increased prevalence of cardiovascular complications and metabolic disorders (Soares et al., 2021; Aguiar et al., 2021).

In Brazil, the intake of these components exceeds the limits recommended by the World Health Organization (WHO), contributing to increased blood pressure and cardiovascular disease cases, mainly among adults (Soares et al., 2021). Easy access, combined with the sensory appeal of these products, reinforces harmful eating habits and creates obstacles for health promotion strategies.

Scientific evidence demonstrates that high sodium consumption is directly related to systemic arterial hypertension (SAH), a multifactorial condition that affects vital organs such as the kidneys, heart, and brain (Soares et al., 2021; WHO, 2012). It is estimated that salt-rich diets increase blood pressure by up to 30%, with table salt and processed foods being the main contributors (Aguiar et al., 2021). Similarly, high consumption of simple sugars — present in soft drinks, cookies, and sweets — has been associated with obesity, insulin resistance, and increased incidence of type 2 diabetes mellitus (Monteiro et al., 2023).

Data from the ELSA-Brazil study indicate that individuals with diabetes and/or metabolic syndrome show higher salt intake levels, intensifying the risks of hypertension and cardiovascular complications, especially among women (Santos-Vieira, 2017). Beyond physiological impacts, unbalanced dietary patterns contribute to the overload of healthcare systems and reduce population quality of life.

Given this scenario, it is urgent to develop and implement effective strategies for reducing sodium and sugar content in processed foods. In this context, the use of innovative food technologies — combined with regulatory policies and educational actions — emerges as a promising alternative for food reformulation and the promotion of healthier eating habits (Awadalla et al., 2018).

This article aims to provide an integrative literature review on technologies applied to sodium and sugar reduction in processed foods, analyzing their potential, limitations, and challenges for large-scale implementation.

II. Material And Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, as proposed by Moher et al. (2009). The methodological design was structured to ensure transparency, rigor, and reproducibility throughout all stages of the research process.

Research Question

The research question was formulated using the PCC (Population, Concept, and Context) mnemonic, where:

i) Population (P): processed food products;
ii) Concept (C): sodium and/or sugar reduction strategies;
iii) Context (C): technological application and implications for sensory acceptance and public health.

Accordingly, the guiding research question was: "What evidence is available on the application of sodium and sugar reduction technologies in processed foods, considering their technological feasibility, sensory acceptance, and public health implications?"

Literature Search

The literature search was conducted between 2010 and July 2025, using the following electronic databases: PubMed, Scopus, Web of Science, SciELO, and Google Scholar. The strategy combined controlled descriptors (MeSH/DeCS) and free-text keywords, in both English and Portuguese.

The main search terms included: *"sodium reduction"*, *"salt reduction"*, *"low-sodium foods"*, *"cloreto de sódio"*, *"redução de sódio"*, combined with *"processed foods"* and *"alimentos processados"*. For sugar-related studies, terms such as *"sugar reduction"*, *"redução de açúcares"*, and *"low-sugar foods"* were paired with public health-related terms such as *"diabetes"*, *"obesity"*, and *"hipertensão"*. Boolean operators (AND/OR) were applied to refine the results. In addition, the reference lists of selected articles were manually screened to identify further relevant studies.

The detailed strategies used for each database are presented in Table 1.

Tabela 1. Search strategies used for each database

Database	Search Strategy
PubMed	("sodium reduction" OR "salt reduction" OR "low-sodium foods" OR "cloreto de sódio" OR "redução de sódio") AND ("processed foods" OR "alimentos processados") OR ("sugar reduction" OR "redução de açúcares" OR "low-sugar foods") AND ("obesity" OR "diabetes" OR "hipertensão")
Scopus	TITLE-ABS-KEY ("sodium reduction" OR "salt reduction" OR "redução de sódio") AND ("processed foods") OR ("sugar reduction" OR "redução de açúcares")
Web of Science	TS=("sodium reduction" OR "salt reduction" OR "redução de sódio") AND TS=("processed foods" OR "alimentos processados") OR TS=("sugar reduction" OR "redução de açúcares")
SciELO	("redução de sódio" OR "redução de açúcares") AND ("alimentos processados")
Google Scholar	("sodium reduction in processed foods" OR "sugar reduction in processed foods" OR "redução de sódio em alimentos processados" OR "redução de açúcares em alimentos processados")

Study Selection

Eligible studies included articles published between January 2010 and July 2025, in English or Portuguese, addressing sodium and/or sugar reduction strategies in processed foods. The review included original research articles, experimental or modeling studies, intervention reports, as well as systematic and narrative reviews.

Exclusion criteria included duplicate records, publications without full-text availability, studies lacking methodological rigor (assessed by clarity of objectives, sample description, and methodological consistency), and articles not directly related to the research scope.

Screening was performed in two stages: (1) title and abstract screening and (2) full-text assessment, both conducted independently by two reviewers. Discrepancies were resolved through consensus.

Data Extraction and Analysis

Data extraction was carried out independently by two reviewers using structured spreadsheets to record: authorship and year of publication, study design and objectives, technologies employed (such as ingredient substitution, reformulation, encapsulation, and gradual reduction), main findings, and implications for sensory acceptance, technological feasibility, and public health.

Methodological Quality Assessment

The methodological quality of the included studies was assessed using adapted criteria from the Joanna Briggs Institute (JBI) checklist for analytical studies and reviews. The evaluation considered clarity of objectives, methodological transparency, appropriateness of interventions, outcome reporting, and consistency between results and conclusions. Studies presenting significant methodological limitations were excluded during the eligibility phase.

III. Result

Studies analyzed demonstrate that reducing sugars and sodium is technologically feasible but faces sensory and cultural challenges, as these components are intrinsically linked to consumer acceptance. In addition, research reinforces the health benefits of these strategies, such as decreasing the incidence of NCDs, including hypertension, type 2 diabetes, and obesity.

To provide a clear and comparative illustration of the evidence, according to the PRISMA protocol adopted for selecting articles, Table 2 summarizes the main reviewed articles, highlighting their objectives and conclusions. This compilation allows for a broad and critical overview of the topic, facilitating the understanding of advances and gaps in sugar and sodium reduction strategies.

Table 2. Papers selected for analysis

AUTHORS & YEAR	ARTICLE	OBJECTIVE	CONCLUSION
Cobb et al. (2012)	Strategies to reduce dietary sodium intake.	Present strategies for sodium reduction in the diet to reduce cardiovascular risk.	Integrated strategies such as public education, dietary counseling, and government policies are essential to reduce sodium intake.
Ignácio et al. (2013)	Efeito da substituição de cloreto de sódio por cloreto de potássio em pão francês [Effect of the substitution of sodium chloride by potassium chloride in French rolls].	Assess the technological and sensory feasibility of partially replacing NaCl with KCl in French bread.	Partial replacement is feasible and does not significantly impair sensory quality.
Trieu et al. (2015)	Salt Reduction Initiatives around the World - A Systematic Review of Progress towards the Global Target.	Evaluate global progress in implementing salt reduction initiatives to achieve WHO's target of a 30% reduction by 2025.	Positive advances in several countries, but broader, coordinated efforts are needed, requiring political commitment and regulatory interventions.
Dinicolantonio et al. (2016)	The Evidence for Saturated Fat and for Sugar Related to Coronary Heart Disease.	Analyze evidence linking saturated fats and sugars to coronary heart disease.	Evidence of excessive sugar intake contributing to coronary heart disease is more consistent and convincing than that against saturated fat.
Lima et al. (2016)	The sugar you eat when you drink: impact of an awareness strategy.	Assess the impact on sales of a visual awareness strategy about sugar content in beverages available in a school cafeteria.	The awareness tactic effectively reduced cola and carbonated soft drink consumption, while increasing water, nectars, and chocolate milk intake.
Ma et al. (2016)	Gradual reduction of sugar in soft drinks without substitution as a strategy to reduce	Examine gradual sugar reduction in soft drinks	Gradual reduction is effective in lowering population sugar intake,

	overweight, obesity, and type 2 diabetes: a modelling study.	without artificial sweetener substitution.	consequently reducing obesity and diabetes.
Chen et al. (2018)	Sodium Reduction, miRNA Profiling and CVD Risk in Untreated Hypertensives: a Randomized, Double-Blind, Placebo-Controlled Trial.	Assess whether sodium reduction alters miRNA expression in untreated hypertensive patients and whether this is linked to improved cardiovascular markers.	Sodium reduction induced miR-143-3p expression, associated with lower systolic and diastolic blood pressure, suggesting miRNA modulation as a molecular mechanism.
McCain et al. (2018)	Invited review: Sugar reduction in dairy products.	Review strategies to reduce sugar content in dairy products.	Public health concerns drive the growing demand for reduced-sugar dairy products.
Oliveira et al. (2018)	Sugar reduction in fruit nectars: Impact on consumers' sensory and hedonic perception.	Analyze how consumers perceive sugar reduction in fruit nectars.	Up to 20% sugar reduction in fruit nectars is possible without sensory compromise.
Souza Paes & Ravazi (2018)	Técnicas para a redução de sódio nos alimentos industrializados [Techniques for sodium reduction in processed foods].	Research techniques to reduce sodium content in the food industry without altering sensory characteristics.	A highly viable solution is combining potassium chloride with yeast extract.
Teixeira (2018)	Sodium content and food additives in major brands of Brazilian children's foods [Conteúdo de sódio e aditivos alimentares das maiores marcas de alimentos destinados para crianças brasileiras].	Assess sodium content and additive use in processed foods targeted at Brazilian children.	Around 20% of products showed sodium content above 210 mg/serving.
Bibbins-Domingo et al. (2020)	Reductions in Cardiovascular Disease Projected from Modest Reductions in Dietary Salt.	Estimate public health benefits of small reductions in salt intake in the U.S.	A modest 3 g/day salt reduction leads to substantial declines in cardiovascular disease and related deaths.
Eyles et al. (2020)	Reducing children's sugar intake through food reformulation: methods for estimating sugar reduction program targets, using New Zealand as a case study.	Outline methods to develop sugar reduction targets (20%) in children's foods and beverages.	Methods show strong potential for creating a national sugar reduction program in New Zealand.
Beck et al. (2021)	Sodium chloride reduction in fresh sausages using salt encapsulated in carnauba wax.	Assess the use of carnauba wax encapsulation of salt to reduce sodium in fresh sausages.	Allowed a 25% salt reduction without impacting sensory profile.
Rios-Mera et al. (2021)	Modification of NaCl structure as a sodium reduction strategy in meat products: An overview.	Investigate strategies for reducing sodium content in meat products while maintaining sensory quality.	Reduce the size of salt particles enchances saltiness perception even with lower sodium concentration.
Chen et al. (2022)	Sugar reduction in beverages: Current trends and new perspectives from sensory and health viewpoints.	Explore technological and sensory challenges in reformulating low-sugar beverages.	Essential for improving public health, particularly in combating NCDs.
Mu et al. (2022)	Effect of sodium reduction based on the DASH diet on blood pressure in hypertensive patients with type 2 diabetes.	Evaluate the effect of sodium reduction via a modified DASH diet on blood pressure in hypertensive type 2 diabetes patients.	DASH diet with sodium reduction significantly lowered systolic blood pressure.
Calcaterra et al. (2023)	Sugar-Sweetened Beverages and Metabolic Risk in Children and Adolescents with Obesity: A Narrative Review.	Map the main contributions of sugar-sweetened beverages (SSBs) to overweight in children and adolescents.	Excessive intake of these beverages is directly linked to insulin resistance, diabetes, and fat accumulation.
Trumbo et al. (2023)	Perspective: Challenges and Strategies to Reduce the Sodium Content of Foods by the Food Service Industry.	Discuss challenges and strategies used by the food service industry to reduce sodium in foods.	Other viable methods, such as using alternative low-sodium ingredients, are also effective.
Wang et al. (2025)	Effectiveness of an mHealth- and School-Based Health Education Program for Salt Reduction (EduSaltS) in China.	Evaluate the effectiveness of scaling up a school-based mHealth program to reduce salt consumption in China.	The EduSaltS program was effective in reducing adult salt consumption and blood pressure, but its effects on children were less significant.

IV. Discussion

Technological Strategies for Sodium in Processed Food Matrices

The reduction of sodium in processed foods is a growing demand in public health, especially due to the strong correlation between high salt intake and the development of NCDs such as hypertension and cardiovascular diseases (Aguiar et al., 2021; Soares et al., 2021). In this scenario, several technological strategies have been proposed to maintain sensory characteristics while significantly reducing sodium. These include physical modifications of NaCl crystals, salt encapsulation, substitution with potassium chloride (KCl), and the addition of natural flavor enhancers.

One of the most promising approaches is structural modification of sodium chloride, particularly by reducing particle size. Rios-Mera et al. (2021) demonstrated that decreasing salt granularity intensifies saltiness perception, allowing smaller quantities to be used without compromising flavor. This technology is simple, easy to implement industrially, and has little negative sensory impact. Complementarily, Beck et al. (2021) evaluated the use of carnauba wax-encapsulated salt in fresh sausages, achieving a 25% sodium reduction without perceptible sensory changes.

Another widely used technique is partial replacement of NaCl with alternative salts such as KCl. This substitution is technically feasible and sensorially acceptable in various products, such as French bread, as demonstrated by Ignácio et al. (2013). Combining salts like KCl with yeast extract has also proven effective in masking undesirable flavors (Souza Paes; Ravazi, 2018). However, exclusive use of KCl may generate bitter or metallic aftertastes, requiring balancing with natural additives.

Additionally, dietary approaches combined with product reformulation have shown efficacy. The modified DASH diet, when associated with sodium reduction, effectively reduced systolic blood pressure in patients with type 2 diabetes (Mu et al., 2022). This highlights the importance of integrated interventions between food science, nutrition, and health policies.

Finally, for these technologies to effectively impact population health, they must be accompanied by regulatory policies and incentives for the food industry. The success of such strategies depends not only on technical feasibility but also on consumer acceptance, product accessibility, and transparent labeling. Integration between technological advances and public health guidelines is fundamental to creating healthier food environments.

Sugar Reduction in Foods and Beverages: Reformulation and Technological Feasibility

The growing prevalence of obesity, type 2 diabetes, and metabolic syndrome, especially among children and adolescents, has driven the search for technological alternatives to reduce added sugars in processed foods and beverages. Excessive consumption of sucrose, glucose, and high-fructose corn syrup is strongly associated with metabolic imbalance and increased visceral fat, in addition to being a risk factor for cardiovascular diseases (Calcaterra et al., 2023; Monteiro et al., 2023). In this context, the food industry has been pressured to develop reformulation methods that ensure sugar reduction without compromising sensory quality, product stability, and consumer acceptance.

One widely studied strategy is the gradual reduction of sugar content in sweetened beverages, without substitution by artificial sweeteners. Ma et al. (2016) modeled the impacts of this approach at the population level and concluded that progressive sugar reduction in soft drinks, even without sweetener replacement, could significantly lower caloric intake and, consequently, reduce obesity and type 2 diabetes prevalence. This approach is technically feasible and avoids potential risks associated with excessive use of artificial sweeteners, while preserving organoleptic profiles in an adaptive manner, as consumer palates gradually adjust over time.

In parallel, studies have shown that it is possible to reduce up to 20% of the sugar in fruit nectars without significantly compromising consumer acceptance (Oliveira et al., 2018). This reinforces the hypothesis that small formulation changes may go unnoticed by consumers, especially when combined with adjustments in other attributes such as acidity, aroma, and texture. In dairy products, sugar reduction is a growing trend, driven by consumer demand for healthier foods and the perception of risks associated with added sugar consumption (McCain et al., 2018). Reformulation in this sector requires special attention to changes in sweetness and texture, which are critical for sensory acceptance, particularly in fermented products such as yogurts.

Other authors, such as Chen et al. (2022), discuss the sensory and technological challenges of sugar reduction in beverages. According to them, sugar reduction must consider not only its sweetening function but also the physicochemical and structural properties sugar provides, such as body, viscosity, and aroma enhancement. Elimination or partial substitution may drastically alter the sensory experience, requiring integrated solutions that combine natural sweeteners, soluble fibers, and texture modifiers. In this regard, botanical extracts and natural aromas have been studied as adjuncts to compensate for palatability losses.

It is important to highlight that technological feasibility of sugar reduction reformulation is intrinsically linked to consumer acceptance. Nutritional awareness campaigns have proven effective in supporting this transition. Lima et al. (2016), for instance, reported that simply displaying visual information about sugar content in beverages sold in a school cafeteria reduced soft drink consumption while increasing preference for alternatives such as water and lower-calorie nectars. These findings emphasize the need to combine technological strategies with nutritional education to foster more conscious consumer choices.

Therefore, sugar reduction in processed foods and beverages must be regarded as a multifactorial strategy that combines technological innovation, sensory sensitivity, and educational engagement. Although industrial limitations exist, the long-term public health benefits justify adopting such measures. Transitioning to lower-sugar products requires a holistic approach that includes palate adaptation, dietary behavior change, and policies encouraging industry reformulation.

Sensory Evaluation and Hedonic Acceptance of Reformulated Products

Sensory acceptability is one of the main obstacles faced in reformulating processed foods with reduced sodium and sugar. Altering components central to taste, aroma, texture, and appearance carries the risk of consumer rejection, compromising reformulation success. Thus, sensory evaluation becomes indispensable for developing products that balance nutritional benefits with consumer preference (Oliveira et al., 2018; Beck et al., 2021).

Studies show that small sugar or salt reductions may go unnoticed if made gradually and balanced with other attributes. Oliveira et al. (2018), for example, demonstrated that reducing sugar content in fruit nectars by up to 20% did not negatively affect hedonic acceptance. This initial tolerance enables progressive reductions over time, promoting collective palate adaptation to lower sweetness. The same applies to sodium, whose perception can be manipulated by reducing salt particle size, as shown by Rios-Mera et al. (2021).

In meat products, Beck et al. (2021) found that carnauba wax-encapsulated salt effectively maintained the sensory profile, even with a 25% sodium reduction. This technological approach allows controlled salt release during consumption, enhancing saltiness perception and minimizing reformulation impacts. In baked goods, partial substitution of sodium chloride with potassium chloride also yielded good sensory results. Ignácio et al. (2013) observed no significant losses in consumer acceptance of French bread reformulated with this substitution.

Another relevant aspect is the consumer's emotional and cognitive response. Lima et al. (2016) demonstrated that visual perception and nutritional information directly influence food choices, particularly among adolescents. Displaying sugar content alerts in beverages led to behavior change, reducing soft drink consumption and increasing preference for healthier options. These findings suggest sensory acceptance is not limited to taste but is also shaped by awareness and education.

Therefore, reformulation success depends on integrating technological development with systematic sensory evaluation. Consumer testing should be incorporated early in the process to ensure nutritional adjustments do not compromise product acceptance. Additionally, nutritional education campaigns and clear labeling can foster gradual changes in consumer preferences, supporting acceptance of lower-sodium and lower-sugar products.

Effects of Sodium and Sugar Reductions on The Prevention of Non-Communicable Chronic Diseases

Non-communicable chronic diseases (NCDs), such as hypertension, type 2 diabetes, and obesity, are among the greatest challenges for global public health. These conditions are directly linked to inadequate eating habits, particularly excessive sodium and sugar intake, common in processed foods. Reducing these dietary components has been widely studied as an effective strategy for preventing and controlling such diseases, with significant impacts on quality of life and mortality reduction (Aguiar et al., 2021; WHO, 2012).

High sodium consumption is strongly associated with systemic arterial hypertension, a condition affecting vital organs such as the heart, kidneys, and brain. Studies show that high-salt diets may raise blood pressure by up to 30%, with table salt and processed foods being the main contributors (Soares et al., 2021). A modest daily reduction of 3 g of salt, according to Bibbins-Domingo et al. (2020), could substantially lower cardiovascular disease rates, underscoring the importance of public policies and industrial reformulations.

Similarly, excessive consumption of simple sugars, found in soft drinks, cookies, and sweets, is associated with obesity and insulin resistance, risk factors for type 2 diabetes. Calcaterra et al. (2023) emphasize that excessive intake of sugar-sweetened beverages is directly linked to fat accumulation and metabolic disorders in children and adolescents. Gradual sugar reduction in processed foods, without artificial sweetener substitution, has proven effective in reducing these risks (Ma et al., 2016).

Beyond physiological impacts, reducing sodium and sugars positively affects public health by easing the burden on healthcare systems. Kwon et al. (2024) notes that individuals with diabetes or metabolic syndrome consume more salt, intensifying cardiovascular risks. Strategies such as partially replacing sodium chloride with potassium chloride in French bread (Ignácio et al., 2013) demonstrate that maintaining sensory quality while lowering sodium is feasible for the food industry.

Finally, implementing integrated policies, including public education, government regulation, and product reformulation, is essential for sustainable changes in eating habits. Trieu et al. (2015) highlight that global salt reduction initiatives have advanced but still require broader coordination and stronger political commitment. Similarly, sugar awareness strategies, such as the visual intervention analyzed by Lima et al. (2016), proved effective in reducing sugary drink consumption. Thus, combining technological, educational, and regulatory efforts is critical for preventing NCDs and fostering healthier populations.

Public Policies, Nutritional Regulation, and Food Education Programs

Implementing effective public policies and nutritional regulation is fundamental to reducing excessive sodium and sugar consumption, contributing to NCD prevention. Given the alarming rise of hypertension, diabetes, and obesity, governments and international organizations have adopted measures combining regulatory, educational, and technological actions (Trieu et al., 2015; WHO, 2012). These initiatives aim not only to raise population awareness but also to encourage the food industry to reformulate products.

A major milestone is the adoption of global targets for salt reduction, such as the WHO's recommendation for a 30% relative reduction by 2025. Trieu et al. (2015) report that many countries have implemented successful programs, including gradual reformulation of processed foods and clearer nutritional labeling. However, progress remains uneven, requiring stronger coordination among governments, industry, and civil society. In Brazil, for example, voluntary agreements with industry have proven effective but require rigorous monitoring to ensure compliance.

Food education programs are also crucial for consumer behavior change. Wang et al. (2025) evaluated the EduSaltS program in China, combining school interventions with mHealth strategies to reduce salt intake. Results showed effectiveness in lowering adult salt consumption and blood pressure, although direct effects on children were less significant. This underscores the importance of multisectoral strategies involving schools, communities, and media to broaden outreach.

Sugar regulation has also gained attention, with countries such as the UK and New Zealand adopting evidence-based policies. Eyles et al. (2020) proposed methods for setting sugar reduction targets in children's products, stressing technical criteria and industry dialogue. Fiscal measures like sugary drink taxation, implemented in Mexico and Chile, have proven effective in reducing consumption (Lima et al., 2016).

Public policies must also be paired with awareness campaigns that help consumers understand the risks of excessive sodium and sugar. For example, Lima et al. (2016) demonstrated that visual sugar-content warnings effectively reduced soft drink consumption. Likewise, Trumbo et al. (2023) highlight that the food service industry can contribute significantly by offering low-sodium options and educating consumers. Therefore, combining regulation, education, and technological innovation is essential to building healthier and more sustainable food environments.

Industrial Challenges and Techonological Limitations in Food Reformulation

Reformulating processed foods to reduce sodium and sugars involves technical and operational challenges that directly affect the food industry. Although there is consensus on the need for healthier products, technological limitations and maintaining desirable sensory attributes pose significant obstacles (Rios-Mera et al., 2021; Chen et al., 2022). Developing safe, stable, and acceptable products requires R&D investments and production adjustments, often increasing costs and hindering large-scale adoption.

For sodium reduction, the main challenge lies in the multifunctional role of sodium chloride (NaCl). Besides imparting flavor, it acts as a preservative, inhibiting microbial growth, and affects technological properties like texture and binding in meat products. Rios-Mera et al. (2021) note that physical modification of salt structure (particle size reduction) enhances saltiness perception but does not fully address preservation issues. Partial substitution with KCl is viable but may introduce undesirable bitterness (Ignácio et al., 2013).

For sugar reduction, challenges are equally complex. Beyond sweetness, sugar contributes to texture, color (via caramelization), and preservation in products like cookies, cakes, and beverages. McCain et al. (2018) highlight that replacing sugar with artificial or natural sweeteners can significantly alter sensory and stability attributes, and consumers often resist products perceived as artificial. Oliveira et al. (2018) showed that a 20% sugar reduction in fruit nectars was acceptable, but more drastic cuts require complex compensatory technologies.

Lack of cost-effective alternative ingredients is another major limitation. Beck et al. (2021) tested carnauba wax-encapsulated salt in sausages, allowing 25% sodium reduction without sensory losses. However, such solutions often involve emerging technologies or expensive ingredients, limiting large-scale application, particularly in lower-income markets. Similarly, yeast extract for flavor enhancement in low-salt products (Souza Paes & Ravazi, 2018) still faces standardization and availability challenges.

Beyond technological barriers, cultural and market resistance also play a role. Consumers tend to reject reformulated products when noticeable differences in taste, texture, or appearance arise (Trumbo et al., 2023). While food education programs can support transitions, habit change is slow. Chen et al. (2022) argue that innovation must be coupled with transparent communication, emphasizing health benefits while meeting sensory expectations.

In sum, overcoming reformulation challenges requires collaboration among academia, industry, and governments, with investments in research, new technologies, and policies that encourage healthier practices without compromising industry viability.

V. Conclusion

The evidence synthesized in this review demonstrates that reducing sodium and sugars in processed foods is technologically feasible and contributes significantly to the prevention of non-communicable diseases. Strategies such as salt particle size modification, encapsulation, partial replacement with potassium chloride, and gradual sugar reduction have proven effective in maintaining sensory quality across different food categories. However, technological and industrial limitations, cultural resistance, and cost implications remain major obstacles to large-scale implementation.

To overcome these challenges, it is essential to foster collaboration between industry, government, academia, and civil society. Regulatory policies, transparent labeling, and nutritional education programs play a decisive role in consumer acceptance and behavior change. Future research should prioritize the development of cost-effective natural alternatives, biotechnological solutions for reformulation, and long-term clinical studies to better understand health impacts. Ultimately, integrating technological innovation with public health strategies represents a crucial step toward building healthier and more sustainable food environments.

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