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To Wrap Or to Not Wrap Cucumbers?

Chandrima Shrivastava[1,2], Eleonora Crenna[3], Seraina Schudel[1], Kanaha Shoji[1], Daniel Onwude[1], Roland Hischier[3] and Thijs Defraeye[1*]

[1] Empa, Swiss Federal Laboratories for Materials Science and Technology, Laboratory for Biomimetic Membranes and Textiles, St. Gallen, Switzerland, [2] ARTORG Center for Biomedical Engineering Research, University of Bern, Bern, Switzerland, [3] Empa, Swiss Federal Laboratories for Materials Science and Technology, Technology and Society Laboratory, St. Gallen, Switzerland

In light of increasing public pressure, retailers strive to remove plastic packaging as much as possible from fresh fruits and vegetables to reduce the environmental impacts along their supply chains. Plastic packaging, however, also has an important protective function, similar to the fruit's peel. For cucumbers transported from Spain and sold in Switzerland, our investigations in the form of a life cycle assessment study showed that the plastic wrapping has a rather low environmental impact (only about 1%) in comparison to the total environmental impacts of the fruit from grower to grocer. Hence, each cucumber that has to be thrown away has the equivalent environmental impact of 93 plastic cucumber wraps. We found that plastic wrapping protects the environment more by saving more cucumbers from spoilage than it harms the environment by the additional use of plastic. If, by using the plastic wrap, we reduce cucumber losses at retail only by 1.1%, its use already has a net environmental benefit. Currently, in the cucumber import supply chain from Spain to Switzerland, the use of plastic wrapping lowers the cucumber losses at retail by an estimated 4.8%; therefore, it makes sense to use it from an environmental perspective. The environmental benefit of food waste reduction due to plastic wrapping the cucumbers was found to be 4.9 times higher than the negative environmental impact due to the packaging itself. Alternative strategies to preserve fresh cucumbers without using plastic wrapping will have to compete with this challenging limit.

Keywords: food packaging, food waste, cucumber, plastic, life cycle assessment, supply chain

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Petronela Švikruhová,
Slovak University of Agriculture, Slovakia

****Correspondence:***
Thijs Defraeye
thijs.defraeye@empa.ch

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INTRODUCTION

Perishable fruits and vegetables wrapped in plastic—such as cucumbers—are a common sight in supermarkets today. However, in recent times, there has been an increasing aversion in consumers toward the use of such plastic packaging. Most consumers identify the sustainability of a food product, especially fresh fruits and vegetables, more so by the minimal presence or complete absence of plastic packaging. They tend to perceive plastic as a symbol of the throwaway society (Wohner et al., 2019). At the same time, consumers use plastic packaging with much less reluctance for other food commodities to keep them fresh, for example, cooked foods, cheese, or meat in the fridge. As the perception of sustainability is increasingly becoming a crucial driver for purchase decisions, there has been a growing interest in retailers to minimize or eliminate the use of packaging, to project a product as environmentally sustainable. But this negative side of plastic packaging is largely overestimated by consumers in comparison to other personal actions with much higher impacts (Wynes and Nicholas, 2017; Bilstein, 2019; White and Lockyer, 2020). A typical example is the controversy of plastic versus paper bags for shopping. Here, paper bags hold a much higher environmental impact due to their higher weight (Hischier, 2019) but are nevertheless perceived to be more environmentally-friendly by many consumers. Therefore, it is imperative that the consumer is periodically made aware of the actual impacts of packaging in relation to the entire supply chain of a food product such as cucumbers, which is precisely the aim of this study.

The protective role of plastic packaging is often not fully known by consumers. The wrapping serves to protect perishable produce from undue moisture loss and contamination, thus prolonging their longevity or shelf life in a similar way as the peel of a fruit or vegetable. Studies have reported that cucumbers wrapped in plastic have a shelf life almost three times longer than unwrapped cucumbers due to reduced moisture loss (Dhall et al., 2012; Barlow and Morgan, 2013; WRAP, 2018). Hence, the plastic wrapping increases the amount of time that the product can be displayed on shelves of a supermarket and that they stay fresh after purchase. This is particularly important for all fruits and vegetables that are imported from abroad. In a situation where such fruits and vegetables (such as cucumbers) are sourced locally, the plastic wrapping can often successfully be omitted due to the much shorter and less time-consuming supply chain. However, the plastic wrapping is much more critical for imported cucumbers, which traverse a longer journey from farm to fork. Recent efforts by several retailers to omit plastic wrapping for cucumbers have actually resulted in much higher amounts of food waste for imported products (see FOCUS Online, 2019). Increased food waste due to the omission of plastic packaging increases the environmental impact due to the embodied energy and natural resources going into the production, distribution, and disposal of the food. The use of plastic wrapping can prevent such food waste, and therefore may not necessarily be an unsustainable solution. However, it is of paramount importance that when removing the plastic wrapping, we do not harm the environment more by increasing the carbon footprint of the supply chain due to higher food losses. This tradeoff is, however, very dependent to the specific supply chain that is targeted.

In the present study, we first answer the question of how relevant is the environmental impact of plastic wrapping within the cucumber import supply chain, compared to the total environmental impacts of the cucumber itself. For this, we target the entire chain of cucumbers imported to Switzerland from Spain and consider plastic wrapping for every single cucumber. Secondly, we answer here the question of how much reduction in food waste must the plastic wrapping bring about, in order that its beneficial effect of reducing food waste outweighs the negative impact of the plastic packaging itself.

METHODS

To answer these two questions, we investigated the supply chain of cucumbers by the support of a simplified Life Cycle Assessment (LCA) study. LCA is a widely used method to record and assess the effects of human activities on the environment, taking into account effects on water, land, and air along the entire value chain of a product or service (Ness et al., 2007), standardized within the ISO 14'040 series. Here we speak about a simplified LCA study, as we used as background system directly the Life Cycle Impact Assessment (LCIA) results from the inventory datasets out of version 3.6 of ecoinvent (Wernet et al., 2016) detailed in the **Supplementary Materials**; LCIA results that then have been linked with the specific data from the investigated cucumber supply chain (i.e., the case-specific life cycle inventory data described in Section Life Cycle Inventory below).

Goal and Scope Definition

For this study, we analyzed the supply chain of cucumbers imported from Spain and sold by retailers in Switzerland. The annual volume of cucumbers imported by a retailer in the Swiss market amounts to 3,408 metric tonnes (or tonnes) of cucumber (Personal communication, 2022). The analysis was conducted for two different scenarios: scenario 1 of a supply chain for cucumbers without plastic wrapping, and scenario 2 of a supply chain for cucumbers with a plastic wrap for each cucumber (**Figure 1**).

The system boundaries considered were each time from farm to point-of-sale (or grower to grocer), including the stages of agricultural production, packaging, distribution, retail, and end-of-life. The consumption stage was neglected due to the lack of data on food waste and consumer behavior in households. This assumption implies that the indirect effect of prolonged shelf life of the packaged cucumber after purchase is neglected, which would have, in turn, lowered the likelihood of food waste in households. The disposal of the packaging material, as well as the end-of-life of food waste during retail, were included in the analysis according to the current practice in Switzerland. For food waste disposal, we considered that 95% is composted (including the fraction actually used for feeding livestock), 3% is incinerated, and the remaining 2% is disposed of in landfill (Baier et al., 2016; Kawecki et al., 2018).

The functional unit chosen in our analysis was 1 metric tonne (i.e., 1 tonne) of cucumbers sold at retail. The functional unit was selected to compare the two systems (with and without plastic wrap) based on the function that is delivered (Cucurachi et al., 2019). For a cucumber supply chain, this function is to deliver a certain quantity of cucumbers to the consumer. Therefore, we defined our functional unit from a retail perspective. Based on this functional unit, we modeled the value chain of cucumber backwards, from retail to cultivation. It was assumed here that 5.5 g of low-density polyethylene (LDPE) is required for wrapping 1 kg of cucumber (Davis, 2011). Therefore, a standard-sized cucumber, typically weighing about 350 g, requires 1.93 g of plastic wrapping.

Life Cycle Inventory

Primary data related to the production and distribution of cucumbers in the Swiss market were obtained directly from a Swiss retailer. The distance for land transport of cucumbers in refrigerated trailers from suppliers in Spain to distribution centers in Switzerland was approximately 1,200 km (Georg, 2019). The data of the food waste of

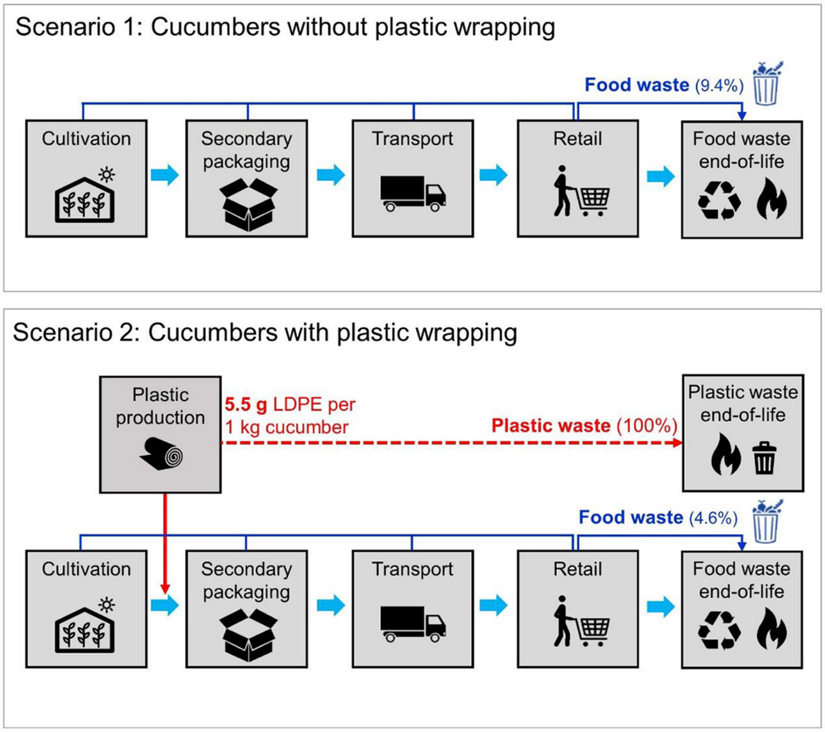

FIGURE 1 | Life cycle stages in the supply chain of cucumbers imported from Spain to Switzerland, corresponding to the two examined scenarios: without plastic wrapping (scenario 1) and with plastic wrapping (scenario 2). The share of food waste in both scenarios (i.e., 9.4 and 4.6%) has been accounted for in the calculations, so that 1 tonne of cucumber is sold at retail for both scenarios. This figure has been designed using resources from Flaticon.com.

Austrian retailers (based on a 6-month observation period in 250 stores) were used to estimate the difference in food waste at retail for cucumbers without plastic wrap (9.4%) and with plastic wrapping (4.6%) (Denkstatt, 2017). The estimated share of food waste at retail was used to back-calculate the starting volume of cucumbers cultivated (1103.75 and 1048.22 kg cucumber for scenarios 1 and 2, respectively), so that resultantly 1 tonne of cucumber is sold at retail for both the scenarios. Such an approach provides a better assessment of environmental impacts due to the embodied upstream resources and energy invested in food.

The end-of-life for plastic packaging waste was evaluated considering the amount of plastic used to wrap all the cucumbers, including those sold and wasted. Pre-harvest food losses during agricultural production were not considered, as we assumed that these losses do not differ between both scenarios. The losses occurring during transportation were omitted due to lack of specific information, acknowledging that this might underestimate the impacts of food waste along the supply chain. Secondary data for energy supply, packaging production, refrigerated transport, and waste treatment were calculated or obtained from literature for similar supply chains (Girgenti et al., 2014; Vinyes et al., 2017). The life cycle inventory of the supply chain of cucumbers according to the scenarios considered in this study is presented in **Table 1**.

Life Cycle Impact Assessment

We assessed the environmental impact of the cucumber supply chain by focusing on climate change. Here, we selected the global warming potential (GWP, kg CO_2-eq) as a measure of the environmental impact from greenhouse gas emission (IPCC, 2013). The GWP for the cultivation of cucumbers in a greenhouse was considered to be 2.13 kg CO_2-eq/kg cucumber, as obtained from collected meta-analysis data (Clune et al., 2017). This study primarily focuses on the GWP, although the trade-off between food waste and plastic packaging will also manifest itself in other impact categories. However, for impact categories such as land use, water use, and eutrophication, the impact of producing food (and consequently food waste) is very large relative to the impacts of plastic wrapping; therefore, these categories were not chosen for a comparative study (Nemecek et al., 2016). Note that in this study, we omitted the impact of eco-toxicity due to microplastics, as their fate and impacts are still not fully understood (Koelmans et al., 2019).

Environmental Break-Even Point Estimation

Dealing with the trade-off between food waste and plastic waste highlighted the importance of pinpointing exactly when it is ecologically better to use plastic wrapping. To this end, we calculated the environmental break-even point. This break-even point corresponds to how much reduction in food losses the

TABLE 1 | Life cycle inventory of the supply chain of cucumbers according to the scenarios presented in this study.

Life cycle stage	Description	Unit	Scenario 1	Scenario 2
Cultivation	Cucumber production in greenhouse	kg	1103.75	1048.22
Primary	Plastic film production (LDPE)	kg	NA	5.77
packaging	Energy for wrapping	kWh	NA	10.48
Secondary	Corrugated board box	kg	81.68	77.57
packaging	Pallet	unit	0.87	0.82
Transport	Lorry with refrigeration machine, cooling	tkm	1423.60	1358.85
Retail	Energy for electricity	kWh	325.47	309.09
	Water sprayed for hydration	kg	11.04	NA
End-of-life food waste	Composting (95%)	kg	98.57	45.81
	Incineration (3%)	kg	3.11	1.45
	Landfill (2%)	kg	2.08	0.96
End-of-life plastic waste	Incineration (100%)	kg	NA	5.77

Scenario 1 represents the supply chain of cucumbers without plastic wrapping and scenario 2 represents the cucumber supply chain with plastic wrapping. The starting volume of cucumbers cultivated (1103.75 and 1048.22 kg cucumber for scenarios 1 and 2, respectively) included the share of food waste in the respective scenarios (i.e., 9.4 and 4.6%), to provide the functional unit of 1 metric tonne of cucumber is sold at retail for both the scenarios. LDPE, low-density polyethylene. NA, not applicable. tkm, tonne × km.

TABLE 2 | Climate change impact expressed as kg CO_2-eq per metric tonne of cucumber sold at retail, for the cucumber supply chain without plastic wrapping (Scenario 1) and with plastic wrapping (Scenario 2).

Life cycle stage	Description	Scenario 1		Scenario 2	
		kg $CO_{2\text{-eq}}$	%	kg $CO_{2\text{-eq}}$	%
Primary	Plastic film production (LDPE)	NA	-	17	0.57
packaging	Energy for wrapping	NA	-	1	0.04
End-of-life plastic waste	Incineration (100%)	NA	-	14	0.45
Cultivation	Cucumber production in greenhouse	2,351	75.14	2,233	74.34
Secondary packaging	Corrugated board box	73	2.34	69	2.31
	Pallet	6	0.20	6	0.19
Transport	Lorry with refrigeration machine, cooling	658	21.02	627	20.90
Retail	Energy for electricity	34	1.10	33	1.09
	Water sprayed for hydration	0	0.00	NA	-
End-of-life	Composting (95%)	5	0.16	2	0.08
food waste	Incineration (3%)	0	0.00	0	0.00
	Landfill (2%)	1	0.04	1	0.02
Total balance	Summation	3,128	100	3,003	100

The share of impact of each stage is reported as a percentage. LDPE, low-density polyethylene. NA, not applicable.

plastic wrapping must induce, so that the use of plastic wrapping results in a net environmental benefit. These calculations were implemented using the Solver add-in of Microsoft Corporation (2016).

RESULTS

Relevance of Plastic Packaging Within the Cucumber Supply Chain (Question 1)

Table 2 presents the climate change-related impacts for the scenarios with and without plastic wrapping. Comparing the absolute numbers for the cucumber supply chain from Spain to Switzerland, the scenario with plastic wrapping leads to a 4% lower impact than the scenario without the wrapping. Considering the total volume of cucumbers sold at retail (3,408 tonnes of cucumber), we observe a net benefit of lowering greenhouse gas (GHG) emissions by about 426 tonne CO_2-eq. If we convert this to the social cost of carbon assigned for every tonne of CO_2-eq. emitted (i.e., CHF 150 per tonne CO_2-eq practiced by Swiss retailers; Gold Standard, 2016), the use of plastic wrapping in this supply chain can lower the net CO_2 emissions by about CHF 64 000 (or USD 71 000) annually in monetary terms. Switzerland generates about 4.35 tonnes of CO_2 emissions per capita per year (Global Carbon Atlas, 2018). This implies that the net reduction in GWP due to the use of plastic wrapping for cucumbers already equates to the annual carbon footprint of 98 Swiss persons.

Our analysis for scenario 2 (with plastic wrapping for cucumbers) revealed that a substantial contribution to the environmental impact comes from the energy-related environmental releases of the greenhouse cultivation of cucumbers (74%). Refrigerated transportation contributes to about 20% of the total impact. The impacts of the production and disposal of plastic packaging are comparably small. Plastic wrapping accounts for only 1% of the GHG emissions in the entire life cycle of an imported cucumber (**Figure 2**). The high climate change impact of cucumber cultivation results in a very high environmental benefit of reducing food waste. Then, every additional cucumber thrown away has a very high environmental cost due to the embodied energy and resources related to its production.

The relevance of plastic packaging within the entire supply chain depends much on the actual impacts of the cultivation phase. Other studies show a relative contribution that varies between 0.5 and 10% (Williams and Wikström, 2011; Wikström et al., 2014; Denkstatt, 2017; Hanssen et al., 2017; Molina-Besch et al., 2019; Wohner et al., 2019). A comprehensive case-by-case analysis is necessary for different fruits and vegetables, as the net environmental impact considering product and packaging systems is very sensitive to small details. Contributing factors include cultivation in open fields instead of greenhouses (Zarei et al., 2019), heat source of the greenhouse, the amount and type of packaging used, and the "food miles" associated with shorter supply chains for locally-sourced produce as opposed to longer supply chains for imported produce (Stoessel et al., 2012; Denkstatt, 2017).

A comparison of the two scenarios revealed that using plastic wrapping for cucumbers clearly reduces the overall climate change impact (**Figure 3A**). This is primarily because the benefit of a reduction in food waste is much more than the additional impact caused by the plastic wrapping. Indeed, when we explicitly compare the impacts caused by food waste and plastic wrapping, we observe that the use of plastic wrapping lowers the environmental impact due to food waste by 157 kg CO_2-eq per tonne cucumber, while itself having an impact of 32 kg CO_2-eq per tonne cucumber. Thus, the benefit of using plastic packaging in reducing food waste is almost 4.9 times higher than the negative environmental impact due to the packaging itself (**Figure 3B**). This impact will likely be larger, as we did not account for the reduced food waste at the consumer level due to wrapping. For easier comparison, the impact of one wasted cucumber (i.e., 0.992 kg CO_2-eq) was equated with the impact of the plastic amount required for wrapping a single cucumber (0.0106 kg CO_2-eq). It was found that every single cucumber thrown away equals the impacts of the plastic packaging needed to wrap 93 cucumbers.

Minimum Reduction in Food Waste (Question 2)

The supply chain of cucumbers without plastic wrap has an estimated food waste of 9.4% at retail, which is more than twice higher than the estimated food waste occurring when plastic wrapping is used, namely 4.6% (Denkstatt, 2017). To assess when it would make sense to use plastic wrapping from the ecological perspective, we calculated the environmental break-even point for using plastic wrapping for cucumbers (**Figure 4**). We quantified the minimum reduction in food loss at retail (ΔW, %) that must be brought about by plastic wrapping, so that the positive impact of food waste reduction exceeds the negative impact due to plastic. The green area in **Figure 4** indicates from which point onwards the use of plastic packaging is worthwhile and beneficial for the environment. In this region, the benefits of food waste reduction on climate change surpass the negative environmental impact due to plastic wrapping.

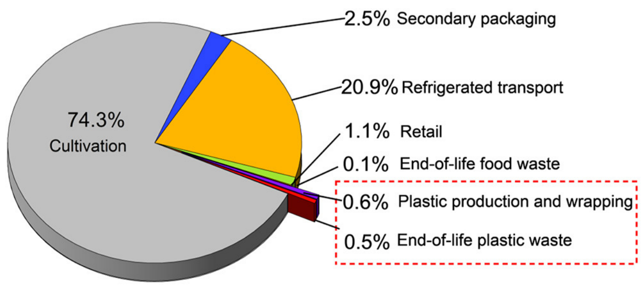

FIGURE 2 | Contribution of each life cycle stage of scenario 2 (supply chain for cucumbers with plastic wrapping) to the climate change impact of the entire cucumber import supply chain, from grower to grocer. The contribution of the plastic wrapping toward the environmental impact is highlighted in the red dotted box.

From our analysis, we found that the environmental break-even point is at a food loss of 8.3%, meaning a reduction of 1.1% for the food waste between the scenarios without and with packaging (indicated by the point of crossover in **Figure 4**). Hence, if the use of plastic wrapping brings down the food loss at retail from 9.4 to 8.3%, it already makes sense to use it from an environmental perspective. Plastic wrapping the cucumbers imported from Spain to Switzerland already lowers food waste at retail by an estimated 4.8% (i.e., from 9.4 to 4.6%) in the current case study (indicated by the dotted blue line in **Figure 4**), with a net lower environmental impact of 125 kg CO_2-eq per tonne of cucumber sold at retail. This reduction in food waste is clearly much more than the environmental break-even point of 1.1%. Therefore, from a climate change perspective, its use makes sense in the current supply chain. Moreover, plastic wrapping contributes further to indirect food waste reduction in households due to prolonged shelf life (Denkstatt, 2017). This presents a very challenging limit to compete with for any other strategies to preserve cucumbers without plastic wrapping, for example, by increased cooling within the supply chain.

DISCUSSION

In the cucumber supply chain from Spain to Switzerland, plastic wrapping has a protective function and is part of the solution to reduce avoidable food waste. Although perceived as an unnecessary evil by consumers, plastic packaging helps to protect the cucumbers from losing moisture, consequently prolonging their longevity and consumer acceptability without the use of additives. Few consumers acknowledge the environmental impact and monetary costs of the food wasted due to the absence of plastic packaging (Aschemann-Witzel et al., 2015).

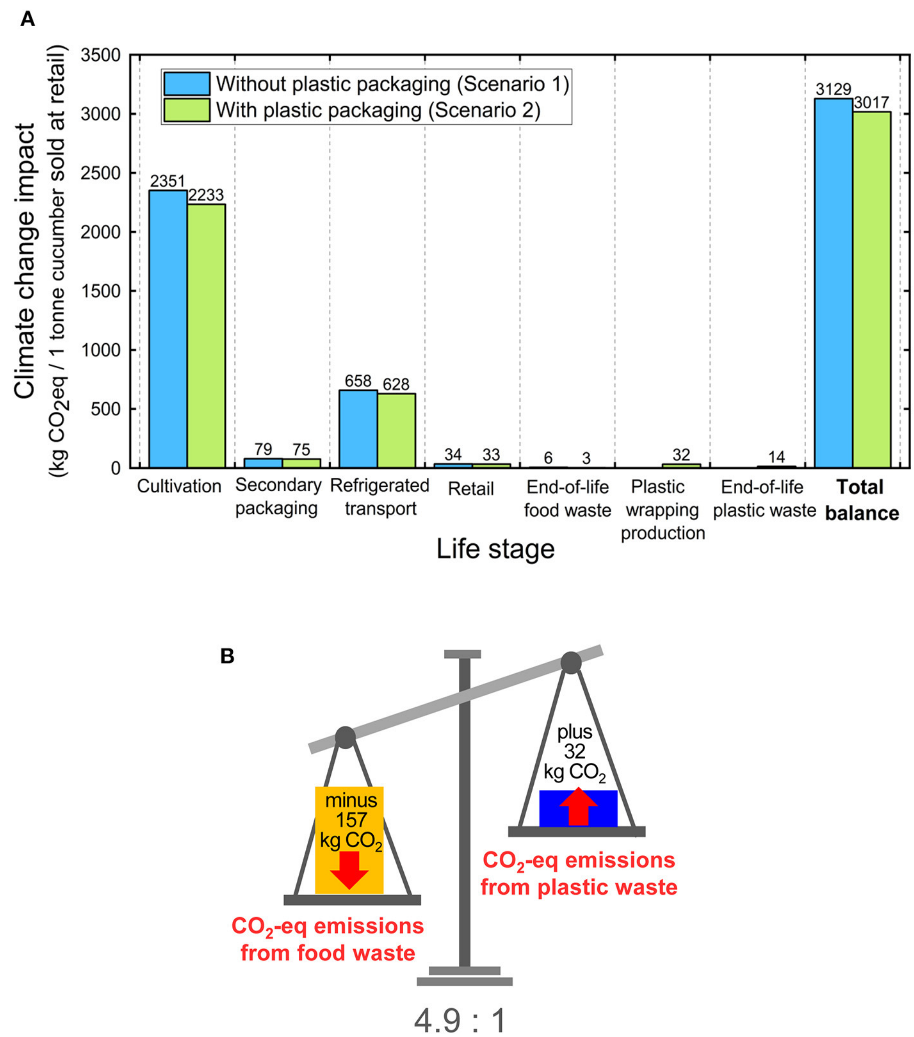

FIGURE 3 | (A) Relative differences in climate change impact throughout the cucumber lifecycle for the reference scenarios: without plastic wrapping (scenario 1) and with plastic wrapping (scenario 2). Here, we explicitly compare the difference in environmental impact arising due to food waste at the retailer, including its upstream impact and the impact due to additional plastic packaging. **(B)** A direct cumulative comparison between CO_2 emissions for the net balance comparing the impact of the reduction in food waste due to packaging with the impact of the packaging itself.

Consumers can be made more aware that cucumbers lost due to inadequate packaging usually have a higher environmental cost than the wrapping. Therefore, in this case study, it makes sense to use plastic packaging as a strategy to lower cucumber waste.

Another matter of concern is that the environmental impact of plastic and packaging is highly overestimated by consumers (Wynes and Nicholas, 2017; Bilstein, 2019). In comparison to the impact due to other personal actions such as lower air travel, the impact due to plastic is, in reality, much lower (Semadeni, 2020). It is crucial to explain the benefit of plastic packaging to consumers, educating them on food waste and the role of packaging in sustainability and lowering food waste. For example, this could be in the form of printing this message on the plastic package, making use of climate labels associated with food miles (Grunert et al., 2014), or conducting awareness-raising campaigns to highlight the necessity of plastic packaging for specific perishable food commodities.

Besides plastic wrapping, other solutions could be applied to lower the food waste in the cucumber supply chain and to prolong the shelf life of cucumbers. These include maintaining a high relative humidity at all times during transport and retail, cooling the cucumbers at retail, or using biodegradable packaging. However, it is imperative to ensure that these solutions do not harm the environment more by causing higher food loss or inducing a much higher energy consumption due to additional refrigeration. Some studies have attempted to replace the plastic wrapping with the use of edible biomaterial coatings such as lemongrass oil, pectin, and gum Arabic (Moalemiyan and Ramaswamy, 2012; Kahramanoglu and Usanmaz, 2019). Additionally, studies have demonstrated the potential in using biodegradable packaging materials such as compostable polyester

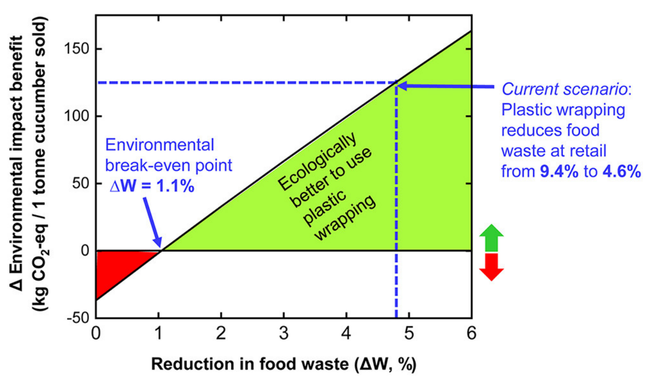

FIGURE 4 | Break-even analysis to indicate when the positive impact on climate change of food waste reduction due to plastic packaging surpasses the negative impact of additional plastic waste. The region shaded in green indicates when it makes sense to use packaging from an environmental perspective. The reduction in food waste (ΔW, %) corresponds to the difference in food waste at retail between scenarios 1 and 2. The Y-axis reflects the corresponding difference in environmental impact. The current scenario is indicated by the dotted blue line, where plastic packaging of imported cucumbers lowers food waste at retail by an estimated 4.8%, with a net lower environmental impact of 125 kg CO_2-eq per tonne of cucumber sold at retail.

blends or polylactic acid to preserve the quality of cucumbers (Li et al., 2021; Owoyemi et al., 2021). However, the environmental impact of these solutions must be evaluated for the respective use case before labeling these as "eco-friendly". A simple example would be if such materials are not locally produced, but rather imported, thus having a larger carbon footprint due to transportation. Break-even analysis emerges as an effective tool to determine the benchmark or threshold criteria that all such solutions need to match, so as to be ecologically equal to or better than plastic wrapping. Also, the findings of this study cannot be generalized to other fruits and vegetables, as every commodity has different drivers for quality loss. Thus, the shelf life extension potential of plastic wrapping, as well as the amount of plastic needed per commodity will be different, and these factors could drastically change the results.

The present study provides a compelling case for unveiling the trade-off between food waste and plastic packaging of food. Even though plastic packaging has its own associated impacts, it can significantly lower food waste in the entire supply chain, thereby lowering the net environmental impacts. Similar findings have been reported for other products such as apples (Silvenius et al., 2011), cheese (Wohner et al., 2019), steaks (Denkstatt, 2017), and bread (Williams and Wikström, 2011). Well-meaning intentions toward sustainability by reducing plastic packaging too much can therefore have an adverse effect by increasing the indirect environmental impact due to food waste (FOCUS Online, 2019). It is paramount for consumers to know and understand that additional vegetables are lost in the absence of packaging, and these losses can have a higher environmental cost than the package itself. Awareness of this balance is important to bring about a shift in the perceptions of food system stakeholders, packaging designers, and consumers alike, as "sustainability" may not always be synonymous with "the absence of packaging".

CONCLUSIONS

Overall, the key conclusions based on this analysis are as follows:

- Plastic wrapping contributes to only about 1.0% of the CO_2-equivalent impacts along the entire cucumber import supply chain from Spain to Switzerland.
- Cucumber wrapping leads to food waste reduction and results in a net benefit in climate change impact in the current supply chain, even when the added impacts of the packaging are taken into account.
- Every unwrapped cucumber thrown away has the same impact on climate change as the amount of plastic used to wrap 93 cucumbers.
- If, by adding the plastic packaging, we lower the food waste at retail even by 1.1%, the net environmental impact of the supply chain will be lower. In the supply chain of cucumbers imported from Spain to Switzerland, plastic wrapping reduces food waste at retail by an estimated 4.8% (from 9.4 to 4.6%). Therefore, the use of plastic wrapping already presents an environmental benefit with respect to climate change, and any other strategies to replace it must compete with this challenging limit.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

TD conceptualized this study, performed the project administration, wrote the proposal, and secured the project funding. TD, CS, EC, and RH developed the methodology for this study. CS and EC performed the calculations, data analysis, and interpretation and revised the manuscript based on their suggestions. CS performed visualization of the results and wrote the original draft of the manuscript with key inputs from TD, EC, and RH. TD, RH, SS, KS, and DO critically reviewed and edited the manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.750199/full#supplementary-material

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