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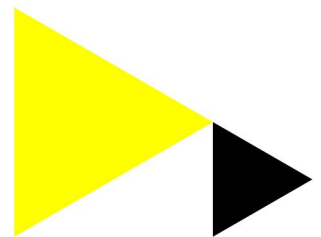
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Well packaged: Tradeoffs in sustainable food packaging design

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Abstract: Making food packaging more sustainable is a complex process. Research has shown that specific knowledge is needed to support packaging developers to holistically improve the sustainability of packaging. Within this study we aim to provide insights in the various tradeoffs designers face with the aim to provide insights for future sustainable food packaging (re)design endeavors. The study consists of analyzing and coding 19 reports in which bachelor students worked on assignments ranging from (1) analyzing the supply chain of a food product-packaging combination to (2) redesigning a specific food packaging. We identified 6 tradeoffs: (1) Perceived Sustainability vs. Achieved Sustainability, (2) Food Waste vs. Sustainability, (3) Branding vs. Sustainability, (4) Product Visibility vs. Sustainability, (5) Costs vs. Sustainability, and (6) Use Convenience vs Sustainability. We compared the six tradeoffs with literature. Two tradeoffs can be seen as additional to topics mentioned within literature, namely product visibility and use convenience. In addition, while preventing food waste is mentioned as an important functionality of food packaging, this functionality seems to be underexposed within practice.

Introduction

The industrialization, production and consumption of food has become more and more separated in time and space, which has led to a need for packaging food (Bruijnes et al., 2020). Food packaging fulfills a whole range of functionalities, from containing and portioning food to providing use convenience, marketing, communication, and transportation (e.g., Santi et al., 2022; Ten Klooster & De Koeijer, 2016). One of the underexposed functionalities of food packaging is food preservation and prolonging shelf life which helps reduce food waste (Guillard et al., 2018). Through these functionalities food packaging can help reduce the environmental impact of food (Wikström et al., 2019; Wohner et al., 2019). This shows the important role packaging fulfills, since packaging accounts for only 10% of the environmental impact as opposed to the food packaged in it, which is 90% (Bruijnes et al., 2020)- at least if recycling at the end of life is done properly.

Both on a European level as well as on national levels the need is felt to make the overall food system more sustainable. Packaging plays an important role in the ambitions to make the food system more sustainable, as it can both prevent food waste and be more sustainably designed itself (Brennan et al., 2021). In the Farm to Fork strategy, for example, the European Union not

only focuses on more sustainable material use, reuse, and recyclability of packaging, but also stresses the focus on preventing and reducing food waste (European Union, 2020). On a national level, the Dutch Plastics Pact committed to replacing single-use plastics for more sustainable alternatives, reducing the use of plastic with 20%, and improving recyclability of packaging by 2025 (Ellen MacArthur Foundation, 2019; Ministry of Infrastructure and the Environment, 2019).

Packaging design can become a complex process when having to balance between all the functionality and sustainability requirements. Designers face a web of tradeoffs when it comes to sustainable packaging design as they must consider factors such as extending product shelf life and improving consumer perception (Ten Klooster & De Koeijer, 2016).

State of the art research shows that specific knowledge that is needed to support designers' considerations when developing sustainable product-packaging combinations is limited. With this paper, we aim to provide insights in the tradeoffs in sustainable food packaging design with the aim of supporting designers in making sustainable packaging (re)design decisions.

Method

To uncover the tradeoffs, we gave students sustainable food packaging assignments ranging from (1) analyzing the supply chain of a food product-packaging combination (systems level) to (2) redesigning a specific food packaging (product level) according to different circularity strategies (e.g., rethink, reuse, recycle). The cases included sustainable redesign of agri-food (e.g., tomato (figure 1) and bell pepper packaging), portion packaging (e.g., margarine) and ready-to-eat meals (e.g., smoothies and microwave meals). Within this paper we focus on the analysis of agri-food-packaging cases to create a complementary list of tradeoffs, as we only managed to gather a wide range of assignments within this category. The students came from various educational backgrounds ranging from Industrial Design Engineering, Packaging Design and Food Innovation spread over three universities of Applied Science in the Netherlands: HAS green academy (HAS UAS), The Hague University of Applied Science (THUAS) and Amsterdam University of Applied Science (AUAS). These three institutes collaborated in a Dutch research project called “Goed Verpakt” (translation: Well packaged). We selected both bachelor graduation reports as well as reports from minor courses about sustainable packaging (design) (see table 1). We analyzed a total of 19 bachelo-level student reports.

Assignment	Institute	Type of report	Reports (#)
Supply chain analysis of chicory and apples	HAS UAS	Bachelor Graduation	1x
State of the art in online and offline agri-food packaging	HAS UAS	Bachelor Graduation	1x
Sustainable redesign of cherry tomato packaging	THUAS	Minor	11x
Sustainable redesign of bell pepper packaging.	AUAS	Minor	5x
Redesign of soft fruit (e.g., blueberries) packaging focusing on the use of paperboard packaging	AUAS	Bachelor Graduation	1x

Table 1: Overview of Agri-food packaging reports



Figure 1 : Cherry Tomato packaging. Foto credit : Greenco

To uncover the tradeoffs packaging designers face when creating sustainable food packaging we coded the reports. The written text proved to be most valuable for our sense-making efforts. Hence, we coded the written information in the reports. We applied the Gioia methodology (Gioia et al., 2012) to ensure qualitative rigor during the analyses process.

During the first step we stayed close to the terminology used by the students in their reports. Through several iterative rounds in which we assessed the essence of each quote so that we could cluster them into first order codes and later second order themes. We used so-called *phrasal descriptors* (e.g., unique packaging shape vs. efficient transport).

To ensure intercoder reliability, two researchers, supported by a research assistant, read each of the reports separately and wrote down all the sustainability tradeoffs that they encountered. We organized two work sessions during the analysis process to gather input from the full team of 8 researchers working on the Well Packaged research project). In the first session on December 2, 2022, we asked the researchers to go through selected reports and write down which tradeoffs they encountered for comparison. In the second session on January 27, 2023, we asked the researchers to categorize the additional tradeoffs that we had found. During this session the researchers also gave feedback on the definitions of the first order codes and the relevance of the findings. We also asked them to check whether the formulated tradeoffs were actual tradeoffs and to categorize them (table 2).

Phases	Activities	People Involved
Report Analysis part 1	First round of analyzing report and formulating tradeoffs	Two main researchers
Pressure cooker	Analyzing six selected reports	Extended research team
Report Analysis part 2	Second round of analyzing reports and formulating (additional) tradeoffs	Two main researchers supported by research assistant
Work session 2	Discussing the definitions of the tradeoffs found in the second round as well as categorizing them and discussing the relevance	Extended research team

Table 2: Overview of research Process

Results

In total we identified 71 first order concepts (a summary of the codes is presented here) and 16 second order themes, which were clustered in a total of 6 aggregated themes (see table 3). We did not find different tradeoffs between reports in which students applied different circularity strategies (e.g., rethink, reuse, recycle).

First order codes	Second order theme(s)	Aggregated themes
<ul style="list-style-type: none"> Replacing plastic with cardboard based on customer perception. (<i>Bell pepper reports; Cherry tomatoes reports; Soft fruit report and State of agri-food packaging report</i>) Considering replacing packaging materials based on the customer's perception of sustainability instead of considering overall environmental impact across the full life cycle (<i>Cherry tomatoes reports</i>) 	<ul style="list-style-type: none"> Making packaging choices based on the consumers' perception of sustainability vs. scientifically proved sustainability 	Perceived sustainability vs. Achieved sustainability
<ul style="list-style-type: none"> Choosing virgin plastic instead of recycled plastics for chicory packaging to prevent the bag from easy tearing during transport and use. Choosing a thicker material to protect the packaging from tearing during transport during transport (<i>Chicory and apples report</i>) Packaging fruit or vegetables to prevent it from getting damaged during transport (<i>Chicory, apples, and soft fruit reports</i>) 	<ul style="list-style-type: none"> Reducing/Saving material to lower the environmental impact (e.g., recyclability) of the packaging vs. Adding packaging to prevent food waste Exchanging the material to lower the environmental impact of the packaging vs. Improving recyclability Exchanging the material to improve recyclability vs. Choosing a material that prevent food waste Exchanging the material to lower the environmental impact vs. Reducing the weight of materials Reducing/Saving material to lower the environmental impact of the packaging vs. Adding packaging to meet requirement of stakeholders in the chain Choosing a packaging shape to prevent food waste vs. Optimizing the packaging for efficient transport. 	Food waste vs. Sustainability
<ul style="list-style-type: none"> Choosing the function of branding over a more sustainable packaging (<i>Cherry tomato, soft fruit reports</i>) Adding a label or a sticker for branding. Making a complicated design to stand out. (<i>Cherry tomato reports; Chicory and apples report</i>) 	<ul style="list-style-type: none"> Increasing the product surface for branding vs. Reducing/Saving materials to lower the environmental impact. Adding extra materials meant for branding vs. Reducing/Saving materials to lower the environmental impact. Choosing a unique packaging shape to stand out on the shelf vs. Optimizing the packaging for efficient transport. 	Branding vs. Sustainability
<ul style="list-style-type: none"> Adding a small window in the packaging so customers can see whether the tomatoes are fresh. This solution often entailed adding a material (e.g., plastic) which means an extra step for the customer to separate the material in the throw-away stage or means getting 	<ul style="list-style-type: none"> Increasing visibility of the product in the packaging (by adding transparent materials, reducing shape integrity, or changing materials) vs. Reducing the environmental impact of the packaging. 	Product visibility vs. Sustainability



plastic in the paper waste. (<i>Cherry tomato reports; Bell pepper reports; Soft fruit report</i>)		
<ul style="list-style-type: none"> Focus on saving costs by buying it from a supplier far away while not considering the environmental impact of for example, production and transport (<i>Cherry tomato reports</i>) Hesitance to invest in making current packaging more sustainable (<i>Cherry tomato reports; Chicory and apples report</i>) 	<ul style="list-style-type: none"> Saving costs vs. Improving recyclability; Saving costs vs. Investing in more sustainable product-packaging combinations; Sourcing cheap materials to save costs vs. Sourcing materials with a lower environmental impact. 	Costs vs. Sustainability
<ul style="list-style-type: none"> Apples being packaged in a more convenient way for the customer (e.g., in a tray per 4) while there is no other need to pack them. (<i>Chicory and apples report; Cherry tomato reports</i>) 	<ul style="list-style-type: none"> Adding packaging to make improve use convenience vs. Reducing packaging to lower environmental impact. Choosing a convenient packaging shape (for the end user) vs. Efficient during transport 	Use convenience vs. Sustainability

Table 3 Overview of 6 main tradeoffs in agri-food packaging

Discussion

Within this study we identified 6 main tradeoffs in sustainable food packaging. While some of the tradeoffs are new, other tradeoffs are further extensions of tradeoffs formulated within literature.

First, the tradeoff **Perceived sustainability vs. Achieved sustainability** is defined as: choosing packaging materials based on customers' perception regarding sustainability instead of based on scientific research about sustainable application of a specific packaging material. This tradeoff was mentioned by de Koeijer et al. (2017) in the context of different organizational roles whereby desired sustainability goals on strategic level do not always match with the perceived and achieved sustainability outcomes on operational level. Within this study we mainly found a contradiction between the last two types of sustainability. This can be traced back to students working on assignments set by industry clients. Yet, this brings into question the influence of the consumer and the potential green washing effect. To what extent do we need to educate the customer about the intricacies of sustainable packaging?

Second, the tradeoff **Food waste vs. Sustainability** is defined as: optimizing only the packaging as opposed to the whole product-packaging-combination (on system's level) for sustainability. Optimizing only the packaging by, for example, choosing less materials could result in food waste throughout the chain. While literature does mention the impact of food waste as opposed to packaging

- food waste accounts for 90% of the environmental impact versus the packaging 10% (Bruijnes et al., 2020) - we could not find literature that extensively mentions the need to sometimes steer away from conventional sustainability guidelines (e.g., reducing the weight of packaging, choosing virgin material instead of recycled material) to prevent food waste.

Third, the tradeoff **Branding vs. Sustainability** is defined as: choosing the function of branding over a more sustainable packaging. This trade off can be found within literature as well. Barriers between achieved and perceived sustainability can be traced back to conflicts between sustainability considerations, and inter alia integration commercial requirements and integration of marketing (de Koeijer et al., 2017). Within our study we found that when the design students focused on redesigning the packaging to make it "look more sustainable" they simultaneously resorted to tactics to add branding surface. This conflicts with general sustainability rules.

Fourth, the tradeoff **Product visibility vs. Sustainability** is defined as: prioritizing visibility of the product in the packaging over sustainability packaging guidelines. This tradeoff is different and should be seen as separate from branding; product visibility was steered by the need to assess the state of the product in the packaging. Within literature we could not find this specific barrier. Yet, an interesting finding within the reports indicated that the way the agri-food products were packaged became irrelevant when they were sold online. This brings into question the need to provide visibility within agri-food packaging.

Fifth, **Costs vs. Sustainability** is defined as: prioritizing saving material and production costs without considering the



environmental impact of the sourcing, production, use and end-of life of the material. It comes down to (1) prioritizing saving material and packaging production costs without considering the environmental impact of sourcing, production, use and end-of life of the material and (2) reluctance to invest in new sustainable packaging innovation. Cost as a barrier for sustainable packaging redesign has been mentioned already in 1992 by Kassaye and Verma (1992) and is still mentioned as an important barrier that can hinder the development of sustainable food packaging (Guillard et al., 2018; Santi et al., 2022). Bruijnes et al. (2020) however stress that although it is hard to put in effort without seeing direct result, it is important to still try and think about the long term.

Last, **Use convenience vs Sustainability** is defined as: prioritizing the use convenience for customers over the actual need to pack certain food items. For example, when it comes to apples which can be found (un)packed in various ways (e.g., unpacked, packed in a tray per 4 or 6, and packed in a plastic bag). This raised the question of the function of the packaging and its environmental impact. Use convenience is one of the elements that is mentioned in literature as a functionality of packaging (Santi et al., 2022). Yet, our study shows that it could in fact hinder sustainable packaging development.

Further Research

First, while not exclusively, this study mainly centered around packaging designers. Yet, in practice, designers are only one of the stakeholders involved in (re)designs packaging. They often receive a specific framed assignment from higher up. This suggest that all involved departments should be made aware of the identified sustainability tradeoffs. One step further would be: management having to work with the stakeholders when developing the sustainability strategy. Further research could investigate how the tradeoffs could be incorporated on a strategic level.

Second, within this study we only looked at student reports. While most assignments were commissioned by real life companies (reflecting which requirements are important to them as well), the outcomes of the reports are influenced by the level of knowledge and experience of the students. Further research should therefore focus on how well the list of tradeoffs resonates with designers in practice

and how this list can be used as a tool during the design process.

Third, we expected to find different tradeoffs in the reports in which students applied redesign in comparison to rethink as they would focus on respectively redesigning the existing product-packaging combination vs. looking at system-level solutions. However, the reports did not show differing outcomes. This could be because we only analyzed reports made by students, who are more inexperienced than designers working in practice. Hence, further research should focus on the extent to which the tradeoffs are linked and how applying a systems level circularity strategy such as *rethink* could help to bypass multiple tradeoffs. Last, the tradeoffs found in this paper were only based on agri-food cases. Hence it would be interesting for further research to what extent the tradeoffs apply to other food packaging categories (e.g., portion and ready-to-eat).

Conclusion

With this study we aimed to provide a list of tradeoffs that designers face when developing sustainable packaging. Based on the analysis of 19 student reports we found 6 main tradeoffs: (1) Perceived Sustainability vs. Achieved Sustainability, (2) Food Waste vs. Sustainability, (3) Branding vs. Sustainability, (4) Product Visibility vs. Sustainability, (5) Costs vs. Sustainability, and (6) Use Convenience vs Sustainability. On their own, these tradeoffs present challenges when developing sustainable (food) packaging, but they also are related to each other. Fulfilling multiple competing functionalities such as branding, product visibility and providing use convenience can all counteract with each other and with environmental sustainability efforts as it can result in more material use. This makes it even more complex for designers to make clear choices. This first overview of tradeoffs forms a base of knowledge that can help designers in practice make more informed decisions concerning sustainable food packaging design.

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packaging-combinations. Goed Verpakt is co-funded by Regieorgaan SIA (RAAK-mkb), part of Dutch research council (NWO).

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