Measuring the Effects of Food Carbon Footprint Training on Consumers

Knowledge, Attitudes, and Behavioral Intentions

By Wayne Wakeland,[1] Lindsay Sears,[2] and Kumar Venkat[3]

Abstract

The supply chains through which foods are produced, processed, and transported can have a significant impact on the environment in terms of the carbon dioxide (CO_2) that is emitted during each of these phases; however, little research has incorporated information about environmental impact into supply chain scenarios. Moreover, many consumers are unaware of how their food choices may impact the environment in this way. To fill these gaps, a tool called CarbonScope was developed to show consumers the CO_2 emissions associated with different food types and food transportation scenarios. A short training was designed that walks participants through various food scenarios using CarbonScope. Participants from a major urban university were given pre- and post-training surveys to capture a) user reactions, b) learning gains, c) intentions to transfer the knowledge gained, and d) changes in beliefs about their individual environmental impact. The training resulted in significantly higher post-training knowledge test scores and environmental impact beliefs. Furthermore, most participants indicated that they intend to use the knowledge they gained from the training than not.

Keywords: carbon dioxide, food, CarbonScope, footprint

Introduction

Probably the most widely acknowledged environmental concern is the need to reduce carbon dioxide (CO_2) emissions on a global scale. Consequently, research on the CO_2 emissions (CO_2 footprint) associated with food production, food processing, and food transport, as well as research on how consumers respond to information about the CO_2 footprint of different foods, is becoming increasingly important. The CO_2 footprint of food varies considerably by food type primarily due to supply chain considerations, including how far the food travels from producer to consumer, what transport methods are used, and how food is packaged and stored.

While research into the environmental impact of foods is growing, there is also a need to educate the public so that people can become more capable and motivated to make sustainable food purchasing decisions. Consequently, the purpose of this study was to educate consumers about the CO_2 footprint of particular foods to help them more carefully consider their food selection decisions, and thereby increase their belief that food choices can influence the environment.

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Tools to assess the environmental impact (CO_2 footprint) of different foods are scarce and oftentimes cumbersome to use. Furthermore, the literature lacks research that measures the degree to which using such tools impacts consumer knowledge, beliefs, and intentions. To address this gap, we developed a web-based tool called CarbonScope that teaches consumers about the CO_2 footprint of different foods, depending on where they are grown or produced and how they are shipped. We also designed a web-based training tool built around the tool to walk learners through several CarbonScope food scenarios. We then conducted an evaluation study to assess the effectiveness of the tool and training.

The study was an interdisciplinary effort that employed engineering analysis to develop the content data, computer science to embed the data into a web-based analysis tool, and psychological expertise to develop the Food Carbon Footprint Training program and to evaluate the effectiveness of the training process. The training evaluation, which employed a quasi-experimental design, had four goals: 1) to gauge user reactions in order to improve the training, 2) to measure learning gains, 3) to capture intentions to transfer or use training, and 4) to assess changes in beliefs about one's individual impact on the environment.

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Research in Food Supply Chain

Food is provided to consumers via a supply chain. With the rapid increase of long-distance trade in recent decades, supply chains are also becoming increasingly complex, consuming significantly more fossil-fuel energy for transportation and emitting much more CO_2 than a few decades ago. For example, fruits and vegetables travel over 1,500 miles on average within the United States (a distance that has been widely quoted as an indicator of high "food miles"), and overall approximately one half of the energy usage associated with food production and delivery is related to transportation.[1] A basic diet with imported ingredients can consume four times the fossil-fuel energy and emit four times the CO_2 compared to domestically produced ingredients.[2]

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Particularly problematic is the growing use of trucks and airplanes instead of slower but more efficient trains and ships. The transportation sector already produces one quarter of all energy-related CO_2 emissions and these emissions are increasing rapidly.[3] In the United Kingdom, road transport has been identified as the largest source of CO_2 emissions.[4] Transportation is the fastest growing energy consumer in the European Union, with a 47% increase since 1985 compared with 4.2% for other sectors.[5]

The frequent deliveries required to preserve food freshness in food supply chains puts considerable stress on the environment.[6] Simons and Mason[6] suggest that producing food closer to the point of consumption and being more responsive to the consumer will lead to a win-win situation where time compression and emissions minimization can occur synergistically. Typical metrics for measuring environmental performance include scrap or non-product output, materials use, hazardous materials use, energy use, water use, air emissions, hazardous waste, and water pollution.[7] The metric used by Simons and Mason[6] divides the supply chain CO_2 emissions by the market weight of product.

Overall, the food production system accounted for 17% of all fossil fuel usage in the US in 2002,[8] and food consumption accounts for nearly a third of our individual CO_2 footprints.[9] The preceding statistics make it clear that sustainability of food supply chains will be a critical component of any effort to build a sustainable economy. Individual consumers play a significant role through their food choices.

Research in Web-Based Training

To create an interactive experience where consumers can effectively learn about their food choices and potentially change their purchasing behaviors, we designed a computer-based training module around the CarbonScope footprint analysis tool (described in greater detail in the Materials section). Computer-based training has been described as the "future of training."[10] This training represents a shift from passive, lecture-style learning in the classroom toward a learner-centered, learner-controlled training environment that is flexible and efficient. Computer-based training is highly effective provided it is well-designed and encourages active learning in participants.[11] Developers can encourage active learning by organizing information so it is easy to use balancing program guidance with learner control, and providing opportunities for practice and feedback.[10]

Computer-based learning has the added capability of producing simulated environments and scenarios in which learners can analyze information and actively interact with the components of the environment. This type of *experiential learning* leads to knowledge gains because learners are placed in a situation requiring their personal involvement in some way, causing them to experience real feelings of accomplishment and failure, as the simulation provides feedback.[12,13] Research also shows that learning is more likely to lead to behavioral change when the training encourages emotional arousal, operates within a "safe environment," and offers a cognitive map of information to guide the learner.[14]

With regard to research design, web-based studies allow researchers to control extraneous variables in the environment, which minimizes the impact of potential confounding variables and strengthens the causal inferences drawn from the data. Further, these tools allow for practice as well as rapid, consistent feedback on performance to a greater extent than instructor-led learning techniques.[12] These features have been linked to better training outcomes with regards to learning and post-training behavior change.[15–17]

Training Evaluation and Hypotheses

It is important to measure the effectiveness of the CarbonScope tool and the Food Carbon Footprint Training program using multiple criteria to provide a comprehensive understanding of their contributions.[18] Kirkpatrick[19] proposed a framework for evaluating training that included four components: reactions, learning, behavior, and results. The present study examined reactions, learning, and behavior outcomes of the training. Results relate to higher-level indicators of post-training change (e.g., a reduced U.S. carbon footprint), which is beyond the scope of the present research.

Reactions

In evaluating a training system, user reactions are important to measure for two reasons: They can be used to improve the training, and they tend to influence other training outcomes. There are two general categories of reactions: *affective reaction*s, or emotional reactions to the training, and *utility reactions*, which are subjective evaluations on the usefulness and effectiveness of the training. Utility reactions have a stronger relationship to learning and use of training than do affective reactions; however, affective reactions have a strong impact on these utility reactions.[21] For instance, people who like the training program will also tend to evaluate it as being useful. Those who rate the training as useful also tend to gain more knowledge and are more likely to use the knowledge than are people who do not find it useful.

To facilitate future tool improvement, we asked participants to rate various types of affective and utility reactions. For affective reactions, we asked about the extent to which the training is liked and fun. For utility reactions, we asked about the extent to which the training was useful, informative, clear, and functional.

Learning

While reactions are important in understanding how the tool and training are perceived, the primary objective was to increase participants' knowledge about ecologically friendly foods. To the greatest extent possible, we incorporated training design elements proven to enhance learning into the infrastructure (e.g., opportunity to interact, practice, feedback).[12] Therefore, we predicted that participant's post-training scores on food sustainability knowledge tests would be significantly higher than their pre-training scores.

Attitudes and Behavior

One aim of the research was to motivate participants to use the knowledge gained in training when making food selection decisions. Since both attitudes and behavioral intentions are thought to be predictive of real behaviors, they were used as proxies for actual behavior.[22–24] We were interested in attitudes about individual environmental influence and intentions to use the knowledge gained. Increased knowledge about the environmental impact of food purchases may change people's attitudes about their ability to influence the environment, and help motivate them to make beneficial behavioral changes.

While studies suggest that the public is becoming increasingly concerned about our ability to solve complex environmental problems, other research has shown that educating the public about problems in our environment can increase feelings of frustration, confusion, and powerlessness.[25] People may feel powerlessness, however, because they lack the tools or knowledge to help solve the problem. By teaching people how specific food purchases result in high/low levels of carbon emissions, the training game also shows people how it is possible for them to make a difference. We would therefore expect to see beliefs about the possibility of influencing the environment increase after the training.

In addition to educating participants about the CO_2 footprint of their foods, the training provides information about the meaning of CO_2 footprints, their impact on the environment, and the long-term implications of such outputs. Drawing from the expectancy theories of motivation, participants who believe that their behavior will lead to desired outcomes are more likely to do that behavior.[26] Therefore, we predict that the training will motivate participants to apply the information they learn, whether it be in their own food selection decisions or to educate others.

Materials

CarbonScope

CarbonScope[27] is an interactive web-based software tool that allows users to assess the energy and environmental impact of their food choices. Users identify their location in the United States, and then select food products from various U.S. and overseas locations. The results screen displays estimated energy consumption and CO_2 emissions, as well as some nutritional information, associated with each item in the list of products. The data used to calibrate the tool were gleaned from government agency resources[28–32] and other websites.[33,34] The data sources for energy use in food production included work by leading researchers.[35–41] Additional details regarding the CarbonScope database are provided elsewhere.[42]

Potentially thousands of foods, delivered over a wide variety of distribution networks—ranging from local farmer's markets to exotic foods air freighted across the globe—can be incorporated into the CarbonScope database. The current prototype includes 114 food items, including meats, seafood, grains, vegetables, fruits, and some processed foods; and three food distribution networks—regional, national, and global. Transportation options include truck, ocean, or air. Packaging and storage are also incorporated into the analysis.

Figure 1 is a screen shot from CarbonScope showing the user interface for adding food items. The user identifies his or her location and then adds as many food items as desired, specifying the amount of each food, where it is produced, and how it is transported.

Food Carbon Footprint Training

A short Food Carbon Footprint Training program was developed that employs the CarbonScope tool.

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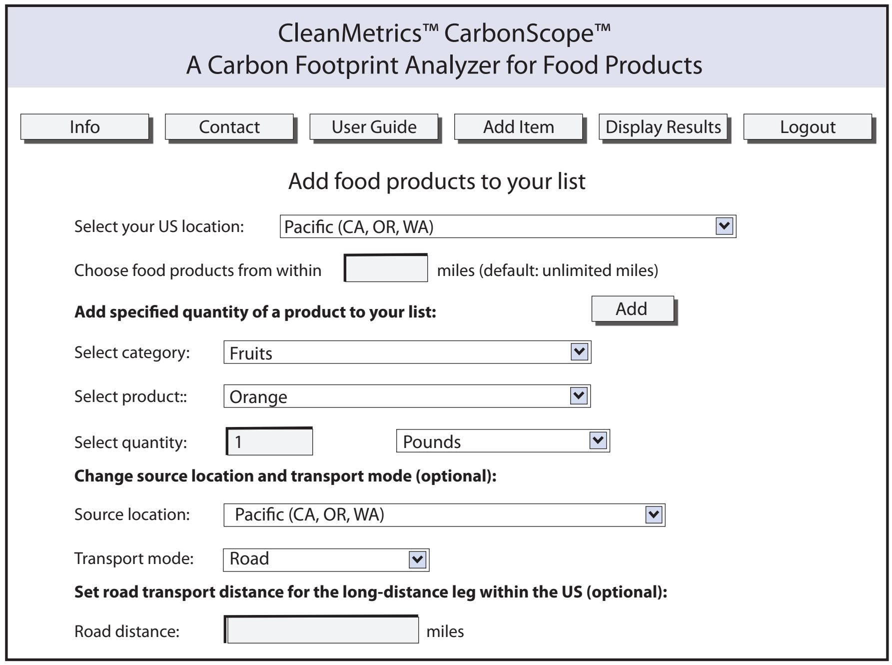


Fig. 1. Screenshot of the CarbonScope user interface for adding items.

The training was designed using best practices to achieve learning goals in this type of training program: repetition, hands-on activities, "what to notice," pop-up feedback windows, opportunities to practice, visual aids, and frequent information summaries. The training introduced the topic by providing information about the meaning of CO_2 footprints, their impact on the environment, and the long-term implications of such effects. The specific learning goals for the training were: a) that animal-based foods generally have a higher CO_2 footprint than plant-based foods, b) that wild meat and seafood have lower CO_2 footprints than their farmed equivalents, and c) that processed foods tend to have higher CO_2 footprints than their unprocessed equivalents.

Figure 2 is a screenshot from the training showing its "look and feel." Adobe Captivate (San Jose, CA) was used to deliver the training via the Web. The training walks the participant through various food scenarios using CarbonScope.

Study Method

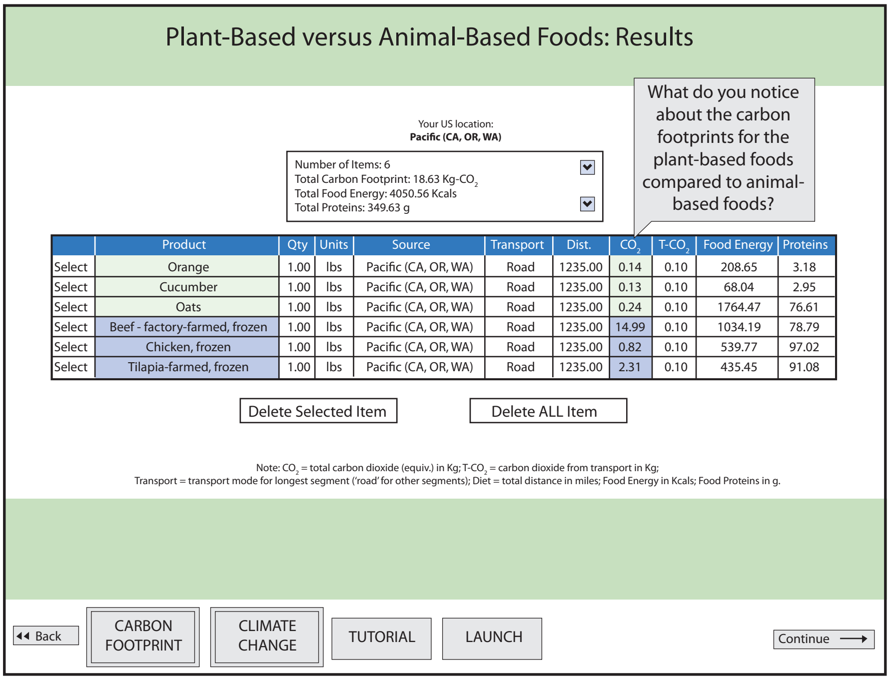
Participants

Graduate and undergraduate students from a public university in the northwestern United States were recruited from business, psychology, urban studies, and physical science classes to participate in the study. Of the approximately 800 students invited to participate, 331 completed the pre-training survey (41.4% response rate), and 268 of those students completed the training and post-training survey (81% retention rate; 33.5% total response rate). The majority of participants were female (62.2%), non-vegetarian (89.6%), non-vegan (99.2%), and Caucasian (76.9%; 11.9% Asian, 3.4% other, 3.0% Hispanic, 2.6% multiracial/multiethnic, 1.5% African American; 0.7% Native American/Pacific Islander). The average age of participants was 24.75 (SD = 6.81).

Procedure

The study employed a quasi-experimental design in which participants received a survey before and after training. Faculty members at the university who taught courses related to supply chain management, sustainability, psychology, and the physical sciences were asked to recruit students from their classes. All participants were entered in a drawing to win one of six $25 gift cards, and some were given extra credit for their participation. Students were given a link to a Web survey, which gave them the option of completing an alternative assignment. Students consenting to participate were directed to an online pre-training questionnaire in which they were asked about their basic demographics, pre-training knowledge about the CO_2 footprint of particular foods, and their environmental influence beliefs.

Participants were then directed to the web-based training program where they were shown how to use CarbonScope to enter food choices. The training also showed how CarbonScope presents the CO_2 footprint of each food choice. Participants were encouraged to experiment with alternative food scenarios. The training also showed whether the carbon resulted from the production, processing, or distribution



	Product	Qty	Units	Source	Transport	Dist.	CO_2	T-CO_2	Food Energy	Proteins
Select	Orange	1.00	lbs	Pacific (CA, OR, WA)	Road	1235.00	0.14	0.10	208.65	3.18
Select	Cucumber	1.00	lbs	Pacific (CA, OR, WA)	Road	1235.00	0.13	0.10	68.04	2.95
Select	Oats	1.00	lbs	Pacific (CA, OR, WA)	Road	1235.00	0.24	0.10	1764.47	76.61
Select	Beef - factory-farmed, frozen	1.00	lbs	Pacific (CA, OR, WA)	Road	1235.00	14.99	0.10	1034.19	78.79
Select	Chicken, frozen	1.00	lbs	Pacific (CA, OR, WA)	Road	1235.00	0.82	0.10	539.77	97.02
Select	Tilapia-farmed, frozen	1.00	lbs	Pacific (CA, OR, WA)	Road	1235.00	2.31	0.10	435.45	91.08

Fig. 2. Screenshot of the Food Carbon Footprint Training: "what to notice."

of the food. The training concluded with a summary of the key learning goals. After the training, participants were directed to an online post-training survey containing the following measures: reactions, knowledge, environmental influence beliefs, and behavioral intentions.

Measures

Demographics. Participants were asked their age, gender, ethnicity, and dietary constraints.

Reactions. Participants responded to six items in order to gauge different types of reactions to the training. One item stated, "In my opinion, the training was likeable." The other items were identical, except the adjective "likable" was replaced with other adjectives: "useful," "informative," "clear," "fun," and "functional." Participants rated the item on a 5-point agreement scale, where higher scores represented greater agreement with the training reaction statements.

Knowledge. Eight multiple choice questions were developed to assess knowledge of the three learning goals of the training. Knowledge items were dummy-coded as either correct or incorrect responses so that a proportion of correct responses could be computed. Higher proportions represent more correct responses.

Environmental influence beliefs. Participants responded to five items designed to assess one's beliefs that their actions can influence the environment. A sample item is, "My everyday decisions impact the Earth." Participants rated the items on a 5-point agreement scale. The scale demonstrated an alpha of 0.83 for the pre-training assessment and 0.79 for the post-training assessment. Item scores were averaged for the analyses. Higher scores represent a stronger belief that one's behavior affects the environment.

Behavioral intention. Participants rated three items designed to assess their intentions to use the knowledge gained in the training on a 5-point agreement scale. A sample item is, "I will use the knowledge learned in this training when I make food selection decisions." This scale demonstrated good internal consistency, with an alpha of 0.89. Item scores were averaged for the analyses. Higher scores represent greater intentions to use the training.

Results

Reactions

We used descriptive statistics to qualitatively assess how participants reacted to the training. Regarding affective reactions to the training, 40.6% of participants agreed that the training was fun (18.0% disagreed, 41.4% were neutral); and 67.2% of participants agreed that the training was enjoyable (6.0% disagreed, 26.5% were neutral). In terms of utility reactions, 86.9% found the training useful (4.1% disagreed, 9.0% were neutral); 93.2% found it informative (2.3% disagreed, 4.5% were neutral); 83.1% found it clear (4.1% disagreed, 12.8% were neutral); and 84.9% found it functional (2.6% disagreed, 12.3% were neutral).

Item scores were averaged for the analyses. Higher scores represent a stronger belief that one's behavior affects the environment.

> College campuses with significant numbers of older facilities have the opportunity to lead the green building movement.

Learning

The results of a paired sample *t*-test suggest that participants scored significantly higher on the post-training knowledge test ($M = 0.78$) than on the pre-training knowledge test ($M = 0.48$; $t(267) = -17.75$; $p < 0.001$), indicating that the training dramatically improved knowledge test scores overall and for each of the three knowledge components. These results lend strong support to our hypothesis that the training would lead to knowledge gains.

Attitudes and behavior

One goal of the training was to influence consumer behavior. As such, attitudinal change and behavioral intentions served as proxies for changed consumer behavior. The results of a paired sample t-test showed that participants had significantly higher environmental influence beliefs after the training ($M = 4.27$) compared with their pre-training score ($M = 4.08$; $t(265) = -5.33$; $p < 0.001$). This suggests that the training results in participants feeling they have more influence over their environment, which supports our hypothesis.

Descriptive statistics were used to determine the extent to which participants intended to use the training in various ways. Of the post-training responses, 69.0% agreed or strongly agreed that they would use the training in food purchasing decisions (10.5% disagreed, 20.5% were neutral); 75.3% said they would use the information the next time they went grocery shopping (9.0% disagreed, 15.7% were neutral); and 79.1% of participants claimed they intended to share some knowledge they learned with friends or family (5.6% disagreed, 15.3% were neutral). These results generally support our hypothesis that most participants would intend to use the knowledge gained in the training.

Discussion

The data provided by the CarbonScope tool showed that food choices can have a significant impact on the environment. The analysis also suggests that there may be interesting and practical trade-offs based on food types (between plant and animal foods, for example), production processes, transport methods, and distances.

Participants reacted well to CarbonScope and the Food Carbon Footprint Training, and offered many constructive suggestions. Their knowledge about the subject increased significantly, and their beliefs about their own environmental influence also increased—that is, participants left the training session with stronger beliefs that their actions can have an impact on the environment. Finally, most of the participants stated that they intended to use the knowledge gained in the training. These results suggest that the tool and training process provide a promising new way to teach and motivate people to consider environmental impact when selecting foods.

Innovative aspects of this research included: a) the use of supply chain sustainability models to analyze the CO_2 footprint for different foods, b) the development of a Web-based training process for educating consumers about food choices and their impact on the environment, and c) explicit measurement of behavioral intentions and change in user beliefs as a result of the training.

Although the results provide general support for the viability of the tool and training program, they should be interpreted with caution since the participants were not representative of the general population. Specifically this was a fairly young student sample that was predominantly female and Caucasian. Also, the training module required the use of computers and access to the Internet, which might restrict its accessibility to some population segments. Because the characteristics of this specific sample might have influenced our findings, future studies should test the training in more diverse samples of participants.

There is also a chance that response bias could have influenced the results. It is possible that people who are more environmentally concerned would be more likely to participate in the study, while those who are less interested in these issues would be more likely to opt out. In compliance with the Human Subjects Review Board, participants could refuse to participate or withdraw from the study at any time. Consequently, this issue is likely to remain a challenge for studies of this type; future research should explore recruitment strategies for appealing to individuals who lack interest in environmental issues.

Another possible limitation stems from the fact that the post-training questionnaire was given directly after training. There is no way to determine how long the knowledge acquired and change in beliefs will persist. Longitudinal studies in the future will address this question by conducting follow-up surveys at later time points. Lastly, the study measured behavioral intentions, which served as a proxy for actual behavior. The present study could not address bona fide behavioral change, but this is another area for future research.

Future plans for CarbonScope include expanding the list of food commodities (possibly to include beverages and highly processed foods), developing finer-grained distance calculations and more accurate farm production figures, and, possibly, adding recipes. Future plans for the Food Carbon Footprint Training include addressing nutritional and cost considerations, increasing the "fun" factor, and making the training process a richer experience overall. We also plan to expand the study to address a broader, larger, more diverse population; and to follow up with participants one and three months later to see if the changes in knowledge, behaviors, and environmental beliefs persist over time and to see if participants actually do change their behavior.

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