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Abstract

As greenhouse gas emissions are reaching an all-time high, consumers are becoming aware of their dietary impact on the environment. However, carbon footprint information for different food items is not widely accessible and there is no legislation in place in the Netherlands that enforces the agri-food sector to provide such information to the consumer. To address this challenge, we have created a Chrome extension for the Jumbo supermarket website that integrates a range-based carbon footprint label onto a food product page. We have tested our solution by extracting a random selection of 49 items from the Jumbo website and find that our tool gives the correct information label for 45% of the items, incorrect for 20% of items, and 35% of the items do not yet have any carbon footprint information stored in our chosen open source database.

Keywords— Carbon Footprint, Food, Labels, Supermarket Website, Online Grocery Shopping, Chrome Extension

1 Introduction

In recent years, climate change has captured the attention of the world as greenhouse gas emissions are reaching an all-time high. The food industry consumes 30% of the total global energy demand and is one of the most emissive industries in the global economy [1]. While most people are aware that their diet might have an environmental impact, taking action is difficult. One of the main challenges is the lack of information available to consumers about the greenhouse gas emissions of different food items and brands. Information is not widely accessible and may require extensive research on the consumer's end [2] Furthermore, compliance from Dutch grocery stores is difficult as there is no legislation in place in the Netherlands [3].

To address this challenge, we are proposing a tool that provides consumers with information on the carbon footprint of the food products they purchase. We have implemented this tool as a Chrome extension, which after installation, integrates a range-based label into the food product page on the Jumbo website[1]. This label provides the consumer with the CO2 equivalent emission of the food group corresponding to the product they are viewing. We also provide a relative "goodness" of that emission based on existing threshold levels, making it easy for the consumer to compare products. Existing research shows that providing this information can alter consumer purchasing habits and deter them from purchasing highly emissive food items [4]. Furthermore, this tool bypasses the compliance of a grocery store as installation and usage of our tool are completely up to the consumer.

We structure our report as follows; we begin by providing some background information on the carbon footprint concept, the impact of CO2 labels on consumer spending behavior, and related work on existing types of labels. This is followed by our design, which includes our method for data collection and designing our product requirements. We then explain our solution in terms of our front-end and back-end, followed by a requirements analysis. We validate our solution through a random population test in which each item is manually checked for correctness. Finally, we end our report with a discussion of our project and provide possible future work.

2 Background

2.1 Carbon Footprint

Although the carbon footprint has been a widely used concept for many years, there are ongoing debates regarding its precise definition. The Kyoto Protocol defines the carbon footprint as the overall amount of carbon dioxide equivalent and other greenhouse gases emitted throughout a product's life cycle, such as storage, usage, and disposal stages [5].

It's worth noting that not all greenhouse gases have the same impact on climate change. To facilitate an honest comparison of carbon footprints among different products, appropriate factors are employed to convert the emissions into the amount of carbon dioxide they represent. For example, methane has a 25 times greater impact on the environment than carbon dioxide, while nitrogen can have an impact up to 298 times greater [1].

2.2 Impact on consumer behavior

The issue of climate change has been a hot topic for some time, and there is a growing concern among consumers about the environmental impact of their actions. Individuals can reduce their carbon footprint by making conscious choices about the type of products they consume. Environmentally aware consumers are increasingly interested in products with a smaller carbon footprint [2]. Despite the increasing interest, there are still relatively few studies that explore consumers' attitudes toward products with a lower carbon footprint [6].

[1] https://www.jumbo.com/

In general, people who attach importance to environmental impact appreciate the quality and added value of environmentally friendly production. Such consumers are also more likely to pay a higher price for products with a lower carbon footprint. Interestingly, studies have also found that female consumers and individuals with a higher income tend to have a more positive attitude toward carbon footprint product information [2]. This may reflect an awareness of environmental issues among these groups, or a larger willingness and opportunity to pay a premium for products with a smaller carbon dioxide footprint.

In addition to consumer attitude, some studies suggest that the presence of a carbon footprint label can influence consumer behavior. One study found that the inclusion of a carbon footprint label led to a 2.7 percent decrease in the selection of high-carbon meals, with consumers opting instead for mid-carbon options [4]. This suggests that providing consumers with clear information about the environmental impact of their choices can have a positive effect on their behavior.

Overall, the available research suggests that there is a growing interest among consumers in products with a lower carbon footprint. With environmental awareness amongst consumers growing, providing carbon footprint information whilst (online) grocery shopping might positively influence consumer behavior.

2.3 Related Work

There are two primary types of carbon footprint information: B2B (Business to Business) and B2C (Business to Consumer) [7]. B2B carbon footprint information covers all production stages, from raw materials such as seeds, fertilizers, and plant protection chemicals, to primary processes on the farm such as storage, loading, sorting, and transport to the farm gate or Point of Sale (POS). B2C carbon footprint information includes the use phase at the consumer level, as well as product disposal or recycling, if applicable. The B2C approach covers the entire supply chain up to the end of the product's life, which can be difficult to assess due to the large variation and often unpredictable consumer behavior after purchasing the product. Considering our product is aimed at informing consumers regarding the carbon footprint of their groceries, we focus on B2C carbon footprint information.

Several ways exist to communicate carbon footprint to consumers [7]. We have extracted the most widely used labels and list them here:

1. A single static CO2 value per packaging unit, per mass or volume
2. Colour-coded communication with a uniform functional unit
3. Communicating the carbon reduction approach/initiative without a distinctive CO2 value
4. Labeling products within a 20% margin of the lowest carbon footprint in the product category

For the consumer, a single static numeric CO2 value can be challenging to judge without comparable CO2 values. Color coding includes every product, including those with large emissions, enabling the consumer to choose not only between more or less emitting production systems within the same product segment but also lower-emitting alternatives within product categories. However, variation in methodology can lead to difficulties in comparing products in the same product segment. Additionally, the data basis for calculation may vary per product (group).

Carbon offset, carbon zero, or climate neutral labels are commonly assumed by customers to be associated with cleaner production, but it may not be communicated to what extent this is implemented. However, this labeling scheme may incentivize companies to join such initiatives to receive the label.

A study conducted recently has examined how consumers respond to carbon footprint labels. The study found that the use of consumer-friendly symbols, such as traffic light colors, on the labels, significantly increases consumers' willingness to pay for sustainable food products. However, when carbon footprint labels are presented alongside other labels such as organic or FairTrade, consumers exhibit the lowest willingness to pay more [8].

Based on these findings, we have decided to use a clear label with a color system to inform online shoppers about the carbon footprint of food products. This approach is expected to increase their willingness to use the extension.

3 Design

Over recent years, online grocery shopping has seen a significant increase, especially after the COVID-19 pandemic [9]. Our objective is to educate consumers on the environmental impact of the products they purchase. Therefore, we decided to develop a Chrome extension for supermarket websites. Our solution currently works for the Jumbo website; a large Dutch grocery chain with a substantial online consumer base. Further development would include expansion to other grocery chains and web browsers.

3.1 Data collection

The data used for the carbon footprint label was collected from a Danish database, The Big Climate Database from CONCITO [10], Denmark's green think tank. An issue with carbon footprint labeling is that information regarding the environmental impact of food products is not widely available. Other existing databases, such as EcoInvent [11] or Agribalyse [12], require a license and the available data is also for other countries, UK and France. Since Denmark and the Netherlands are both EU-based countries that import roughly 12% of their food, we feel the Denmark data can be used to estimate the carbon footprint of food in the Netherlands as well.

The carbon footprint of food products calculated by CONCITO is an average over the available product, i.e. Pink Lady and Elstar get the same score since they are both a type of apple. The database consists of around 500 of the most common food products and is therefore the largest open-source database containing this information.

3.2 Requirements

Before implementation, a requirement analysis was done using the MoSCoW prioritization technique. This was done in order to reach a common understanding with the team of our product requirements and their corresponding priority level. Below we list the must haves, should haves, could haves, and won't haves that we agreed upon.

1. **Must have**
   - 1.1. The product must work on one large Dutch grocery chain website
   - 1.2. The product must be in the form of a Chrome extension
   - 1.3. The product must provide the customer with CO2 information on a product page for some products
2. **Should have**
   - 2.1. The product should provide the customer with CO2 information on a product page for the majority of the products on the website
   - 2.2. CO2 information should be related to a products food group, i.e. a Pink Lady apple should provide the consumer with the CO2 grams equivalent of producing an apple
   - 2.3. CO2 information should be in the form of a label that provides the customer with information relative to all other products
3. **Could have**
   - 3.1. The product could work on multiple (Dutch or international) grocery chain websites
   - 3.2. CO2 information could be related to the specific food item, i.e. a Pink Lady apple could provide the consumer with the CO2 grams equivalent of producing a Pink Lady apple
   - 3.3. The product could provide the CO2 label on all products on the product browsing page rather than just on a specific product page
4. **Won't have**
   - 4.1. The product won't provide the customer with a summation of CO2 grams equivalent for the content of their grocery basket
   - 4.2. The product won't provide alternatives for food items with a high CO2 score
   - 4.3. The product won't be extendable to mobile phones

4 Solution

We split the explanation of our solution into three sections. We first describe the front-end, which consists of what the user will see and experience when using our product. We continue our explanation by describing the back-end of our product, this provides information on how we obtain our CO2 information and connect it to the product extracted from the grocery store website. We end with a requirement evaluation in which we discuss to what extent we were able to implement our MoSCoW requirements.

4.1 Front-end

The produced product consists of a Chrome extension which can be found and installed manually via our GitHub repository[2]. After installation, the extension recognizes when the user enters the Jumbo website on their Chrome browser. Once a user clicks on a product page, such as this one[3], the Chrome extension will automatically add a label that contains the CO2 grams equivalent of the product. An example of the label can be found in Figure 1.

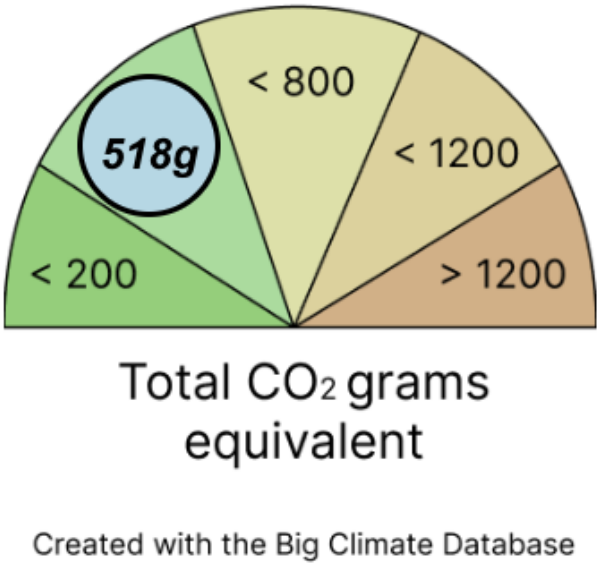

Figure 1: Example of Label for Product: Paaseitjes

The label contains five different thresholds; <200, <600, <800, <1200, >1200. The thresholds are given corresponding colors with green representing "good" and red representing "bad". The threshold levels are taken from existing labels and correspond to widely accepted ranges [7]. The label contains a blue circle that contains the CO2 grams equivalent that is needed to make that product. This circle is placed in the corresponding threshold slot, which is according to the standard of existing range-based labels. Our label also informs the customer that the label is created using the Big Climate Database in order to provide transparency and acknowledgment of our chosen data source.

4.2 Back-end

In order to present the correct information to the user, the extension must extract data from the web page, search for the product in the database, and then construct the label. In order to correctly match products from the website and the database, we have created a Dutch version of the database where each item is translated from English to Dutch. The first step, extracting data, must be adjusted for each website, as each grocery chain organizes its website information differently. For Jumbo, we found that the best way to obtain a match with the database, was to iteratively search for the product category, starting from the most specific. An example of these categories taken from a Jumbo web page can be found in Figure 2. We search the categories from right to left.

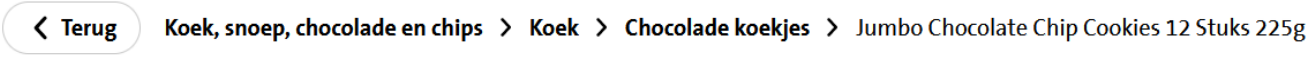

Figure 2: Jumbo's product categories

When searching for a category in the database, the extracted string is split into multiple words, if possible, and then we

[2]https://github.com/GasparinoRocha/SSE_Project2
[3]https://www.jumbo.com/producten/jumbo-paaseitjes-melk-wit-puur-chocolade-massief-500g-213727ZK

check if any category in the database contains any of those substrings. If a match is found, the corresponding CO2 value is retrieved, and the label is constructed. This label is then injected into the HTML of the Jumbo product page.

4.3 Requirements evaluation

Given the short duration of the project, we mainly focused on the must have and should have requirements as these had the highest priority. We were able to implement requirements 1.1-3; the product works on the Jumbo website, it is in the form of a Chrome extension and the product provides customers with CO2 information for some products. The second must have requirement, 1.2 the product must be in the form of a Chrome extension, could be further improved upon by making our Chrome extension publicly available via the Chrome store rather than a GitHub repository. For the should haves, we were able to implement requirements 2.2-3. Our product links the CO2 information to a product's food group and we provide a label that scores this product in relation to an existing range-based metric, making it easy to compare to other products. For requirement 2.1, we were not able to provide CO2 information for the majority of products. This was mainly due to the structure of information on the Jumbo website and the sparsity of the CO2 database being used. We highlight these challenges in our evaluation of the solution in the next section.

Due to time constraints, we were not able to implement any of our could have requirements. In order to implement 3.1, we would need to generalize our solution. This would mean restructuring the data of multiple large grocery stores and would require more resources. In order to restructure this data, you might be able to make use of Natural Language Processing techniques to extract the semantic meaning of a product title or it may require a team of people going through all the entries and extracting/linking the products manually. It was not possible to implement requirement 3.2 as there are no open-source CO2 databases for specific product brands. We could, however, see that such databases do exist, but they are behind a hefty paywall and often do not contain specific Dutch brands. Requirement 3.3 could easily be implemented in a future iteration of our product and would be a nice extension of the functionality that we provide.

For the won't have requirements, we listed possible future extensions of our product, such as providing alternative products or giving a sum total of the CO2 emissions of a customer's grocery basket. Lastly, making the product available for mobile phones would be a natural next step.

5 Solution assessment

To test the correctness of our product, we developed a tool that randomly selects items that are then manually checked for correctness. The tool works by having two buttons overlaid over the Jumbo website, one of which is for going to a random product overview page and the other for choosing a random product from the current product overview page. Each product and product page is chosen with equal uniform probability. For the manual part, the reviewer has to choose from one of three options: "Correct", "Incorrect", and "Missing in Database". "Correct" is chosen if the extension is able to link the correct item in the database to the product page. "Incorrect" is chosen if the item is in the database but the wrong information is displayed and "Missing in the Database" is chosen if there is no corresponding item in the database. Our tool always links a CO2 value; when the item is "Missing in the Database", our tool will link to another incorrect item in the database.

We have conducted our own evaluation of the Chrome extension using this evaluation tool for a random selection of 49 items. The results for this evaluation are summarized in Figure 3, and for a detailed overview see the Excel file in the repository[4]. We find that our tool is able to correctly link 45% of the 49 items and provides the incorrect CO2 information for 20% of the items. Figure 3 also shows that for a substantial number of products, (35%), the database is lacking information.

Our review is reproducible via the GitHub repository and we have made the evaluation tool publicly available.

[4]https://github.com/GasparinoRocha/SSE_Project2

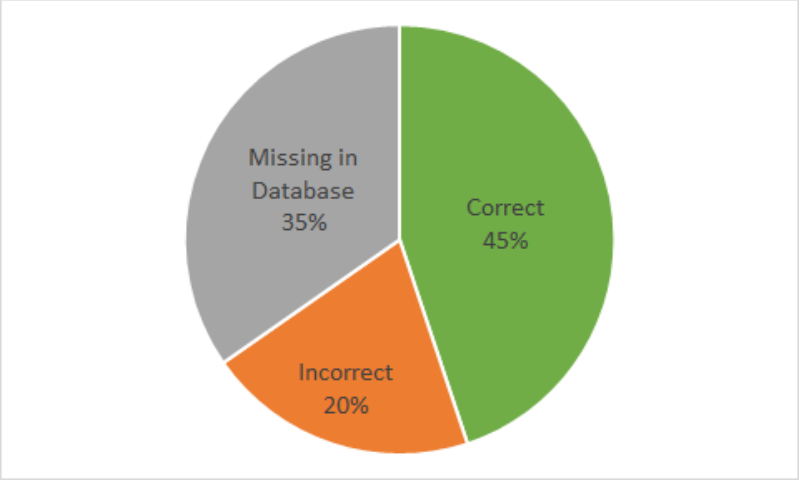

Figure 3: Classification percentages out of 49 random items

6 Discussion

In this project, we have implemented a Chrome extension that adds CO2 information labels to food products on the Jumbo website. A random sample shows that our tool only provides the correct information for roughly 45% of the items, and is incorrect for the remaining items. We also found that around 35% of the items are not yet represented in our chosen open-source CO2 database and are therefore incorrectly labeled.

Our solution to the food industry's impact on greenhouse gas emissions has a few beneficial impacts. The first is that the consumer is a key deciding factor in how much supply is created. By altering the consumers' spending behavior, we can alter the production amount of a certain food. As outlined in our background research, customers who are environmentally conscious are susceptible to these types of CO2 labels and are likely to alter their purchasing patterns. If we make the assumption that such customers are willing to install our Chrome extension, they would be likely to alter their purchases and therefore decrease the supply of highly emitting foods. The second benefit is that there is currently no legislation in place in the Netherlands concerning CO2 food labels and therefore gaining compliance with grocery stores may be difficult. Our tool bypasses this by simply letting the consumer decide whether they want access to this information and provides emission information in an intuitive way.

The main limitations of our product are the sparsity of the open-source database used and the linking between products extracted from the Jumbo website and their corresponding food group in the CO2 database. Due to the sparsity of open source data on CO2 emissions of food production, we made the generalization of food products to food groups. This means that there is no distinction between two apples coming from two different manufacturers. Generalizing this information means that suppliers who are actively reducing their CO2 consumption will not be given a representative value by our label. However, as this information is not yet available or not yet open source for many food brands, this generalization gives a nice first step and might motivate brands to provide such information in the future. And even with this generalization, we find that there are still many food groups missing from the existing open-source data. There is a need for more CO2 information for food items. The second limitation, linking of the data, is one that can be solved given more time and resources.

7 Future work

There is a lot of work to be done when it comes to the robustness of the extension. Firstly, on Jumbo's website, there is useful information that is either unobtainable as of now or unused. This extra data could help find better matches in the database. Secondly, the extension scope should include other websites, such as Albert Heijn, Plus, or Lidl. The basis for this expansion would be a study of these supermarket's HTML structures.

Another important addition would be including more databases. For example, instead of showing the emission for a certain food group, it could be extended to include information on specific brands. The missing entries can also be substituted by other databases. Although this would allow for a broader range of products being evaluated, it could also create problems related to consistency and user-friendliness, as the large dataset could result in higher perceived latency.

The extension should also be published to the Google Chrome Web Store and other browsers. This would make our tool more accessible to a wider audience. While not particularly challenging, this would require a financial investment, as these

platforms usually require a developer entry fee. Finally, the tool could be expanded with additional functionalities based on this information, such as the total emissions of a recipe or grocery basket.

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