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What Is Carbon Labeling of Food and Does It Work? A Preliminary Review of the Potential Impact of Carbon Labeling on Consumer Choice

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Abstract: Carbon labeling involves placing written or pictorial information on packaging, menus, or price tags to inform consumers about the carbon (CO_2) emissions associated with the entire life cycle of a product or service, thereby empowering them to make environmentally conscious purchasing choices. Various carbon labeling practices are in use, but there is limited understanding about their effectiveness in impacting consumer choice. ***Method:*** A preliminary review examining the effectiveness of carbon labeling was conducted by searching major scientific literature databases. Quantitative studies on data on the reduction in CO_2 emissions achieved through the provision of carbon labeling of meals were searched and examined. ***Results:*** Twelve studies were identified, six utilized computer-based virtual consumer choice simulation and six were conducted in real-world retail environments. Studies utilizing virtual simulations demonstrated potential double-digit reductions in CO_2 output, but real-life studies identified far much modest reductions of only 2-5%. Labeling using rating-based systems, such as with traffic lights, was identified as more effective in directing consumer choice. ***Discussion:*** This preliminary literature review demonstrates that carbon labeling has the potential to direct consumers toward purchasing lower-carbon emission products. However the relatively small number of studies on this topic indicates the need for further research. Clearly, greater business engagement, and possible government intervention, is needed to advocate for carbon labeling and ensure its wider use.

Keywords: sustainable behavior, carbon labeling, population, planetary boundaries, nutrition industry

1. Introduction

Although food is absolutely essential for survival, the production and transport of such items is a major contributor to climate change, accounting for 30-35% of greenhouse gas emissions (GHGs) worldwide [1, 2]. Reducing pollution at all stages of the food chain is an integral part of meeting the Paris Agreement and the United Nations Sustainable Development Goals (UN SDGs)[1].

Many proposed solutions have focused on advancing technological innovation in the agricultural and production process to reduce emissions [3]. Consumer choice offers another way to foster change, empowering consumers with information to choose more environmentally friendly food products can promote sustainable development. However, this task is inherently complex due to the diverse motivations that influence food choices [4, 5]. Providing eco-carbon labeling that shows the amount of GHG emissions caused by the purchased product is one possibility to inform consumers. However, can it really sway consumers to favor low-carbon emission products?

Individual studies have examined the effectiveness of different labeling designs, often by comparing one design to another, but no study has examined a range of designs or attempted to synthesize previous works. Thus the motivation for this research was to bring together the previously disparate results from such individual research in order to form an overall conclusion about which labeling system is most effective.

Based on the literature review, this study focuses on three research questions:

1) How much influence do carbon labeling schemes have on consumers to choose products with lower environmental impacts?
2) Is there a difference in consumer behavior between virtual and in-person trials?
3) Does the type of label have a measurable impact on its effectiveness in promoting sustainable choices?

[1] Sustainable Development Goals:Improving human and planetary wellbeing. http://www.igbp.net/download/18.62dc35801456272b46d51/1399290813740/NL82-SDGs.pdf

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This review is structured as follows: First, a literature review is conducted to explain what eco-labeling in general is, and carbon labeling in particular. Examples are given, and their consistency with design theory is explained. This is followed by a systematic review of research examining the effectiveness of carbon labeling. Recommendations and policy implications are derived from this review of literature.

2. Literature and Underlying Theory Related to Carbon Labeling

2.1. Consumer food attitudes

In today's society, adopting a green self-identity is becoming increasingly common [6]. However, this identity has not been formally recognized as a distinct dietary style. Empirical research suggests four distinct types of self-reported dietary identities. These are (a) healthy, (b) carnivore, (c) emotional, or (d) picky [7]. However, increasingly green conscious individuals are making choices based on environmental factors, which is not reflected in such a framework. For example, some individuals may opt for a vegetarian diet for environmental reasons, but this is obscured because others make such options based on the perception that it is consistent with a healthier lifestyle [8–14]. Instead the concepts of pro-environmental behavior (PEB) and pro-environmental actions have gained significant traction in recent years, reflecting the growing emphasis on environmentally sustainable practices [15, 16]. The concept of green identity should be encouraged and made possible for consumers to make corresponding choices, "nudging" them to strengthen environmentally friendly consumption [17]. In this respect, self-identity-based interventions can effectively promote sustainable consumption [18].

2.2. What is carbon labeling?

The main objective of carbon labeling is to present a concise, easy-to-understand symbol or image on a product packaging that indicates its environmental impact [19, 20]. Considering that the food industry is a major contributor to climate change, substantial attention has been paid to labels that provide information on the carbon (CO_2) emissions of products. Governments and organizations are increasingly prioritizing such carbon labeling because of their potential to foster sustainable consumer behavior. Carbon labeling enhances transparency by providing consumers with accessible information about the environmental impact of their choices.

Eco-labeling gained widespread consumer acceptance in the 1970s [21]. In 1999 the International Organization for Standardization (ISO) developed the ISO 14020 standard, which is divided into three distinct internationally recognized categories based on the stringency of the requirements [22].

Type I labels are awarded based on a multi-criteria environmental assessment conducted by an impartial third-party accrediting body [23, 24]. These labels are usually sector-specific and subject to rigorous certification procedures based on standardized accreditation rules [23]. For example, food products with the Rainforest Alliance label, shown in Figure 1 [23, 24], fall into this category.

Type II labels consist of standards and certificates developed internally by a manufacturer or other stakeholders [23, 24]. As such these are self-proclaimed. The credibility of these labels depends entirely on the transparency and accuracy of the data provided by the issuer. These labels can prove effective for specific issues, such as raising allergy awareness, encouraging recycling, or showing nutritional information, as seen in the Nutri-Score label in Figure 2 [23, 24].

Finally, type III labels represent the most stringent category of voluntary eco-labels and require extensive quantitative data obtained from external predetermined parameters, often alongside supplemental environmental data. A Life Cycle Assessment (LCA), based on external product category rules in accordance with ISO standards, is required for type III certification [23, 24]. Different requirements need to be met depending on whether the product is from business to business (B2B) or from business to consumer (B2C). Fair Trade Certified labels are often used on food products.

Figure 1
Rainforest Alliance type I label.

Figure 2
Nutri-Score type II label.

2.3. What different label designs exist?

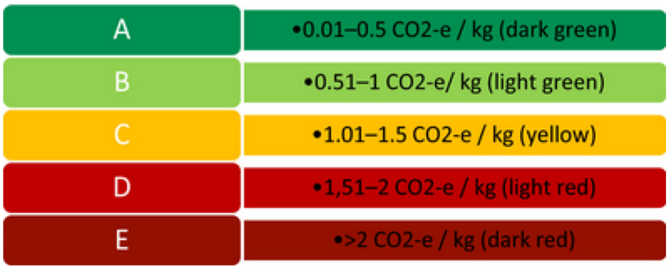
In addition to these categories, labels can also vary in design and presentation formats used. This influences consumer understanding and effectiveness. Specifically for carbon labeling, Feucht and Zander [21] identified four main formats of carbon label design: certificate, ordinal, quantitative, and ordinal + quantitative, as shown in Figure 3 [21].

1) Certificate: Binary YES/NO indicator to state whether the product fulfills a certain criterion, e.g., organic, carbon neutral, or a good climate choice [21]. Only products meeting the corresponding requirements are labeled.
2) Ordinal: Generally uses a traffic-light or other color scheme analogy, sometimes together with letters. This format has been used to associate products with their nutritional value [21].
3) Quantitative: Displays CO_2 emissions/kg as a number, with no other imagery [21].
4) Ordinal + Quantitative format: This hybrid format combines grading scale and numerical data, thus integrating visual and quantitative elements, as shown in Figure 4 [20, 21, 25, 26, 27].

Figure 3
Types of carbon labeling.

APROACHES TO CARBON LABELING	EXAMPLES
Certification (picture: e.g. organic/carbon-neutral)	Organic
Ordinal (gradation: e.g., traffic lights, A-E grades)	A B C D E
Quantitative Amount of emission: the CO_2 number)	0.3 kg CO_2/kg
Ordinal + Quantitative (a mix of traffic light and CO_2 numbers)	0.5 kg CO_2/kg · 1.1 kg CO_2/kg · 2 kg CO_2/kg

Figure 4
Climate Score label proposition.



Each labeling paradigm is designed to ensure that customers can accurately associate the eco-label with the intended environmental indicator [20].

2.4. Label design theory

As carbon labeling aims to enlist consumers as agents of change toward sustainable development, any product label must be designed so that individuals can use them to guide their consumption choices. For consumers to make informed purchasing decisions, labels must be easily recognizable and provide easy-to-understand information. Babakhani et al. [28] stated that capturing customers' attention within the first five seconds is crucial for effective interaction with labels. Carbon labeling must effectively communicate details on the CO_2 emissions of products through the use of color, background, fonts, and icons. Research shows that individuals form strong associations between colors and shapes [29, 30]. Carrero et al. [31] reported that labels with a predominantly red color, and bordered as a warning, were particularly effective in capturing consumers' attention. These labels indicate the potential "danger" of purchasing high-emission products, thereby encouraging people to make more environmentally conscious choices. This effectiveness could be further enhanced by integrating new labels with already well-recognized ones, or by adopting a "front-of-pack" approach [32].

Research shows that consumers are better able to perceive clear color contrasts, such as those found in traffic lights [31, 33]. However, the psychological mechanism underlying the effectiveness of traffic-light-based nudging remains underexplored and requires further investigation [34]. Carbon label design is based on a number of theories, which are summarized in Table 1.

2.5. How is carbon label grading determined?

The standard method for reporting the CO_2 footprint of a food product involves conducting an LCA [41]. In general, LCA is used as an analytical tool to evaluate the resource load across each step of a food product supply chain [42]. The LCA considers the relative ability of each substance to absorb heat, each with its own weight, and then adds the weights all together. It is provided as the CO_2 equivalent (CO_2e), measured in kilograms) per one kilogram of food (kg CO_2e/kg) [43].

Two possible approaches can be taken to conduct an LCA on a food product. The first approach is cradle-to-gate, which aims to measure "the total greenhouse gas emissions from the extraction of raw materials through to product manufacture up to the factory gate" [44]. The second approach is cradle-to-grave, which serves to indicate "the total greenhouse gas emissions from the extraction of raw materials through to the product's manufacture, distribution, use, and eventual disposal" [44]. Business-to-client transactions, such as the sale of food by retailers to consumers, typically use the cradle-to-grave approach [41]. Figure 6 [42] illustrates the life cycle process of a restaurant meal.

Animal-based products and certain exotic goods produce a substantially higher CO_2 footprint than vegan alternatives [2, 45]. Lemken et al. [25] argued that the target CO_2 food footprint for Europe should be limited to 1.25 kg CO_2e/kg of food. However, official dietary recommendations in many countries lead to footprints higher than this threshold, e.g., 2.25 kg CO_2e/kg food for Germany or 3.83 kg CO_2e/kg for the USA [46].

2.6. Expected impact

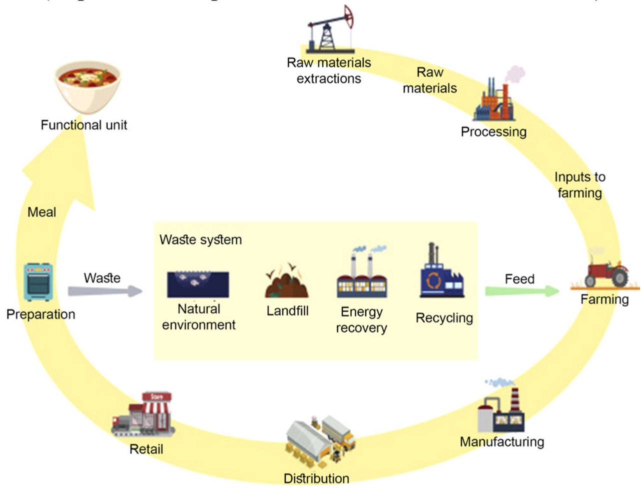
Carbon labeling schemes have piqued the interest of both industry and government stakeholders, as they are perceived as effective tools to empower consumers to make informed food choices with CO_2 emissions in mind. The average CO_2 footprint of consumers in industrialized countries is substantially higher than developing countries, so measures aimed at influencing consumer behavior will have a larger influence in the most affluent societies [47]. A meta-review by Osbaldiston

Table 1
Theories behind carbon labeling.

	PEB Model	Engel-Kollat-Blackwell Model	Labeling reaction model
Fundamental idea	Considers that consumer behavior is motivated by environmental concern	Focuses on consumers' mental processes by which they decide to purchase, become loyal customers, or reject certain products [35]	Thøgersen [36] presented the Labeling Reaction Model to explain how consumers react to additional product information related to external costs, particularly different eco-labeling schemes, as shown in Figure 5 [34].
Examples	Local food to prevent transportation pollution, purchasing organic products, recycling, and using eco-friendly products when possible [37]	30,000 consumers in France rated taste, health, locally sourced production, and price over environmental concerns when making their food choices [38, 39].	One survey on organic labeling showed that consumers often trust private labels less than official state-sponsored initiatives [40].

Figure 5
Labeling reaction model.

Figure 6
LCA elements for a cradle-to-grave review in the food industry (Reprinted with permission obtained from Cucurachi.)



et al. [48] indicated that the use of techniques such as social modeling and prompting can encourage environmentally friendly behavior by consumers. However, the effectiveness of eco-labels is not universal. In some instances, consumers may misinterpret the information provided, or the labels may fail to have a sufficient nudging influence on their dietary choices [49]. As a result, the success of nudging strategies through eco-labels remains inconsistent [50, 51].

3. Research Methodology

3.1. Preliminary review: search methods and inclusion criteria

A review of published literature on this topic was conducted. The literature search utilized a keyword-based strategy, focused on the terms “carbon labeling” AND “food”. Only studies conducted in the English language were included. Only peer-reviewed articles published in recognized scientific journals were included in the analysis. The search was based on four standard scientific databases: Science Direct, Umbrella, Semantic Scholar, and PubPsych. Data on the number of articles found and those initially filtered out are provided in Table 2.

Only quantitative studies that conducted virtual or field experiments, conducted over the last ten years, and which measured the difference in consumption patterns between CO_2e labels and no labels were included. Consequently only studies reporting statistical findings on the changes in customer purchasing choices under experimental (with carbon labeling) and control (without carbon labeling) conditions were included.

Table 2
Literature search results.

Database	Initial entries	Filtered as relevant	Selected entries
Science Direct	1725	6	[52] [53]
Umbrella	17	1	[54]
Semantic Scholar	144	21	[28] [55] [56] [57] [58] [59]
PubPsych	14	6	[14] [33] [38]

This review included both online simulations and field experiments. Field experiments were conducted in diverse settings, including grocery supermarkets and restaurants or canteens. All articles were manually reviewed and the quality of studies was assessed based on established criteria [60]. Research was processed manually by the authors; no bibliographic software was used.

4. Results

4.1. Study details

An overview of the identified and assessed articles is given in Figure 7. A total of twelve articles met the criteria outlined in Table 2. Ten of the included studies used a sample size of more than 100 participants, while two relied on a sample size of less than 50 participants. In ten out of twelve studies the study period was clearly stated. All twelve studies randomized samples and included a control group, increasing the reliability of their findings, as shown in Table 3. Of the twelve selected articles, half utilized online simulations using hypothetical consumption choices. The remaining six analyzed sales data from field experiments, with the experimental and control periods serving as their basis for comparison. Categorizing labels into ISO types was not feasible, as most of them used hypothetical labels rather than officially recognized ones.

In most studies the quantitative outcome measured was CO_2 equivalent per kg. In some instances, arbitrary sustainability scores were used. The reduction in emissions or impact was calculated as the percentage difference between the experimental (label) and control (no label) groups. In total, three trials used ordinal labeling, while six studies implemented the hybrid (ordinal + quantitative) eco-labeling paradigm. Two studies focused on comparing ordinal and quantitative eco-labeling approaches and one tested a certificate label.

Three distinct variations in the implementation of the experiments were identified: scene, labeling design, and target sample. Online experiments exposed participants to hypothetical choices in an online setting through web-based or eye-tracking technologies. The studies continued until the targeted sample size in both experimental and control groups was achieved. In contrast, field experiments measured sales data in real-world settings, such as restaurants, canteens, or grocery supermarkets, and over specified periods. In terms of labeling design, all four of the standard CO_2e labeling formats (certificate / ordinal / quantitative / ordinal + quantitative; see Tables 4 and 5) were utilized across the studies. As regards the target sample, the online studies predominantly recruited students and university staff, while the field experiments included a more diverse representation of the general public.

4.2. What reductions in CO_2 emissions were seen?

Significant effects were observed in eleven of the twelve trials examined, although the magnitude of these effects varied considerably. When comparing virtual online studies with field-based experiments, a notable difference in the level of reduction was evident. Online experiments showed a reduction of 3-17% while real-life trials saw a reduction of 1-5%. The final results of the reviewed entries are summarized in Figure 7.

Details on the sample sizes and the reduction percentage from the online experiments are shown in Table 4. Online simulations involving hypothetical choices led to double-digit reductions, regardless of the

Figure 7
Results by type of study and label paradigm.

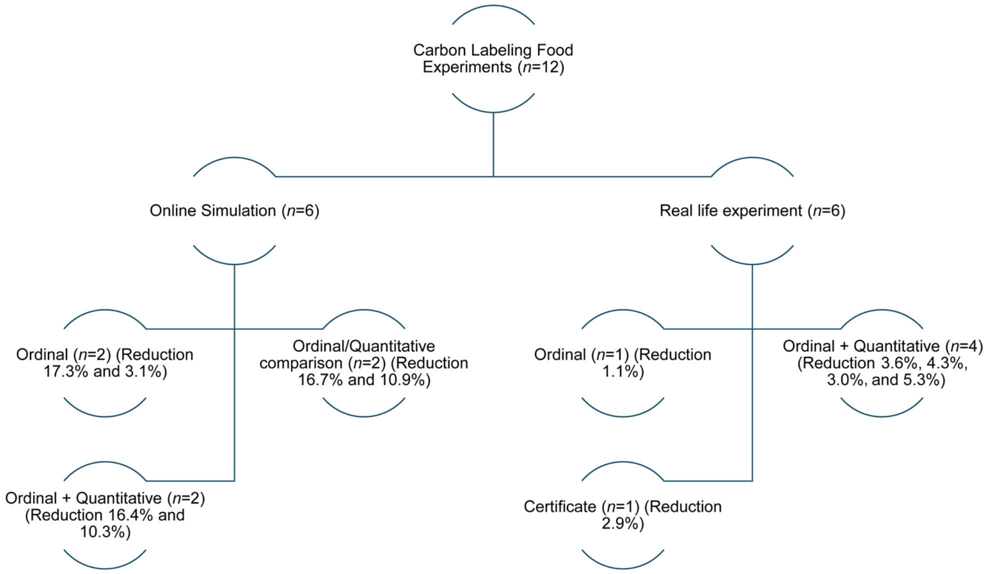


Table 3
Study quality assessment.

Reference	Author, Year, State	Sample Size	Duration	Randomization	Control Group	Missing Information	Rating
[28]	Babakhani et al. (2020), Australia	Small (<50)	Eye-tracking done once	Yes	Yes	-----	****
[34]	Osman and Thornton (2019), UK	Large (>100)	6 weeks	Yes	Yes	-----	****
[39]	Visscher and Siegrist (2015), Switzerland	Large (>100)	2 weeks	Yes	Yes	-----	****
[53]	Lohmann et al. (2022), UK	Large (>100)	3 months	Yes	Yes	-----	****
[53]	Pechey et al. (2022), UK	Large (>100)	7 months	Yes	Yes	-----	****
[54]	Brunner et al. (2018), Sweden	Small (<50)	9 weeks	Yes	Yes	------	****
[55]	Hallez et al. (2021), Finland	Large (>100)	---	Yes	Yes	Information on study duration cannot be found	***
[56]	Muller et al. (2019), France	Large (>100)	---	Yes	Yes	Information on study duration cannot be found	***
[57]	Betz et al. (2022), Germany	Large (>100)	2 weeks	Yes	Yes	-----	****
[58]	Spaargaren et al. (2013), Netherlands	Large (>100)	3 months	Yes	Yes	-----	****
[59]	Vlaeminck et al. (2014), Belgium	Large (>100)	2.5 weeks	Yes	Yes	-----	****
[61]	Neumayr and Moosauer (2021), Germany, Austria	Large (>100)	3 months	Yes	Yes	-----	****

Notes:

- Weak (three or more key details of methodology are missed, unclear/poor presentation of study)*
- Moderate (one or two key methodology details are missed, satisfactory description of study)**
- Strong (one or two key methodology details are missed, clear and thorough description of study)***
- Very strong (no key methodology details are missed, clear and detailed presentation of study) ****
- (Data quality assessment is made based on the gradation proposed by Nørnberg et al. [60].

Table 4
Review of online experiments.

Reference	Date, Country	Scene	Carbon Labeling Design	Sample Size (Control/Experimental)	Reduction
[28]	2019, Australia	Eye-tracking	Ord + Quant	17 / 19 (students+staff)	16.4%
[34]	2019, UK	Online restaurant	Ord	374 (within subjects; students)	17.3%
[55]	2021, Finland	Online survey	Ord / Quant*	56 / 98 (students)	16.7%
[56]	2019, France	Online supermarket	Ord / Quant*	59 / 216 (public)	10.9%
[57]	2022, Germany	Online restaurant	Ord + Quant	265 / 265 (public)	10.3%
[61]	2021, Germany, Austria	Online supermarket	Ord	190 / 200 (public)	3.1%

Notes: Cert (Certificate), Ord (Ordinal), Quant (Quantitative), Ord + Quant (Ordinal and Quantitative)
*Hallez et al. [55] and Muller et al. [56] made a further comparison of results from ordinal and quantitative labeling and detected a higher change with the ordinal paradigm.

Table 5
Real-life field experimental results.

Reference	Date, Country	Scene	Carbon Labeling Design	Running Time (Control/Experimental)	Reduction
[39]	2015, Switzerland	University canteen	Cert	5 days / 9 days (students+staff)	2.9%
[52]	2022, UK	5 university cafeterias	Ord + Quant	3 months (students+staff)	4.3%
[53]	2022, UK	28 lunch restaurants	Ord	7 months (public)	1.1%
[54]	2018, Sweden	University canteen	Ord + Quant	5 weeks / 4 weeks (students+staff)	3.6%
[58]	2013, Netherlands	University canteen	Ord + Quant	5 weeks / 7 weeks (students+staff)	3.0%
[59]	2014, Belgium	Supermarket	Ord + Quant	9 days / 9 days (public)	5.3%

Notes: Cert (Certificate), Ord (Ordinal), Quant (Quantitative)

labeling paradigm. Notably, studies that predominantly involved academic participants exhibited greater responsiveness to labeling; trials with university-based participants showed a large reduction.

Table 5 details the sample size of the experiments and the reduction percentages in the field experiments. The reviewed field trial studies accounted for an estimated 3-6% label-related reductions in CO_2e generated emissions.

This finding suggests that, while labels make green nudges to customers, the information in a CO_2 report competes with other factors about the product in capturing a customer's attention. These factors include pricing, seasonality, healthiness, aesthetic appeal, and other important considerations related to the subjective meaning of goodness of the product, all which remain essential for consumers [53].

4.3. What design of labels is most effective?

From the studies examined, it was challenging to determine which label designs and types were most effective. In the studies, two of the online experiments listed in Table 4, used separate groups to compare different labeling types. These experiments showed that the ordinal format had a greater impact on consumer behavior than the quantitative format [55, 56]. Studies using rating-based systems, such as traffic-light labeling, appeared to be more engaging and more effective in aiding consumer understanding than numerical representations alone.

A review examining the more general topic of labeling about sustainability [62] found that in 60 of 76 studies, the labeling intervention had a significant positive effect on consumer choice. However, no clear difference was observed between the effectiveness of labels incorporating a logo, text, or a combination of both. This inconsistency in carbon labeling systems complicates efforts to identify which designs are most relevant or effective. Consumers are likely to focus on familiar information that they already consider informative. Further studies are required in this area to provide a definite answer regarding the most effective label design.

4.4. Limitations of the studies

The online simulations often involved small sample sizes and exhibited evidence of social desirability bias. This may explain the significant behavioral shifts observed, which are unlikely to be replicated in real-life situations. A notable discrepancy may exist between self-reported behavior and actual behavior. Online participants may be indulging in self-deception, overestimating their natural plasticity in supporting climate-friendly alternatives, as noted in previous work [28, 57, 63]. Consequently, online virtual simulations may lead to overestimation of PEB.

Another limitation of the reviewed studies is that they are predominantly focused on Europe, with only one study [28] conducted outside of Europe (Australia). The lack of relevant studies in other developed regions, particularly North America, is notable. This highlights a potential gap in knowledge regarding cross-cultural differences in consumer acceptance to labeling. The extent to which consumers of different ethnic, social, cultural, or international backgrounds respond differently to various forms of labeling remains largely unexplored. Further research is needed to determine whether the observed patterns are universally applicable.

Another limitation is the relative homogeneity of the sample participants, which is often not reflective of the general population. Most of the reviewed studies primarily involved students or individuals associated with educational institutions. Therefore, the findings may not be generalizable to the wider population. Consumers vary in socioeconomic status, education, and national background; how these factors influence consumer responses to labeling remains unclear. Future studies should address these differences to better understand the impact these factors have on labeling effectiveness.

5. Conclusions

Carbon labeling shows the CO_2e emissions of a food product throughout its life cycle and offers consumers the opportunity to make informed decisions about the environmental impact of their purchasing decisions. Several initiatives have been launched to explore various approaches to food labeling, including text, graphics, or a combination of both (hybrid). This review contributes to the subject of carbon labeling by synthesizing previous research on different label types to provide a better understanding of which labels are most effective. Although other studies have examined carbon labeling, few have summarized the existing literature as thoroughly as done here.

The twelve reviewed studies confirm that carbon labeling can have a significant impact on consumer choices. Labeling was shown to nudge a reduction in CO_2 emissions by 10-15% in online simulations and 1-5% in field experiments. The findings suggest that graphical labels (i.e., the traffic-light analogy) are preferable and more effective than quantitative information. Likewise, a graphical-number combination was found to have the highest impact on consumer behavior.

Future research should evaluate the efficiency of different label designs across different retail contexts, such as supermarkets, restaurants, or online. Furthermore, the potential risk of informational overload due to multiple labeling systems can also be addressed. Government-sponsored initiatives based on standardized labeling principles may prove more effective than current voluntary schemes, emphasizing the need for targeted government intervention.

Recommendations

An analysis of the identified studies suggest that carbon labeling for food products can serve to reduce emissions through a dual purpose: 1) achieve emission reductions and 2) increase customers' awareness and acceptance of environmental issues, and laws and regulations. Several aspects to improve the implementation of carbon labeling have been identified:

1) Combination of messaging: The success of low-carbon foods could be improved by integrating this information with other product attributes that consumers value, such as health benefits or pricing. According to the reviewed studies, the effect of labeling is significantly stronger when combined with price incentives [28, 64–66]. Additionally, measures that complement carbon labeling, such as a CO_2e tax, could help reduce GHG emissions from food production [67].
2) Engaging business: The adoption of sustainable practices is increasingly being recognized as providing a significant competitive advantage for businesses [68]. A growing number of organizations have acknowledged the inseparable connection between business performance, purchasing behaviors, and the environment [68]. Today, customers are actively demanding for green products, and businesses must be capable to fully meet this demand by adopting environmentally responsible production and consumption methods [69]. By constructing a green-identity brand image, businesses can not only meet consumer expectations but also strengthen their corporate responsibility by prioritizing safety standards and cultivating healthy and responsible consumption [70].

It is important to adopt holistic and nonbinding approaches, such as that advocated in the SDGs framework, to ensure the future decarbonization of the business sector [71]. Adhering to the focus of the SDGs can provide targets and benchmarks that may not be justified at the government or macro level but can be effectively applied at the industry level. Specifically, "Goal 3 – Good Health and Wellbeing," "Goal 12 – Responsible Consumption and Production," "Goal 13 – Climate Action," and "Goal 17 – Partnerships for the Goals" are directly related to the need for CO_2e labeling [20].

3) Requirement for standardized framework or third-party standards: When labeling is organized solely by industrial business entities, consumers often have less trust in them. This can reduce the likelihood of behavior change [20]. To mitigate this issue, businesses should incorporate the SDGs into a complementary framework and adopt a third-party standard, thus enhancing their credibility. This integrated approach can also provide reassurance to consumers that the information provided by a carbon label is accurate [72].
4) Requirement for increased consumer literacy: According to a recent survey conducted by the Carbon Trust, two-thirds of the 10,000 shoppers surveyed, who came from the USA and Europe, supported carbon labeling [73]. However, only 22% responded that they do consider the level of CO_2 emissions released by products they purchase [73]. The results of this study emphasize the importance of implementing educational initiatives that increase consumer awareness and understanding of carbon labeling. This must happen before it can be widely adopted.

Some authors argue that initiatives aimed at improving environmental literacy are vital for increasing consumer compliance [58, 65]. It is believed that when consumers fail to understand the relevance of a label, its perceived importance decreases during the information processing stage [74, 59]. Visscher and Siegrist [39] found that low-carbon dishes were not perceived as less tasty than high-carbon meals. Strength of habit and familiarity is a vital determinant when making food decisions, and is estimated to account for 20% of purchase variations [75].

Increasing public knowledge about CO_2e emissions is essential to enable informed purchasing decisions. This goal can be achieved by creating specific labeling schemes, coupled with educational content that foster the momentum needed for adoption among producers and consumers.

5) A need for government monitoring?: Contemporary labels are, in most cases, organized by the industry itself, and use third-party vendors or nongovernmental organizations for accreditation. Despite the growing interest in eco-labeling, the continual roll-out of new label formats is causing considerable confusion and difficulty for consumers to understand [76, 77]. In cases where confusion is compounded by a general lack of consumer knowledge about CO_2/CO_2e emissions, it is evident that a new label alone is not enough to achieve widespread adoption [78, 79]. Even consumers who are aware of climate change may be skeptical about their effectiveness as a tool to mitigate environmental problems.

Several authors emphasize that the government needs to play a more active role, as Edenbrandt et al. [80] pointed out in their study of behavioral changes among different personality types. They recommended that carbon labeling be mandatory for all products, labels be user-friendly, and implementation be supported by awareness campaigns. The European EcoScore Initiative is an example of an effective awareness campaign. The Climate Score uses a traffic-light analogy and recommends a target level of 1.25 kg CO_2e/kg per person [44] (Figure 4).

Specific Policy Recommendations

A number of policy implications can be made from this review of the literature that can help government or industry leaders. Primarily, the review shows that recommendations on carbon labeling need to detail the optimal design and format to use. Ideally, a standard design that utilizes the best principles identified here needs to be recommended and its use encouraged. The use of a standard design will aid consumers understand such labeling.

This research shows that carbon labeling can effectively influence in the reduction of CO_2 emissions. It therefore suggests that mandatory use of such labels or voluntary industry compliance should be an option. Business groups that advise individual producers, or set industry standards, will find this research useful in providing guidance to their members. Another possible policy implication is that assessment and labeling could serve as the basis for CO_2 tax on each product.

Ethical Statement

This study does not include any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest related to this work.

Data Availability Statement

Data are available on request from the corresponding author upon reasonable request.

Author Contribution Statement

Håkan Lane: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review and editing, Visualization, Supervision, Project administration. **Oksana Pokutnia:** Conceptualization, Methodology, Validation, Investigation, Writing – original draft, Visualization. **Mark David Walker:** Writing – original draft, Writing – review and editing. **Jayanna Killingsworth:** Conceptualization, Writing – original draft. **Michal Valko:** Writing – original draft, Writing – review and editing. **Ana Rita Farias:** Conceptualization, Writing – original draft.

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