# Edible Materials Lab

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**Situated within an increasingly complex global reality, any critical consideration of materiality in contemporary design requires an eco-systemic approach to resources and their circulation in space and time. Through their lifecycles materials travel not only geographically and temporally, but also flow across seemingly incompatible industries, technologies, and markets. Edible Materials Lab focuses on a set of possibilities for material innovation by investigating relationships between the constructed environment and the food supply system.**

### INTRODUCTION

The role of materials and material innovation in contemporary architecture has been redefined by a number of factors, including developments in digital design technologies, transformations in industrial mass production, and evolving notions of sustainability.[1] Materials research by architects has the potential to embed considerations of materiality into the design process in new ways as well as reimagine architecture's broader role in organizing flows of material resources beyond the conventional boundaries of a single architectural project. In shifting from object-centric thinking to ecological thinking,[2] it is possible to expand the value of materials research beyond its immediate applicability as either an exercise of pre-design or a reiteration of standardized means-and-methods procedures. Such research enables design disciplines to construct new material relationships that link seemingly incompatible and otherwise disconnected industries, technologies, and markets across larger geographic territories and wider timeframes. Within such an expanded field, it may be possible to discover new opportunities for architecture's influence and effectiveness as a material practice.

Edible Materials Lab, conducted as a studio-based project at The University of Texas at Austin, explores the role of materials research as a form of design practice. The project focuses on materials as a framework for investigating relationships between design and food. Developed as a public program for an ArtPlace America-funded creative place-making event – a part of a planning charrette for an ecologically sensitive urban site in Austin, Texas – the project is motivated by three interrelated concerns that extend from not only my own existing research trajectories at the university and in my studio practice, but also reflect some of the broader priorities for design today. First is the ambition to contribute to contemporary design's interest in custom materials, partially a result of the potential for customization unleashed by digital design and fabrication. Advances in digital technology have effectively expanded architectural form's capacity for customization, while retaining the efficiency levels of mass production. Custom form, however, still encounters limited formats of standardized materials, thus necessitating new strategies for material customization. One could say that in the era of digital production, off-the-shelf materials ought to be replaced by made-from-scratch materials, framing in this way material as designed rather than given. Second is the search for more sustainable approaches to materials, which take into account the scarcity of some resources while at the same time considering staggering quantities of waste. Negative byproducts like toxicity and pollution by otherwise beloved materials – such as plastics – necessitate explorations of more appropriate alternatives. And third, while the relationship between design and food has already been articulated in architecture and its allied disciplines in numerous ways –from urban farming and food-oriented building programs to various aesthetic and technique-driven commonalities – the link between the two has not yet been sufficiently made through materiality.

### EDIBLE MATERIALS LAB

[The notion of edible materials inspires fantasy and elicits a sense of wonder, but also reveals unusual affinities between material substances that we build with and those that we ingest. A conventional perception is that the materials that surround our bodies – from the scale of clothing to buildings and beyond – significantly differ from edible ingredients that we consume. Perceived differences between materials and edibles are a result of their inherent properties, but are also formed by cultural values, social rituals, and technological processes. The motivation behind Edible Materials Lab is not to conflate the two or entirely obliterate their distinguishing differences, but rather to better understand where, how and why they may


Figure 1: Edible Materials Lab exhibition at thinkEAST, Austin, Texas, 2015.

intersect presently and potentially. In this way, we are interested in those materials whose constituent substances are related to edible ingredients and products biologically or chemically, thus allowing us to identify new connections between material and food production. A well-known example of another project that explores similar relationships is Christien Meindertsma's PIG 05049, which traces all products made from a single pig and includes findings such as ammunition, photo paper, electrical switch plates, heart valves, brakes, chewing gum, porcelain, face cream and cigarettes. For Meindertsma, the project is a way to bridge the distance between the living organism and the consumable product, renewing a sense of awareness of materials' origins otherwise abstracted and obscured by industrial production.[3] 'Edible' as an umbrella term in our own research likewise is used as a way of bridging that distance.

Edible Materials Lab provided an exceptional opportunity for integrating teaching, research, and service within the perimeters a single project. It was organized as a collaborative effort between the advanced design studio that I conducted with 16 students at the School of Architecture and the UT Materials Lab directed by Jen Wong. The studio's role was to generate research and produce original content for the exhibition, which Wong and I jointly curated (Figure 1). The exhibition brings together a selection of material samples from the Materials Lab along with the studio work and was presented to a general audience along with a series of public programs that featured a diverse set of participants, including Virginia San Fratello from Emerging Objects. (Emerging Objects also produced a series of objects 3D-printed from salt, sugar, tea, and coffee). Chosen from the collection of 27,000 samples at the Materials Lab – the largest collection of its kind in the world – the exhibited materials reflect innovations from the design industry currently available on the market. Fully functioning as structural composites, paneling, membranes, insulation, upholstery, and finishes such products all contain substances that are in some way related to edible ingredients. In the exhibition the products are organized and identified according to their associations with food. The selected material samples and prototypes by students, on the other hand, demonstrate a range of possibilities for material innovation using common edible ingredients. Animal and plant-based polymers, microbial cellulose, mycelia, minerals, fibers, and natural gums found in ordinary foods are transformed through experimentation and iterative tests. Through a combination of advanced technologies and do-it-yourself methods, students examined what it means to make materials from-scratch rather than simply working with existing ones.

The 15-week studio was organized into a series of phases centered on research based on making, observation, documentation, and speculation. We pre-emptively identified a set of edible ingredients that we already knew were addressed by designers in some way, but were still experimental in nature: SCOBY, mycelium, salt, plant fiber, gums, gelatin, starch, and agar. Each student team focused on one ingredient in order to identify its properties, find precedents for how it may have been used to produce a material, and figure out a method for making that material. Then, during a period of trial-and-error experiments, the aim was to arrive at a working set of material samples, taking into account the range of properties that it can to capture. In the next phase, the intention was to make a leap from material samples to a pre-functional prototype (i.e. not yet belonging to any typology of "useful" objects), open-ended and experimental, but that captures the essence of a material's potential for application. The object was to be more than a material sample, an opportunity to forecast and showcase its properties, qualities and experiences it may afford. This may include its formal or tectonic possibilities, assembly strategies, textures, etc. Students investigated how their ability to shape a material's properties influence the design process. The final task for the last weeks of the studio, following the exhibition, was to speculate upon the material's further use by proposing a concept for a product.

Figure 2: SCOBY cellulose prototype by Amy McDonnold and Amy Witte.

### SCOBY

Symbiotic colonies of bacteria and yeast (SCOBY) produce the well-known fermented drink kombucha. SCOBY metabolizes nutrients in sweetened tea as it ferments, producing a mat of cellulose fibers as its byproduct. Removed from the tea, the mat - which is 95% water - dries and condenses. Depending on the characteristics of the mat prior to dehydration, the material ranges from thin and paper-like to thick and flexible (Figure 2). Factors such as the age of the colony and type of nutritious substrate in which the SCOBY was grown determine the resulting color, finish, and texture.

This material has been explored in a variety of fields including medicine, acoustics, and papermaking. Fashion designer Suzanne Lee, in her project BioCouture, has used the material to "grow" clothing. As a material for design, bacterial cellulose has many notable characteristics, including translucency, fusibility, the ability to take dye, and adaptability – the SCOBY will grow to the extents and shape of the vessel in which it lives and it can be molded to a form during drying. It is also strong, with a tensile strength similar to that of steel. When exposed to metal, the material oxidizes, becoming dark, shiny, and stiff.[4]

### MYCELIUM

Mycelium is the element of fungus that plays a similar role to the roots of a plant. It is made of thread-like, branching hyphae that grow radially outwards, seeking nutrient material. Once grown into a full circle the fungus ingests its inner self, leaving a web-like ring. Individual hyphae nodes join with others to form fungal colonies that have been known to cover areas of up to four square miles.

The radial growth of mycelia makes it an excellent binder. Fibers link both horizontally and vertically as they seek nutrients and communicate information to the system. Colonies of mycelia can be grown within nutrient-rich soil or on substrates such as logs, animal feed and grain waste. When grown in a constrained environment and provided the proper nutrients, the organism forms a dense network of fused hyphae and will take on the shape of its boundaries. When heated and dried, the material becomes inert and is naturally waterproof and flame retardant. Companies such as Ecovative have recently tapped into the unique advantages of dried mycelium, producing innovative alternatives to packaging, building insulation, and even foam surfboards.[5]

### SALT

200 million tons of salt are produced annually on a global scale, extracted in vast quantities from salt mines or through the evaporation of seawater. Salt is commonly used in a wide variety of applications including food production, agriculture, roadwork, and filtration. Less conventional uses of salt can be found in the world of architecture, design, and even medicine. Emerging Objects, a design firm that specializes in the innovation of 3D printed materials, has used salt to fabricate modular components that can aggregate to create inhabitable structures. Combining salt with natural binders such as xantham and arabic gum can produce a masonry-like material that is strong, lightweight, and relatively smooth. The material is easily shaped through both casting and 3D-printing before it is heat-dried.[6]

### PLANT FIBER

Fiber from food supply chain waste is available in abundance. Although there are many sources of food waste, the emphasis here is on industrial sources that produce uniform, high cellulose content waste: coffee, corn, and pomace or juice pulp. More than 600 billion cups of coffee are consumed every year globally, leading to 8 million tons of coffee ground waste produced. Similarly, fruit and vegetable pulp has high annual waste with orange production alone totaling over 68 million tons. Corn production yields over 400 million tons of waste per year. These vast amounts of food waste possess fibrous qualities and functionalized molecules that allow them to be repurposed into new materials. Coffee grounds, with the help of a binder, can be made into a moldable fiber board. Such boards are comparable to fiber boards available on the market and can be used in furniture production, sheathing, and compression molded custom parts. Using thermoplastic starch or gelatin as a binder leads to sturdy biodegradable sheets that can be used for temporary construction. The use of plant-based epoxy resin as a binder yields a high-strength, waterproof material that may have a variety of applications (Figure 3).[7]

### GUM

Gum is a popular food additive produced by various trees, plants, and beans in the form of a substance called latex. Most natural gums such as guar and xanthan gum can increase a substance's viscosity and are therefore used as thickeners and stabilizers. Gums are also good emulsifiers, enabling the combination of two incompatible substances such as oil and water. Gum arabic, which is harvested from two species of the acacia tree, possesses adhesive and binding properties and

Figure 3: Coffee fiberboard, CNC-milled from flat board (left) and cast in custom formwork (right), by David Thompson.

is a key ingredient in the industrial production of glue, ink, and paint. Natural gums are also used in industries ranging from healthcare, cosmetics, paper, textiles, mining, and oil drilling.

In this investigation the compressive material properties of a quick-setting expansion cement have been redefined using guar and arabic gum as additives. When mixed with guar gum, the cement becomes a thick paste that is easy to manipulate and can be applied to a mold or form. The tensile qualities of guar gum allow the form to be manipulated for a brief period of time before hardening. Cement mixed with arabic gum produces a much thinner material that displays flexible qualities without warping. The addition of both arabic and guar gum produces a thin, paper-like material that has the surface texture of concrete with the flexibility of paper. Concrete, a material that is typically monolithic and strong in compression, has been transformed into a material that is light and highly tensile.[8]

**GELATIN**

Gelatin is derived from the partial hydrolysis of collagen, which is extracted from the skin, bones, and connective tissues of animals. Gelatin is a thermoplastic - it is pliable and moldable above a specific temperature, but solidifies upon cooling. Because it is derived from renewable bio-based sources, it is also considered a bioplastic. The material is translucent, colorless, brittle, and water-soluble at room temperature. It is commonly used in pharmaceutical capsules, glue, cosmetics, photographic films, and theatrical lighting equipment. Additives and preservatives can be used to alter and improve its properties. Glycerin, for example, is a plasticizer that may be added to increase flexibility. Gelatin also absorbs color easily; various tints and opacities can be achieved with different combinations of dye and titanium dioxide.

Gelatin bioplastic can be poured into a variety of shapes and molds to produce thin, flat sheets or thicker forms. After the initial setting stage, gelatin can be further manipulated before it cures into its final state. Textures and surface patterns can be embedded with surface molds. Laser etching produces a white, opaque residue that contrasts with the transparency of the plastic. Gelatin bioplastic shares many properties with petroleum based plastics, but one major advantage of gelatin bioplastic is biodegradability. Gelatin plastic decomposes through the action of living organisms and bacteria.[9]

**STARCH**

Starch is a carbohydrate extracted from potatoes, wheat, corn, rice, tapioca, arrowroot, and other staple foods. It is the most common carbohydrate in the human diet, and is produced by most green plants. Starch is employed as an adhesive across a wide spectrum of industrial applications, including cardboard corrugation, paper coating, concrete block binding, and gypsum board binding. Starch has also been incorporated into industrial thermoplastics and foams. Starch is a powerful adhesive with the application of heat, and is well suited to use in thermoplastics. The material offers a vast spectrum of textures, colors, strengths, flexibilities, thicknesses, and forms.

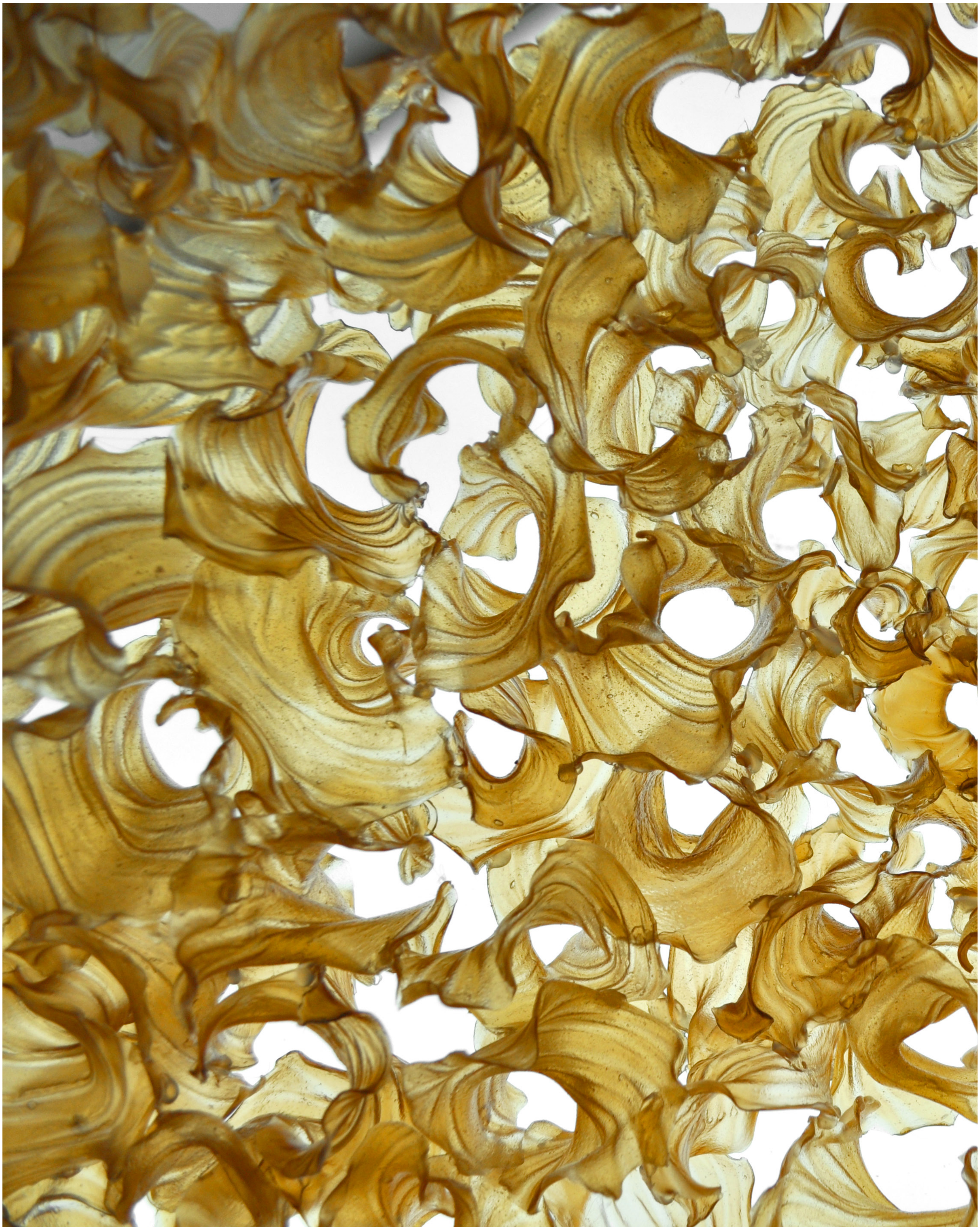

Figure 4: Agar-based bioplastic prototype by Gisella Allen and Zach Walters.

This multiplicity is possible due to starch's compatibility with additives (including plasticizers, denaturers, and colorants) and because of the poly-identity of starch itself. Potato starch, which yields a viscous material during the plasticization process, lends itself to extrusions and other structural techniques. Arrowroot starch, being thin, fluid, and translucent, performs well as a film. Rice starch, which is composed of larger, discolored granules, produces a frosted, matte film with a sand-like texture and color. The possibilities of starch thermoplastic applications are vast; the wide range of results from experimentation suggest that starch plastic could be employed as a diverse material in the built environment.[10]

## AGAR

Agar is derived from the polymeric carbohydrate agarose, found in the cell walls of certain species of red seaweed. The two primary species of seaweed used for agar, Gelidium and Gracilaria, have traditionally been gathered from boats, by scuba divers, or after they have been washed ashore. Agar is commonly used in food as a vegetarian alternative to gelatin and in microbiology as a growth medium in petri dishes.

Commercially available in the form of powder, agar transforms into a gelatinous substance after boiled in combination with water, plasticizers, and other additives. Once cured, the solution forms a bioplastic that ranges from a thin and flexible film to thicker and more rigid sheets. The final texture of the bioplastic can be controlled by changing the substrate on which the agar is dried. For example, curing the agar on acrylic produces a smooth and translucent bioplastic - whereas curing on wax paper produces a wrinkled and opaque bioplastic.

Without the addition of plasticizers, agar has a tendency to curl - naturally creating dynamic, sculptural forms. When poured on parchment paper, parallel ridges form in the substrate as a result of moisture in the agar mixture. These ridges cause the agar to set with areas of different thicknesses that cure at different rates, causing the material to curl inwards. The anticlastic curvature of the resulting component is controlled to a certain degree, while also allowing for a level of inherent variation. Here the component has been aggregated based on defined rules that generate a modular system (Figure 4). This process allows for a dialogue between natural form-finding in biobased materials, computational design, and fabrication techniques.[11]

## CONCLUSIONS

As a study, Edible Materials Lab yielded a number of insights with implications for further research and design pedagogy. Almost immediately, our consideration of materials and food brought us to food waste as a pressing problem, perhaps best explained by the reality that roughly a third of food produced in the world for human consumption every year is wasted.[12] Throughout the study, it also became important to articulate that this kind of approach toward materials is meant to improve and not compete with food-based agriculture. Understanding this kind of material production as a part of a complex network of processes at multiple scales and geographic locations, we were also aware that further studies would benefit from utilizing accounting methods for embodied energy in order to calculate efficiencies across a product's entire lifecycle. How these material products may be integrated into the constructed environment is at this moment easier to answer in the realm of architectural interiors and landscapes, but more challenging – given certain requirements for durability – at the scale of buildings. Both academically and commercially, the need for further interdisciplinary research and industry-based collaborations will advance the initial premise of this project. Pedagogically, Edible Materials Lab provided an opportunity for students to consider materials as a design problem, rather than a given. Having to "make" one's own material before that which is designed can be fabricated or prototyped, changes the ethos of the studio environment: it is not unlike having to grow a tree before you can make a wood-frame building with it.

## ENDNOTES

1. For a further discussion about the changing role of materiality in contemporary architecture, see Löschke, Sandra Karina, ed. *Materiality and Architecture*. London: Routledge 2016.
2. This shift – from object-centric thinking to ecological thinking – is the framework for the session for which this paper was prepared, defined by its organizers/chairs.
3. See Meindertsma, Christien. *PIG 05049*. Amsterdam: Flocks, 2008.
4. Student work and research on SCOBY-based cellulose is by Amy McDonnold and Amy Witte, The University of Texas at Austin.
5. Student work and research on mycelium-based foams, masonry, and surfaces is by Mary Kate Feldman and David Mora, The University of Texas at Austin.
6. Student work and research on cast and 3D-printed salt is by Laurel Morrow and Benjamin Vela, The University of Texas at Austin.
7. Student work and research on plant-based fibers and fiberboards is by Diane Collins and David Thompson, The University of Texas at Austin.
8. Student work and research on gum and gum-modified concrete is by Toheed Khawaja and Stephanie Vidal, The University of Texas at Austin.
9. Student work and research on gelatin-based bioplastics is by Heather Sutherland and Yingqian Zhuang, The University of Texas at Austin.
10. Student work and research on starch-based bioplastics is by Stephanie Betesh and Piper Cain, The University of Texas at Austin.
11. Student work and research on agar-base bioplastics is by Gisella Allen and Zach Walters, The University of Texas at Austin.
12. Food and Agriculture Organization of the United Nations. "SAVE FOOD: Global Initiative on Food Loss and Waste Reduction" Accessed June 28, 2016. http://www.fao.org/save-food/resources/keyfindings/en/