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Dear editor at Trends in Food Science and Technology,

I herewith submit the commentary ‘The dual role of upcycling in reducing food loss and waste’ for consideration in Trends in Food Science and Technology. Upcycled food is a new trend on the market with various definitions presented by academics and stakeholders. However, we think that these do not yet shed sufficient light on the two types of products that we see emerging, and that it is currently undervalued how upcycled food in its more radical sense can not only avoid food waste, but broaden the food available. We thus suggest expanding the definition of upcycled food with the two-folded definition that we explain in this commentary. We also think that to further holistic food system thinking, it is important to highlight that upcycled food entails a dynamic over time and is interdependent. We thus explain the boundaries that this entails and discuss how different actors should deal with it.

We hope you can see the value of this topical commentary for the readership of Trends in Food Science and Technology.

Thank you very much in advance.

On behalf of the authors, Jessica Aschemann-Witzel

The dual role of upcycling in reducing food loss and waste

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JEAW conceptualized the content and wrote the draft. All other authors contributed otherwise equally to the discussion preceding the commentary and finetuning of the content and to the manuscript and are therefore listed in alphabetical order.

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None.

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Abstract

Background: Food loss and waste over-uses natural resources and is responsible for a considerable share of greenhouse gas (GHG) emissions. Moreover, increasing food prices and growing food insecurity internationally make instances of food wastage appear even more irresponsible and showcase the inefficiencies of the current food system. A new concept in the toolbox for fighting food loss and waste is upcycling – value enhancing use of ingredients otherwise wasted – that leads to upcycled food. However, not all products currently called 'upcycled food' live up to the resource-saving and value-adding promise entailed in the idea of 'upcycling', and products markedly differ in how 'radical' the upcycling is from a consumer perspective.

Scope and Approach: To shed light on this, we introduce a two-folded definition that hinges on current consumer edibility perception and has a view to changing consumer perception; We show that there are two types of upcycled food which each have a distinct role and contribution to preserving natural resources - one is avoiding resources are wasted that have gone into food production, thus constituting upcycled foods through *alternative* use, the other is diversifying and broadening the food resource base, thus constituting upcycled foods through *novel* use. We provide examples of these upcycled food types and highlight potential boundaries from a sustainable development goal perspective.

Key Findings and Conclusions: Mainstreaming the idea of upcycling in food systems has huge potential for improving circularity in the food system. Untapping this potential needs collaboration across the whole value chain and taking a food system perspective, such as when being well-aware of the boundaries arising from the dynamic nature of the topic and the interdependencies.

Keywords

Food waste; Consumer behaviour; Upcycling; Waste to value; Definition; Concept

Introduction

The food system alone is responsible for a third of global greenhouse gas (GHG) emissions (Crippa et al., 2021; Foley et al, 2017; Poore & Nemecek, 2018). Food waste (common term used to cover both food loss and waste) account for circa 8-10 % of total human caused GHG emissions (IPCC 2019). This inefficient use of up to a third of our food (UNEP, 2021) unnecessarily heightens the strain that agriculture puts on the planetary ecosystems (Steffen et al. 2015; Godfray et al., 2010). In addition, in a situation with increasing food prices and growing food insecurity around the world (FAO, 2021, 2022; Hasegawa, 2021; van Dijk et al., 2021), wastage of nutrients or food reveals the inefficiencies in the current food system and appears irresponsible in the light of the sustainable development goals (EC, 2020a). Luckily, the issue of food waste has been acknowledged internationally. There are more and more initiatives taken to exchange knowledge and data on how to curtail food waste across the value chain and in public-private partnerships (for example: EC, 2022; WFP, 2022; FAO, 2022). Food waste, however, is a complex challenge not easily solved, and needs a broad and diverse range of actions (Aschemann-Witzel 2016).

A new concept in the toolbox of food waste reduction is upcycled food. The term is increasingly used in the food area and trend reports predict a huge market potential (BusinessWire 2021; FMCG Gurus, 2022; Forbes, 2021; The Washington Post, 2021; Euromonitor, 2022). Upcycled food has also been discussed under the terms waste-to-value, value-added-surplus products, or side-stream valorization (Aschemann-Witzel & Stangherlin, 2021; Teigiserova et al., 2020; Coderoni & Perito, 2020). Upcycled food introduces a key concept from circular economy, the upcycling, to the food sector. It is well in line with policy trends towards supporting 'closing the loop' in major industries, including the food and agriculture sector (EC, 2020b). At the same time, upcycling is also a term gaining popularity as a green consumer behavior trend (Wilson, 2016: Kamleitner et al., 2019; Adıgüzel & Donato, 2021). Environmental concern,

climate change worries and willingness to take sustainability into account in food choice and diets are rising – 78% of Europeans regard climate change as a serious problem (Eurobarometer, 2021). The Eurobarometer (repeated European-wide surveys funded by the European Union) 513 showed that up to 2 out of 3 Europeans see the food industry (i.e. producers, manufacturers) as "the most important actor to make food systems sustainable" (p. 47). Due to these reasons, 'upcycled food' can be expected to entail an important potential for the sustainable transition of the agriculture and food sector. Given such a sustainable transition of the production as well as consumption of food needs more diversity as well as more plant- and less animal-based foods, we argue that upcycled foods are well in line with the planetary diet suggested by the EAT-Lancet report – they are about uncovering new and diverse sources of food, and most upcycled food are plant-based (Willet et al., 2019).

However, pursuing upcycling needs a clear definition of the concept and being aware of the boundaries and pitfalls that arises from the dynamic nature of the definition. Looking at the market, we see two product groups emerging that differ in how radical upcycling of 'waste' is from a consumer point of view because they differ in edibility perception, and these two groups contribute to solving the problem in different ways. To put it more bluntly, we assess that one of the two groups rather tackles the symptoms but not the underlying issues and thus has a valuable but more intermediate contribution. The other group, in turn, goes more to the root of food waste and sustainability issues, and thus has a more long-term and profound contribution. We have written this piece and suggest the distinction because we are concerned that the first gets more attention than the latter. If upcycled food is understood as restricted to the first group of examples, it also restricts the contribution that the idea of upcycling can bring to sustainability of food systems.

To strengthen awareness of this, we first pinpoint the main characteristics of current definitions, and then expand previous definitions by introducing a two-folded definition of the upcycled

food concept which encompasses two product groups that we see emerging in the food sector, and which each have a unique and different role in tackling food loss and waste. We highlight which boundaries there are for their contribution to a sustainable food system, and why it is important to adapt and change business models and communication along with the dynamic change in both consumer perception and technological innovation.

What is upcycling

The word 'upcycling' was coined in contrast to recycling, which is understood as 'downcycling'. It goes back to the groundbreaking cradle-to-cradle (C2C) design concept, where it was defined as "cyclical, cradle-to-cradle 'metabolisms' that enable materials to maintain their status as resources and accumulate intelligence over time" (Braungart et al. 2007, p. 1338). Braungart et al. (2007) criticized that the 'recycling' far too often meant that the material was downgraded and lost its value, as for example if different types of plastic is mixed and melted together as park benches, with the recycling just another stage on the way to disposal. 'Upcycling' in contrast would be ways of re-using that allow the material to become purer and better or add additional value to society. Phrased simpler, upcycling has been defined as "reuse of discarded materials which results in an increase in 'value'" (Bridgens et al., 2018, p. 146), or "a process of converting materials into new materials of higher quality and increased functionality" (Ellen McArthur foundation, 2019). Examples of upcycling in its ideal form are hard to find, but ideas approximating it are metals such as aluminium re-melted and becoming purer each time, and compostable packaging produced so that is improves soil and adds seeds.

What characterizes upcycled food

Upcycled food as a term has gained traction in the past years. In the USA, an upcycled food association has recently been formed, developing both a definitional framework as well as launching a certification for ingredients and products (Upcycled Food Association, 2022). The association writes that "Upcycled food is the easy way for anyone to prevent food waste via the products they buy …". The definition that they suggested in 2020 is phrased as follows: "Upcycled foods use ingredients that otherwise would not have gone to human consumption, are procured and produced using verifiable supply chains, and have a positive impact on the environment" (Upcycled food definition task force, 2020).

Comparing the various definitions in the literature of the field (e.g. Bhatt et al., 2018, 2020; Spratt et al., 2021; Peschel & Aschemann-Witzel, 2020), we identify three important and common characteristics in the definitions. When these three come together, the food can be regarded as 'upcycled food'. Accordingly, a food can be called upcycled food if it is 1) a product consisting of or containing materials that otherwise would be *waste*, this material is 2) turned into a *food* product for human consumption, and this is done via 3) a process that involves an increase in *value*. We explain each point in the following.

Waste

Firstly, the starting point is a product or ingredient that is or would otherwise be 'waste'. Upcycled foods are usually defined as waste-to-value products, that is, "foods made from surplus ingredients that would have been otherwise wasted" (Bhatt et al., 2018, p. 57) or "foods that are manufactured from ingredients that are by-products from producing another food product" (Bhatt et al., 2020, p. 3), or "foods that contain ingredients previously wasted in the supply chain" (Aschemann-Witzel & Peschel, 2019, p. 1). With regard to the inverted waste hierarchy pyramid (EC, 2008), it practically means that upcycled food begins with rescuing

material from the lowest end, which is the food disposal stage. The waste hierarchy provides a hierarchy of preference for actions in how to deal with waste from an environmental perspective: Waste should be properly disposed, but it would be even better to recycle it, and even better than recycling is to avoid the waste. 'Upcycling' moves the items from the disposal and brings them back to the intended use (see figure 1 for a simplified illustration of this).

Insert Figure 1 here

Food

Secondly, the resulting product is for human consumption. This holds logically for all definitions specifying that it is about 'foods'. However, also those definitions who do not do so, typically exemplify the concept with food examples (Peschel & Aschemann-Witzel, 2020). This characteristic is important to underline because even though a re-use as feed or pet food might as well be a valuable upcycling of material, it is not an example of upcycled food, given food is per definition for human consumption.

Value

The third crucial element is that the process involves an increase in value. This value can be of two types. First, definitions of upcycled food (Spratt et al., 2020) or waste re-use in the circular bioeconomy (Teigiserova et al., 2020) often refer to the (food) waste hierarchy (EC, 2008). This hierarchy ranks actions to reduce waste by how favorable it is for the environment, giving top priority to avoidance. Upcycling in this context means that the ingredient, product, or process should contribute value by moving the use 'back up' to the upper levels in the hierarchy. This benefit has a positive impact on the environment or society, as for example the Upcycled Food Association underlines: society gains by a contribution to environmental

protection, reduction of strain on natural resources, and greater efficiency of the food system. Second, definitions also stress that there can be an additional benefit and value of the product itself, mostly for the user directly. This can result from the innovation entailed, as for example expressed in the following definition "innovatively re-applied in new products with a greater value as a result" (Peschel & Aschemann-Witzel, 2020, p. 1). For example, when the upcycling increases fiber content of the food, the resulting product has a nutritional benefit for the user directly.

Introducing a two-folded definition

On the basis of the three characteristics, we propose that there are in fact two types of upcycled food which each have a distinct potential contribution to preserving natural resources. One is avoiding that those resources which have gone into food production are wasted, thus introducing upcycled foods through alternative use, the other is diversifying and broadening the food resource base by introducing upcycled food through novel use. The crucial distinction is based on the consumer perception of whether the starting point is food or not, that is, whether it is currently perceived as edible or not.

Upcycled food through alternative use

The first is upcycling in an 'alternative use sense', because it is about food or ingredients that could as well be eaten and are rescued from the threat of disposal, upcycling it in one way or other into alternative foods, and contributing value to society through avoidance of food being wasted. Because many current upcycled food examples are of this type, this first circle is larger in the figure (see figure 1). These products contribute especially to *food waste* avoidance.

Upcycled food through novel use

The second is upcycling in a 'novel use sense'. The difference to the first is that it starts with ingredients that are not regarded or commonly seen as edible, but by upcycling these in one way or other, results in new foods. This process contributes value to society through ensuring these ingredients become food, thus leading to more food available. Because fewer upcycled food examples are of this type, this second circle is smaller in Figure 1. These products make use of inedible parts of food or uncover food potential in yet widely underused sources, and they majorly contribute to avoidance of *food loss* because they untap a food potential. With regard to the inverted waste hierarchy pyramid (EC, 2008), the starting point is then an ingredient that is not even regarded as edible yet – which practically means that there is no awareness yet of the wastage of potential for food taking place.

However, as individuals and societies differ by culture, practice, and awareness in what they regard as edible in the first place, what is 'novel use' of something considered inedible for some, can be commonplace as an edible ingredient for others. Therefore, the two circles overlap. We suggest that the distinction between one and the other should hinge on consumer and not on professional perception, but this necessarily means that there is overlap and a dynamic difference.

Insert Figure 2

Examples of upcycled foods

Examples of 'upcycled food in an alternative use sense' are ketchup, soup or jam made from surplus or suboptimal fruit and vegetable, bread gone stale or nearing/passing the date label reprocessed into a beverage such as beer, or sunflower seed pressings and brewers spent grain processed into flour instead of being used as feed (e.g. Grasso & Asioli, 2020). This can also

196 be examples where excess supermarket counter or canteen food is repurposed to new products,
197 for example soups, meals or broth (Aschemann-Witzel et al., 2017). This is food currently
198 wasted, often due to overproduction or because it is perceived as 'suboptimal' (Aschemann-
199 Witzel et al., 2005) - or side-streams regarded as edible but not used as food turned into
200 alternative foods and contributing value by avoidance of food waste. This upcycled food does
201 not avoid the use of resources such as water, energy, packaging material, transport, storage that
202 has already gone into the food being produced, and it adds use of further resources in the
203 process of upcycling, but it avoids the loss of the ingredients, the resources used in disposal,
204 and ensures the food is used as food after all.

205 Examples of 'upcycled food in a novel use sense' is spent coffee turned into flour, olive leaves
206 processed into crackers, fish skin made into a snack, protein extracted from grass (Aschemann-
207 Witzel & Peschel, 2019; Perito et al., 2019) or made from pine tree needles or bark. These are
208 ingredients or side-streams commonly regarded as unavoidable food waste or not as food in
209 the first place. Using these as food ingredients contributes to value by uncovering new food
210 potential that is currently overlooked. Note that many of these novel uses might fall under the
211 novel food regulation in in the European Union. However, given the novelty of the use is based
212 on the consumer perception, upcycled food in a novel use sense might as well also be examples
213 of food that are not novel to Europe, but are novel to the majority of today´s consumers. This
214 is also relevant when considering that upcycling might tap into 'forgotten' traditions or
215 practices from times of scarcity that most current consumers have not experienced. In fact, the
216 above-mentioned examples of grass as well as pine are sources of food that have been explored
217 or used decades ago, but today´s consumers are not aware of that.

218 Two examples of the overlap between alternative and novel use are given below and highlight
219 how dynamic and context dependent the distinction can be. One example of the overlap is
220 sweets made from the cashew nut fruit (see figure 2). Consumers of cashew 'nuts' in the

221 countries with colder climates are mostly unaware of the wastage and even of the existence of
222 the cashew fruit – for them, this is a novel use, because they did not know it can be eaten.
223 However, for consumers in the countries that grow cashew, producing sweets from the fruit is
224 an alternative use, because they might traditionally use the fruit, but they know about the waste
225 of the otherwise perfectly edible cashew fruit in the export-oriented production chain of cashew
226 nuts (Casju, 2022; Aschemann-Witzel et al., 2021). Another example is sunflower seed
227 pressings and brewers spent grain – we categorize this as alternative use because sunflower
228 seeds and grains are commonly regarded as edible ingredients by consumers, even though these
229 side-streams are currently fed to animals. However, from a food processing professional
230 standpoint, these are ingredients along a continuum of market diffusion and acceptance, with
231 spent coffee simply a relatively new idea, while brewers spent grain is more established. The
232 two examples given highlight that we suggest the distinction should hinge on what the major
233 consumer perception entails, and that it should change when this perception shifts over time.
234 In this sense, spent coffee grain and fish skin might as well become upcycled in an alternative
235 use sense, once a much greater share of consumers regards these as edible or a straightforward
236 source of food ingredients.

237 Insert Figure 3

238

239 **Boundaries of the value contribution due to dynamic interactions**

240 We suggest that adopting the two-folded definition of upcycled food can help pinpointing what
241 is upcycled food, and what is not, and sharpens awareness of the two contributions that
242 upcycling in the food sector can make – to food waste avoidance on the one hand, to food loss
243 avoidance by untapping food potential on the other hand. To safeguard that upcycled foods

contribute value to a sustainable food system, we caution that actors should be aware of two boundaries of the value contribution by the respective two types of upcycled foods.

First, **the value of food otherwise wasted being turned into alternative foods needs to be assessed on a case-by-case basis as well as continuously.** This is because when the opportunity to use the 'rescued food' as food in its original state (re-)arises, this might as well be more resource efficient. If that is the case, it would render the upcycling an inefficient deviation. This is because the 'rescuing' of food in many cases only tackles the symptoms, the actual wastage, but not the cause, such as standards, perception and overproduction. Being aware of this ensures that the repurposing of the food to upcycling is well-considered against other, maybe more favorable options.

To give an example: Reprocessing ugly fruit and vegetable into an alternative processed product is only adding value to the extent that these fresh products cannot be sold. If consumers aesthetic standards shift and a broader variety of 'ugly' fruit and vegetable can be sold 'as is', doing so might be the more resource efficient option. Another example is old or close to/past the date bakery products used to produce high-end alcoholic beverages. As long as the bakery products are disposed as waste, this is of value. However, in case an opportunity arises to redistribute the bakery products to populations in need before they become old, this might be of even higher value from a sustainable development goal perspective. These opportunities might be for example technological or societal innovations such as new digital applications that can efficiently organize the redistribution.

Second, **upcycled ingredients and foods should only be called upcycled as long as they are commonly wasted.** When the process of upcycling ingredients currently not regarded as edible becomes a common and familiar process and is not innovative anymore, the food can also not be called 'upcycled' anymore, because the ingredient has become a food ingredient in the

perception of most actors. Being aware of this ensures that the upcycling definition raises the bar for future innovations.

To give an example: In the past, whey protein was a mere side-stream diverted to waste or feed in dairy production in Northern Europe. In the wake of the protein trend, whey has been successfully established as a much sought-after ingredient, at times even making whey the more valuable 'main-stream' of the production. Now, it is not needed to call the use of whey 'upcycling'. Whey is well established as a food ingredient, and this is rightly so – this way the focus is shifted to the next frontier in change of perception. The same will happen with other upcycled food ingredients – once it is achieved, for example, that brewers' spent grain is commonly used for food, using this ingredient for food ceases to be an avoidance of food waste – the ingredient is not 'otherwise wasted' anymore. Thus, with the dynamic change in perception, the understanding of the ingredient´s must change as well, and with it the communication to the end consumer.

Conclusions and implications - what different stakeholders can do

There is huge potential for reducing food loss and waste in the food system. There can be many diverse and conflicting opinions about how best to reduce food waste. The idea of upcycled food creates a lot of controversy. This is because it appears to simply re-introduce 'old' ideas as part of a 'fancy' new market trend, but in particular, because many examples of upcycled food currently seen in the market 'only' address the symptoms but not the root cause. Despite of this, we argue that among the many routes to a sustainable and circular food system, the idea entailed in upcycling has a huge potential to contribute.

For this to happen, the idea of upcycling needs to become 1) streamlined in how it is understood to avoid confusion, 2) mainstream thinking among all food value chain members in order to

achieve upscaling, and 3) repeatedly re-assessed against the boundary conditions to check if a particular application still delivers the value intended.

Of course, the idea of upcycling is not completely new – it is partly a re-establishment of the 'use all that you have' thinking or 'frugality' (Aschemann-Witzel et al., 2022). Traditionally, in times of scarce resources, a lot of produce has been made into foods in diverse forms. This can be also seen in traditional recipes and cookbooks. This diversity was reduced in the wake of industrialization of agriculture and food production, where not every side-stream or part of a produce was economical to process further. Also, consumer preferences have shifted to the 'best parts' in increasingly affluent societies, creating side-streams that end as waste or not as food due to lack of demand. This is why cashew fruit are wasted in production focused solely on the cashew nuts, or less-valuable parts of slaughtered animals end as pet food. What is new in the interest in upcycling today is the motivation to establish a more sustainable food system, mitigate environmental effects and climate change. The motivation has shifted from economic scarcity to voluntary natural resource efficiency.

To establish upcycling of yet underused or otherwise wasted ingredients across the system requires circularity or system thinking by all stakeholders. Systems thinking in the food system means being aware of the interdependencies and complexities, such as the boundary conditions described in this perspective, and to take them into account when seeking the best solution in each value chain and case (e.g. Meadows, 2008). This awareness and thinking is needed among both value chain stakeholders, and consumers. Currently, barriers to the circular economy are not that much of technological nature – the most prominent barriers have been identified to be company and consumer patterns of practices and thinking (Kirchherr et al., 2018).

Value chain stakeholders

316 Producers and processors should push harder to seek and establish alternative uses and new
317 food applications, even when the business model is not apparent from the start (Donner et al.,
318 2020). Collaborations and knowledge exchange across and between value chains is key for
319 this, as well as a resolute sustainability strategy that supports employees in this endeavor and
320 channels financial investments in respective research and innovation. Once an upcycled food
321 production is established, stakeholders should frequently check if the solution chosen is still
322 creating most value for society – or if there is a better and more efficient opportunity arising.

323

324 *Consumer-citizens*

325 Consumers can support food waste avoidance through upcycling via their purchase behavior
326 for these products and the new ingredients or processing behind them. This requires more
327 awareness and knowledge about how upcycled food contributes to food waste avoidance,
328 climate change mitigation, and at times provides even a nutritional benefit to the user. This
329 calls for education and information efforts. In the long run, citizens might also need to become
330 active supporters of upcycling in society via their behavior, as for example through their use
331 of water, their waste treatment and sorting, or composting, supporting e.g. local nutrient cycles.

332

References

Adıgüzel, F., & Donato, C. (2021). Proud to be sustainable: Upcycled versus recycled luxury products. *Journal of Business Research*, *130*, 137–146. https://doi.org/10.1016/j.jbusres.2021.03.033

Aschemann-Witzel, J., de Hooge, I., Amani, P., Bech-Larsen, T. & Oostindjer, M. (2015). Consumer-related food waste: Causes and potential for action. Sustainability, 7 (6), 6457–77.

Aschemann-Witzel, J. (2016). Waste not, want not, emit less. *Science*, *352*(6284), 408–409. https://doi.org/10.1126/science.aaf2978

Aschemann-Witzel, J., de Hooge, I. E., Rohm, H., Normann, A., Bossle, M. B., Grønhøj, A., & Oostindjer, M. (2017). Key characteristics and success factors of supply chain initiatives tackling consumer-related food waste – A multiple case study. *Journal of Cleaner Production*. doi: http://dx.doi.org/10.1016/j.jclepro.2016.11.173

Aschemann-Witzel, J., Asioli, D., Banovic, M., Perito, M. A., & Peschel, A. O. [Anne Odile] (2022). Communicating upcycled foods: Frugality framing supports acceptance of sustainable product innovations. *Food Quality and Preference*, *100*, 104596. https://doi.org/10.1016/j.foodqual.2022.104596

Aschemann-Witzel, J., Bizzo, H. R., Doria Chaves, Ana Carolina S., Faria-Machado, A. F., Gomes Soares, A., Oliveira Fonseca, M. J. de, . . . Rosenthal, A. (2021). Sustainable use of tropical fruits? Challenges and opportunities of applying the waste-to-value concept to international value chains. *Critical Reviews in Food Science and Nutrition*, 1–13. https://doi.org/10.1080/10408398.2021.1963665

Aschemann-Witzel, J., & Peschel, A. O. (2019). How circular will you eat? The sustainability challenge in food and consumer reaction to either waste-to-value or yet underused novel

ingredients in food. *Food Quality and Preference*, *77*, 15–20. https://doi.org/10.1016/j.foodqual.2019.04.012

Aschemann-Witzel, J., & Stangherlin, I. D. C. (2021). Upcycled by-product use in agri-food systems from a consumer perspective: A review of what we know, and what is missing. *Technological Forecasting and Social Change*, *168*, 120749. https://doi.org/10.1016/j.techfore.2021.120749

Bhatt, S., Lee, J., Deutsch, J., Ayaz, H., Fulton, B., & Suri, R. (2018). From food waste to value-added surplus products (VASP): Consumer acceptance of a novel food product category. *Journal of Consumer Behaviour*, *17*(1), 57–63. https://doi.org/10.1002/cb.1689

Bhatt, S., Ye, H., Deutsch, J., Ayaz, H., & Suri, R. (2020). Consumers' willingness to pay for upcycled foods. *Food Quality and Preference*, *86*, 104035. https://doi.org/10.1016/j.foodqual.2020.104035

Braungart, M., McDonough, W., & Bollinger, A. (2007). Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design. *Journal of Cleaner Production*, *15*(13), 1337–1348. https://doi.org/10.1016/j.jclepro.2006.08.003

Bridgens, B., Powell, M., Farmer, G., Walsh, C., Reed, E., Royapoor, M., . . . Heidrich, O. (2018). Creative upcycling: Reconnecting people, materials and place through making. *Journal of Cleaner Production*, *189*, 145–154. https://doi.org/10.1016/j.jclepro.2018.03.317

BusinessWire (2021). Whole Foods Market Forecasts Top 10 Food Trends for 2021. Retrieved from https://www.businesswire.com/news/home/20201019005038/en/Whole-Foods-Market-Forecasts-Top-10-Food-Trends-for-2021

Casju (2022). Cashew fruit caramels. Retrieved from https://www.casju.dk/

Coderoni, S., & Perito, M. A. (2020). Sustainable consumption in the circular economy. An analysis of consumers' purchase intentions for waste-to-value food. *Journal of Cleaner Production*, *252*, 119870. https://doi.org/10.1016/j.jclepro.2019.119870

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. *Nature Food*, *2*(3), 198–209. https://doi.org/10.1038/s43016-021-00225-9

Donner, M., Gohier, R., & Vries, H. de (2020). A new circular business model typology for creating value from agro-waste. *Science of the Total Environment*, *716*, 137065. https://doi.org/10.1016/j.scitotenv.2020.137065

EC (2008). Waste Framework Directive 2008/98/EC (WFD). Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN

EC (2020). European Commission, Directorate-General for Communication, Circular economy action plan: for a cleaner and more competitive Europe. Retrieved from https://data.europa.eu/doi/10.2779/05068

EC (2020). Farm to Fork Strategy: For a fair, healthy and environmentally-friendly food system. Retrieved from https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en

EC (2020). Report of the 5th SCAR Foresight Exercise Expert Group - Natural resources and food systems: Transitions towards a 'safe and just' operating space. Retrieved from https://scar-europe.org/images/FORESIGHT/FINAL-REPORT-5th-SCAR-Foresight-Exercise.pdf

EC (2022). EU Platform on Food Losses and Food Waste. Retrieved from https://ec.europa.eu/food/safety/food-waste/eu-actions-against-food-waste/eu-platform-food-losses-and-food-waste_en

Ellen MacArthur Foundation (2019). Circularity Indicators. An Approach to Measuring Circularity, Methodology. Retrieved from https://ellenmacarthurfoundation.org/material-circularity-indicator

Eurobarometer (2021). Eurobarometer 513 - Climate Action and the Environment, Climate Change. Retrieved from https://europa.eu/eurobarometer/surveys/detail/2273

Euromonitor International (2022). Top 10 global consumer trends 2022. Retrieved from https://www.euromonitor.com/article/what-are-the-10-global-consumer-trends-in-2022

FAO (2021). The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. Rome, FAO.: FAO, IFAD, UNICEF, WFP and WHO. Retrieved from https://doi.org/10.4060/cb4474en

FAO (2022). FAO Food Price Index. Retrieved from https://www.fao.org/worldfoodsituation/foodpricesindex/en/

FAO (2022). Technical Platform on the Measurement and Reduction of Food Loss and Waste. Retrieved from https://www.fao.org/platform-food-loss-waste/en/

FMCG Gurus (2022). FMCG Gurus – Top Ten Trends for 2022 – Global Report. Retrieved from https://fmcggurus.com/reports/fmcg-gurus-top-ten-trends-for-2022-global-report/

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., . . . Zaks, D. P. M. (2011). Solutions for a cultivated planet. *Nature*, *478*(7369), 337–342. https://doi.org/10.1038/nature10452

Forbes (2021). Upcycled food is the coolest trend you've probably never heard of. Retrieved from https://www.forbes.com/sites/daphneewingchow/2021/05/31/upcycled-food-is-the-coolest-trend-you-probably-never-heard-of/?sh=352135e2f0ab

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., . . . Toulmin, C. (2010). Food security: The challenge of feeding 9 billion people. *Science*, *327*(5967), 812–818. https://doi.org/10.1126/science.1185383

Grasso, S., & Asioli, D. (2020). Consumer preferences for upcycled ingredients: A case study with biscuits. *Food Quality and Preference*, *84*, 103951. https://doi.org/10.1016/j.foodqual.2020.103951

Hasegawa, T., Sakurai, G., Fujimori, S., Takahashi, K., Hijioka, Y., & Masui, T. (2021). Extreme climate events increase risk of global food insecurity and adaptation needs. *Nature Food*, *2*(8), 587–595. https://doi.org/10.1038/s43016-021-00335-4

IPCC (2019). Special report: special report on climate change and land: chapter 5. Retrieved from https://www.ipcc.ch/srccl/chapter/chapter-5/

Kamleitner, B., Thürridl, C., & Martin, B. A. (2019). A Cinderella Story: How Past Identity Salience Boosts Demand for Repurposed Products. *Journal of Marketing*, *83*(6), 76–92. https://doi.org/10.1177/0022242919872156

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the Circular Economy: Evidence From the European Union (EU). *Ecological Economics*, *150*, 264–272. https://doi.org/10.1016/j.ecolecon.2018.04.028

Meadows, D. H. (2008). *Thinking in Systems: A Primer: A primer* ([11th printing]). White River Junction, Vermont: Chelsea Green Publishing.

Perito, M. A., Di Fonzo, A., Sansone, M., & Russo, C. (2020). Consumer acceptance of food obtained from olive by-products. *British Food Journal*, *122*(1), 212–226. https://doi.org/10.1108/BFJ-03-2019-0197

Peschel, A. O., & Aschemann-Witzel, J. (2020). Sell more for less or less for more? The role of transparency in consumer response to upcycled food products. *Journal of Cleaner Production, 273,* 122884. https://doi.org/10.1016/j.jclepro.2020.122884

Poore J., & Nemecek T. (2018). Reducing food's environmental impacts through producers and consumers. *Science, 360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Spratt, O., Suri, R., & Deutsch, J. (2021). Defining Upcycled Food Products. *Journal of Culinary Science & Technology*, *19*(6), 485–496. https://doi.org/10.1080/15428052.2020.1790074

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., . . . Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), 1259855. https://doi.org/10.1126/science.1259855

Teigiserova, D. A., Hamelin, L., & Thomsen, M. (2020). Towards transparent valorization of food surplus, waste and loss: Clarifying definitions, food waste hierarchy, and role in the circular economy. *Science of the Total Environment*, *706*, 136033. https://doi.org/10.1016/j.scitotenv.2019.136033

The Washington Post (2021). Upcycling food waste onto our plates is a new effort. But will consumers find it appetizing? Retrieved from https://www.washingtonpost.com/science/upcycling-food-waste/2021/09/17/90fd81b2-0045-11ec-85f2-b871803f65e4_story.html

UNEP (2022, May 5). UNEP Food Waste Index Report 2021. Retrieved from https://www.unep.org/resources/report/unep-food-waste-index-report-2021

Upcycled Food Association (2022). Retrieved from https://www.upcycledfood.org/

Upcycled foods definition task force (2020). Defining Upcycled Foods: A Definition for Use Across Industry, Government, and Academia. Retrieved from https://chlpi.org/wp-content/uploads/2013/12/Upcycled-Food_Definition.pdf

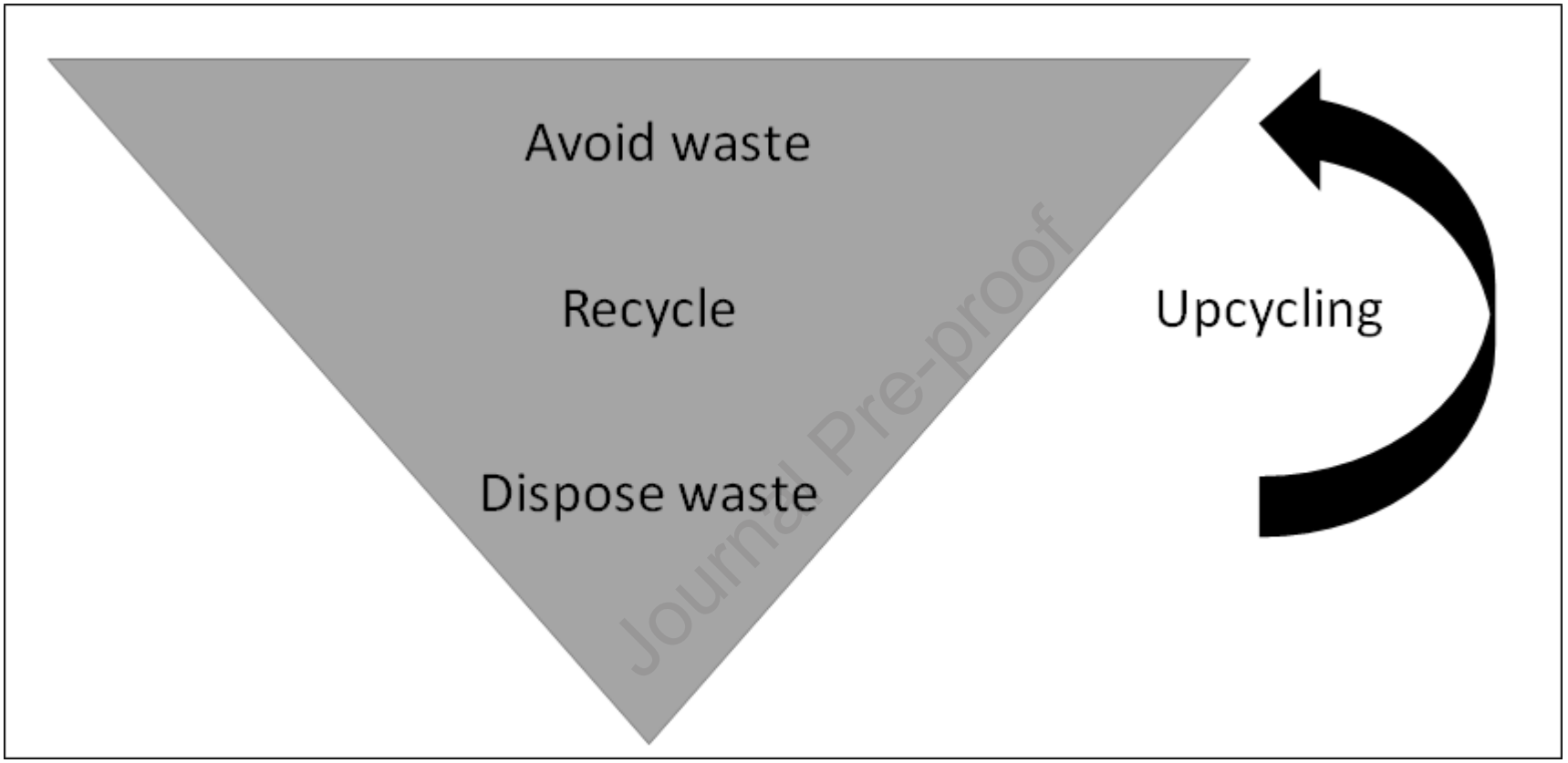
Van Dijk, M., Morley, T., Rau, M. L., & Saghai, Y. (2021). A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050. *Nature Food*, *2*(7), 494–501. https://doi.org/10.1038/s43016-021-00322-9

WFP (2022). #STOPTHEWASTE. Retrieved from https://www.wfp.org/support-us/voices/stop-waste

Willet, W. et al. (2019). Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. Lancet, Feb 2; 393 (10170), 447-492. doi: 10.1016/S0140-6736(18)31788-4.

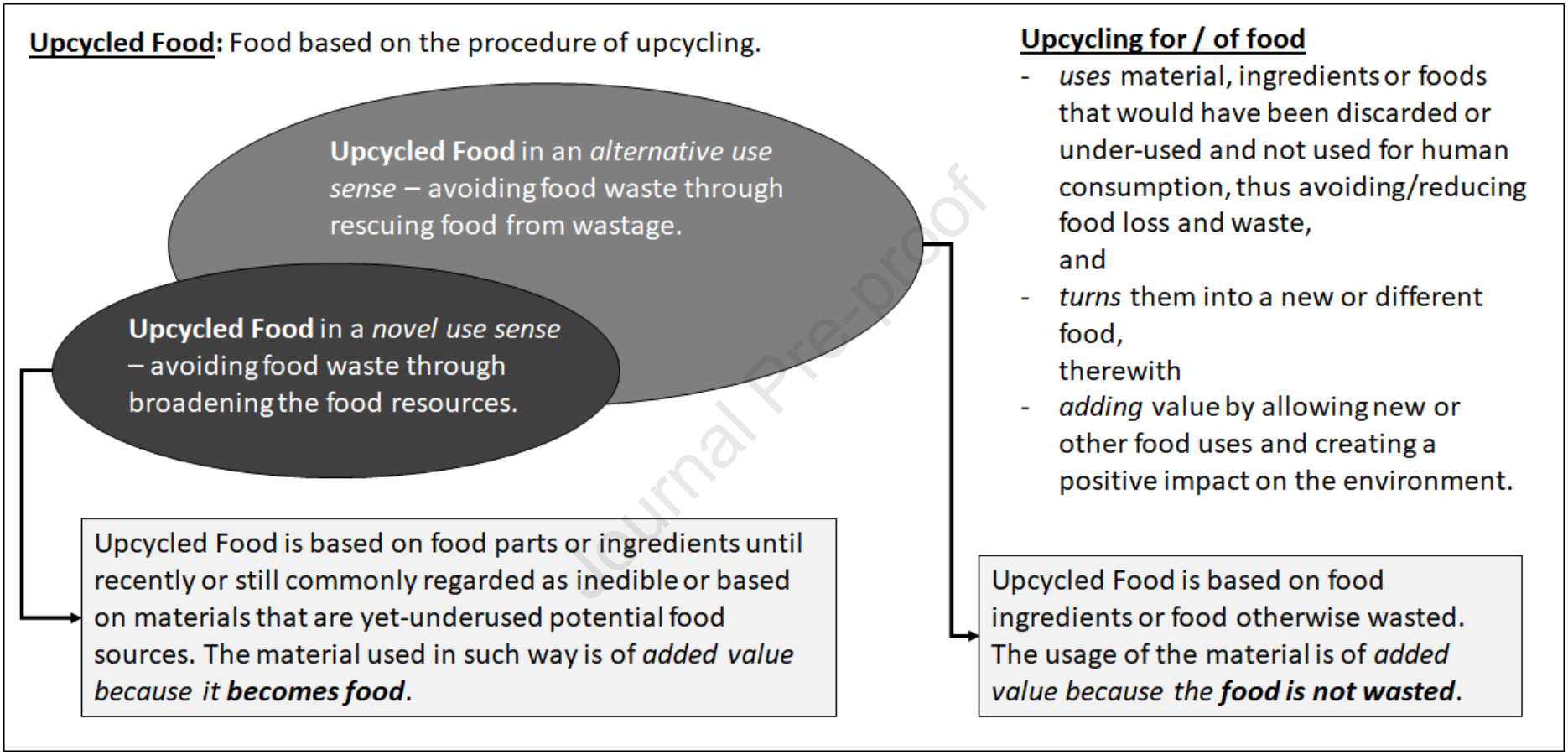
Wilson, M. (2016). When creative consumers go green: understanding consumer upcycling. *Journal of Product & Brand Management*, *25*(4), 394–399. https://doi.org/10.1108/JPBM-09-2015-0972

Figure 1. A simplified waste hierarchy and the contribution of upcycling.



Source: Own.

Figure 2. Two-folded definition of upcycled food.



Source: Own.

Figure 3. Cashew fruit as an example for upcycling in food production, and example of sweets made of cashew fruit.

Source: Colourbox and https://www.casju.dk/.

The dual role of upcycling in reducing food loss and waste

- Upcycling can tackle food waste but its definition and boundaries are unclear
- We introduce two-folded definition differentiating alternative versus novel use
- Each of the two types has an own contribution to food loss and waste
- We outline the boundaries arising from the dynamic and interdependent nature of upcycling