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Bridging the Gap Between Food Labels and Consumer Understanding: Challenges, Opportunities, and Future Directions

Soumil Santoki, Krish Patel, Raxit Gamdha, Saish Waghmare, Aparajita Biswal
Computer Science And Engineering , Parul Institute of Engineering and Technology , Gujarat , India

Abstract- This paper explores the theoretical and practical feasibility of enhancing consumer awareness of packaged food products through food labelling systems and digital technologies. The research focuses on the psychological, educational, and technological mechanisms that shape consumer decision-making, particularly in the context of India's rising dependence on processed foods and increasing burden of lifestyle-related diseases. Drawing from studies on nutrition literacy, front-of-package nutrition labelling (FoPNL), and mobile health applications, the paper examines how interpretive labelling systems, such as warning symbols and star ratings, simplify complex nutritional information and influence healthier purchase intentions. Mathematical comparisons of labelling formats, including reference intakes versus interpretive scores, are discussed to quantify consumer comprehension and behavioural impact. The role of mobile applications, equipped with barcode scanning, optical character recognition, and artificial intelligence, is analysed to determine their effectiveness in providing real-time ingredient breakdowns and personalized dietary recommendations. The integration of these digital systems with educational interventions and media campaigns is highlighted as a pathway to improving national food literacy. Practical challenges such as unreliable food databases, regional disparities in awareness, and the cognitive biases introduced by label design are also addressed. Furthermore, the paper discusses the potential applications of these technologies in aiding vulnerable populations, such as adolescents and individuals with chronic health conditions, while outlining regulatory and infrastructural constraints. By synthesizing existing literature, this study emphasizes that combining education, policy, and technology can bridge the gap between product information and consumer understanding, ultimately contributing to improved dietary choices and long-term public health outcomes.

Keywords: Consumer awareness, Food labeling, Nutrition literacy, Front-of-Package Nutrition Labels (FoPNL), Mobile health applications, Artificial intelligence, Packaged foods, Public health, Food databases, Dietary decision-making, Digital nutrition tools.

I. INTRODUCTION

In recent years, there has been a growing concern over health-related issues in India due to the increased consumption of processed and packaged food products. With lifestyle-related diseases on the rise, consumer awareness regarding food ingredients, additives, and nutritional value has become more important than ever. Despite the availability of food labels intended to inform buyers about the content and health impact of products, comprehension remains low across diverse segments of the Indian population [2],[19],[22]. This limited understanding is exacerbated by the complex scientific language used on packaging and a lack of general awareness regarding nutrition.

Rising diet-related diseases have fueled interest in front-of-package nutrition labeling (FoPNL) [1] as a quick, accessible nutrition guide. Systems vary from numerical reference intakes to interpretive star ratings and color codes. Studies show that label type, design, and placement significantly affect consumer engagement and understanding [19],[22],[25],[31].

FoPNL also influences food industry reformulation and policy adoption[1].Understanding consumer awareness regarding product information, especially in the context of food and dietary choices, is increasingly critical in today's health-conscious environment. With the rise in non-communicable diseases and obesity in India, particularly among adolescents and young adults, there is a growing demand for accurate and accessible food information. Labels on food packages serve as a critical bridge between manufacturers and consumers, offering essential details on ingredients, nutritional values, and potential allergens[19,22]. However, studies indicate that many Indian consumers find it difficult to interpret these labels, often due to the technical language and lack of nutrition literacy [1].In India, especially in urban regions, the dietary profile is increasingly becoming imbalanced due to the rising consumption of processed and packaged foods [1,2]. This highlights the importance of consumer awareness about the nutritional quality of food[19],[22]. The current literature suggests a need for better labelling practices, clearer communication through packaging, and the development of intelligent mobile tools to aid in real-time decision-making. [9],[10],[25],[26]This review aims to explore how consumer awareness, aided by technological tools, impacts food choices in India and discusses the potential for expanding these tools to serve individuals with specific nutritional needs[3],[11],[13],[15].

II. LITERATURE REVIEW

Studies have consistently shown that Indian consumers face significant challenges in understanding nutritional information on food packaging. Gupta et al. [1] and Oddson et al. [2] highlight that adolescents and adults in India struggle with the technical language and dense scientific terminology used on labels. This lack of comprehension often leads to poor dietary decisions, exacerbating the prevalence of non-communicable diseases (NCDs). Kuriyan et al. [3] further emphasize the growing imbalance in dietary profiles among urban Indian youth, reinforcing the urgent need for effective and accessible labeling systems.

International evidence provides strong support for front-of-pack nutrition labelling (FoPNL) as a mechanism to promote healthier food choices and encourage industry reformulation. In Chile, the 2016 Law of Food Labelling and Advertising mandated the use of black warning labels for products high in sugar, sodium, or saturated fat. Following implementation, the proportion of products classified as "high in" these nutrients decreased significantly, particularly in categories like soft drinks, breakfast cereals, and snacks [4]. Roberto et al. [5] and Egnell et al. [6] further demonstrate that labeling policies can stimulate manufacturers to reformulate their products to avoid negative labels. Similarly, Ni Mhurchu et al. [7] found that the voluntary Health Star Rating system in New Zealand encouraged gradual reductions in sodium and sugar content across multiple food categories. Bonsmann et al. [8] and Machado et al. [9] provide comprehensive reviews of global labeling schemes, noting that interpretive labels such as Nutri-Score or star ratings are generally more effective than numerical reference intakes alone.

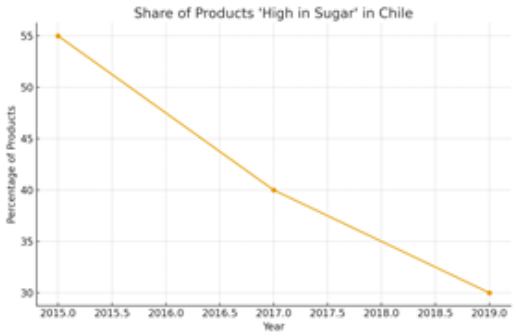

Figure 1: Decline in 'High in Sugar' products in Chile after mandatory FoPNL.

Despite the success of FoPNL internationally, evidence shows that labels alone are insufficient to drive long-term change. Graham and Jeffery [10] used eye-tracking studies to demonstrate that consumers only pay attention to nutrition information when it is prominently placed. Talati et al. [11] showed that interpretive designs, such as

color codes or warning symbols, are more effective than numerical systems. In India, however, limited nutrition literacy and language diversity exacerbate the challenge, often resulting in consumers ignoring or misinterpreting the information presented.

To address these gaps, digital solutions such as mobile food scanner applications have gained attention. Javadi et al. [12] and NutrifyAI [13] describe how AI-powered barcode scanning and real-time recognition can help consumers make healthier choices. Behavioral studies suggest that scanner apps can outperform FoPNL when consumer trust in packaging information is low [14]. In the Indian context, where smartphone penetration is among the highest in the world, these tools offer a practical way to bridge the literacy divide and make nutrition data accessible.

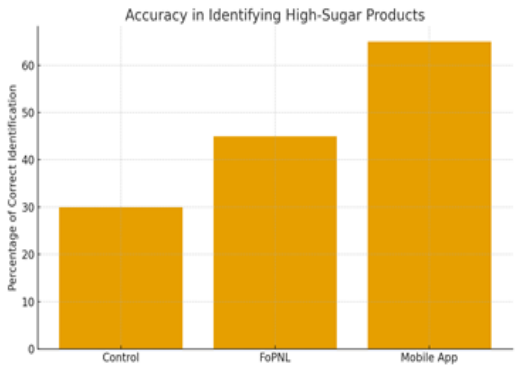

Figure 2Comparison of consumer accuracy under different labelling conditions.

The literature increasingly suggests that the most effective strategy combines regulatory approaches like FoPNL with digital and educational interventions. In India, where the Food Safety and Standards Authority of India (FSSAI) is exploring FoPNL implementation, there is significant potential to integrate traditional labeling with AI-powered apps and nutrition education campaigns [6], [8]. Such integrated approaches can create a feedback loop where consumers demand healthier products, and companies reformulate to meet that demand, ultimately improving public health outcomes.

Mobile application development plays a pivotal role in bridging the gap between consumers and nutritional awareness. Beyond basic barcode or QR code scanning, modern apps now integrate artificial intelligence (AI) and machine learning (ML) models to provide personalized insights for users with specific dietary needs. For example, individuals with diabetes, gluten intolerance, or hypertension can benefit from applications that automatically filter out products high in sugar, gluten, or sodium, offering healthier alternatives in real time [1], [2].

The accessibility of such applications is equally important in ensuring inclusivity. Features such as multilingual support, text-to-speech for visually impaired users, and culturally adapted dietary recommendations can make food label comprehension universally accessible [3]. This inclusivity allows both urban and rural consumers to make informed choices, even when nutrition literacy is low. Moreover, integration with wearable devices and health monitoring tools opens the door to personalized diet management, where food recommendations are dynamically adjusted based on biometric indicators like blood sugar levels or cholesterol readings [4], [5].

Ultimately, mobile applications have the potential to act not just as information tools, but as comprehensive health assistants that empower consumers to navigate food markets more effectively. By combining front-of-pack labeling (FoPNL) regulations with mobile innovations, India can drive both product reformulation by manufacturers and informed decision-making by consumers [6], [7].

Finally, the literature suggests the importance of user experience design in enhancing adoption[9],[20]. Aesthetically appealing interfaces, intuitive navigation, and minimal data input can lead to higher engagement[10],[15]. Features such as push notifications, seasonal dietary suggestions, and integration with fitness apps can transform food label readers into comprehensive health assistants[13],[15]. Such applications can significantly influence not just what consumers eat,

but how they think about nutrition on a daily basis[3],[9].

Using one of the research projects referred in references [24] we used a randomized pilot study to draw conclusion on how prior information about product composition affects the decision making of consumers. The analysis of the provided data alongside findings from Frontiers in Nutrition (2022) reveals that the use of front-of-pack nutrition labels (FoPNL) and ingredient scanning applications significantly improves consumers' ability to identify products high in sugars, saturated fats, and sodium.

The charts indicate that Mexican FoPNL formats consistently outperform control conditions in correct identification of high-sugar products (39% vs ~30% for control), and lead to higher decision-making scores for both quick purchase judgments and overall buying intent. Similarly, nutrient-specific recognition improves markedly when FoPNL formats are applied, with Brazilian FoPNL showing the highest accuracy for saturated fat identification (~93%), and Mexican FoPNL excelling in sugar recognition (~82%). To also demonstrate this factors easily we also have attached some charts to help emphasize our conclusions.

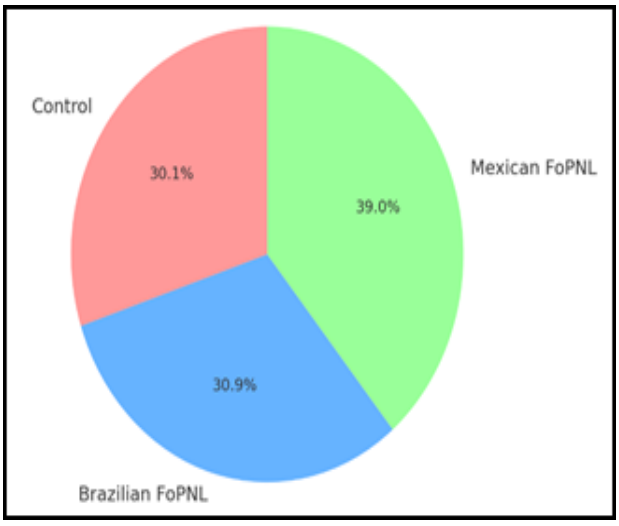

Figure 3: Correct Identification of High Sugar Products [1] , [2] , [20]

Figure 4: Consumer Scores for Decision Making [24], [25], [26], [27], [28], [29], [30], [31]

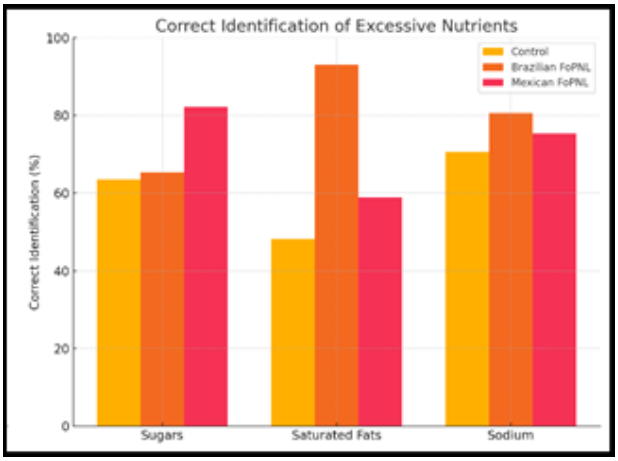

Figure 5: Correct Identification of excessive Nutrients [24] , [25] , [26] , [27] , [28] , [29] , [30], [31]

Hawley et al. [25] and Talati et al. [26] provide evidence that interpretive labels—those that summarize nutritional information into a simple score or visual indicator—are generally easier for consumers to understand than numerical-only formats. Talati et al. [26] found that labels with interpretive content increased the perceived healthiness of products and shaped purchase intentions more strongly than non-interpretive labels. Similarly, Egnell et al. [30], in a multi-country experiment, reported that Nutri-Score and warning labels consistently outperformed other systems in helping consumers identify healthier products. Graham and Jeffery [28] used eye-tracking methodologies to demonstrate that consumers are

more likely to engage with nutrition information when it is placed prominently on the front of the package, reinforcing the importance of both design and positioning in label effectiveness. Roberto et al. [27] found that FoPNL can create an indirect but significant impact on public health by encouraging manufacturers to reformulate products to achieve more favorable label ratings. Ni Mhurchu et al. [29] confirmed this in the case of the Health Star Rating system, where voluntary adoption led to measurable improvements in the nutritional profiles of products over time.

Bonsmann et al. [31] provide a comprehensive review of FoPNL adoption across different countries, highlighting the balance between regulatory frameworks and voluntary schemes. Machado et al. [32] emphasize that FoPNL plays a critical role in addressing the high consumption of ultra-processed foods by guiding consumers towards products with lower levels of nutrients linked to chronic diseases.

However, the research also emphasizes a cognitive bias: consumers can be misled by proportional differences in nutrient composition. For example, products with smaller serving sizes or visually minimized nutrient bars can create a perception of being healthier despite having high nutrient densities. This aligns with behavioural findings from the Frontiers in Nutrition [24] study, where visual framing and proportion scaling altered perceived healthfulness, sometimes leading to underestimation of high nutrient risks.

Overall, combining FoPNL with mobile-based ingredient scanning offers a powerful tool for improving dietary choices, but user education is essential to mitigate manipulation through label presentation. Without clear guidance, consumers may still be swayed by deceptive proportion graphics or serving size framing, limiting the full public health potential of such interventions [24]–[27].

Real-world evidence demonstrates a compelling link between increased consumer awareness via front-of-package (FoPO) nutrient labels and measurable reductions in unhealthy nutrients in products[25],[27],[31]. In Chile, the introduction of mandatory warning labels triggered significant product reformulation: the share of items labeled "high in" sugar, sodium, or saturated fat fell markedly across food categories as the regulatory thresholds tightened [29]-[31]. Similarly, evaluations of Australia and New Zealand's voluntary Health Star Rating (HSR) system reveal that labeled products experienced a ~2.3% decrease in sugar content and a 4.0% reduction in sodium(in NZ), compared to unlabeled counterparts. Collectively, these findings suggest that enhanced consumer-facing labeling—raising awareness and interpretive understanding—exerts market pressure that encourages manufacturers to lower sugar, sodium, and saturated fats in packaged foods.

The growing health concerns in India, largely driven by the increasing consumption of processed and packaged foods, highlight the urgent need to strengthen consumer awareness about food ingredients and nutritional composition. Studies indicate that most consumers find it difficult to interpret food labels due to the complex scientific language used and low nutrition literacy levels [1],[2],[19],[22]. This challenge emphasizes the importance of embedding food literacy into educational curricula and leveraging multiple media platforms to reach diverse demographics across India.

Schools and universities provide a powerful platform to instill lifelong healthy eating habits among adolescents and young adults. Research highlights that Indian adolescents, despite being frequent consumers of packaged food, lack the necessary understanding of nutrition labels [19]. Integrating food label literacy into classroom education can bridge this gap. Curriculum reforms that emphasize practical nutrition education—such as workshops where students analyze real-world food labels—can build early familiarity with ingredient lists, allergens, and preservatives [16],[17]. Such approaches also align with global trends, where nutrition education has been shown to improve knowledge-attitude-practice (KAP) outcomes among adolescents [17].Beyond formal education, media campaigns play a vital role in shaping consumer awareness.

Studies demonstrate that front-of-package nutrition labels (FoPNL) and digital interventions, such as mobile scanner apps, significantly improve consumer understanding of harmful nutrients [24],[25],[26]. However, awareness is most effective when coupled with public campaigns across television, social media, and community-level outreach programs [8]. Campaigns that use simple visuals, local languages, and relatable messaging can demystify ingredient lists and make information accessible to populations with limited literacy levels [7],[19]. For example, behavioral studies in Europe using QR codes revealed that when consumers accessed ingredient information through interactive media, comprehension and engagement improved [7].

A combination of educational strategies and digital platforms offers the most impactful approach to improving consumer food literacy. Mobile applications with AI-driven scanning and real-time recognition provide personalized insights, helping individuals—especially those with dietary restrictions such as diabetes or gluten intolerance—make informed choices [3],[11],[13]. When these technologies are integrated with school-based learning and supported by mass media, they create a reinforcing cycle of awareness. Moreover, the Food Safety and Standards Authority of India (FSSAI) can play a central role by collaborating with educators, media, and developers to ensure consistent and regulated information dissemination [25],[31].

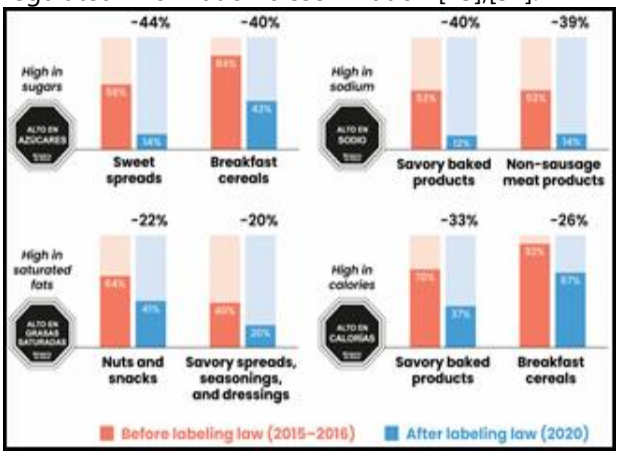

Figure 6: Before and After Introduction of New Labelling Law [21]

III. CONCLUSION

In conclusion, awareness of food products and their nutritional content among Indian consumers is still evolving. Despite the growing health consciousness, many still struggle with understanding ingredient labels and making informed food choices. The advent of mobile technology and AI-powered apps offers a promising avenue for increasing awareness and enabling healthier decisions. By simplifying complex nutritional data and presenting it in accessible formats, these tools empower consumers to take control of their health.

The study concludes that consumer awareness of food products and nutritional content in India is still developing. Despite rising health consciousness, many people find ingredient labels hard to understand, which hampers informed decision-making. Mobile technologies and AI-powered apps offer strong potential by simplifying complex nutritional data into user-friendly formats. Evidence suggests that food scanner apps and Front-of-Package Nutrition Labels (FoPNL) can influence healthier food choices, encourage manufacturers to reformulate products, and reduce diet-related health risks. For these tools to be effective, they must be inclusive, reliable, and tailored to Indian dietary contexts, with emphasis on user-centric design, localized languages, and accurate databases. Additionally, educational efforts in schools, health institutions, and communities are essential to complement technology and foster long-term food label literacy.

FUTURE SCOPE

The future direction lies in creating AI-integrated, comprehensive food product databases that include both Indian and international products with real-time updates on additives and nutrition. Personalized features for special groups (e.g., diabetics, gluten-intolerant individuals, vegans) can provide tailored alerts and suggestions. Integration with wearables and health-monitoring devices could enable dynamic, health-based food recommendations, improving adherence to dietary goals.

Collaboration with government bodies, nutritionists, and manufacturers will help standardize labelling practices and ensure data accuracy. Expanding accessibility with vernacular languages, audio-visual aids, and community-driven platforms will ensure inclusivity, especially in rural India. Ultimately, technology-driven awareness, combined with education and regulation, can build a healthier, better-informed consumer base.

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