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NEW EARTH

*EXPLORING SUSTAINABLE PRACTICES
WITH CLAY AND FOOD WASTE*

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INDEX

LIST OF FIGURES

ABSTRACT

Ceramic craft is rooted in centuries of tradition and continues to evolve with the infusion of innovative materials and sustainable practices. The research in this paper is a testament to this evolution, focusing on the development of ceramic production processes using clay recipes that incorporate food waste. The inclusion of food waste in clay recipes results in less waste in landfills as well as a lower volume of clay needed to create ceramic items. Both eggshells and spent coffee grounds will be explored as primary ingredients as they are both readily available waste products that have intriguing foundations of existing research within the ceramic field.

The clay recipes will be developed with press molding and slip casting production techniques in mind. By using different ratios of clay and food waste with production methods that are widely used in both large and small ceramic facilities, the clay recipes can more quickly and effectively be incorporated into existing production assemblies. This research includes a series of tests that offer a basis for understanding what food waste ratios are possible in the press molding and slip casting techniques as well as the observable characteristics of the resulting pieces.

This research approach is aimed at small-scale ceramic productions that can improve the circularity of food products at a community level. Through exploration and experimentation, this paper seeks to bring increased sustainability and novel aesthetic possibilities to ceramic craft using food waste in clay bodies and widely used production methods.

key words: clay; craft; food waste; production; slip casting; press molding

1 INTRODUCTION TO CLAY

Ceramic production is an industry where artistic expression can be synthesized with materials research to address growing environmental challenges. This research paper seeks to build upon these investigations by focusing on the incorporation of egg shells and spent coffee grounds in slip casting and press molding techniques.

With origins reaching back thousands of years, clay craft has a rich history that has maintained its relevance in modern society. Developments in ceramic technology provided ancient civilizations with a means to efficiently store food, cook, and use utilitarian vessels in their everyday lives (Barker & Majewski, 2006). Individuals today still reach for their favorite ceramic mug after brewing their morning coffee, enjoy the pleasures of a fresh bouquet in their ceramic vase, and have their favorite fall soup out of a ceramic bowl. Clay is a medium that touches people daily and as such, holds immense potential to reduce waste if sustainable ingredient choices are incorporated into the production recipes. Utilizing eggshells and spent coffee grounds in clay recipes not only extends the life cycle of waste that would otherwise end up in the landfill but can also enhance the structural and aesthetic qualities of ceramic products. By exploring the impact of readily available eggshell and coffee ground waste, the potential of these ingredients is accessible to many makers. This accessibility is also why this research explores slip casting and press molding production techniques. Both are quite commonly utilized in craft productions for their precision and consistency, making them ideal for producing intricate, high-quality ceramics for an individual's coffee-drinking, flower-holding, or soup-eating needs. This research seeks to demonstrate how doing what is best for the environment works in tandem with the continued evolution of ceramic craft.

1.1 BRIEF HISTORY

Ceramics stand out as a significant and early achievement in human history. Considered one of the first manufactured items, the creation of ceramics showcases a mastery of fire control and clay manipulation that has maintained its importance in material culture for millennia (Del Rio et al., 2022). Around the world, ceramics play a crucial role in economic activities, cultural heritage, and artistic expression that represents the regional and historical contexts of their creation (Del Rio et al., 2022). The term "ceramics" is derived from the Greek word "keramos" meaning 'burned earth' and are defined as solids obtained from firing inorganic powders (Rödel et al., 2008). These vital items of 'burned earth' are characterized by their high strength, low density, chemical stability, corrosion resistance, and other field-specific characteristics (Rödel et al., 2008).

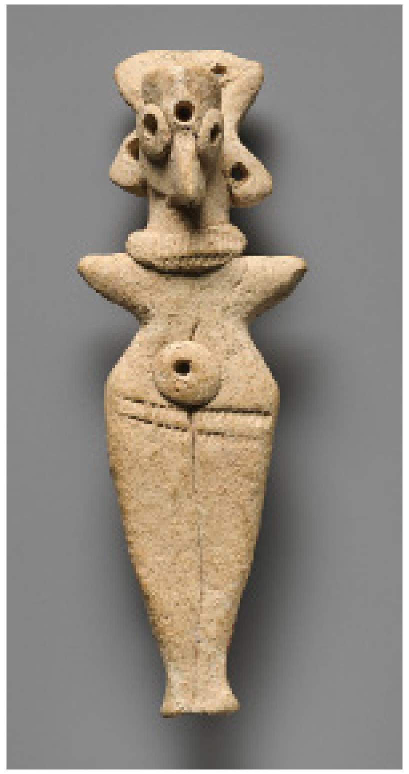


Fig.01: Nude female figure
2 millenia BCE
Met Museum

Ceramics constitute the most extensive category of objects found during archaeological excavation in historical locations, allowing researchers to map and better understand societies long past (Barker & Majewski, 2006). Ceramic craft is special in that it has maintained its relevance in society over time. The same technology that created the fragmented ceramic pieces exhumed after thousands of years can be traced to the highly advanced technical applications of ceramics in the aerospace, automotive, and technological sectors of today. With significant material qualities and an intense depth of history, ceramics has been and continues to be the subject of substantial materials research.

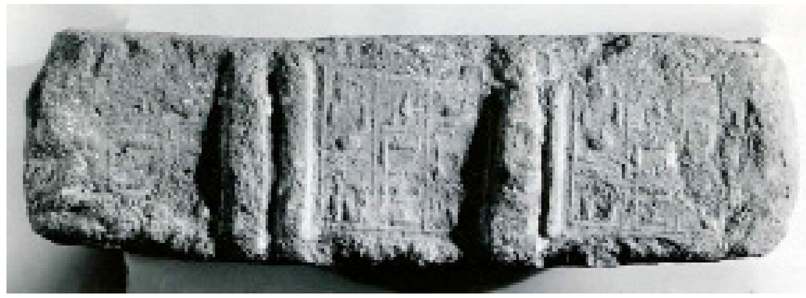


Fig.02: Stamped Brick the Goldsmith Amenhotep and His Wife Nofretiry
ca. 1550–1295 B.C.
Met Museum

1.2 CLAY & WASTE

Clay is an ideal medium for food waste inclusion because it is malleable and absorbent, making the mixing process for food waste relatively simple (Kumari & Mohan, 2021). It is also a material that must be subject to high temperatures to complete its transformation into a finished ceramic piece. At high temperatures, food waste can create an abundance of unique results depending on the nature of the waste and its mineral makeup. This means that in addition to lowering the volumes of waste headed to the landfill, it can offer entirely new aesthetic and functional possibilities for clay craft.

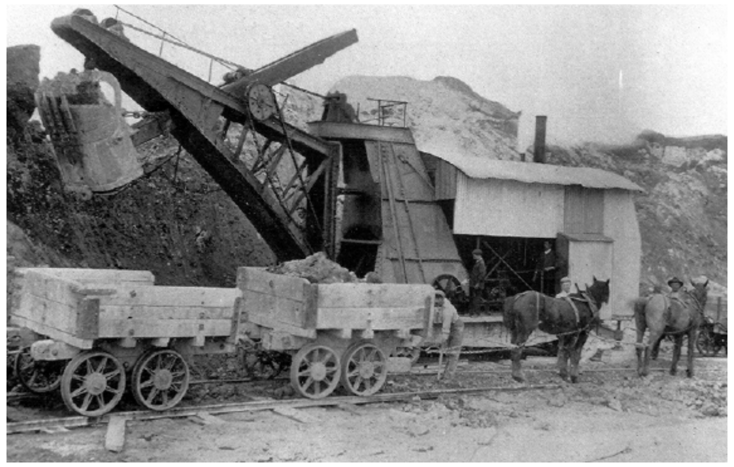


Fig.03: Digging for China clay: A Ruston Dunbar, believed ex-Manchester Ship Canal Co, in Dubbers Pit
ca. 1908
Heritage Machines

1.3 SOURCING CLAY

One of the key issues when developing a more sustainable clay production is the environmental impact of the mining practices of clay suppliers. 'Natural' clay is abundant and can be found at various locations worldwide but differs in availability and specific characteristics from region to region (Ito & Wagai, 2017). The type of clay often used in ceramic studios is manufactured using specific minerals such as silica, feldspar, kaolin, quartz, etc (Kumari & Mohan, 2021). These minerals must be mined at specific locations, processed, and then distributed.

Fig.04: Panorama of Melbur Kaolin Clay Quary

Fig.05: Natural Clay from Oriental coast of Sicilia, Italy
2020-2022
Unurgent Argilla

Understandably, ceramicists would want to use these highly specialized manufactured clays as they offer ideal functionality and predictably that natural clays cannot replicate with ease. However, the resource depletion, habitat destruction, and land degradation common at mining sites have negative environmental impacts (Anju & Jaya, 2022; Saha, 2023). In addition, the distribution of raw materials and finished ceramic pieces results in carbon emissions that contribute to the environmental footprint of the ceramic industry (Del Rio et al., 2022). Integrating food waste produced locally into clay production is one step towards improving the circularity of local economies. In tandem with food waste experimentation, potters could also open their minds to the exciting possibilities and challenges involved in sourcing their clay more locally and more sustainably.

1.4 CRAFT, CULTURE & CIRCULARITY

The Association for Psychological Science suggests that sustainability and environmentalism must be grounded in a cultural shift where individuals should "think globally but act locally" (Armstrong, 2021; Versey, 2021). Local craftspeople can make sustainable choices that will impact the collective culture of their communities. Recognizing the role of the local maker, ceramic craft can become a more circular exchange where local outputs are valued as finite commodities but also as a means to form a collective identity (Bellver et al., 2023).

Ceramic makers can seek to reduce waste in their communities while also providing beauty and function through their ceramic pieces.

A study aimed at connecting the social and natural sciences that intertwine when considering the sustainable development goals set forth by the UN warns that an approach "that overlooks local culture might be unworkable or, at least, unable to generate results with its original intentions" (Zheng et al., 2021). This is not to say that there is any one fix to climate change or that it's any one individual's responsibility. The impact of unsustainable consumption is collective and systemic (Zheng et al., 2021). On a less grand scale, it can be understood that no one fix can solve the waste problem surrounding coffee or eggshells. It can also be understood that a finite amount of clay minerals exist and like many materials, can be used in ways that are both sustainable and unsustainable. Local ceramic producers make decisions that impact their communities. It is with this responsibility in mind that craftspeople can make the choice to utilize food waste in their practice.

1.4.1 CASE STUDY OF CERAMIC TABLEWARE: ECODESIGN ASPECTS OF CERAMICS

A study conducted in the Czech Republic holistically reviewed five scenarios of ceramic production to determine the key factors impacting the environmental footprint of ceramic production. The five scenarios include ceramics from a small ceramic studio produced either on the pottery wheel (PW) or using slip casting (PSC),

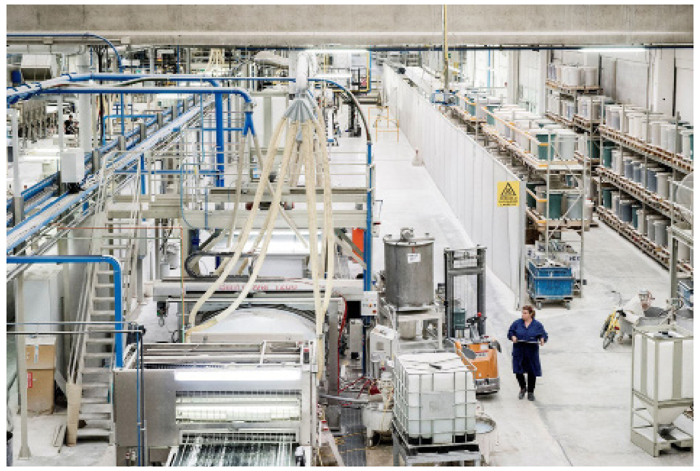


Fig.06: Ceramics factory in Fiorano Modenese, Italy
2018
Fabrizio Annibali

ceramics made in a small studio using an alternative technique of high energy rate formation (HERF), ceramics from an automatized factory (FAC), and experimental reconstruction of ceramics made with ancient technology (ANC) (Železný et al., 2023).

Fig.07: Mae Ceramics Studio
2023
Mae Ceramics

It was found that small studio manufacturers (PW & PSC) reach lower material losses than factories (FAC). This is due to the small production capacity, allowing each piece more individual focus and flaw prevention during fabrication. Additionally, the simplified space in small studios makes it easier for artisans to spot flaws and prevent inputting further energy and materials on items that do not meet quality standards Alternatively, the study found that the FAC scenario exhibited the highest energy efficiency and lowest fuel consumption. This is in part due to the more stringent regulations placed on industrial facilities. Factory facilities use large, often expensive, production and building systems to make it easier for them to keep their energy use lower. An example of this is heat recovery during the firing process that is used in alternative production steps. Even with the factory discarding approximately eleven percent of the final products for not meeting production standards and seven percent of pieces for defects after bisque firing, they proved to be more energy efficient than small ceramic studios. Suggestions for increased energy efficiency in factories include a lowering of product quality standards or implementing closed-loop recycling of pots that are determined to be unsellable.

These study results highlight the multifaceted nature of making ceramics at different scales. By understanding the issues of both small and large-scale production, ceramicists can seek to improve both energy and material efficiency. The utilization of food waste in clay recipes is one of the tools available to improve the environmental footprint of ceramic production.

2 PRODUCTION METHODS

2.1 SLIP CASTING

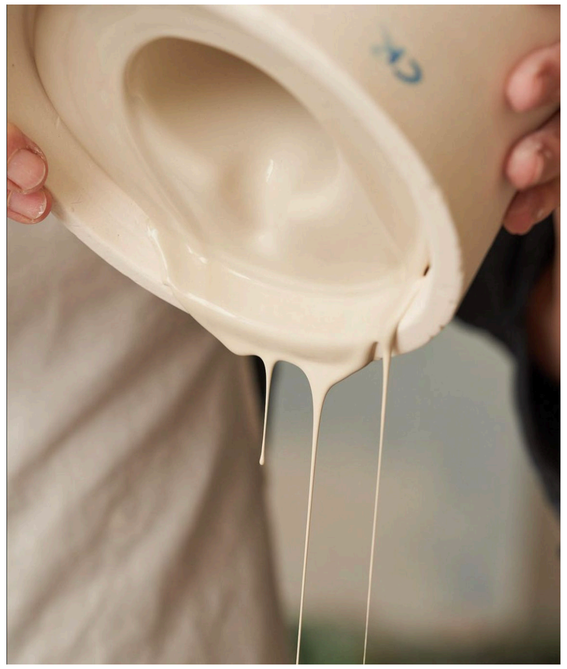


Fig.08: Slip casting process
2023
Sue Pryke

Slip casting is one of the two methods of ceramic production focused on in this paper. Slip casting is a traditional ceramic production technique that has existed for thousands of years, tracing back to ancient civilizations like the Egyptians, Greeks, and Romans. Slip casting involves pouring slip, a liquid clay mixture, into plaster molds (Adams, 1971). The absorbent mold removes moisture from the slip, flocculating the liquid to form a solid outer layer of clay on the mold interior (Evans, 2008). When the layer of clay within the mold is determined thick enough, the excess slip is poured out of the mold. The clay remaining in the mold dries over time and can then be removed for firing, glaze application, and more. Slip casting allows artisans and manufacturers to efficiently create uniform, intricate ceramic pieces with precise dimensions and surfaces (Adams, 1971). Because of this, slip casting is particularly efficient in the mass production of ceramics. Examples of slip cast items include dinnerware, decorative items, tiles, and industrial building materials.

2.2 PRESS MOLDING

Press molded items have been unearthed alongside ancient slip cast pots. Press molding was used to produce many items but it was particularly suited to creating intricate patterns and relief decorations for tiles, plates, and other ceramic objects (Peterson & Peterson, 2003).

With the Industrial Revolution and the development of unique machinery, press molding has become an essential ceramic manufacturing process that has evolved beyond its decorative roots. Similar to slip casting, press molding allows for precise replications of designs, complex patterns, and textures that can cater to both commercial and artistic productions. Unlike slip casting, however, press molds involve the use of a standard clay body that is not liquid. The clay is pressed either manually or mechanically into molds of various shapes and sizes to take on the shape of the mold cavity (Peterson & Peterson, 2003). The applied pressure helps evenly distribute the clay as it takes on the shape of the mold. Once the clay has taken on the intended shape, excess material is trimmed away leaving the final piece to be fired and glazed as needed.

Fig.09: Press molded plates drying
in plaster molds in Kurja, India
Ankana Sen

2.3 BENEFITS OF MOLD FOCUSED TECHNIQUES

Slip casting and press molding are widely used production techniques, making clay recipe development specific to their use an intriguing area of study. Additionally, they are methods that I focus on in my ceramic work. These methods were chosen as the focus of this paper both because of their practical applications as well as my ceramic skillset.

Fig.10: Slip casting molds
2022
Shipley Goods

In 2019, I commissioned a fellow ceramic artist to make three slip casting molds for the production of small pots that I had previously been throwing on the pottery wheel. After using the molds for several months, I became fascinated with the process and attended a mold-making class that further transformed my clay craft. My interest in slip casting and press molding has only expanded since. I immensely value the ability to create ceramic pieces of consistent quality because I find great satisfaction in seeing my perfectionist visions come true. Moreover, these methods have also saved me significant time and material costs.

Fig.11: Slip casting production
2022
Shipley Goods

Though the waste reduction potential of slip casting and press molding varies depending on how they are applied, from experiences in both my production and at various studios, they often result in less waste than alternative methods like hand-building and wheel-throwing. For makers at a community level, this means slip casting and press molding are production methods that are scalable, efficient, and create results that can be anticipated and controlled. Utilizing predictable production methods while testing food waste materials enables artisans to gain comprehensive insights into the material's characteristics, and potential applications leading to more informed creative decisions.

3 CLAY & WASTE: CASE STUDIES

PROJECT 6:1
BY KIRSTIE VAN NOORT
2012

Kirstie van Noort operates her design studio in Eindhoven, engaging in collaborations with industries as a material researcher (New Material Award, n.d.). In 2011, van Noort began field research at the kaolin quarries in Cornwall, UK where she discovered how intensely damaging the production of porcelain clay can be. This work was done in collaboration with the company Imerys, the largest supplier of kaolin in the United Kingdom (van Noort, n.d.). For every kilo of fine porcelain produced, six kilos of waste were produced (van Noort, n.d.). Additionally, the landscapes where these minerals were mined became irrevocably changed. The six kilos of waste produced in porcelain processing are not used in ceramic production, it is instead dumped in landfills or used in the construction industry. Project 6:1 is the result of over one year of testing where for every 6 pieces made from the waste byproduct, one porcelain item is made (van Noort, n.d.). Highlighting the "inanity of savouring purity over utility", van Noort's work introduces the aesthetic and functional possibilities of what has traditionally been considered waste (New Material Award, n.d.). The first 6:1 collection was presented in 2012 but her research continued as she resumed waste collection directly from kaolin mining sites through 2014 (van Noort, n.d.).

By collaborating with Imerys, van Noort's 6:1 project demonstrates the benefits of collaborating with companies on areas where sustainable practices should be considered. In an era where companies seek to create wealth from waste, artisans and small producers can act as incubators for ideas that can create positive changes for the environment. By creating beautiful ceramic pieces from what Imerys would consider to be waste, van Noort starts a conversation on why kaolin mining byproducts are considered waste. With this conversation, craftspeople can begin to view waste as a means to create unique colors, textures, and structural qualities in their ceramics.

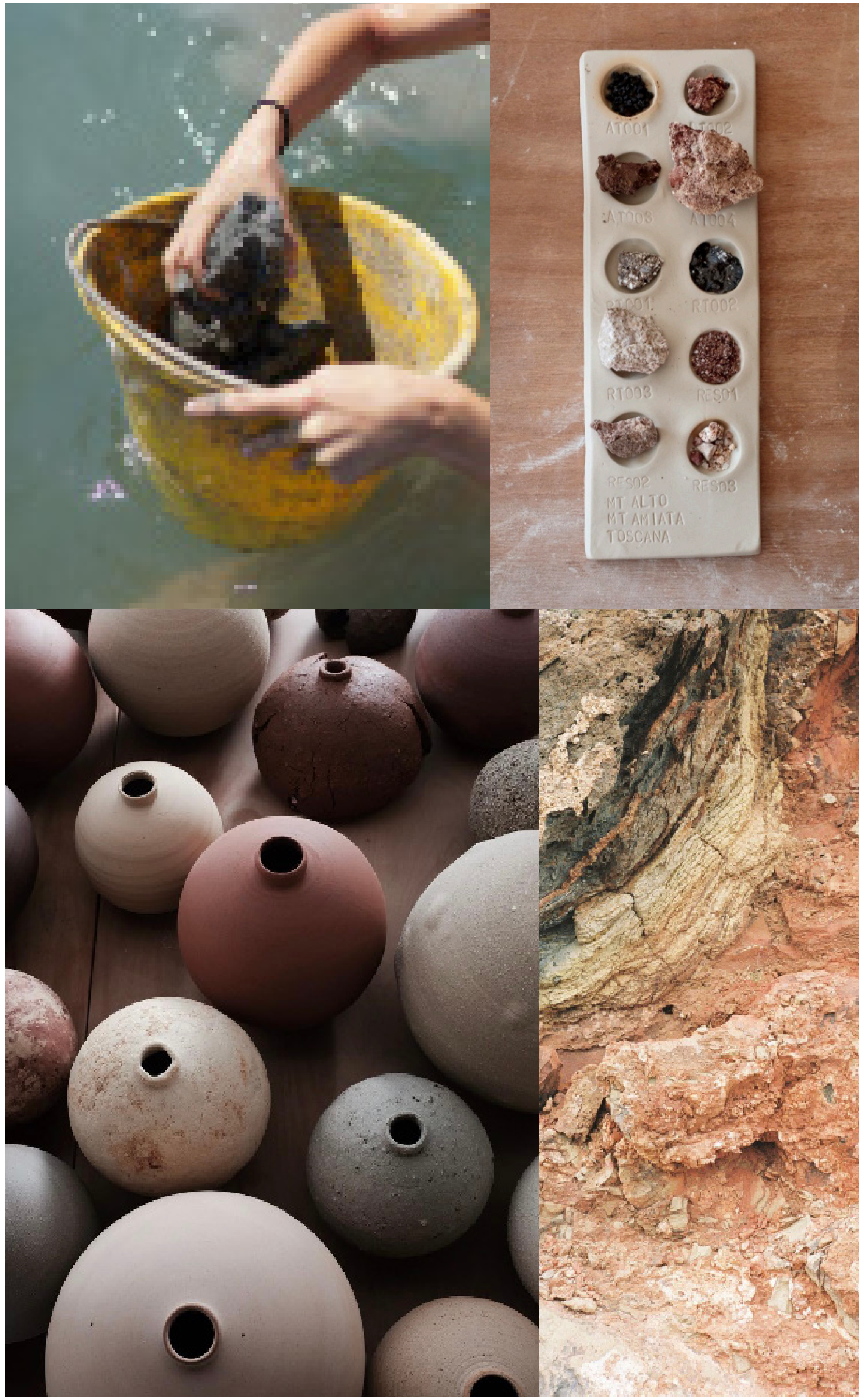
3.2

UNURGENT ARGILLA BY NINA SALSOTTO CASSINA
2019

Unurgent Argilla started in 2019 when artist and researcher Nina Salsotto Cassina encountered a natural clay deposit on Mount Bisalta during a hike in the Maritime Alps. The discovery of this clay sparked the beginning of an in-depth classification and archive of soil and clay types from 13 natural deposits in France and Italy (Officine Saffi, n.d.). The repeated round-shaped pots in Cassina's work seek to create a cohesive language, or "canvas" where viewers dive into the complexity of connections that a uniquely tangible form of craft can provide (Unurgent Argilla, n.d.). The circular vessels in Unurgent Argilla can be mapped across landscapes, connecting each piece to the essence of its origin (Officine Saffi, n.d.). Cassina summarizes this beautifully, describing her work as something that

> *[roots] itself partly in the science, in the poetry and in the politics of soil and land. Soil (or clay) is tangible especially when you forage it, yet [she finds herself] perceiving it more and more fragmented and partial, almost distant in a sense. The eccentricity and unfamiliarity of certain clays, but also the quiet commonness of others, makes this exercise fascinating, complex and contradictive, often going outside the boundaries of what's expected, imagined and linear. (Unurgent Argilla, n.d.)*

These words describe the experience that clay offers. More than a material, clay is **earth.** Clay cannot always be a resource to be processed and sold as a commodity in increasingly automated economies. It can, should, and has remained a means for expression, connection, and storytelling for makers worldwide. Food waste can be a part of those stories.



3.3

CRANGON CRANGON BY JADE RUIJZENAARS
2019

In her project Crangon Crangon, Dutch designer Jade Ruizenaars utilizes waste from the shrimp industry to develop unique ceramic glaze effects. Seventy percent of shrimp is inedible, leading to a significant amount of waste in the industry. Typically, shrimp harvested on Dutch coasts is first shipped to Morocco where it is peeled and returned to Europe for distribution. The disconnection of this system of distribution and waste allocation was partially resolved when an automatic peeling center in Groningen, Netherlands was opened. With 60,000 kilograms of waste material being produced each week at this singular facility, Ruizenaars had access to significant volumes of shrimp waste right in the Netherlands.

Ruizenaars experimented with shrimp peels to discover that when fired at high temperatures, the calcium present in the peels gives the glaze a cloudy white effect. Using varying types of clay and different application techniques resulted in unique outcomes that added not only visual interest but also a unique story to the ceramic pieces. In addition to calcium, chitin is a polymer present in shrimp peels that can be processed and produce chitosan, a material that has applications in medicine, packaging, bioplastics, water purification, and agriculture. I mention the varying potential uses of shrimp peels because the opportunities also apply to the domain of eggshell and coffee ground waste. With such significant consumption, shrimp peels, eggshells, and coffee grounds must be utilized in many different ways and in many different industries to develop a more circular use cycle. Ruizenaar's Crangon Crangon project shows the application of shrimp peels in the ceramic world in a similar manner to which my tests apply eggshells and coffee grounds.

3.4

CLOSER
BY MAREN JANSEN
2016

In her 2016 graduation project from Eindhoven University, ceramic artist Maren Jansen used sand collected from areas near Syria to create ceramic disks that tell a story. Her work is a marker of the refugee crisis of 2016 where she sought to question and map the available routes for refugees through the collection of sand from the areas that people were fleeing (Studio Marin Jansen, n.d.). By working with people willing to try and reach Syria to collect sand, Jansen uses the sand as an additive within her clay recipes (Studio Marin Jansen, n.d.). Each unique ceramic disk specifies how far from the Syrian border the sand was collected, offering a visual representation of the social networks developed during her project as well as the physical routes out of the war-torn country (Studio Marin Jansen, n.d.). Her work combining material experimentation with topical social commentary is something I greatly admire.

Jansen's use of clay and sand additives to tell a story indicates how other additives, such as coffee and eggshell, can be used to create a wider conversation around food waste and climate change. While this research explores recipes and specific techniques, further experimentation could also speak to the social issues of our time. The physicality of ceramics means additives within the clay can become enshrined in a tactile, interactive object.

4 EGGSHELLS

With so many potential materials to incorporate into clay recipes, it is important to better understand why this paper focuses on eggshells and coffee waste specifically.

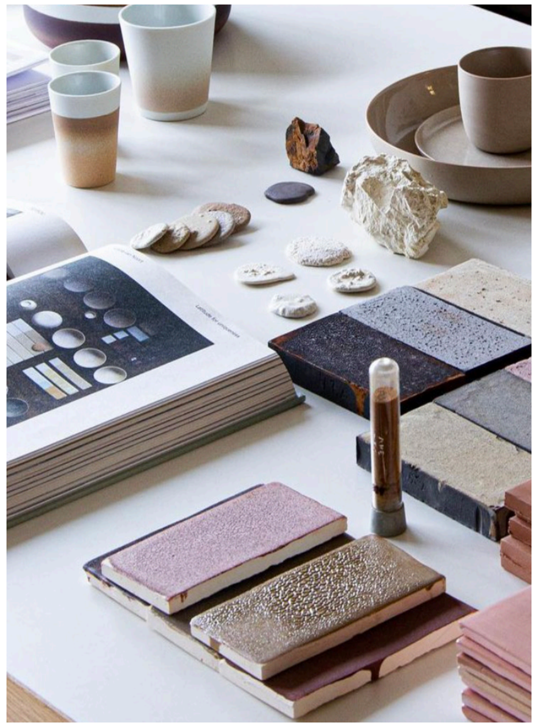


Fig.12: Studio details
2023
Kirstie van Noort

The utilization of eggshell waste is a fast-growing body of research in materials science that spans from highly technical applications to more simple craft approaches (Baláž et al., 2021). Some reasons for this increasing interest include the availability of eggshell waste, the chemical makeup of the material, and growing interest in using food waste as a tool to combat climate change (Baláž et al., 2021). This research comes as companies are seeking to create wealth from waste. Food waste volumes are estimated to reach 2.1 billion tons representing 1.5 trillion dollars in lost economic value by 2030 (Saberian et al., 2021). While profit-driven endeavors are admirable as long as they keep sustainability at their core, this paper seeks to focus less on profitability and more on the diversion of waste and how local makers and artisans can make small-scale, positive environmental impacts in their communities. s

4.1 EGGSHELL WASTE & PRODUCTION

To better grasp why eggshell waste should be recycled, it is best to start with understanding the volume of eggshell waste that is and will continue to be created. In the last ten years, egg production has increased by eighteen percent globally with China, the United States, and India being the highest consumers (Waheed et al., 2020).

There were seventy-eight million metric tons of eggs produced in 2018, resulting in approximately 8.58 million metric tons of eggshell waste (Waheed et al., 2020). The majority of these calcium-rich eggshells were discarded as waste and dumped into landfills that are often already at capacity. Egg consumption is only expected to rise worldwide, meaning more waste in an already unsustainable system. The volume of the waste is not the only concern, it is also the material make-up of the shells. Eggshells are ranked as the fifteenth worst food industry pollution by the Environmental Protection Agency because the protein-based film on the inside of the shell attracts vermin to landfill sites and can provide the environment for fungal growth that can be harmful to human health (Waheed et al., 2020). The high mineral content of eggshells also means they decompose very slowly. However, the mineral content that is a problem at the landfill is a key component to reducing eggshell waste.

Fig.13: Free range egg farm
Virginia, USA
Sunrise Farms

In addition to waste concerns, it is also important to consider the resources and energy that go into creating the ideal conditions for hens to lay eggs with eggshells of consistent quality and mineral composition. Composed of ninety-five to ninety-seven percent calcium carbonate, eggshells exist as a means to protect and facilitate the growth of embryos within eggs, offering physical protection as well as a porous gas exchange barrier needed for life to grow (Hunton, 2005). For those who produce eggs for our food systems, eggshells offer built-in mechanical and pathogen protection to the product that will be packaged and eventually eaten (Rose & Hincke, 2009).

With such an essential role, producers have come to understand how to provide the proper diet and environment necessary for hens to lay eggs with consistent, high-quality eggshells. Hens take an impressive 18-20 hours to produce solely the eggshell for their eggs and require sources of calcium within their diet that their bodies can turn into calcium carbonate (Hunton, 2005).

Fig.14: Egg process plant
2019
Iowa State University

Up until the 1960s, it was common for breeders to offer finely ground limestone as the calcium supplement. When eggshell quality began to wane and impact profit in the 1960s, research was conducted to determine that oyster shell waste was a superior form of calcium for hens because the larger pieces of shell took longer for hens to digest meaning more calcium could be absorbed into their bodies (Hunton, 2005). The work in monitoring, maintaining and improving eggshell quality is a multifaceted endeavor that is fueled by egg producer's desires to get as many eggs to market as possible (de Abreu Fernandes & Litz, 2017). When consumers send their eggshells to the landfill, they are throwing away a unique natural resource that has required significant time, energy, and research to be produced. It is this time, energy, and research that individuals must keep in mind when striving to reuse food waste.

4.2 CALCIUM CARBONATE

The utilization of the calcium carbonate in eggshells is not new to the ceramics industry. The specific historical timeline for the use of eggshells in pottery is difficult to pinpoint as it has been part of various cultural and traditional pottery-making methods for a long time.

Eggshells have been used for a variety of applications, most prevalently in the development of glazes and as additives in clay bodies (Ferraz, Gamelas, Coroado, Monteiro, & Rocha, 2018).

Fig.15: Oyster shells for chicken food
Capiz, Philippines
Jocelyn Mae Fegarido

When fired at high temperatures, calcium carbonate decomposes by releasing carbon dioxide and leaving behind calcium oxide (Avelino, Soares, Peña-Garcia, & Lobo, 2023). Calcium oxide, also known as lime, reacts with other glaze ingredients to form silicate glass structures essential for glazes. While commercially available calcium carbonate is often mined, potters also make their own using eggshells (Avelino, Soares, Peña-Garcia, & Lobo, 2023). By firing them at bisque temperatures, approximately 1000 degrees Celsius, the eggshells can be ground down into a powder and used in raw glaze recipes (Ferraz, Gamelas, Coroado, Monteiro, & Rocha, 2018). Using eggshells as a glaze ingredient is a method most commonly used by smaller ceramic studios because commercial ceramic producers prefer the predictability and convenience of mined calcium carbonate. The ability of smaller productions to embrace variability in their productions therefore makes them more likely to use locally available food waste in their work. With eggshells already being a material associated with the ceramic field, further exploration into its potential uses can be part of its natural evolution.

Fig.16: Eggshells
2023
Mary Shipley

4.3.1

EGGSHELL CASE STUDIES: BIOCERÁMICS BY CYNTHIA NUDEL
2023

Cynthia Nudel is an Argentinian visual artist living in Spain who is dedicated to the exploration of different materials and techniques using organic waste (Nudel, n.d.). Starting with a passion for ceramics, she questioned the energy-intensive process of ceramic production and sought to find a biomaterial alternative (Isola Design, n.d.). She found this alternative in eggshell waste. By combining dried, ground eggshells with brown algae-derived calcium alginate and water, she creates a thick paste that is applied to the interior of plaster molds. Her eggshell paste application is unique as it is neither slip casting nor press molding. The paste is too thick to slip cast and too wet for press molding. Instead, Nudel uses a tool to smooth the 'bioceramic' paste through the interior of the plaster molds by which she can create elegant, classic vase shapes with uniform wall thicknesses (Isola Design, n.d.). Not only saving eggshells from the landfill, her pieces can air-dry without any additional energy output from a kiln (Isola Design, n.d.). Once dry, she applies natural pigments made of other food waste to the exterior of the pieces (Isola Design, n.d.). The resulting fully biodegradable pieces look like earthy brown, black, green, and white, pleasantly textured vases that in photos resemble decorative ceramics. Nudel's Biocerámics seeks to highlight the disconnection between people and nature, staying true to her intention to "unite artistic creation with the need to generate a social and environmental impact" (Nudel, n.d.).

Nudel's eagerness to experiment with food waste materials is a testament to a growing culture of sustainable thinking. As an artist, she speaks through both the process and the final output of her work. Her technical understanding also provides an education for those who find her pieces and want to experiment with their own recipes and production techniques. While her pieces are largely decorative, her use of the material and plaster molds inspires this research. When the idea for this paper was first developed, the plan was to use eggshells and coffee as the main ingredients in the resulting recipes, similar to Nudel.

However, upon initial experimentation, I was disappointed with the apparent fragility and lack of utility in the final results. While eggshell biomaterials are often likened to ceramics, they lack a significant connection to the reason ceramics are so widely used today: functionality. Functionality in this sense relates to durability, hardness, heat resistance, insulation, and other properties that allow ceramics to be used repeatedly for very long periods. Within the context of Nudel's work, the lack of functionality makes sense. She is foremost an artist who experiments with the primary goal of sharing a message of humanity's disconnectedness with the natural world while also "inviting] us to join a change of paradigm" related to our relationship with waste (Isola Design, n.d.). In part through her work, I realized that the area of material experimentation I am interested in is more grounded in the characteristics of ceramics that cannot be replicated when using food waste material as the primary ingredient. Therefore, the recipes included in this research have clay as at a minimum, fifty percent of the final material. By maintaining fifty percent or more clay in the recipes, the resulting tests and potential future experiments out of the research maintain more of the ceramic functionality than a food-waste-based product.

4.3.2

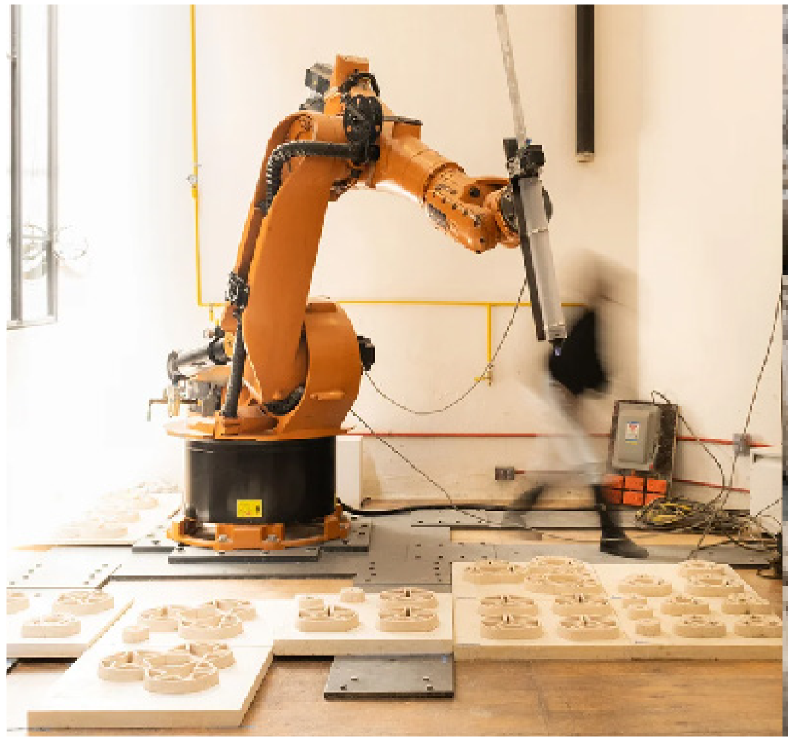
THE EGGSHELL PROJECT BY MANUFACTURA
2022

MANUFACTURA is a design studio based in Mexico that developed a research project focusing on the utilization of eggshell waste in 3D-printed building blocks that can be used in a variety of architectural applications (MANUFACTURA, 2023). With expertise in the 3D printing field, MANUFACTURA is particularly well-positioned to utilize emerging technologies to help foster a sustainable relationship between materiality and the environment (MANUFACTURA, n.d). The Eggshell Project was developed to address two primary concerns: the negative environmental consequences of ceramic production and the significant food waste in Mexico. MANUFACTURA's criticisms of the ceramic production process include the "gas emissions from firing and fuels to their waste management, transportation, and energy consumption" (MANUFACTURA, 2023). To temper the apparent divide between sustainable practices and ceramic production, the MANUFACTURA team chose to focus on a product made primarily with the widely available, lightweight material of eggshells. Combined with unspecified bio-based binders, The Eggshell Project developed a recipe and manufacturing process that "'allows less waste production, geometrical freedom, precision, and repeatability'" (MANUFACTURA, 2023). The eggshell bricks printed by their KUKA KR-15o robotic arm feature the quintessential layers of a 3D printed object and a neat repeated criss-crossing design that hints to its intended structural applications. With a muted gray/cream tone, it is not obvious that the bricks primarily consist of waste that would otherwise be in a landfill.

The Eggshell Project demonstrates the growing interest in the marriage of sustainability, ceramics, and food waste. It is also a valuable example of how different areas of expertise can work together toward improving the problem of food waste at a local level. The Eggshell Project is a technology driven whereas the slip casting and press molding techniques explored in this paper are decidedly ancient techniques. All can be used to improve the environment through the reduction of waste.

However, it is worth noting a few of the many ways these differing techniques can prove useful in practical applications. Where 3D printing is superior in creating intricate and complex designs, 3D printing is often limited to small-scale productions. Producing more simply shaped clay pieces using plaster molds with slip casting

and press molding is often more affordable for makers and is suitable for larger scales of production. In addition to highlighting food waste innovation in the ceramic sphere, the alternative goal in spotlighting this case study is to highlight the ability of 3D printers to use a wide variety of clay or clay-like materials, like the eggshell recipe developed in The Eggshell Project. According to my research, press molding and slip casting are techniques that have not been as widely explored as potential avenues of food waste reduction in ceramic production. It is understandable as technology tends to be the area first embraced when considering sustainable innovation. Companies like MANUFACTURA seek to "foster a new dialogue between [humankind] and machine" (MANUFACTURA, 2023). Stepping back from machines, the research in this paper seeks to foster a new relationship between ceramic tradition and sustainability.



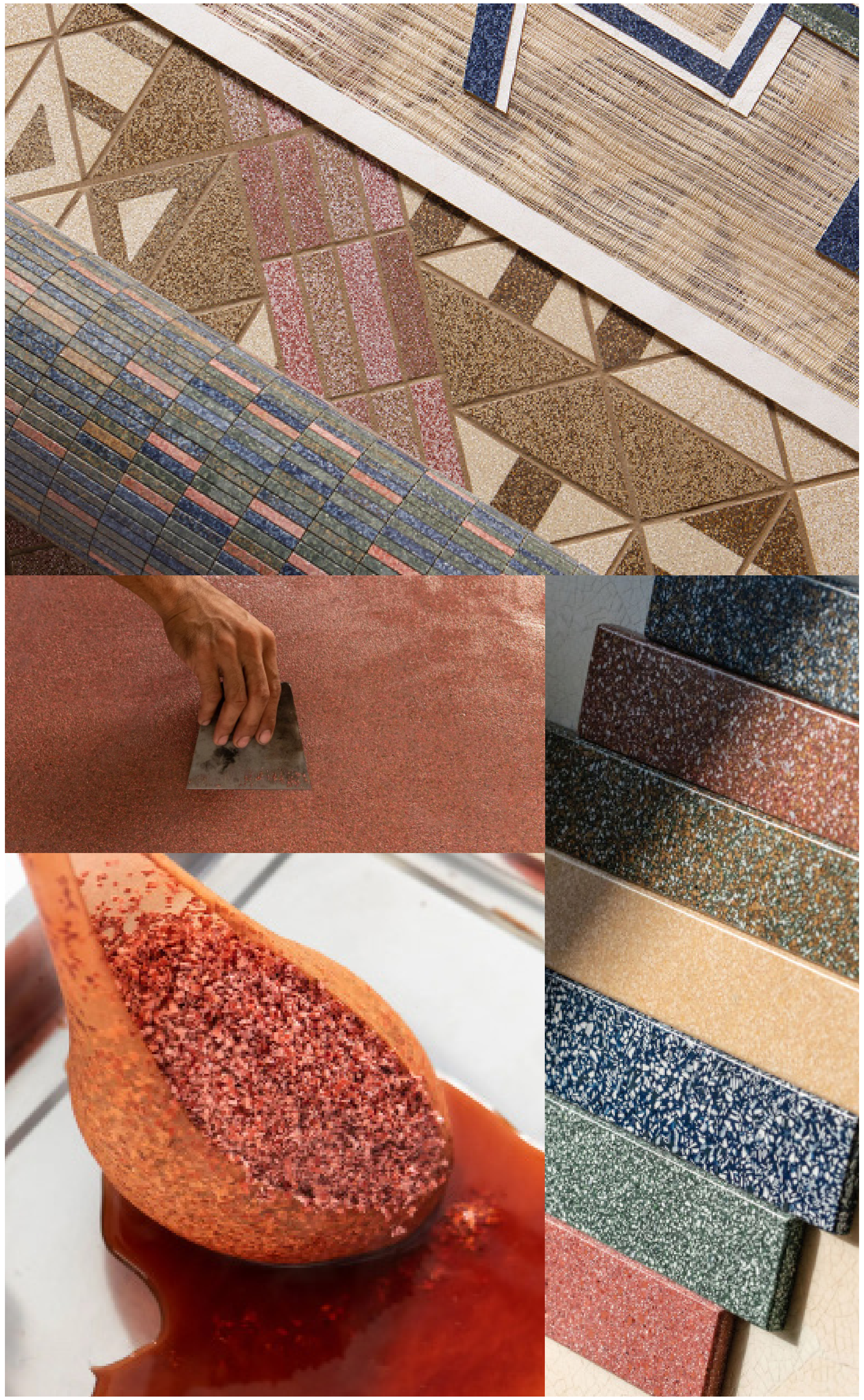
4.3.3

CARRELÉ BIOCERAMIC TILES BY ELAINE YAN LING NG & NATURE SQUARED

2021

CArrelé bioceramic tiles are high-performance building materials crafted from eggshell fragments and binding agents (McNulty-Kowal, 2022). The eggshells used in the collection are gathered from local bakeries and kitchens in the Philippines and then processed and cured into tiles. Ranging in size from sand grains to three millimeters, the varying sizes and colors of the eggshells create unique, terrazzo-like patterns on each tile (McNulty-Kowal, 2022). Once molded together with varying binding agents, the eggshell-based tile is left to dry and room temperature. CArrelé tiles combine durability with functionality and are ideally suited for bathroom and kitchen applications because they are waterproof and easily wiped clean (McNulty-Kowal, 2022).

Ng was inspired to create the collection after recognizing the natural durability of eggshells as applied in the medical industry (McNulty-Kowal, 2022). The calcium-rich tiles create truly striking results in application. Like Ng, other designers and artists can be inspired by alternative fields seeking to utilize the naturally occurring minerals in eggshells.



4.3.4

EGGSHELL CERAMIC BY ATELIER LVDW

2019-2020

The Netherlands is the world's leading egg exporter, producing around 10 billion eggs annually. While some of the eggshells in this industry are used as soil enhancers in agriculture, Atelier LVDW's Eggshell Ceramic project seeks to use the eggshells in alternative ways (Atelier LVDW, n.d.). Atelier LVDW's eggshell ceramics can be used as decorative objects in the home that can eventually be upcycled into calcium water. Calcium carbonate is a nutrient beneficial for plants that thrive in alkaline conditions such as butterfly bushes, boxwoods, tomato plants, and many more (Atelier LVDW, n.d.).

The Eggshell Ceramic material research and project evolution is ongoing and is rooted in the desire to raise awareness for food waste and soil health. The first iteration of the Eggshell Ceramic project is characterized by striking vessels that resemble ceramics. The vessels feature varying gray hues mixed with distinct eggshell cream and brown colors. The structurally complex, organic shapes highlight the material strength potential craft applications of eggshells.

GEX BIO-CALCIUM BY SPARK SOURCING
2023

GEX bio-calcium is resin made by converting eggshells into an ultra-fine calcium powder and then pressing the material into pellets (Packaging Europe, 2023). When combined with virgin plastic, the GEX resin reportedly reduces the plastic content of the manufactured item by thirty to fifty percent. GEX is also compatible with recycled plastic and bioplastics, increasing the options for eco-conscious packaging (Castim, 2023). Packaging products made with bio-calcium resin are recyclable and offer superior product quality than mined calcium carbonate alternatives (Cree, Owuamanam, & Soleimani, 2023). The applications for the material range from pharmaceutical packaging to household items, bags, straws and more.

According to Spark Sourcing founder Andrew Bliss, GEX resin is an ideal option for companies needing to reach mandates and sustainability goals. By creating a product that can be seamlessly integrated into existing package manufacturing systems, they increase usership by saving relevant companies time and money (Packaging Europe, 2023).

With granted patents in the USA, UK, Taiwan, China, and more, GEX bio-calcium is an example of research, technology, and food waste coming together. Not only does it create more circularity in the food economy, the food waste in the material recipe offers superior function.

5 COFFEE

5.1 COFFEE WASTE & PRODUCTION

Unlike eggshells, coffee waste has experienced a more recent introduction into the ceramics field. Coffee is one of the most traded commodities globally and produces significant amounts of waste. In 2022, the import of fruits and nuts into the European Union, including coffee, tea, and cocoa represented the third-highest imported agri-food product, growing from 21.9 billion euros to 26.9 in a single year (European Commission, 2023). Coffee imports represent 4.6 of the 5 billion increase, the highest growth for a single agricultural commodity in value terms in 2022 (European Commission, 2023). The increased trading is not expected to slow, with the United States Department of Agriculture projecting global coffee production to increase by 258 million kilograms from 2023 to 2024 (USDA, 2023). With millions of kilograms of coffee entering the market yearly, a large volume of coffee byproducts are generated.

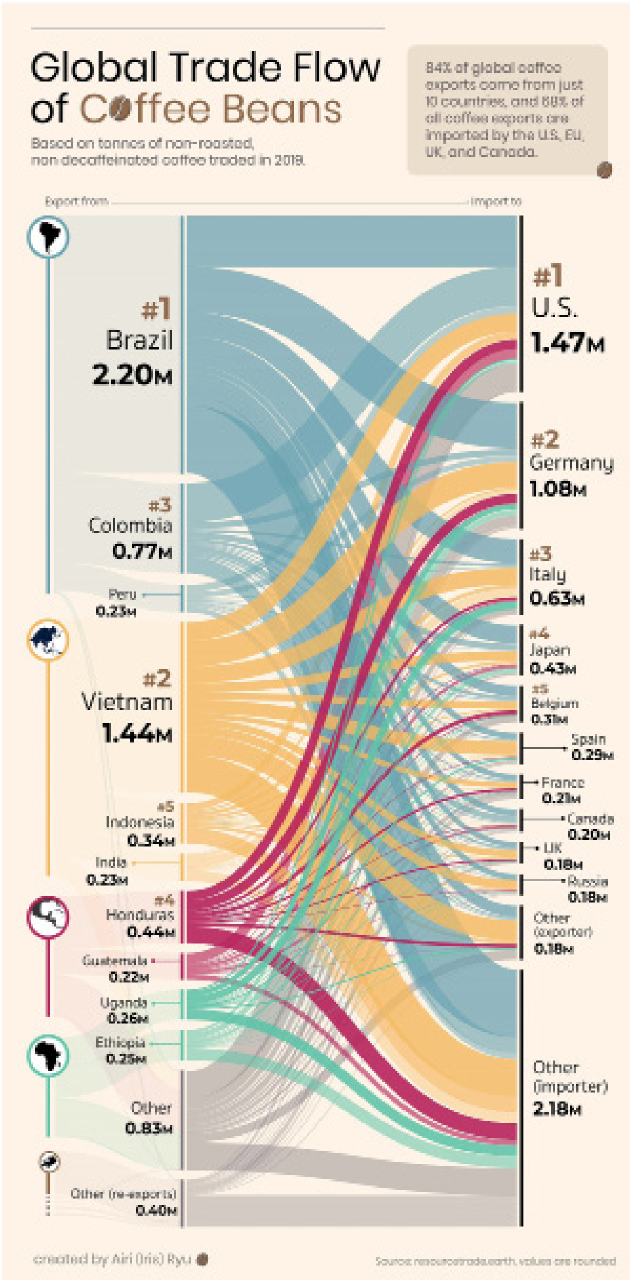


Fig.17: Visualizing the Global Coffee Trade by Country
2023
Airi (Iris) Ryu

Though different types of byproducts are manufactured at each step of the coffee production process, the spent coffee grounds available after the coffee brewing process are the waste material focused on in this paper. Spent coffee ground waste is estimated at 60 million tons annually, representing the most abundant waste generated by coffee preparation and instant coffee production (Forcina et al., 2023)

The breakdown of organic waste deposited in landfills generates methane gas, which holds a global warming potential 21 times greater than carbon dioxide (CO_2) (Roychand et al., 2023). It is estimated that one ton of green coffee produces nearly 650 kg of spent coffee grounds, making it a low-cost and abundant organic material (Forcina et al., 2023).

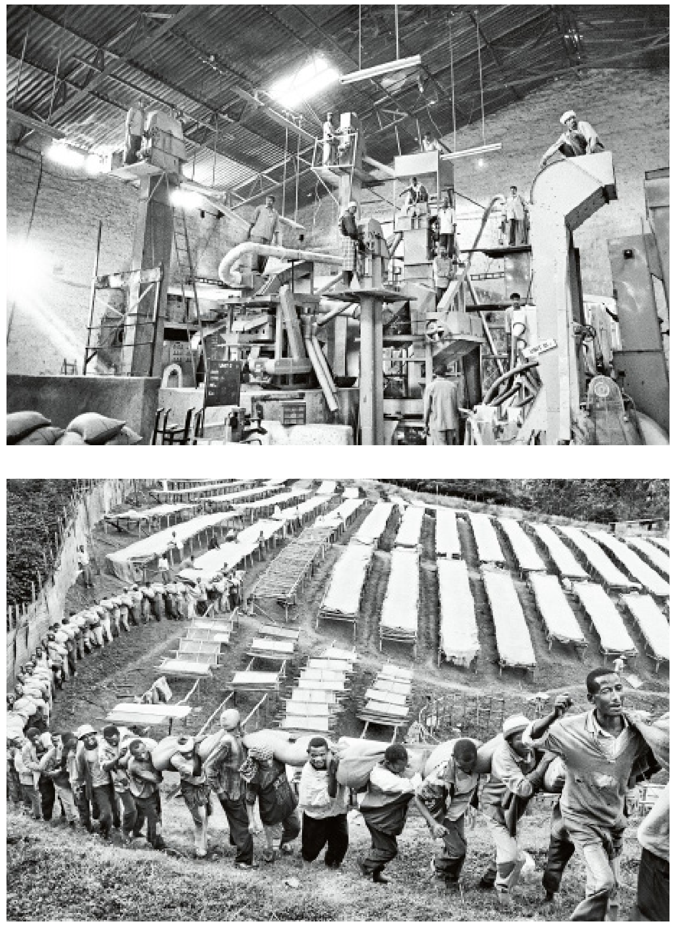


Fig.18-19-: Collecting & processing coffee Brazil
2002-2014
Sebastião Salgado

By focusing on waste management within the coffee industry, companies can reduce their environmental footprint and create opportunities for value innovation. It is estimated that by 2030, global food waste will reach 2.1 billion tonnes, representing 1.5 trillion dollars lost economic value. The growing visibility of waste concerns surrounding coffee production has resulted in a significant increase in research studies dedicated to the revalorization of coffee byproducts (Serna-Jiménez et al., 2022). A study by the Agricultural and Agro-Business Sciences Faculty at the Universidad Tecnológica de Pereira in Colombia found that publications on the Web of Science including the words “by-product coffee” and “waste coffee” expanded fourfold in the last ten years (Serna-Jiménez et al., 2022). This growth indicates the increased importance coffee

Fig.20: Coffee Clay
2022
Sara Silva

byproducts are playing in sustainable development. Coffee waste research connects with the societal push towards economic circularity, where the goal is to reduce environmental impact while also creating new value (Pujol et al., 2013). Without new value surrounding the materials society has historically demarcated as waste, the economy will continue to move linearly toward environmental ruin.

Fig.21: Porous coffee clay beads
2023
Mary Shipley

In several of the papers developed in the new wave of coffee research, clay is used as the binder for coffee ground waste with intriguing results. Being an organic material, coffee is burnt away during the high-temperature firings in the ceramic production process. By burning away from the clay medium, the coffee grounds leave a highly porous, lightweight clay material that can have strategic functional and aesthetic value.

5.1 COFFEE CASE STUDIES

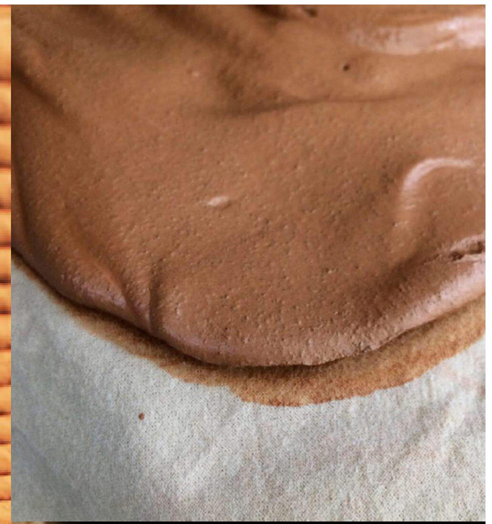
5.2.1

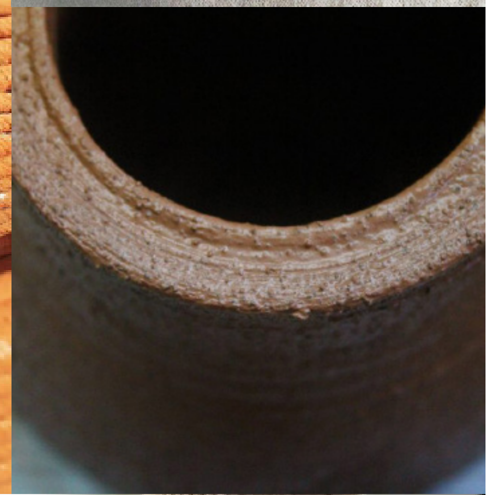
BARRO DE CAFÉ (COFFEE CLAY) BY SARA BAPTISTA DA SILVA

2022

Sara Baptista da Silva's Coffee Clay project emerged with the goal of repurposing coffee waste. Da Silva sees Product Design as a way to mitigate waste and provide a more purposeful approach to design (Silva, 2022). The project was divided into two stages. First, da Silva developed ceramic recipes with varying amounts of spent coffee grounds. Those recipes were then fired and tested in a laboratory for absorption, strength, durability, and sustainability. At 400 degrees celsius, the organic coffee material burned off in the kiln (Silva, Fonseca, & Mitchell, 2022). Resulting tests showed that the coffee clay had increased porosity and brittleness compared to typical ceramics. With mechanical enhancement in mind, ceramic forms were made using additive manufacturing and hand molding techniques.

The final products promote a healthier environment in multiple ways. With the increased porosity, the coffee clay can act as a natural humidifier, releasing water through evaporation over time. They can also act as air filters/aerators by releasing air bubbles through the porous structure. The oxygen flow through the material can improve food preservation and maintain optimal water levels for plants (Silva, 2022). With such benefits, further adaptation of coffee clay recipes can provide new avenues for research and application.





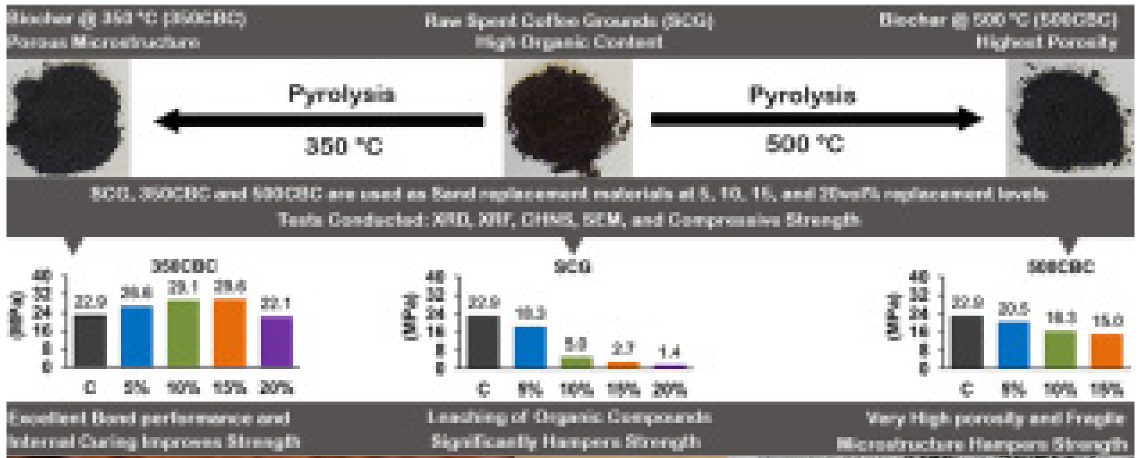
5.2.2

COFFEE GROUNDS & CONCRETE BY RMIT UNIVERSITY ENGINEERS

2023

Researchers at RMIT University in Australia have utilized spent coffee grounds to increase the strength of concrete by nearly thirty percent. The high organic of the spent coffee grounds makes it unsuitable for use in structural concrete. The RMIT team therefore developed a method to create biochar from coffee grounds. Biochar is a lightweight residue resembling charcoal that can be made by pyrolyzing spent grounds from 350 to 500 degrees Celsius (Roychand et al., 2023). Pyrolysis is a roasting process similar to what is used for unroasted coffee beans. The RMIT team uses an oxygen-deprived setting and lower-than-average pyrolyzing temperatures to avoid carbon emissions (Lu, 2023). The biochar was tested as a replacement for sand in concrete mixtures at five, ten, fifteen, and twenty percent volumes. The resulting bricks were then put through a series of tests including X-ray fluorescence (XRF), Carbon, Hydrogen, Nitrogen, and Sulfur (CHNS) analysis, laser diffraction particle size analysis, X-ray diffraction (XRD), scanning electron microscopy (SEM) and compressive strength (Roychand et al., 2023). The results found that biochar pyrolyzed to 350 degrees and included at a fifteen percent volume increased concrete strength by nearly thirty percent. The five and ten percent volumes also performed better than regular concrete with only the twenty percent volume falling slightly under the base concrete performance.

The use of coffee waste in structural concrete decreases food waste and lowers the amount of sand needed in standard concrete mixtures. The continuous extraction of natural sand to fulfill the escalating demands in the construction sector poses significant environmental concerns and challenges for long-term sustainability. The use of spent coffee grounds is one of a diverse list of byproduct materials under investigation as sand alternatives. The RMIT team estimates that all 75,000 tons of Australia's annual spent coffee grounds could produce 22,500 tons of biochar (Roychand et al., 2023). Australia uses 28.8 million tons of sand annually to create 72 million tons of concrete (Lu, 2023). With such exciting results, the University team is now collaborating with local councils for upcoming infrastructure projects, focusing on the construction of walkways and pavements.



5.2.3

CAFFEINATED TEXTURE BY WIM BORST

2008

Wim Borst is a ceramic artist who incorporates organic materials into his work. In his Caffeinated Texture series, he uses coffee to create distinct textures in the clay. Borst first adds crushed coffee beans into various pigmented slabs of clay and then rests them under plastic for four to five weeks (Wim Borst, n.d.). Once the coffee in the slabs has softened, the slabs are cut and shaped into unique forms. Borst uses a variety of customized molds to create angular, structural vases with unique textures (Caffeinated Texture, 2008). Once dry, his pieces are fired to 960 degrees Celsius and meticulously wet-sanded to achieve the desired surface texture. The burnt-away coffee beans leave a texture akin to stone with deep, inset, dark-colored marks. Once sanding is complete, the pieces are carefully glazed and then fired to 1260 degrees Celsius in an electric kiln (Caffeinated Texture, 2008).

While Borst's motives for integrating coffee are aesthetic, his craft approach is grounded in experimentation. His making technique is unique to his own practice making his work quite distinct. Coffee beans are part of the reason his artistic voice is so clear. With his work in mind, other ceramicists can seek out materials like coffee to develop their own craft language.

6 RESEARCH THROUGH DESIGN

6.1 DESIGN EXPERIENCE

The path that brought me to a master's degree in Product Design and a career in ceramics was winding. I want to share some of that story to provide context for why this area of study is important to me. I want to share some of that story. In 2016 I graduated from American University with degrees in International Relations and Art History. I worked for several years in fine art logistics and then became a project engineer for a general contractor in the Washington, DC area. I had always been interested in ceramics and in 2018, I decided to sign up for a wheel throwing class organized by a studio called District Clay. It was there that I developed my passion for ceramics. It was also there that I began my ceramics business, Shipley Goods. When the COVID-19 pandemic began in 2020, I was forced to take a step back from my busy life and better understand what my professional choices meant for my well-being. I was not happy at my project engineering job and found myself waiting for my eight-hour workday to be over so I could race to the clay studio to make ceramics. Time would fly so quickly in the studio that I would have to force myself to leave so I could wake up early for my job that paid my rent. Reflecting on how much joy ceramics brought me is the reason I applied for the Integrated Product Design masters program at Politecnico di Milano. I decided that to pursue my passion for ceramics and grow my business, I needed to get a formal education in design. Ceramics is the reason I left the United States for Milan and Politecnico.

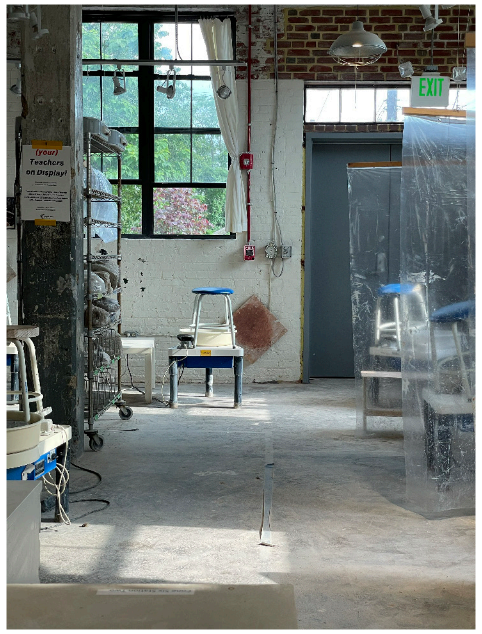


Fig.22 & 23: Match Striker production, District Clay Studio
2021
Shipley Goods

I was deliberate in my choices and knew that to find a fulfilling career I needed to work with clay in some capacity.

The time came to secure an internship position. Understanding that most internships in Milan are unpaid work, I knew that if I was going to work for free, it had to be something that related to my reason for coming to school in the first place. From my research, I found Officine Saffi Lab.

Fig.24: Plaster molds for press molding beads
2023
Mary Shipley

Officine Saffi Lab is a ceramic studio focused on bringing ceramic ideas to life. It is a place of creativity and technical knowledge where they "draw upon Italy's ancient tradition while refining international techniques and processes. [They] fire at high and low temperatures; are skilled in making large-scale, multidimensional projects; and [their] ongoing research around raw materials has led us to develop hundreds of recipes for [their] own one-of-a-kind glazes" (Officine Saffi Lab, n.d.). The potential of this opportunity was exciting and fit precisely into the career I had pictured for myself when I left the United States. Upon being accepted as an intern, I began my three-month internship that developed into a working position. I am incredibly inspired both professionally and creatively by the work that I do at Officine Saffi. The prototyping, testing, and experimentation in the studio have been a direct inspiration for my interest in developing this research topic.

In addition to clay, another source of inspiration is the people I work with. Being surrounded each day by people as passionate about ceramics as I am has been heartening

Fig.25: Elisa Ossino Furniture Collection
2018
Officine Saffi Lab

and further solidified my study and career choices. Ceramics is a medium where knowledge is most effectively passed down through direct interaction and demonstration. Working with experienced artisans has been incredibly educational and contributed to my interest in small-scale ceramic production. Craft is a very intimate art form and is communal in nature. Techniques are shared between people to create a legacy of learning for those who seek to connect with others in their field. The local focus of the research in this paper was first inspired by the community that I was welcomed into at Officine Saffi Lab. I have experienced firsthand how makers can positively influence each other's work and life. My more formal research around the power of local action to spark global cultural shifts has confirmed my lived experience. Experimentation in ceramic is valuable not only in the physical outcome of the test tiles that emerge from the kiln. Experimentation also encourages new connections in local ceramic communities.

Fig.26: Glaze Obession Projects
Officine Saffi Lab

The organization and implementation of the tests introduced below are modeled on the experimentation I witnessed and took part in at Officine Saffi Lab. The majority of the experiments at Officine Saffi Lab involve glaze development. Colleagues are testing glazes by first determining a base recipe to altar slightly with specific glaze ingredients and minerals. This glaze experimentation requires patience, expertise, and intricate record-keeping. Additional challenges arise when considering the many variables that impact consistent outcomes such as firing temperatures, clay type, application style, mineral sourcing, etc. I strove to create a simple yet effective test structure with this modeled test framework.

6.2 TESTING

6.2.1 MATERIALS & METHODS

1 CLAY used for all press molding tests is the CIBAS WM
White semi-refractory dough
Without chamotte

2 CLAY SLIP used for all slipcasting tests is CIBAS Impasto R10
White semi-refractory casting mixture already liquid
40% chamotte

3 PLASTER molds produced for this testing.
One slip casting mold
One press mold

4 EGGSHELLS prepared according to the Eggshell Composite 'Ceramic' Eg02 recipe provided on Materiom (Materiom, n.d.)

5 SPENT COFFEE GROUNDS collected from the Moka pot in my home and stored in the fridge to dry over time.

6 WATER used to adjust recipes throughout the testing process.

Eggshells and coffee were tested in four different ratios using both slip casting and press molding techniques.

SLIP CASTING

COFFEE/SLIP: 10/200, 20/200, 30/200, 40/200 grams
EGGSHELLS/SLIP: 20/200, 40/200, 60/200, 80/200 grams

PRESS MOLDING

COFFEE/CLAY: 5/20, 10/20, 15/20, 20/20 grams
EGGSHELL/CLAY: 5/20, 10/20, 15/20, 20/20 grams

6.2.2

SLIPCASTING COFFEE
TEST #1

COMPOSITION

20 grams dried spent coffee grounds / 200 grams slip

20 grams additional water

CASTING TIME

7 minutes

FIRING

N/A

NOTES & OBSERVATIONS

* Test could not be completed because the slip cast piece would not release from the mold
* Coffee is much less dense than eggshells and the amount to be mixed in is a higher volume than eggshells
* The slip became very dark and thick because coffee is absorbent and removes a lot of the liquid in the slip. An additional 20 grams of water was added to make the slip viable for pouring
* Despite the thick slip, the application of clay on the interior of the mold was even
* The cast had to be chipped out of the mold
* The cast was cracking throughout, indicating that the dry rate was not even

ADJUSTMENTS

* I will halve the coffee content to see if the lower ratio will allow the cast to release from the mold

TEST #2

COMPOSITION

10 grams dried spent coffee ground / 200 grams slip

20 grams additional water

CASTING TIME

5 minutes

FIRING

N/A

NOTES & OBSERVATIONS

* Test could not be completed because the slip cast piece would not release from the mold
* The slip became very dark and thick because coffee is still absorbent and removes a lot of the liquid in the slip
* The cast had to be chipped out of the mold

ADJUSTMENTS

* The next test will include a powder barrier on the mold to encourage release
* I will add a layer of regular slip before adding the coffee mixture. If the coffee mixture is not touching the mold it may release easier.

6.2.2

TEST #3

COMPOSITION

10 grams dried spent coffee ground / 200 grams slip

* first layer regular slip only

10 grams additional water

CASTING TIME

1 minute with regular slip

6 minutes coffee slip

FIRING

980 Celsius bisque firing

1250 Celsius high firing

NOTES & OBSERVATIONS

* First successful coffee slip casting test
* The coffee slip flowed easily with the extra water and worked well in the mold after the regular slip

ADJUSTMENTS

* With a successful test, I will continue using a base layer of regular slip before using the coffee slip
* 10/200 ratio is successful so I will move forward with 20, 30, 40 coffee ratios

6.2.2

TEST #4

COMPOSITION

20 grams dried spent coffee ground / 200 grams slip

* first layer regular slip only

20 grams additional water

CASTING TIME

30 seconds with regular slip

6 minutes coffee slip

FIRING

980 Celsius bisque firing

1250 Celsius high firing

NOTES & OBSERVATIONS

* Successful test
* The slip was slightly thicker than the 10/200 ratio but was still workable
* The regular slip was only used for 30 seconds to see if the method will still work

TEST #5

COMPOSITION

30 grams dried spent coffee ground / 200 grams slip

* first layer regular slip only

30 grams additional water

CASTING TIME

30 seconds with regular slip

6 minutes coffee slip

FIRING

980 Celsius bisque firing

1250 Celsius high firing

NOTES & OBSERVATIONS

* With several successful tests with regular slip as the first layer, I anticipate this test being a success

6.2.2

TEST #6

COMPOSITION

40 grams dried spent coffee ground / 200 grams slip

* first layer regular slip only

40 grams additional water

CASTING TIME

30 seconds with regular slip

6 minutes coffee slip

FIRING

980 Celsius bisque firing

1250 Celsius high firing

NOTES & OBSERVATIONS

* Final coffee slip casting test
* With the additional water, the slip flows quite well

Regular Slip / 10/200 / 20/200 / 30/200 / 40/200

6.2.3

SLIPCASTING EGGSHELLS TEST #1

COMPOSITION

20 grams eggshells / 200 grams slip

CASTING TIME

7 minutes

FIRING

980 Celsius bisque firing

N/A high firing

NOTES & OBSERVATIONS

* The density and non-absorbent properties of the eggshell made the mixture quite easy to work with because it still closely resembled the original slip texture/flow
* The chamotte in the slip is a similar size to the eggshell so it incorporated quite well
* Took a long time to be dry enough to remove from the mold but that could be due to the plaster in the mold and not the slip itself
* When removed from the mold it looks very similar to a slip that does not have any additives
* More texture on the inside than outside, the outside is quite smooth
* This test could not be completed because after fired to bisque temperature, it disintegrated slowly

6.2.3

TEST #2

COMPOSITION

40 grams eggshells / 200 grams slip

CASTING TIME

7 minutes

FIRING

980 Celsius bisque firing

N/A high firing

NOTES & OBSERVATIONS

* The piece was removed easily from the mold
* Cleaning up the cast piece when still partly wet was manageable
* Because of the high chammotte content in addition to the stiff pieces of egg-shells, any places where seams are removed or the opening is cut away have a very grainy texture.
* This test could not be high fired because after fired to bisque temperature, it disintegrated slowly

This test was taken out of the bisque firing on the afternoon of November 14th. These photos track the slow disintegration.

November 16 10:09

November 16 18:30

November 17 17:45

6.2.3

TEST #3

COMPOSITION

60 grams eggshells / 200 grams slip

CASTING TIME

7 minutes

FIRING

980 Celsius bisque firing

N/A high firing

NOTES & OBSERVATIONS

* The mixture was much more thick so required a tool to help the remaining slip out of the mold
* This test could not be high fired because after fired to bisque temperature, it disintegrated

ADJUSTMENTS

* The next cast I will add water to avoid using too-thick slip

TEST #4

COMPOSITION

80 grams eggshells / 200 grams slip

20 grams additional water

CASTING TIME

9 minutes (because additional water)

FIRING

980 Celsius bisque firing

N/A high firing

NOTES & OBSERVATIONS

* The consistency is indistinguishable from the container with regular slip
* This test could not be high fired because after fired to bisque temperature, it disintegrated quickly
* Overall, slip casting with eggshells was quite seamless and proved much easier than the coffee
* The material, however, did not react as expected in firing

6.2.4

80/200 60/200

BISQUE FIRING
NOVEMBER 14

NOVEMBER 15
17:16

NOVEMBER 15
17:15

NOVEMBER 16
10:01

6.2.3

PRESS MOLDING COFFEE TEST #1 [GREEN DOT]

COMPOSITION

5 grams dried spent coffee ground / 20 grams clay

Four beads made

FINAL AVERAGE WEIGHT PER BEAD

3.06 grams

FIRING

980 Celsius bisque firing

1250 Celsius high firing

NOTES & OBSERVATIONS

* Extra water was needed to integrate all the coffee into the clay
* The texture of the mixture was easy to work with
* The finished bead was dark in color
* It was successful in the mold but did not release easily, I anticipate issues with higher ratios

TEST #2 [WHITE DOT]

COMPOSITION

10 grams dried spent coffee ground / 20 grams clay

Five beads made

FINAL AVERAGE WEIGHT PER BEAD

2.14 grams

FIRING

980 Celsius bisque firing

1250 Celsius high firing

NOTES & OBSERVATIONS

* Extra water (more than test #1) was needed to integrate all the coffee into the clay
* The texture of the mixture was quite crumbly and was therefore quite hard to work with in the mold

TEST #3 [RED DOT]

COMPOSITION

15 grams dried spent coffee ground / 20 grams clay

Five beads made

FINAL AVERAGE WEIGHT PER BEAD

1.82 grams

FIRING

980 Celsius bisque firing

1250 Celsius high firing

NOTES & OBSERVATIONS

* Extra water (more than test #2) was needed to integrate all the coffee into the clay
* The mixture was far too crumbly and wet to use in the press mold (similiar issue as the first coffee slip casting tests
* The press mold could not be used I shaped the balls with my hands with a light touch

6.2.4

TEST #4 [BLUE DOT]

COMPOSITION

20 grams dried spent coffee ground / 20 grams clay

Five beads made

FINAL AVERAGE WEIGHT PER BEAD

1.52 grams

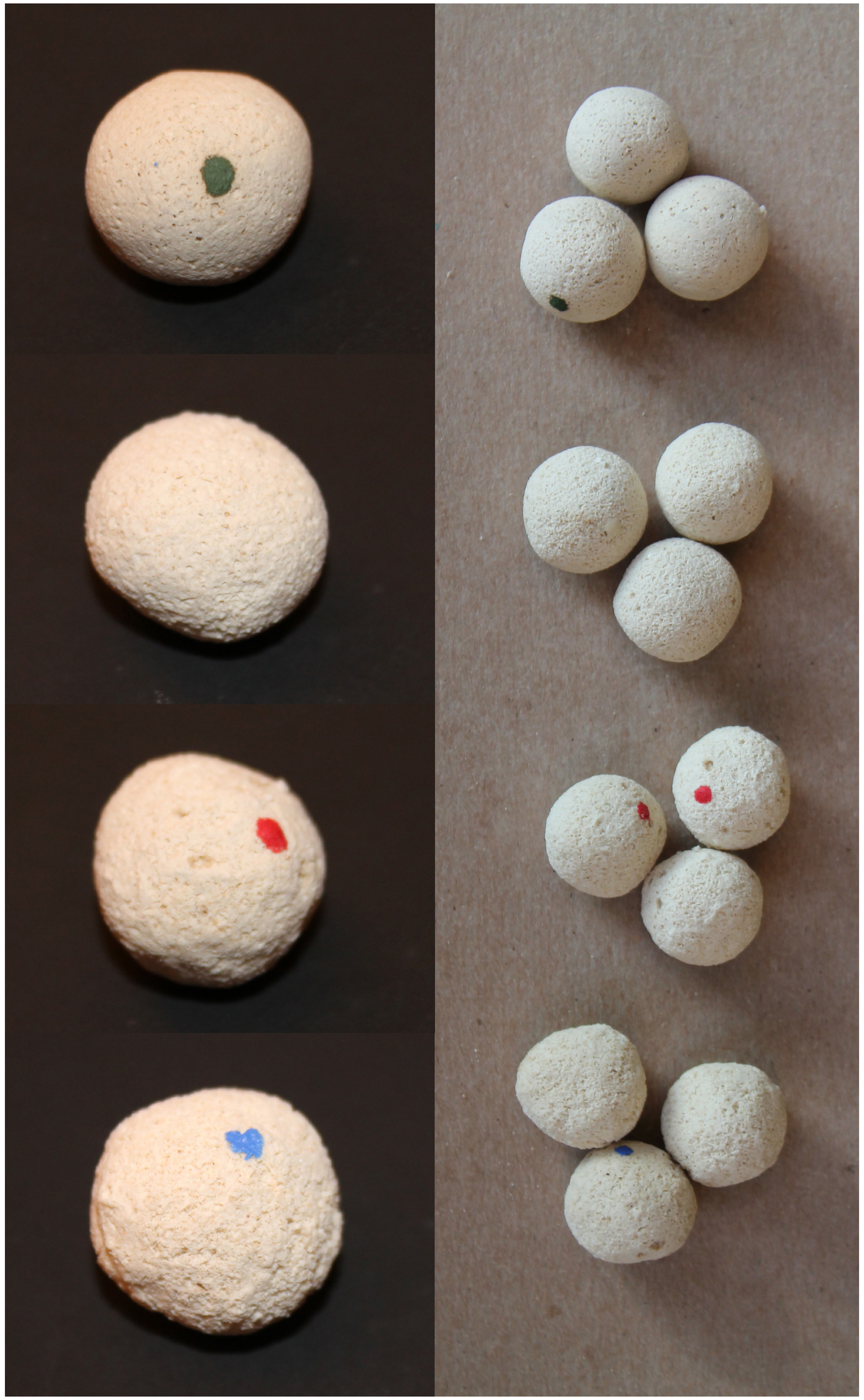
FIRING

980 Celsius bisque firing

1250 Celsius high firing

NOTES & OBSERVATIONS

* A lot of extra water was needed to keep the material together
* The press mold could not work with a material so crumbly and wet
* The beads were shaped by hand and did not hold shape well
* The mixture felt like very wet mud mixed with sand
* The greenware beads were visibly much larger than the other tests because of the amount of water added to the mixture (see page 95)



6.2.5

PRESS MOLDING EGGSHELLS TEST #1 [GREEN DOT]

COMPOSITION

5 grams eggshells / 20 grams clay

Four beads made

FIRING

980 Celsius bisque firing

1250 Celsius high firing

NOTES & OBSERVATIONS

* Seamless integration into the clay
* Some water needed but not as much as the coffee
* The mixture press molded well
* The finished bead is slowly disintegrating but still intact

TEST #2

COMPOSITION

10 grams eggshells / 20 grams clay

Five beads made

FIRING

980 Celsius bisque firing

1250 Celsius high firing

NOTES & OBSERVATIONS

* Very easy to work with
* Some water needed
* Press molded successfully
* The finished bead fully disintegrated

TEST #3

COMPOSITION

15 grams eggshells / 20 grams clay

Five beads made

FIRING

980 Celsius bisque firing

1250 Celsius high firing

NOTES & OBSERVATIONS

* Took time and additional water to work the eggshells in evenly
* The texture of the mixture is quite rough but does not fall apart like the coffee
* Press molded successfully
* The finished bead fully disintegrated

6.2.5

TEST #4

COMPOSITION

20 grams eggshells / 20 grams clay

Five beads made

FIRING

980 Celsius bisque firing

1250 Celsius high firing

NOTES & OBSERVATIONS

* Though it took time and extra water, the beads press molded successfully
* The texture of the mixture is quite rough but does not fall apart like the coffee
* The finished bead fully disintegrated
* Overall press molding with eggshells was quite seamless and proved much easier than the coffee
* The material, however, did not react as expected in firing
* The slow disintegration of the eggshells piece was fascinating to watch
* It would be interesting to see if the cracking could be controlled and used for aesthetic purposes

EGGSHELL COFFEE

20/20

15/20

10/20

5/20

Greenware beads (just made)


Grecia

6.3 REFLECTIONS

While the eggshell appeared to be the waste material that would be easiest to work with when making the tests, it proved to be a more chemically complex material to work with. The spent coffee grounds were a much more predictable material though it required more experimentation during the making of the tests.

The porosity of the coffee tests is very interesting and would be ideal for ceramic pieces that need to be light but not water-tight. As an example, slip casting a piece of ceramic jewelry with a coffee/slip mixture so it would have a solid outer shell but the interior would be porous and more light than standard clay. The slip cast coffee tests are largely indistinguishable from the control, encouraging further experimentation into how glaze could interact with the interior surface. The press molded coffee samples have a unique texture and are significantly lighter than the control. I am intrigued to see how glaze applies to the textured surface. The success of the coffee tests encourages further experimentation into glaze and ratio adaptation.

I anticipated the eggshells to be the easiest material to work with as there is such a history of eggshell use in ceramics. However, my lack of understanding of the chemical reactions of calcium carbonate proved to be a problem. Regardless, it was interesting to see how certain tests disintegrated over time. After discussing the results with my colleagues at Officine Saffi Lab, it was clear that the 980 Celsius bisque firing made it so the eggshells were still absorbent, making it take on water over time. The slow absorption of water from the air caused the disintegration. This also explains why the items with the higher eggshell content disintegrated more quickly. Even more intriguing are the tests that survived (for now). I look forward to continuing the eggshell tests now that I better understand what to expect and how I might work around the issues.

Though many tests did not survive, I still learned a lot and am excited to continue to involve food waste in my future ceramic practice. The first areas of interest would be glaze application and additional eggshell tests.

7 CONCLUSION

This research endeavors to bridge the ancient artistry of ceramics with the urgent demand for sustainable practices. Throughout history, ceramics have remained an essential part of human civilization, boasting diverse applications across cultures and eras. From utilitarian vessels of ancient civilizations to the intricate, high-quality ceramics of modern production, the enduring relevance of ceramics underscores its adaptability and material qualities.

By infusing clay with readily available food waste and employing widely used production techniques like slip casting and press molding, this study seeks to usher in a new era of sustainability in ceramic production. The utilization of eggshells and spent coffee grounds not only extends the life cycle of waste but also promises to enhance the structural and aesthetic properties of ceramic products. This innovative approach holds the potential to positively change small-scale ceramic productions at a community level, aligning environmental stewardship with novel aesthetic possibilities.

By conducting a series of clay experiments, this research contributes to the growing resources for future endeavors aimed at improving circularity in material usage, reducing waste, and promoting sustainable practices in ceramic craft. Through exploration, experimentation, and the integration of innovative materials, this study advocates for a paradigm shift in ceramic production, emphasizing the harmonious coexistence of artistry, tradition, and environmental responsibility.

In essence, this research underscores the imperative of embracing sustainable practices in ceramics, exemplifying how the fusion of ancient craftsmanship with contemporary ecological consciousness can lead to a more harmonious and sustainable future for ceramic artistry and production.

BIBLIOGRAPHY

Adams, E. F. (1971). Slip-cast ceramics. High Temperature Oxides (pp. 145-148). Academic Press.

Anju, P. S., & Jaya, D. S. (2022). Impacts of Clay Mining Activities on Aquatic Ecosystems: A Critical Review. International Journal of Engineering and Advanced Technology, 11(4), 128-134.

Armstrong, K. (2021). Cultivating cultures of sustainability. APS Observer, 34.

Atelier LVDW. (n.d.). Eggshell Ceramic Water Collection 2020-2023. Atelier LVDW. https://www.atelierlvdw.nl/eggshellceramicwatercollection

Avelino, F. P., Soares, R. A. L., Peña-Garcia, R. R., & Lobo, A. O. (2023). The Effect of the Addition of Eggshell Residues in Mass Formulation for Ceramic Coating. Minerals, 13(9), 1123.

Baláž, M., Boldyreva, E. V., Rybin, D., Pavlović, S., Rodríguez-Padrón, D., Mudrinić, T., & Luque, R. (2021). State-of-the-art of eggshell waste in materials science: recent advances in catalysis, pharmaceutical applications, and mechanochemistry. Frontiers in Bioengineering and Biotechnology, 8, 612567.

Barker, D., & Majewski, T. (2006). Ceramic studies in historical archaeology. na.

Bellver, D. F., Prados-Peña, M., García-López, A. M., & Molina-Moreno, V. (2023). Crafts as a key factor in local development: Bibliometric analysis. Heliyon.

Caffeinated Texture. (2008, March 17). Caffeinated Texture Wim Borst. Ceramic Arts Network Daily. https://ceramicartsnetwork.org/daily/article/Caffeinated-Texture

Castim, Daniela. (2023). Eggshell-Derived Biomaterial Reduces Plastic Content by Half. World Bio Market Insights. https://worldbiomarketinsights.com/eggshell-derived-biomaterial-reduces-plastic-content-by-half/

Silva, Sara. (2022). Barro de Café (Coffee Clay). Future Materials Bank. https://www.futurematerialsbank.com/material/ceramic-coffee-ground/

Cree, D., Owuamanam, S., & Soleimani, M. (2023, September). Mechanical Properties of a Bio-Composite Produced from Two Biomaterials: Polylactic Acid and Brown Eggshell Waste Fillers. In Waste (Vol. 1, No. 3, pp. 740-760). MDPI.

de Abreu Fernandes, E., & Litz, F. H. (2017). The eggshell and its commercial and production importance. In Egg Innovations and Strategies for Improvements (pp. 261-270). Academic Press.

Del Rio, D. D. F., Sovacool, B. K., Foley, A. M., Griffiths, S., Bazilian, M., Kim, J., & Rooney, D. (2022). Decarbonizing the ceramics industry: A systematic and critical review of policy options, developments and sociotechnical systems. Renewable and Sustainable Energy Reviews, 157, 112081.

European Commission. (2023, March). Monitoring agri-food trade: Developments in 2022. https://agriculture.ec.europa.eu/system/files/2023-04/monitoring-agri-food-trade_dec2022_en.pdf

Evans, J. R. G. (2008). Seventy ways to make ceramics. Journal of the European Ceramic Society, 28(7), 1421-1432.

Ferraz, E., Gamelas, J. A., Coroado, J., Monteiro, C., & Rocha, F. (2018). Eggshell waste to produce building lime: calcium oxide reactivity, industrial, environmental and economic implications. Materials and Structures, 51(5), 115.
Production, 385, 135727.

Forcina, A., Petrillo, A., Travaglioni, M., di Chiara, S., & De Felice, F. (2023). A comparative life cycle assessment of different spent coffee ground reuse strategies and a sensitivity analysis for verifying the environmental convenience based on the location of sites. Journal of Cleaner Production, 385, 135727.

Hossain, S. S., & Roy, P. K. (2020). Sustainable ceramics derived from solid wastes: A review. Journal of Asian Ceramic Societies, 8(4), 984-1009.

Hunton, P. (2005). Research on eggshell structure and quality: an historical overview. Brazilian Journal of Poultry Science, 7, 67-71.

Isola Design. (n.d.). Designer Projects: Bioceramics. Isola Design. https://isola.design/Designer-Projects-Biocer%C3%A1mics

Ito, A., & Wagai, R. (2017). Global distribution of clay-size minerals on land surface for biogeochemical and climatological studies. Scientific data, 4(1), 1-11.

Kumari, N., & Mohan, C. (2021). Basics of clay minerals and their characteristic properties. Clay Clay Miner, 24, 1-29.

Lu, Donna. (2023, August 22). Full of beans: scientists use processed coffee grounds to make stronger concrete. The Guardian. https://www.theguardian.com/science/2023/aug/23/full-of-beans-scientists-use-processed-coffee-grounds-to-make-stronger-concrete

MANUFACTURA. (2023, March 3). 3D-printed bioceramic bricks use eggshell waste as building materials. Designboom. https://www.designboom.com/technology/3d-printed-bioceramic-bricks-eggshell-waste-building-materials-manufactura-03-03-2023/

MANUFACTURA. (n.d.). MANUFACTURA - Design Studio. https://manufactura.co/en/

Materiom. (n.d.). Eggshell Composite 'Ceramic' Eg02. Materiom Commons. https://commons.materiom.org/data-commons/recipe/649c36218e0f06dcab0b7d0a

McNulty-Kowal, S. (2022, February 10). Made from eggshell fragments, these bioceramic tiles are designed to mitigate the effects of biowaste. Yanko Design. https://www.yankodesign.com/2022/02/10/made-from-eggshell-fragments-these-bioceramic-tiles-are-designed-to-mitigate-the-effects-of-biowaste/amp/

New Material Award. (n.d.). 61 and Caeramic Paint Collection Cornwall. https://new-material-award.nl/en/61-and-caeramic-paint-collection-cornwall/

Nudel, C. (n.d.). Bio. Cynthia Nudel. https://cynthianudel.com/bio/

Officine Saffi. (n.d.). Unurgent Argilla - Nina Salsotto Cassina. Officine Saffi. https://officinesaffi.org/en/project/8-unurgent-argilla-nina-salsotto-cassina

Officine Saffi Lab. (n.d.). Know-How. Retrieved November 11, 2023, from https://officinesaffilab.com/en/know-how

Packaging Europe. (2023, July 11). Bio-Material Derived from Eggshells Claims Up to 50% Plastic Content Reduction. Packaging Europe. https://packagingeurope.com/news/bio-material-derived-from-eggshells-claims-up-to-50-plastic-content-reduction/10038.article

Peterson, S., & Peterson, J. (2003). The craft and art of clay: a complete potter's handbook. Laurence King Publishing.

Pujol, D., Liu, C., Gominho, J., Olivella, M. À., Fiol, N., Villaescusa, I., & Pereira, H. (2013). The chemical composition of exhausted coffee waste. Industrial Crops and Products, 50, 423-429.

ödel, J., Kounga, A. B., Weissenberger-Eibl, M., Koch, D., Bierwisch, A., Rossner, W., ... & Schneider, G. (2009). Development of a roadmap for advanced ceramics: 2010–2025. Journal of the European Ceramic Society, 29(9), 1549-1560.

Rose, M. L., & Hincke, M. T. (2009). Protein constituents of the eggshell: eggshell-specific matrix proteins. Cellular and molecular life sciences, 66, 2707-2719.

Roychand, R., Kilmartin-Lynch, S., Saberian, M., Li, J., Zhang, G., & Li, C. Q. (2023). Transforming spent coffee grounds into a valuable resource for the enhancement of concrete strength. Journal of Cleaner Production, 419, 138205.

Ryu, Airi. (2023, November 24). Global Trade Flow of Coffee Beans [Visualization of global coffee trade]. https://www.visualcapitalist.com/cp/global-coffee-trade/

Saberian, M., Li, J., Donnoli, A., Bonderenko, E., Oliva, P., Gill, B., ... & Siddique, R. (2021). Recycling of spent coffee grounds in construction materials: A review. Journal of Cleaner Production, 289, 125837.

Saha, B. (2023). Environmental Footprints and Occupational Hazards of Clay Mining–A Case Study from Patel Nagar, Birbhum, West Bengal, India. The Nucleus, 60(2), 127-131.

Serna-Jiménez, J. A., Siles, J. A., de los Ángeles Martín, M., & Chica, A. F. (2022). A Review on the Applications of Coffee Waste Derived from Primary Processing: Strategies for Revalorization. Processes, 10(11), 2436. https://doi.org/10.3390/pr10112436

Silva, S., Fonseca, A. R., & Mitchell, G. (2022). Optimization of a New Material with Clay and Waste Coffee Grounds for Additive Manufacturing. Materials Proceedings, 8(1), 69.

Studio Marin Jansen. (n.d.). Closer - the quest for Syrian sand. Studio Maren Jansen. http://marinjansen.weebly.com/closer---the-quest-for-syrian-sand.html

United States Department of Agriculture. (2023, June 22). Coffee: World Markets and Trade. Retrieved from https://apps.fas.usda.gov/psdonline/circulars/coffee.pdf

Unurgent Argilla. (n.d.). About. Unurgent Argilla. https://www.unurgentargilla.com/about

van Noort, K. (n.d.). Porcelain Pits Cornwall. Kirstie van Noort. https://www.kirstievannoort.com/portfolio/porcelain-pits-cornwall

Versey, H. S. (2021). Missing pieces in the discussion on climate change and risk: Intersectionality and compounded vulnerability. Policy Insights from the Behavioral and Brain Sciences, 8(1), 67-75.

Waheed, M., Yousaf, M., Shehzad, A., Inam-Ur-Raheem, M., Khan, M. K. I., Khan, M. R., ... & Aadil, R. M. (2020). Channelling eggshell waste to valuable and utilizable products: a comprehensive review. Trends in Food Science & Technology, 106, 78-90.

Wim Borst (n.d.). Wim Borst. Double Decker. https://www.double-decker.org.uk/wim-borst/

Železný, A., Kulhánek, J., Pešta, J., & Kočí, V. (2023). LCA Case Study of Ceramic Tableware: Ecodesign Aspects of Ceramics Production from Ancient Technology to Present Factory. Sustainability, 15(11), 9097.

Zheng, X., Wang, R., Hoekstra, A. Y., Krol, M. S., Zhang, Y., Guo, K., ... & Wang, C. (2021). Consideration of culture is vital if we are to achieve the Sustainable Development Goals. One Earth, 4(2), 307-319.

NEW EARTH

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POLITECNICO DI MILANO SCUOLA DEL DESIGN

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