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Method& Critique *Frictions and Shifts in RTD*

Crafting Bioplastics: Materially Reconfiguring Everyday Food Practices

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Abstract: First proclaimed an amazing innovation, now plastic permeates everything—our homes, food, earth, oceans, many living creatures, including ourselves. The use of plastic is problematic, but hard to change. It is culturally situated, commercially embedded, learned, ingrained, often automatic. And, while alternatives are available, they can be hard to find and more expensive than their plastic counterparts. To engage with this issue, we undertook a design-based investigation of DIY bioplastic, edible and hyper-compostable tableware. Our aim was to render such alternatives more accessible. DIY recipes are available online.

Yet, often lack vital information to make their use easy. We discovered how to 'tame' fabrication of plastic alternatives by adding information about cooking and curing to the recipes. Our experiments suggest that 'at home' production of bioplastics and the accompanying re-design of cutlery and tableware, engender new, more sustainable, eating habits by—literally—designing new ways of eating. They also afford reframing of food 'waste' into material resource. We present a hand-made book and material sample set that make our findings tangible and accessible to design researchers, amateur gastronomists, DIY enthusiasts, and others curious about plastic alternatives. Our findings support a move of scientific practices from the lab to people's homes.

Keywords: bioplastics; DIY practices; sustainabillity; plastic alternatives; materiality; research through design.

Introduction
Bioplastics are defined as materials that contain biopolymers in various percentages and can be molded by heat action and pressure (Queiroz and Collares-Queiroz, 2009). They may be used as alternatives to conventional thermoplastic polymers of petrochemical origin, such as polyolefins and polyesters. This research unfolds within the larger context of a research program that uses food as a starting point for thinking about real-world material practices (Wilde, 2018). It aligns itself with the upsurge of interest in DIY practices (Kuznetsov and Paulos, 2010; Nascimento and Pólvora, 2018) and parallel moves to democratize scientific practices (Instructables, 2018). Our objective in undertaking this research was to discover what it would take to make bioplastics without prior experience or specialist knowledge: to create functional, hypercompostable tableware using only open source instructions and the background design knowledge of the authors. Plastic is a key environmental issue (Wagner et al., 2014). It is commonly used to cook, distribute, eat, store and dispose of food. It was first proclaimed an amazing innovation. Now we find it permeates everything—not only the tools we use to handle food, but the food itself, the soil and water that our food grows in, many living creatures on our planet, including ourselves (Rochman Chelsea M., 2018). This research has as its aim to broaden our understanding of how people might engage with plastic and plastic alternatives.

It is increasingly common to find alternatives to plastics in different industries (Mohanty, Misra and Drzal, 2002). Such products are often more expensive than their plastic counterparts and—despite the assumptions that accompany bio- and eco- goods (Emadian et al., 2017)—not all are eco-friendly. Corn, for example requires harsh chemical processing to transform it into a bioplastic. Growing corn is also environmentally damaging due pesticides and water use (Karlen et al., 2012). We thus felt it important to nuance our relationship to plastics and bioplastics and determined to do so using a DIY making process (Hemphill and Leskowitz, 2012).

Our investigation unfolded over four months, during which we determined (a) to master the process of DIY fabrication of bioplastics, and (b) discover if other people might be interested in making bioplastics at home. We used research-through-design (RtD) to engage with open source biology, and participatory RtD to bring varied stakeholders together to grapple with the question: **How can we shift our material practices around food towards ecological flourishing, using tableware as the locus of our attention?** Our participatory experiments consisted of a 'research lab in the wild'—a participatory event that conflates exhibition, studio and lab to expose early research in process to public scrutiny (Wilde, 2015) and a workshop undertaken in the context of the Nordic-Baltic BioMedia symposium focused on FOOD+[material practices].

Our findings are gathered in a book and accompanying collection of material samples. The book is at once a design artefact, a report, an invitation and a call to arms. It includes a collection of instruction sets—modified recipes, empirically tested through two participatory RtD experiments—material samples and our reflections on the process and outcomes.

Related work
The DIY movement has permeated society with a vast number of approaches well suited to our research question. Experts and expert-amateurs leverage the popularity of DIY to democratise anything from industrial products to technology and science (Kuznetsov and Paulos, 2010; Watson and Shove, 2008). In terms of bioplastics, the number of recipes available online has risen significantly with the rise of open source materials and the maker movement (Gobble & Euchner 2013), particularly as plastic alternatives become more available on the market (Sandler Research, 2016). While writing this article, we discovered newer and better bioplastic instructions which were not available a few short months before, when we conducted our research.

We found two types of bioplastic recipes online. The first approach provides ingredients, measurements and step-by-step instructions (cf. Instructables, 2018; wikiHow, 2018). The other is more experimental: authors specify ingredients but do not provide amounts, rather, they encourage readers to discover for themselves the elasticity, thickness or finish they prefer. For example, Davis (2017) provides no detail on the variables of the curing process in her instructions. Instead, she gives tips in the form of bullet points to consider. Similar to an artisinal craft practice, every step of making bioplastics invites people to explore, alter the amount of ingredients, try out techniques that haven't been used before to develop new, unexpected outcomes. The DIY craft with the longest tradition and largest catalogue of documented cases is food-making. There are countless approaches for documenting the secrets of cooking. We therefore found inspiration for our bioplastic recipes, in recipes for food.

Methodology
Our process involved iterative prototyping and development, a research lab in the wild and a workshop. We discarded the idea of solution-driven research that simplifies a design space to known technologies and comfortable outcomes (Dobbins, 2009). We instead opened up our process using speculation and participation. Speculation supports the emergence of new practices. It slows down the decision-making process, and affords consideration of the implications of a design before it is brought into the world. It short-circuits reactive decision-making and encourages deep, nuanced reflection (DiSalvo, 2012). When diverse actors are invited into the speculation process, their varied perspectives can bring to light new imaginaries, or ways of seeing the world, make concrete previously hidden or under-expressed values, prompt essential discussions and lead to new practices.

To understand the possibilities and limitations of bioplastics, we began with iterative prototyping. We cycled through mould making, material explorations, cooking and casting. Through this process, we developed a collection of design artefacts and methods to take to the public (Figure 1a, b). We initially focused on producing cutlery that feels and looks like regular plastic cutlery. Following some challenges in the production process—forks and spoons that were unable to hold the weight of food; knives that struggled to cut—we shifted our focus to the development of new shapes that do what cutlery does, without necessarily looking how cutlery currently looks. This shift better positioned us to craft bioplastic cutlery. As discussed below, we tested our interim outcomes first in a research lab in the wild, then in a workshop. In both testing scenarios we used open interviews and participatory methods to engage people in making and discussing the potential of bioplastics for a sustainable future. These activities enabled us to reflect on the methods used to make bioplastics, and contributed to development of new instruction sets.

Our research is not limited to the operational concerns of improving instruction sets or creating design artefacts; it is an investigation of people's interaction with and acceptance of bioplastics. Our intention—through the research lab in the wild and FOOD+[material practices] workshop—was to bring together people from divergent backgrounds, bring attention to environmental issues and discuss future scenarios involving bioplastics and alternative, sustainable practices.

Food For Thought
The ecological footprint that the plastic industry leaves in its wake is a prominent issue. Twenty years ago it would have been hard to imagine mountains of plastic waste drifting in the open sea. Today, images and videos of this very scene fill social media channels and news feeds, forming a constant reminder of the impact humans have on the planet, and the responsibility that lies behind our simple everyday decisions. DIY bioplastic is rich in interaction, and ideally positioned to prompt discussion of the sustainability of plastic-related practises.

Experiments
With no prior knowledge of bioplastics, we set out to learn which ingredients are required to produce plastic-like materials, and which methods are most convenient when making them. We used only open-source materials—recipes and presentations, available online. We tested seven bioplastic recipes. The majority had six ingredients or less, all readily available in supermarkets and pharmacies in Denmark. Despite the familiarity and accessability of ingredients, moving from ingredients to a viable outcome proved to be challenging. Most recipes describe bioplastic preparation in a simple step-by-step tutorial, but the steps were not as straightforward as we anticipated and the out-

a.

b.

Figure 1a, b. Gelatine bioplastic samples. Exploring material limitations and possibilities in creating design artifacts. Photo: Jekaterina Aleksejeva.

comes often less than satisfying (Figure 3.). We quickly discovered that bioplastics have a complicated and sometimes unpredictable nature. Casein bioplastic—made with milk and vinegar—appears greasy and smells similar to parmesan cheese. Agar bioplastic evaporates dramatically (up to 90%). In our first test we thought the entire sample had disappeared, until we discovered a barely perceptible layer of material on the surface of our mould. When heated, gelatine bioplastic changes colour and emits a very unpleasant smell. None of these properties were mentioned in the recipes. As a result, we were confronted with unexpected challenges. Overall, we found the instructions sets incomplete and inconsistent in their description. Yet, we relied on them to develop a strategy for our material explorations and systematise our knowledge.

The general process of developing bioplastics, from selecting materials to the final bioplastic sample, consists of the following steps: select recipe, gather ingredients, prepare mould, mix ingredients, heat (cook), mould and dry (cure). Common ingredients used to 'plasticise' materials include casein, gelatine, starch and agar.

A suitable mould for bioplastic experiments needs several characteristics: it must hold its shape, be easy to re-use and have a smooth surface to facilitate removal of the cured bioplastic. Additionally, having several moulds in a single sheet is convenient to organise and observe samples during the curing process, in particular when different material variations need to be compared. For our moulds, we explored a range of materials: cardboard, gypsum, MDF, 3D printed PLA and vacuum-formed plastics (Figure 2b.). We acknowledge that many of these materials go counter to the underlying aims of the project to move towards sustainable practices. Nonetheless, we felt it important to experiment with what we had to hand. This approach aligns with the need to balance concerns around environment and social justice (Liboiron, 2017). We were not in a position to purchase expensive pressure moulds and did not want to give up on our project when our experiments with cardboard and gypsum failed.

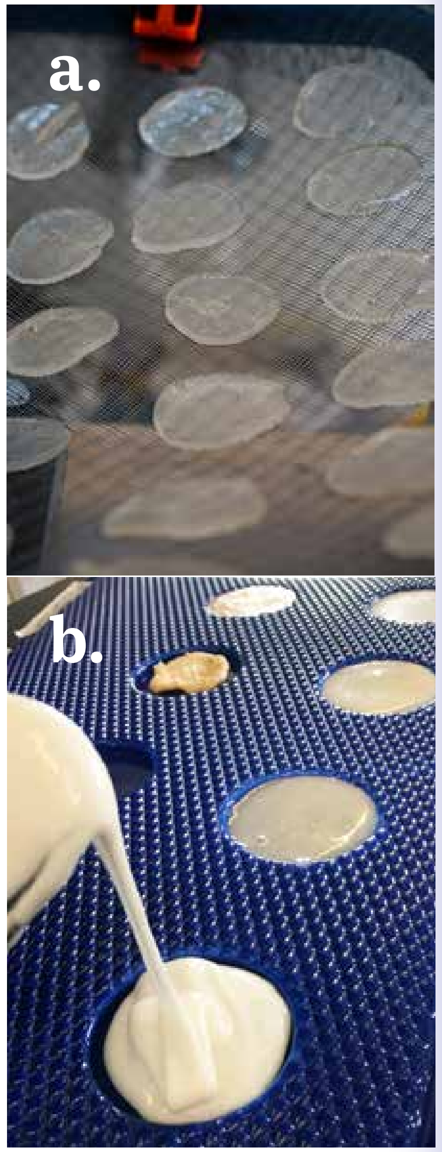

Figure 2a. Agar bioplastic samples during casting. The material almost fully dissolved during the casting process. Photo: Paul Biedermann.
Figure 2b. Vacuum formed plastic sheets. Used for casting and organizing bioplastic samples. Photo: Paul Biedermann.

<Figure 3. Bioplastic foil. Some of the samples produced, showed that bioplastics can create a variety of outcomes – from solid samples to foils and flexible materials. Photo: Paul Biedermann.

The aim of this research is to understand how to democratise DIY bioplastic, edible and hypercompostible table-ware making. This aim requires us to grapple with all of the challenges that may arise, including the unsustainable practices we commonly use in our design processes. Laser cutting forms out of MDF, while not sustainable from a material point of view, best corresponded to the requirements of the mould. Vacuum-pressed forms were also suitable as they were well sealed, easy to wash and reuse. Such moulds are less time-consuming to fabricate than 3D printed moulds, for example, and produce forms more stable than gypsum.

We found vacuum-pressed forms to be most useful when experimenting with additives, as they enabled us to easily prepare, and thus compare, uniform samples. Adding used coffee grounds and dried orange peel to gelatine bioplastic created a completely different result compared with the plain bioplastic. Adding coffee grains changed both the smell and texture. This result expanded our view towards combining ingredients (Figure 4.). We repeated this process for starch-based bioplastics, and the results were different again. In this case, it took more time for the material to cure. Samples of gelatine bioplastic mixed with coffee grains were hard and robust rather than brittle, while starch-coffee ground samples were flexible and fragile. This outcome indicated that the time taken for curing may be an important step in determining the final outcome.

Figure 4. Combining additives and bioplstics. To create more robust materials we experimented by adding different organic materials to bioplastic. Photo: Ona Orlovaite.

Most of the bioplastics we experimented with—casein, gelatine, starch and agar—dried at room temperature over a few hours or days. The exact time for curing depended on the amount of surface area exposed to air and material thickness. Overall, we found balancing the material properties to achieve ideal curing times and stiffness to be the most challenging aspect of working with bioplastics. At the conclusion of this exploration phase, we determined that gelatine and starch-based bioplastic were the easiest to manage and would suit our purpose of crafting tableware. We gathered a collection of material samples, and prepared our first public experiments.

Do new materials require new aesthetics?

Engaging publics

Our public experiments were undertaken at two events at the University of Southern Denmark (SDU). The first was a Research Lab in the Wild held as part of SDU's 50th anniversary Jubilee event; the second was a workshop, held a month later, during the Nordic-Baltic BioMedia network's 4th international symposium: FOOD+[material practices] (Wilde, 2018).

Research lab in the wild

SDU's jubilee event brought around a hundred people to the Kolding campus for talks and exhibitions of research. We took advantage of this event to create our first experiment, a research lab in the wild—a participatory event that is both exhibition and research in progress. Our aims were (a) to explore if visitors were willing to engage in our processes, (b) to determine how relevant they find the idea of creating bioplastic objects themselves using the methods we made available, and (c) to understand what issues people think they might face while doing so.

Figure 5. Bioplastic exibits. The collection of design artifacts showcased at the FOOD+ symposium. Photo: Jekaterina Aleksejeva.

To realise these aims, we had a dispay table on which we showcased our material samples and artifacts. The table included a workspace to cook and create bioplastics together with interested spectators (Figure 6a.). Through the event we had the opportunity to engage people in the bioplastic making process. This approach gave us a sense of interest and perceived necessity for such practices. While cooking, we noticed that our process was understood by most participants. Many claimed it to be similar to jelly making, which also uses gelatin as a base. Our visitors were intrigued and excited about the look and feel of the outcomes but didn't seem convinced by their functionality or ability to replace disposable cutlery made from synthetic plastics. In contrast, the examples for food wrapping alternatives were readily accepted. It seemed an issue for participants that food wrapping is unsustainable, yet many use it on a daily basis in their kitchens. The collected findings from the event were used to improve the instruction sets we were creating for our second public intervention: a workshop at the Nordic-Baltic BioMedia network FOOD+[material practices] symposium at SDU a month later (Wilde, n.d.).

Workshop

The fourth Nordic-Baltic symposium brought together key actors in bio media from the Nordic and Baltic region, Germany and Switzerland to participate in workshops, discussions and research presentations about FOOD+ [material practices]. It included workshops and presentations on bioplastic and hyper-compostable cutlery, biotextiles and microplastics. The symposium was our opportunity to test our most recent instruction sets, understand in more depth how others engage with bioplastics, and observe and improve the way we communicate such practices. The instruction sets we prepared consisted of a series of clearly articulated, short steps with explanations to reassure novices that they are doing the right thing. The overall design was minimalistic and had a fun recipe look.

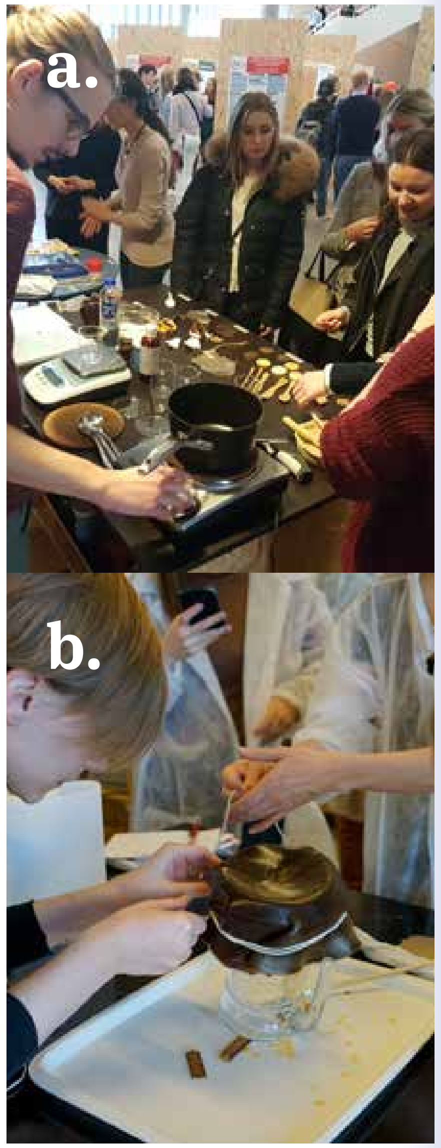

Figure 6a Research lab in the wild. Exhibiting design artifacts and creating bioplastics with participants. Photo: Iulia Gavriliuc.
Figure 6b Food+ Symposium. Engaging workshop participants in bioplastic fabrication process. Photo: Iulia Gavriliuc.

<**Figure 7.** Ramsons pie on an estragon-gelatine bowl. Incorporating taste by adding herbs and spices into bioplastic tableware. Food made by Design School, Kolding. Photo: Paul Biedermann.

The workshop began with a short presentation of outcomes, then participants were invited to make their own bioplastic and hyper-compostable cutlery using our instruction sets. People could choose from 3 different instruction sets: gelatin-based bioplastic, starch-based bioplastic and edible cutlery made from pie crust or pizza dough. Working in pairs, they first analysed the instructions, then reflected on how the product should look and taste before going ahead and making their tableware. As facilitators, we observed how different experiments unfolded and engaged directly with participants, giving advice or assisting with the process as needed. The starting point of the workshop was cutlery, yet, we observed other interesting practices such as:

- using Bioplastics as repair material for broken glassware (Figure 6b., 8.)
- Creating jewellery from bioplastic elements
- Casting bioplastic tubes for use as weaving threads
- embedding herbs in the bioplastic gel to infuse the resulting dishes with flavour as they are eaten
- using centrifugal energy in an experiment to render the mixing process more uniform

Some of these approaches were modifications of techniques we proposed. For example, our samples included bowls with herbs and spices embedded within them (Figure 7.). By moving the spices to the cutlery, our workshop participants made the flavour experience portable between dishes. It thus constituted a bold move towards playful gastronomy (Wilde and Altarriba Bertran, 2019). Other experiments, such as using bioplastics to create unconventional repairs (Figure 8.) and centrifugal force to hack the making process, relate to notions such as making things apart, de-construction, repair and obsolescence, foregrounding material literacy, playful hacking and un-crafting (Murer, 2018). These approaches afford recombining, reconfiguring, and recontextualizing material relationships, in this case to food-related material practices.

Figure 8. Bioplastic kintsugi. Recreating the ancient art of kintsugi - repairing broken pottery with gold. Photo: Paul Biedermann.

The workshop raised many new perspectives on how bioplastic can be used. Our observations and discussions with participants, enabled us to determine what elements were missing from our instruction sets and how their design might be changed to better assist the bioplastic cooking—and experimenting—process. For example, providing greater detail about the changing properties of gelatin when it cooks and a "warning" regarding the unpleasant smell it produces. The outcomes helped us shape new instruction sets, identify what was needed for an exemplar of material samples and build a guide for DIY bioplastic preparation in the home kitchen.

The Book

The findings from this project are brought together in a book: **Food for thought – your DIY guide for creating bioplastics** (Figure 9a.). The book comes with a material sample box (Figure 9b.) and instruction sets to prepare the presented materials (Figure 9c.). The book is designed, organised and presented to attract people's curiosity. The cover is made of MDF with laser cutouts of a tableware setting, filled with lightly colored, vanilla-scented bioplastic in the style of stained glass windows. The cutlery and tableware samples developed over the course of the research lab assist us to introduce the topic. Their irregular shapes, colors and ingredients elevate them beyond the utilitarian purpose of containing or handling food to become an artistic exploration and interpretation of cutlery and tableware.

The book discusses the problem of plastic and our intention to contribute to developing alternative ways of dealing with this problem. It reflects on our experiences with this topic and how this experience helped us to shape the bioplastic samples and instruction sets. The design and layout of the book is carefully considered. It combines high end photography and food prepared by chefs at Design School Kolding. It is designed to contrast with existing online instruction sets and guides, working from the premise that if regular cookbooks can adopt a highly aesthetic look, so can a DIY bioplastic guide. We therefore tried to create a book that looks interesting enough for anyone to pick up and explore.

<**Figure 9a.** DIY guide on creating bioplastics. Photo: Iulia Gavriliuc.

Figure 9b. Material sample box. Photo: Paul Biedermann. Figure 9c.DIY instruction sets. Photo: Paul Biedermann.

Discussion

The following sections reflect on our process and present the most frequently discussed topics during the research lab in the wild and workshop, categorised in under the following headlines: Bioplastics are not for everyone; Evolution of recipes; and Sustainability.

Bioplastics are not for everyone

Our journey from the first bioplastic recipes to the final cast product was a constant process of trial-and-error-based learning marked with multiple moments of frustration. Over the course of this process we began to understand that the production of bioplastic design artefacts is definitely not for everyone. Many of the recipes we tested skipped important steps, neglected to mention effects such as fumes or rapid changes of consistency while boiling. They left out information regarding material properties and colour-changes after casting. Almost all tutorials ended with the liquid raw material, making it challenging for non-experts to craft 3D shapes. These insights helped us to understand which values and principles are essential to include in a bioplastic recipe set if we want to provide the user with a positive first-time bioplastic-making experience.

We received positive feedback at both public participation events. Yet, many participants stated that they don't consider making bioplastics at home a functional solution for disposable cutlery. The products we created did not solve their problems—they were imperfect. In reflecting on this outcome, we must admit that the search for solutions permeates our thinking, it sneaks up on us when we are not watchful. Yet, at the outset we determined that we were not looking for solutions. The intention of our material explorations was to allow us, and to prompt the reader, to imagine alternative futures, to open up thinking about culturally ingrained habits, to reflect upon use of plastic and reconsider our values: "Critical designs defamiliarise technologies and trends that we might otherwise take for granted creating a space for reflection and critique" (Blythe et al., 2016). Our purpose is not to dictate how to use bioplastics; it is to inform people that there are alternatives and engage them in a conversation.

Evolution of recipes

Making bioplastics is attractive for people who are concerned about the environment and seek to craft sustainability in their daily life. On the internet it is possible to find a range of DIY tutorials that propose alternative ways to look at well-known issues related to the use of plastic. Written by different people, with different backgrounds and sets of expertise, these tutorials rarely follow the same pattern. As discussed, our experiments were often accompanied by frustration and insecurity of what outcomes to expect. Similar to a translation from DIY tutorials to DIY recipes (Dalton et al., 2014), we transformed the format in which we delivered cooking instructions for bioplastics. With the aim of making hyper-compostable tableware more attractive for 'everyday designers', we added information about physical properties of bioplastics at certain transformational levels. When bioplastic is exposed to heat, water, even oxygen, it can change its smell, plasticity and material resistance. We noted these changes under headings: 'Water Resistance', 'Temperature Resistance' and 'Material Evaporation'. We found these dimensions important. They bring attention to material properties and enable the maker to critically reflect on the bioplastic-making process while they are engaged in it.

Sustainability

With good cause, some participants questioned the sustainability of our production methods. Some argued that the MDF sheets used as moulds would contradict our assurance of an environmentally friendly product. We want to emphasize here, that our aim is not the creation of fully sustainable processes or design artefacts. Instead we are trying to open our readers to new ways of thinking and creative practices they can potentially implement in their everyday life. Through these actions we hope that people might be empowered to reflect upon and perhaps slowly reduce the environmental impact of plastic use in their households. Using plastic to create alternative materials to replace plastic in the future, might appear paradoxical. The MDF we used in the casting process was an available, functional casting method that enabled us to go on with our prototyping iterations.

Other concerns were directed towards the use of starch as a curing agent. Corn cultivation has become a significant contributor to deforestation and climate change the world over (Karlen et al., 2012). Gelatine as a material choice also caused some insurrection. Some participants claimed that, as an animal product, gelatine cannot be sustainable in any way. The use of these ingredients has been a concern for us since we started with our first experiments. We determined that, as a so-called ‘waste’ product from the animal industry, gelatine corresponds in some way to using recycled coffee grounds or orange peel in bioplastics. Corn starch might be a big driver of pollution but can potentially be cultivated with sustainable farming methods. Despite the complex problematics inherent in their use, both materials function as extraordinary hardening agents. In using them we experienced far better results than other hydrocolloids such as the algae-based agar agar powder. Future collaborations with materials scientists might enable us to find alternative, more sustainable, substitutes.

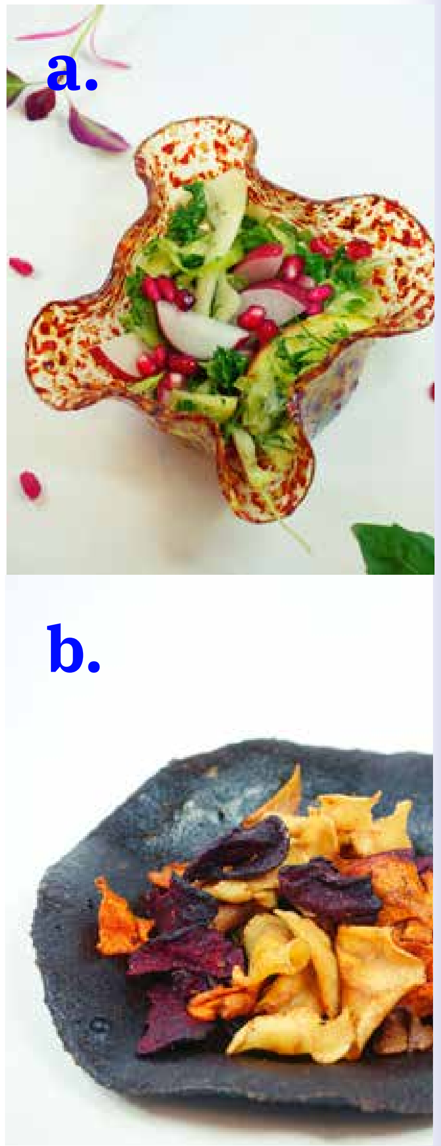

Figure 10a, b. Bioplastics in use Chilli flake gelatine bowl (a) and root vegetable chips on a coffee based bioplastic plate (b). Food by Design School, Kolding. Photo: Paul Biedermann, Jekaterina Aleksejeva.

<Figure 11. Bioplastics in use. Cold asparagus soup served in the chilli flake gelatine bowl. Food by Design School, Kolding. Photo: Paul Biedermann.

Conclusion

Our aim with this research was to investigate the viability and social acceptance of DIY bioplastic tableware as an eco-friendly alternative to disposable plastic cutlery. Using research through design we determined how to create and shape bioplastics using only open source techniques. The process was not straightforward. Using participatory RtD we presented our initial bioplastic prototypes to different publics, through a research lab in the wild and a workshop. We engaged participants in making bioplastics and discussed the possibility of a sustainable future and the role that bioplastics might play in that future. Throughout, we discovered novel features of bioplastics that can enhance the eating experience, such as the infusion of hot and liquid foods with herbs and spices that can be embedded into food-safe plates, bowls or cutlery. We also discovered a need to modify our aesthetic expectations. The seeming clumsiness of the aesthetics of our outcomes raises the question if these new materials might both demand and engender a new aesthetic? We argue here that bioplastic and hyper-compostable cutlery could be viable alternatives for plastic cutlery moving forward. Indeed, commercial options are increasingly available on supermarket shelves. People in the DIY community are already engaging with the production of bioplastics, yet there are many challenges to overcome before the general public will apply these practices at home. We see these challenges as potent opportunities for raising thoughtful discussion and debate.

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Figure 12. Experimental composition. Photo: Jekaterina Aleksejeva. Minimalistic and aesthetic visualization of bioplastics.