Information Disclosure and Climate-Friendly Consumption: Assessing the Impact of Carbon Labelling at a University Dining Hall

Alejandra S. Marquez

ABSTRACT

Global dietary patterns are increasingly reliant on animal products, which are highly carbon intensive and significantly contribute to climate change. While transitioning towards plant-based diets is regarded as an important way to mitigate climate change, the best strategies to encourage this transition are less understood. This paper looks at the role of information disclosure in swaying consumers towards sustainable dietary practices. Through a field experiment at one of UC Berkeley's dining halls, this study analyzed the effects of implementing a label with greenhouse gas emissions information. A traffic-light colored carbon label was added for every dish in a dining hall serving approximately 1,300 meals every day. The dining hall's service records were used to calculate the quantity served to students for each dish both during a baseline period prior to the introduction of the labels and an experimental period in which the labels were implemented. The study finds that servings of red labelled dishes (high emission) decreased by 33% compared to the baseline, leading to a 13% reduction in emissions per serving.

KEYWORDS

carbon labelling, climate label, mitigation, field experiment, meat consumption, dining hall

INTRODUCTION

Consumption of animal-based food products is a central contributor of greenhouse gas emissions. Meat-centered diets are approximately four times higher in carbon intensity per calorie consumed than plant-based diets (Gravert & Kurz, 2019). Thus, shifting dietary patterns towards a lower reliance on animal products in developed countries— which are heavily reliant on meat and animal products— has been identified as an essential measure to meet climate change mitigation targets (Cleveland & Jay, 2020).

Despite the large role that food consumption plays in anthropogenic climate change, evidence suggests that most people are unaware of the environmental impact of food products. Two large knowledge gaps have been identified in the scientific literature. The first knowledge gap comes from consumers' lack of understanding of the environmental impact of their food choices. A study looking at people's estimates of GHG emissions associated with food products found that, on average, consumers vastly underestimate the emissions of food, particularly of animal-based products (Camilleri et al., 2019). In another study, Sanchez-Sabate et al. (2019) find a similar lack of awareness of the environmental impact of meat. They further argue that consumers' perception of food as detached from the environment is an important perceptual barrier that hinders more sustainable food choices. The second knowledge gap highlights consumers' difficulties in understanding the factors that contribute most to the environmental impact of food. In a cross-sectional study looking at consumers' beliefs about ecological food consumption, Tobler et al. (2011) found that participants believed avoiding excessive packaging had the strongest impact on the environment and that purchasing organic food and reducing meat consumption were least environmentally beneficial. In reality, meat consumption has the largest impact among the options considered in the study. Therefore, the literature suggests that consumers are largely uninformed or misinformed about the role of food choices in the environment (Hartikainen et al., 2014).

Information disclosure— for example, through the provision of informational labels— is one method by which consumers' knowledge gaps could be addressed. In doing so, food consumption patterns could be changed on a voluntary basis. Various sustainability-related food labels such as Fair Trade, Rainforest Alliance and Animal Welfare, are now commonly seen in grocery stores (Grunert et al., 2014). Information disclosure has also been used in public health efforts through calorie labelling. A systematic review and meta-analysis of recent studies provides evidence that calorie labelling effectively reduces energy ordered and consumed in restaurants and cafeterias (Littlewood et al., 2016).

Climate labels are much less common and, therefore, less researched. Some studies have been conducted to assess the potential of climate labels to sway consumers' food choices towards low-carbon options (Brunner et al., 2018; Emberger-Klein & Menrad, 2018; Khanna, 2019; Matsdotter et al., 2014; Muller et al., 2019; Spaargaren et al., 2013; Visschers & Siegrist, 2015; Vlaeminck et al., 2014). In a field experiment conducted in 17 grocery stores in Sweden, adding a climate label to climate-friendly milk products resulted in a 7% increase in demand (Matsdotter et al., 2014). Similarly, Visschers & Siegrist (2015) found that adding a "climate-friendly choice" label in a canteen resulted in a 20% increase in sales of labelled options. Climate labels have recently been introduced in the restaurant industry with chains such as Panera Bread, Chipotle Mexican Grill and Just Salad adding their own carbon emission labels to menu items.

Consumers' stated responses indicate positive reactions towards climate labels. Hartikainen et al. (2014) show that 90% of survey respondents believe that carbon labels would have at least a small influence in their choices and 90% wanted more information on carbon footprints. Similarly, Tan et al. (2014) find that 76% of surveyed participants respond positively to carbon labels. These findings can serve as evidence that consumers may be prepared to switch towards lower carbon food options if they are informed about climate impact at the point of sale. However, there is limited evidence regarding the effectiveness of climate labelling in shifting consumer demand towards more climate-friendly consumption.

The purpose of this paper is to investigate if a color-based carbon labelling scheme alters food choices at a university dining hall. The field experiment design used in this study allows for the investigation of food choice behavior in a natural setting. This study focuses on the short-term impact of carbon labelling and is thus limited in scope. However, by focusing on a university dining hall where prices of food do not play a role in consumers' choices, this study fills a gap in the literature and contributes to existing research on the potential for climate labelling to reduce food emissions.

METHODOLOGY

Carbon Emission Calculations

To calculate the carbon footprints of each dish, I used the Cool Food calculator (Version September 30, 2019) by the World Resources Institute which sourced its greenhouse gas emissions data from Poor and Nemecek (2018) and Searchinger et al. (2018). The data for each food category includes all upstream GHG emissions from agricultural supply chains (production, transport, processing, packaging and food losses) except emissions associated with land-use change. Using this data, provided in kilograms of carbon dioxide equivalents per kilogram of food product (kg CO_2-eq / kg of food), I calculated the carbon emissions for each ingredient used in Cal Dining's recipes. Ingredients such as herbs, spices, ketchup, and mustard were not included in the calculations, as their contributions to the overall footprint of a dish are insignificant (given that their contributions to the weight of a dish are negligible). Taking account of the portion size of each ingredient, in each recipe, Cal Dining's menu management system was able to track the amount of carbon emissions produced by each dish. I analyzed this data and set a threshold for the high, medium, and low emissions categories, based on the emissions associated with different types of foods. Thus, the green labels are associated with vegetarian dishes; the yellow labels are associated with pork, chicken, or fish dishes; and the red labels are associated with beef dishes. This does not mean however, that each label color captures only the type of food that it is associated with; there are some overlaps, for example, with chicken dishes that have only a few pieces of chicken and are thus in the emissions category for green labels.

Label Design

A traffic-light colored labelling scheme was chosen for this study based on evidence from the literature indicating that this type of labelling scheme makes it easy to compare between food categories and is often preferred by consumers (Emberger-Klein & Menrad, 2018; Hartikainen et al., 2014). The label is composed of a cloud image with "CO_2" printed in the middle, colored in accordance to the amount of emissions of the dish (see Figure 1). The chosen label is qualitative and does not include the numerical carbon emission quantities because research suggests that quantitative information on climate impact can be cognitively difficult for consumers to process

(Matsdotter et al., 2014). The traffic-light colored scheme reflects which types of food are low (≤ 1.3 kg CO_2-eq/100g), medium (1.4-5 kg CO_2-eq/100g), or high emitting (> 5 kg CO_2-eq/100g), using the colors green, yellow and red respectively. This design is intended to be simple for consumers to notice and comprehend, with additional information provided through other educational posters and materials, such as the one shown in Figure 1.

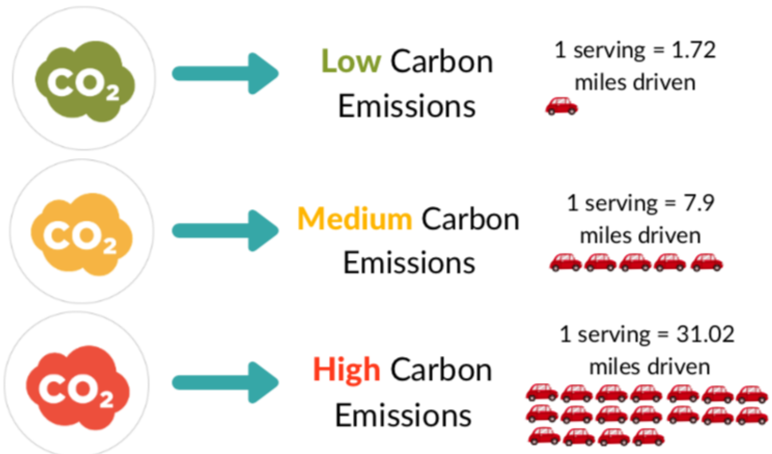

Fig. 1. Informational poster illustrating the labels used and their emission equivalents in miles.

Experimental Design

The labelling scheme was implemented at Crossroads dining hall at the University of California, Berkeley during the fall semester of 2020. Students could choose any dish they wanted from the different stations available, including plant forward, grill, allergen friendly, and pasta stations. The dining hall follows a prepaid meal plan format through which students pay for meal passes instead of food items, so there are no prices for different dishes inside of the dining hall. This allowed the study to be conducted in a natural setting where price is not a factor in consumers' food choices.

The experiment was conducted in two phases— the control (baseline) phase prior to the implementation of carbon labels from September 14th to September 28th and the label phase (experimental phase) from October 5th to October 19th of 2020. Both phases had a duration of two weeks (14 days) and in both phases, the same menu items were offered at the dining hall, allowing for the observation of students' food choices of the same menu before and after labels were implemented.

During the label period, the carbon labels were added to the online menu in Cal Dining's website and to the physical menu cards at Crossroads, next to all of the dishes available except daily snacks or pre-ordered items such as daily soups, desserts, fruit, coffee and drinks. Along with the labels themselves, educational information on the carbon footprint of different foods and on how to use the carbon labels was added to Cal Dining's website and displayed in physical posters around the dining hall (Fig 1).

Hypothesis

Various studies have used a traffic-light colored labelling scheme to inform consumers about the environmental impact of different food products (Brunner et al., 2018; Khanna, 2019; Leach et al., 2016). These types of labels are easy for consumers to interpret and compare between different options. The green label conveys positive information while the red label conveys negative information; and the yellow label can be interpreted as a middle step between the two, leading to a trickle-down effect (e.g. beef buyers substituting beef for yellow-labelled chicken and chicken buyers substituting chicken for green-labelled veggie burgers) as was found by Vlaeminck et al.

Evidence suggests that consumers give more attention to negative information and thus are more likely to change their behavior away from negative-labeled products (Grankvist et al., 2004). Additionally, when informed about the environmental impact of food, consumers' food choices change mostly away from beef as opposed to other food categories. A study looking at the effects of a food-based environmental course on undergraduates' dietary carbon footprint found that the beef component of students' diets decreased to a significantly larger extent than adjustments in other food categories. For the case of this paper, negative information coincides with beef selection, since only beef dishes carried a red label. I therefore hypothesized that students would react most strongly to the red-labeled beef dishes. However, there are other drivers behind consumers' attention towards labels, such as their prior environmental beliefs and their goals in regards to their food consumption. Shewmake et al. (2015) show that climate labels are most effective when consumers are concerned about the environment and when the label conveys new information that helps them update their understanding on the environmental impact of the labelled good. Thus, I could rule out that selection of green items would be more strongly affected due to students' prior beliefs, a factor which is outside of the scope of this paper.

Hypothesis 1**:** Red labels affect the selection of dishes negatively while green labels affect the selection of dishes positively, with yellow labels acting as a middle step to encourage substitution from high emitting dishes to lower emission dishes. Beef dishes (carrying a red label) will be most affected by the addition of labels.

Environmental information disclosure strategies that aim to alter consumers' behavior in favor of more sustainable options have been shown to achieve modest decreases in the overall greenhouse gas emissions produced. For example, Brunner et al. (2018) found a 3.6% decrease in emissions after implementing a carbon label at a restaurant and Spaargaren et al. (2013) applied a climate label resulting in an emissions reduction of 2%.

Hypothesis 2**:** The dining hall's overall carbon footprint will be slightly lower for the label period when compared to the baseline period.

Procedure

The managers at Crossroads dining hall routinely collect data on the number of servings (equivalent to 100g) provided for each meal period. The staff at the dining hall record the servings by hand and a manager subsequently inputs the data into Cal Dining's menu software (Eatec). Although human error and inconsistencies are possible in this system, the Cal Dining team's awareness of and support for this research project helped ensure a careful inputting of the data. After both the baseline and label phases were completed, I was able to access the service records— containing the number of servings for each day and meal period at Crossroads— on Eatec. There were various days with missing data during the baseline period, largely due to the fact that the dining team's focus was concentrated on adjusting to the new modes of operation during the COVID-19 pandemic. Because of the inconsistencies, the data was limited to only one meal period for each day (instead of looking at all meal periods). Since there were no gaps in the data for the label phase, I chose the meal periods that matched the data available during the baseline phase, so that the resulting data reflected the same meal periods for both phases.

The vast majority of customers at Crossroads are undergraduate students, with some UC Berkeley staff, faculty, and external visitors also coming to eat at the dining hall. During the baseline phase, there were a total of 7,040 meal swipes, or around 503 meal swipes per day (meal swipes represent the number of people using their meal pass to eat at the dining hall; once they swipe in, they can get as many servings as they like). For the label phase, there were a total of 7,736 meal swipes (around 553 swipes per day). Due to the pandemic, Crossroads operated as a take-out service, where customers entered the dining hall only to choose and pick up their meal. To promote efficiency, the entire menu was displayed at the front of the dining hall (carbon emission labels included) with one menu card for each station in the dining hall (see Figure 2). Although customers could go to as many stations as they liked, the vegan menu items (usually lower in emissions) were located at a different station from other options. This could pose a limit to the experimental procedure since customers who want to choose a lower-emission substitute (for example choosing a vegan burger instead of a beef burger) have to go to an entirely different station. As an additional measure towards efficiency, the meal options were pre-plated by Cal Dining staff (as shown in Figure 2). However, customers could request a customized plate with whichever of the dish options they wanted from that particular station.

Figure 2. Menu display at Crossroads entrance.

The labels were also displayed on menu cards at the front of each individual station (see Figure 3) and on the online menu, which students were encouraged to look at before entering the dining hall.

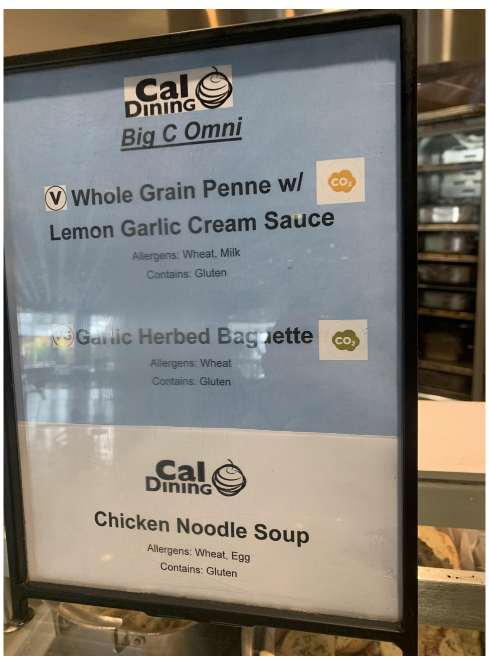

Figure 3. Menu card in front of Big C Omni station at Crossroads.

The original dataset (from the selected meal period for each day of the baseline and label phases) consisted of 100,434 observations, representing individual servings; 53,552 belonged to the baseline phase and 46,882 to the label phase. The dataset included items that were not included in the carbon emissions calculations and thus did not have labels assigned to them.

These were pre-ordered items such as daily soups, desserts, fruit, coffee and drinks. After removing these items, 89,982 observations remained— 47,374 from the baseline phase and 42,608 from the label phase. There were also observations for which carbon emissions calculations were not possible because of missing ingredient lists, and other observations which had inconsistencies between their carbon emissions and their assigned label (for example, the dish's emissions were low but Eatec had assigned a yellow or red label, or vice-versa). I was able to track these inconsistencies by referencing a spreadsheet with the correct label colors and emissions which had been created previously for the original calculations. These observations, which represented ten different menu dishes, were removed. The final sample consists of 83,194 observations; 43,491 observations belong to the baseline phase and 39,703 to the label phase.

To test my first hypothesis— regarding the effect of the labels on selection of dishes— two analyses were conducted. In the first analysis, I compared the selection of dishes by label color across the two phases. To test for significant differences in dish selection of each label color, I first conducted a chi-square independence test (allowing me to determine if there is dependence between the variables overall) and, since dependence was observed, I conducted a two-proportion Z-test for each label color (e.g. proportion of green in baseline phase vs. proportion of green in label phase) The large number of observations ensures that the sample properties the test relies on are met. The second analysis was intended to examine specific substitutions in the selection of dishes. For this analysis, I looked at direct dish substitutes (i.e. dishes that had a lower emission version and a higher emission version offered on the same day and meal period, such as vegan tenders and chicken tenders) across the two phases. To test for significance, I conducted a two-proportion Z-test, which looks at the proportion of the low-emitting dish in the baseline phase vs the proportion in the label phase and tests for significant changes. To account for multiple testing, I applied a Bonferroni correction to all p-values obtained.

To test my second hypothesis I compared the average emissions per serving across the two phases. I used average emissions instead of total emissions because the number of observations is not the same across both phases. To test for a significant difference in average emissions, I conducted a t-test. The large number of observations ensures that the assumptions that the test relies on are met.

In addition, I analyzed changes in the number of meal swipes across the baseline phase and the label phase. The number of meal swipes reflects the number of students choosing to eat at Crossroads dining hall (i.e. the number of people who "swipe in" at Crossroads by using one meal pass). Analyzing changes in meal swipes is thus important to reveal unintended side effects of introducing a carbon label, given that students could choose to eat at a different dining hall to avoid the labels. However, if large changes are found, I will not be able to determine the specific cause of the changes— meal swipes could potentially be impacted by other factors such as timing of midterms, big celebrations on campus, etc.

RESULTS

Number of meal swipes and servings

Table 1 shows the total meal swipes and servings for the baseline and label phases. While the number of servings is higher for the baseline phase (43,491 for the baseline phase and 39,703 for the label phase), the number of meal swipes is higher for the label phase (7,040 for baseline and 7,736 for label), which indicates that students were not opting out of Crossroads during the label phase. The number of servings per swipe is higher during the baseline period (6.2 servings per swipe for the baseline phase and 5.1 for the label phase), showing that students were getting more servings on average during the baseline phase (at the start of the semester) than later in the semester. This might be explained by the tendency to eat more in a buffet-style setting when there are many new food options, as is the case with first-year students during the start of the semester.

Table 1. Meal count and number of servings during the baseline and label phase

Period	Meal count (swipes)	Number of servings	Servings per swipe
Baseline phase	7,040	43,491	6.2
Label phase	7,736	39,703	5.1
Total	14,776	83,194	5.6

Distribution of Choices Across Label Color and Substitution in Selection of Dishes

Table 2 shows the distribution of choices across the three different labels in both phases. Green labels decreased by 4.6 percentage points (representing a 6% difference), yellow labels increased by 7 percentage points (representing a 40% difference) and red labels decreased by 2.5 percentage points (representing a 33% difference). The results from the z-tests show significant p-values and 95% confidence intervals for all three differences in proportions, as shown in Table 2.

Table 2. Summary statistics. Percentage of servings by color during the baseline and experiment phases

Label Color	Percentage in baseline	Percentage in experiment	Percentage point difference	Confidence Interval for % difference	p-Value
Green	75.1%	70.5%	-4.6	(-5.15, -3.93)	<0.001
Yellow	17.4%	24.4%	7.0	(6.47, 7.58)	<0.001
Red	7.5%	5.0%	-2.5	(-2.81, -2.15)	<0.001

***: $p < 0.01$, **: $p < 0.05$, *:$p < 0.1$. z-test of proportions, H0: no difference in the distribution of attributes between the control and label phase. P-values are adjusted using a Bonferroni correction for multiple testing.

Table 3 shows the distribution of choices between a high-emission dish and its low-emission substitute. The seven dishes in this analysis were selected because they had direct substitutions (the same dish was offered in a high-emission and low-emission version during the same day and meal period). For all seven dishes, the high-emitting dish carried a yellow label and the low-emitting dish carried a green label. The percentage of low-emission dishes in each period (columns 3 and 4 in Table 3) is given in reference to the total number of servings from both versions of the dish (servings from the high-emission and low-emission dish added together). The z-tests of proportions determined significant results for all but one of the dish substitutions (Cream Pasta vs Lemon Pasta, with a p-value of 0.731). Five out of the seven dish substitutions analyzed have a positive percentage point difference, indicating an increase in selection of the low-emission dish. Figure 4 illustrates the percentage point difference in selection of the low-emission substitute during the label phase when compared to the baseline phase.

Table 3. Percentage of servings for low-emission substitute compared across phases

Name of high-emission dish	Name of low-emission dish	% of low-emission dish in baseline period	% of low-emission dish in label period	Percentage point difference	Confidence Interval	P-Value
Chicken Tenders	Vegan Tenders	28.6%	20.0%	-8.6	(-13.01, -4.13)	<0.001
Cream Pasta	Lemon Pasta	52.2%	58.9%	6.7	(-0.66, 14.18)	0.731
Chicken Pasta	Tomato Pasta	27.3%	46.5%	19.2	(14.91, 23.55)	<0.001
Mushroom Cream Pasta	Marinara Pasta	72.0%	54.2%	-17.8	(-22.96, -12.71)	<0.001
Chicken Sub	Vegan Sub	14.3%	24.2%	9.9	(4.56, 15.36)	0.004
Al Pastor Torta	Spicy Bean Torta	16.7%	27.3%	10.6	(5.12, 16.09)	0.002
Shrimp Pasta	Primavera Pasta	15.2%	23.1%	7.9	(4.40, 11.45)	<0.001

***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$. z-test of proportions, H0: no difference in the distribution of attributes between the control and label phase. P-values are adjusted using a Bonferroni correction for multiple testing.

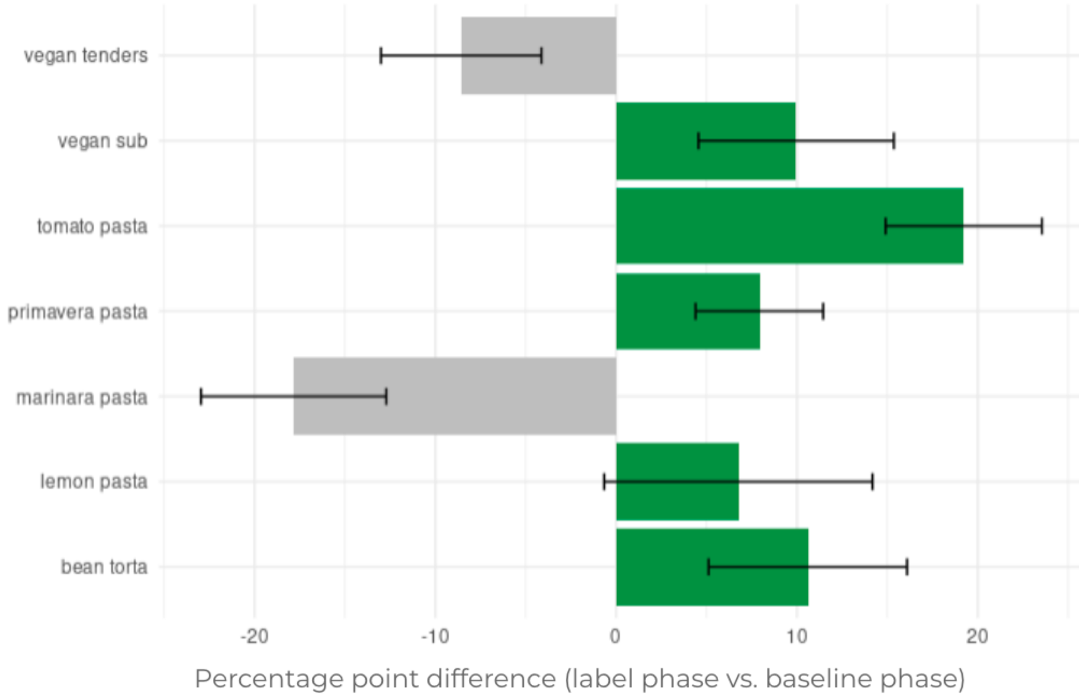

Fig. 4. Percentage change in the selection of low-emission dish substitutes compared to its higher-emitting counterparts

Effect on Greenhouse Gas Emissions

Given that the same menu items were offered at the dining hall during the control and label phases, I was able to directly compare the average emissions for the servings in the control phase and for those in the label phase. Figure 5 illustrates this comparison, showing the average emissions per serving for each phase and in aggregate (i.e. average of both phases) by label color. The grey bars represent the average emissions per serving for the baseline phase and experiment phase respectively. The average emissions per serving during the label phase decreased by 0.212 kg of CO_2-eq (from 1.58 to 1.37 kg of CO_2-eq), with a 95% confidence interval of (0.177, 0.247) given by the two-sample t-test performed ($p < 0.001$). The observed reduction of 0.212 kg of CO_2-eq per serving thus represents a significant 13% decrease in emissions compared to the baseline phase. As shown in Figure 5, the red labels drove this decrease in emissions, while the green and yellow labels didn't affect emissions.

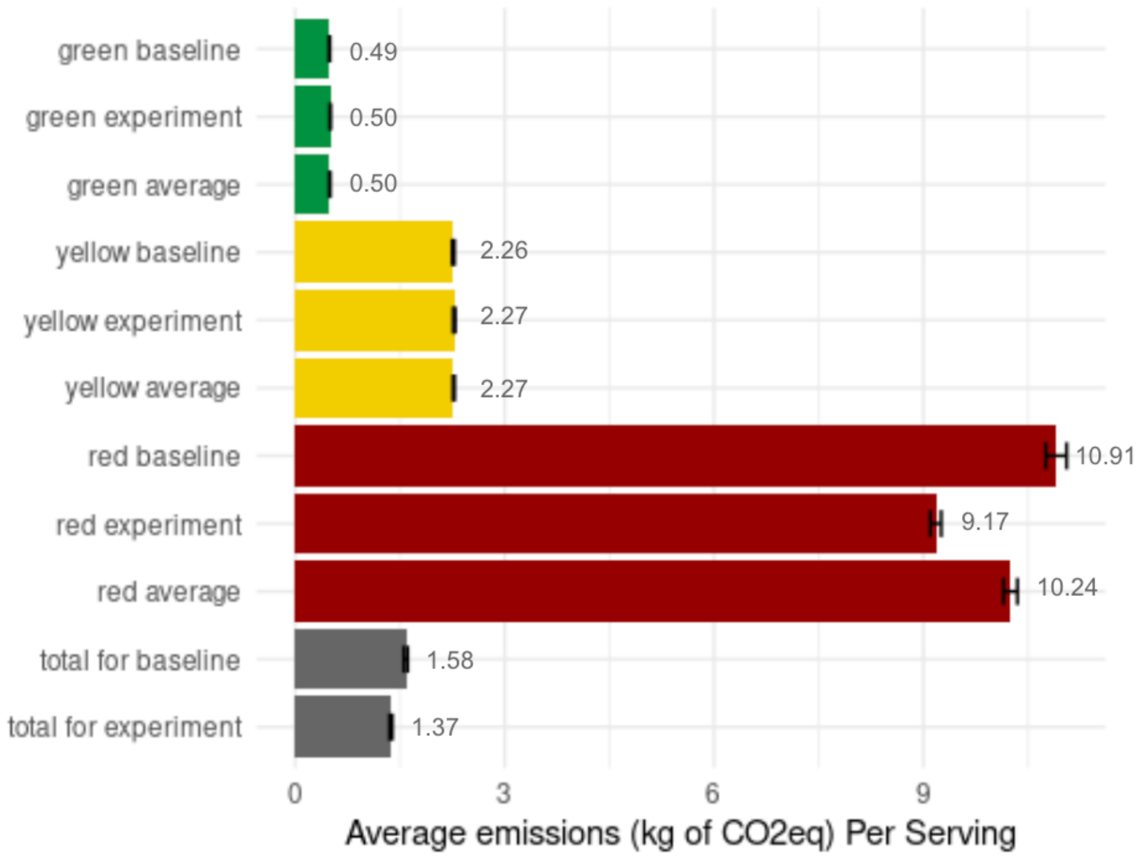

Fig. 5. Average emissions per serving (in kg of CO2eq), disaggregated into each label color and each phase and also including joint emissions (average of baseline and label phase) for each label color. The grey bars show average emissions per serving for all servings during the baseline period and experiment period respectively.

Total emissions between the label and baseline phases decreased by 14,426.8 kg of CO_2-eq. However, given that there were more observations in the baseline phase, this statistic does not indicate a reliable estimate for total emissions reduction. To obtain a reliable measure of the total emissions reduction between phases, I calculated the emissions reduction that we would have observed if the number of observations had stayed the same (using the average of observations across phases). Thus, if the number of observations had been 41,597 across both periods, and given the reduction in average emissions per serving, the total emissions reduction would be approximately 8,834 kg of CO_2-eq.

DISCUSSION AND LIMITATIONS

Discussion of Results

Contrary to Hypothesis 1, the proportion of green-labelled dishes decreased rather than increased, suggesting that the green labels did not have a positive effect on the selection of dishes. However, red labels did affect selection of red dishes negatively, as expected in

Hypothesis 1. The largest difference was observed in the yellow dishes with a 40% increase in selection, which can be explained by the decreases observed at the margins (in red and green labels) that caused the proportion of yellow dishes to rise as a consequence. The magnitude of change seen in the red-labelled dishes was similarly large, with a decrease of 33% compared to the baseline phase. Green labels only had a 6% difference between phases.

The lack of a positive effect of green labels on selection of green dishes could be explained by the proximity in emissions between yellow and green labels. Given that green and yellow dishes have more similar emissions than red dishes (which have much higher emissions)— and given that students were aware of these differences in emissions through educational posters put up at Crossroads (Figure 1)— it is possible that students were less motivated to choose green dishes over yellow dishes because both options might be perceived as environmentally-friendly, especially when compared to red dishes. Unlike studies by Vlaeminck et al. (2014) which found a trickle-effect on food choices (red dish consumers moving towards yellow, and yellow dish consumers moving toward green), this study suggests that while the red labels appear to affect consumers' choices, yellow labels don't appear to nudge consumers towards green dishes. However, without data on consumers' perceptions of the labels, this interpretation of the observed changes in selection of dishes is purely hypothetical and should be further studied.

The distribution of choices between direct dish substitutes showed a general trend toward selection of green-labelled dishes over their higher-emitting counterparts (yellow-labelled dishes). Therefore, while at the aggregate level green dishes decreased and yellow dishes increased during the label phase, we see that for dishes with direct low-emitting substitutes, students were generally choosing more of the green-labelled dishes. Thus, having direct dish substitutes might make carbon labelling projects more effective because consumers may be more motivated to choose the lower-emitting option when this option directly substitutes a higher-emitting dish that they would have normally preferred. This might have an even greater impact if direct dish substitutes were available for red-labelled dishes.

The observed emissions reduction of 0.212 kg of CO_2-eq per serving (representing a 13% reduction compared to average emissions per serving in the baseline phase) confirms Hypothesis 2. This is a larger greenhouse gas emissions reduction than previous studies have found (Brunner et al., 2018; Spaargaren et al., 2013). The observed decrease in red-labelled dishes drove this reduction in overall emissions, while changes in yellow and green dishes did not affect emissions. This finding suggests that lowering the selection of red labelled dishes should be prioritized in carbon labelling projects that aim to reduce greenhouse gas emissions. The importance of red labels in driving down emissions has also been shown in other studies (Brunner et al, 2018; Shewmake et al., 2015).

Limitations of Data and Method

The results of this study indicate that carbon labels do have an effect on consumers' food choices. However, the use of a dining hall for the field experiment conducted in this study limits the generalizability of the results. The sample in this study was comprised mostly of undergraduate students, whose awareness of and education on environmental issues likely differs significantly from the general population. These factors should be taken into account when using and interpreting the results of the study.

One of the main limitations came from the set-up at Crossroads which separated some of the vegan menu items from non-vegan options and placed them in a separate station. This posed a limitation to the experimental procedure because customers who wanted to choose a lower-emission substitute (for example choosing a vegan burger instead of a turkey burger) had to go to an entirely different station. By not placing all of the low-emission items in the same station as their higher-emitting counterparts, this set-up may have limited the effectiveness of the carbon labels.

Another limitation comes from the short-term scope of the field experiment. The effects of carbon labels over a longer period of time might differ from their short-term effects, as shown by Slapø and Karevold in a study that found that consumers returned to old consumption habits shortly after eco-labels were added (2019). Future studies should thus investigate the long-term effects of carbon labels at a university dining hall.

Lastly, the field experiment for this study was carried out amid the global coronavirus pandemic. This context limited the possibility of gathering qualitative data through surveys or focus groups, which could have led to insights on the knowledge, attitudes, and beliefs of students at the dining hall. The context of a global pandemic also impacts food choices and behaviors (Shen et al., 2020) which may have impacted the results of this study. Further research exploring the effects of the pandemic on food choices and integrating qualitative data on consumers' attitudes and beliefs will give a better understanding of the results.

This study provided evidence of the effects of a carbon label on food choices, using a university dining hall as a living laboratory (which provided a setting in which prices do not affect food choices). The study fills a gap in the literature and contributes to existing research on the potential for climate labelling to reduce food emissions.

CONCLUSION

This study suggests that information provision in the form of a traffic-light colored carbon labelling scheme, supplemented with additional educational posters, positively affects students' food choices at a university dining hall and leads to lower food-related emissions overall. The reduction in selection of red-labelled dishes was most significant at reducing overall greenhouse gas emissions. Therefore, lowering sales of red-labelled dishes should be a priority in climate labelling efforts that aim to decrease emissions. Further studies should test the long-term effects of traffic-light colored carbon labels on food choices as well as how perceptions, knowledge and attitudes change as a result of adding these labels.

ACKNOWLEDGEMENTS

Thank you to my mentor Ricardo San Martin PhD, and to my faculty sponsor Timothy Bowels PhD, for their guidance and assistance. Thank you to my YES Program research group Dr. Kristine Madsen, Emily Altman MPH, Richard Pulvera, Lizette Avina, and Taylor Young for their feedback and suggestions. And thank you to my friends and family for their love and support during this project.

REFERENCES

Brunner, F., Kurz, V., Bryngelsson, D., & Hedenus, F. (2018). Carbon Label at a University Restaurant – Label Implementation and Evaluation. *Ecological Economics*, *146*, 658–667. https://doi.org/10.1016/j.ecolecon.2017.12.012https://doi.org/10.1016/j.ecolecon.2014.10.019

Camilleri, A. R., Larrick, R. P., Hossain, S., & Patino-Echeverri, D. (2019). Consumers underestimate the emissions associated with food but are aided by labels. *Nature Climate Change*, *9*(1), 53–58. https://doi.org/10.1038/s41558-018-0354-z

Cleveland, D. A., & Jay, J. A. (2020). Integrating climate and food policies in higher education: A case study of the University of California. *Climate Policy*, *0*(0), 1–17. https://doi.org/10.1080/14693062.2020.1787939

Emberger-Klein, A., & Menrad, K. (2018). The effect of information provision on supermarket consumers' use of and preferences for carbon labels in Germany. *Journal of Cleaner Production*, *172*, 253–263. https://doi.org/10.1016/j.jclepro.2017.10.105

Grankvist, G., Dahlstrand, U., & Biel, A. (2004). The Impact of Environmental Labelling on Consumer Preference: Negative vs. Positive Labels. *Journal of Consumer Policy*, *27*(2), 213–230. https://doi.org/10.1023/B:COPO.0000028167.54739.94

Gravert, C., & Kurz, V. (2019). Nudging à la carte: A field experiment on climate-friendly food choice. *Behavioural Public Policy*, 1–18. https://doi.org/10.1017/bpp.2019.11

Grunert, K. G., Hieke, S., & Wills, J. (2014). Sustainability labels on food products: Consumer motivation, understanding and use. *Food Policy*, *44*, 177–189. https://doi.org/10.1016/j.foodpol.2013.12.001

Hartikainen, H., Roininen, T., Katajajuuri, J.-M., & Pulkkinen, H. (2014). Finnish consumer perceptions of carbon footprints and carbon labelling of food products. *Journal of Cleaner Production*, *73*, 285–293. https://doi.org/10.1016/j.jclepro.2013.09.018

Khanna, K. (2019, April). *Analysing Consumer Behaviour towards Implementation of Carbon Labels at a University Canteen*. ResearchGate. https://www.researchgate.net/publication/339166980_Analysing_Consumer_Behaviour_towards_Implementation_of_Carbon_Labels_at_a_University_Canteen

Leach, A. M., Emery, K. A., Gephart, J., Davis, K. F., Erisman, J. W., Leip, A., Pace, M. L., D'Odorico, P., Carr, J., Noll, L. C., Castner, E., & Galloway, J. N. (2016). Environmental impact food labels combining carbon, nitrogen, and water footprints. *Food Policy*, *61*(Significance 5 2008), 213–223. https://doi.org/10.1016/j.foodpol.2016.03.006

Littlewood, J. A., Lourenço, S., Iversen, C. L., & Hansen, G. L. (2016). Menu labelling is effective in reducing energy ordered and consumed: A systematic review and meta-analysis of recent studies. *Public Health Nutrition*, *19*(12), 2106–2121. https://doi.org/10.1017/S1368980015003468

Matsdotter, E., Elofsson, K., & Arntyr, J. (2014). *Got green milk? A field experimental trial of consumer demand for a climate label* (Working Paper Series 2014:2). Swedish University of Agricultural Sciences, Department Economics. https://econpapers.repec.org/paper/hhsslueko/2014_5f002.htm

Muller, L., Link to external site, this link will open in a new window, Lacroix, A., & Ruffieux, B. (2019). Environmental Labelling and Consumption Changes: A Food Choice Experiment. *Environmental and Resource Economics*, *73*(3), 871–897. http://dx.doi.org.libproxy.berkeley.edu/10.1007/s10640-019-00328-9

Sanchez-Sabate, R., Badilla-Briones, Y., & Sabaté, J. (2019). Understanding Attitudes towards Reducing Meat Consumption for Environmental Reasons. A Qualitative Synthesis Review. *Sustainability*, *11*(22), 6295. https://doi.org/10.3390/su11226295

Shen, W., Long, L. M., Shih, C.-H., & Ludy, M.-J. (2020). A Humanities-Based Explanation for the Effects of Emotional Eating and Perceived Stress on Food Choice Motives during the COVID-19 Pandemic. *Nutrients*, *12*(9), 2712. https://doi.org/10.3390/nu12092712

Shewmake, S., Okrent, A., Thabrew, L., & Vandenbergh, M. (2015). Predicting consumer demand responses to carbon labels. *Ecological Economics*, *119*, 168–180. https://doi.org/10.1016/j.ecolecon.2015.08.007

Slapø, H. B., & Karevold, K. I. (2019). Simple Eco-Labels to Nudge Customers Toward the Most Environmentally Friendly Warm Dishes: An Empirical Study in a Cafeteria Setting. *Frontiers in Sustainable Food Systems*, *3*. https://doi.org/10.3389/fsufs.2019.00040

Spaargaren, G., Koppen, C. S. A. (Kris) van, Janssen, A. M., Hendriksen, A., & Kolfschoten, C. J. (2013). Consumer Responses to the Carbon Labelling of Food: A Real Life Experiment in a Canteen Practice. *Sociologia Ruralis*, *53*(4), 432–453. https://doi.org/10.1111/soru.12009

Tan, M. Q. B., Tan, R. B. H., & Khoo, H. H. (2014). Prospects of carbon labelling – a life cycle point of view. *Journal of Cleaner Production*, *72*, 76–88. https://doi.org/10.1016/j.jclepro.2012.09.035

Tobler, C., Visschers, V. H. M., & Siegrist, M. (2011). Eating green. Consumers' willingness to adopt ecological food consumption behaviors. *Appetite*, *57*(3), 674–682. https://doi.org/10.1016/j.appet.2011.08.010

Visschers, V. H. M., & Siegrist, M. (2015). Does better for the environment mean less tasty? Offering more climate-friendly meals is good for the environment and customer satisfaction. *Appetite*, *95*, 475–483. https://doi.org/10.1016/j.appet.2015.08.013

Vlaeminck, P., Jiang, T., & Vranken, L. (2014). Food labeling and eco-friendly consumption: Experimental evidence from a Belgian supermarket. *Ecological Economics*, *108*, 180–190. https://doi.org/10.1016/j.ecolecon.2014.10.019

SUPPLEMENTARY DATA

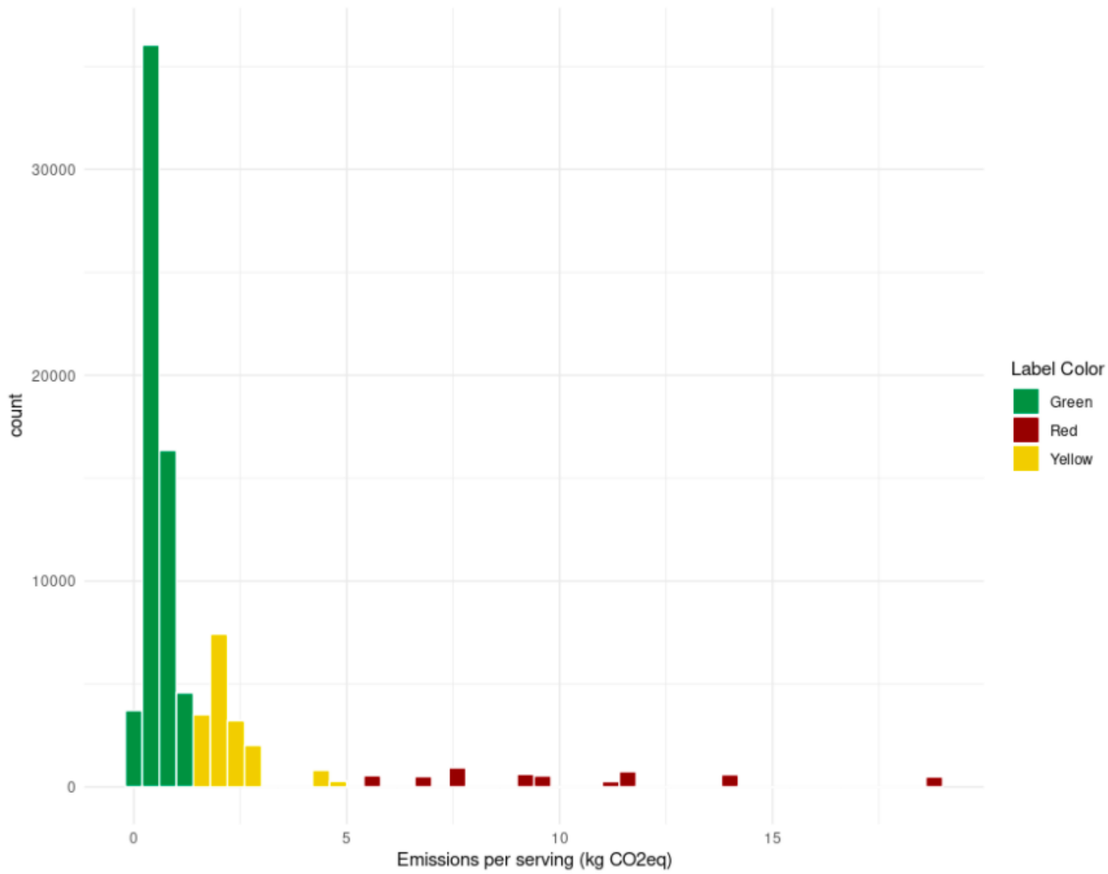

Figure 6. Histogram of emissions per serving, showing thresholds for label colors.