UTILIZATION OF COCOA BEAN SHELL

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To the loved ones and things.

ABSTRACT

Considering our world's limited resources, the linear economy model that operates as take- make- dispose is not sustainable anymore. There is a need to find new ways of doing business and managing resources. The food industry also started to focus on this problem since it has been reported that we waste one-third of our food. Utilization of this food waste is a significant problem both economically and environmentally. It is important to stop seeing it as waste and consider it a resource. Even though they lack technical knowledge, designers started to get into the material development process with the help of open sources and the democratization of production techniques. While developing materials, designers pay attention to both technical and experiential characteristics of products to create meaningful experiences for users. One of the sources they use for material development is food waste and byproducts. Considering these, the study aims to contribute to the utilization of cocoa bean shells, one of the main byproducts of the cocoa bean production industry, through material development. It seeks to answer how users experience the materials developed using cocoa bean shells. The study first developed two material recipes through Material Tinkering, emphasizing active learning and experimenting while doing and practicing. Then, the two developed materials' technical and experiential characterization were evaluated using Materials-to-Experiences at four levels (Ma2E4) toolkit. According to the results of these evaluations, suggestions were made for further studies.

keywords; *food waste, materials experience, experiential characterization of materials, material tinkering, DIY-Materials, cocoa bean shells, soapwort extract*

ÖZET

Dünyamızın sınırlı kaynakları düşünüldüğünde, *al-yap-at* şeklinde işleyen lineer ekonomi modeli artık sürdürülebilir değildir. İş yapmanın ve kaynakları yönetmenin yeni yollarını bulmaya ihtiyacımız var. Gıdamızın üçte birini boşa harcadığımız bilinirken gıda sektörü de bu soruna odaklanmaya başladı. Gıda atıklarının değerlendirilmesi hem ekonomik hem de çevresel açıdan önemli bir sorundur. Onları atık olarak görmeyi bırakıp bir kaynak olarak görmek önemlidir. Tasarımcılar teknik bilgiye sahip olmasalar da açık kaynaklar ve üretim tekniklerinin demokratikleşmesi ile malzeme geliştirme sürecine dahil olmaya başladılar. Tasarımcılar, malzemeleri geliştirirken, kullanıcılar için anlamlı deneyimler yaratmak için ürünlerin hem teknik hem de deneyimsel özelliklerine dikkat ederler. Malzeme geliştirmede kullandıkları kaynaklardan biri de gıda atıkları ve yan ürünleridir. Tüm bunlar göz önünde bulundurularak bu çalışmada, kakao üretim endüstrisinin ana yan ürünlerinden biri olan kakao çekirdeği kabuğunun malzeme geliştirme yoluyla değerlendirilmesine katkıda bulunmak amaçlanmıştır. Kullanıcıların kakao çekirdeği kabukları kullanılarak geliştirilen malzemeleri nasıl deneyimledikleri yanıtlanmaya çalışılmıştır. Çalışma, ilk olarak aktif öğrenmeyi, yaparken ve uygularken denemeyi vurgulayan Material Tinkering metodu aracılığıyla iki malzeme tarifi geliştirmiştir. Geliştirilen iki malzemenin teknik ve deneyimsel karakterizasyonu, Dört düzeyde Malzemeden Deneyime (Ma2E4) araştırma seti kullanılarak değerlendirilmiştir. Bu değerlendirmelerin sonuçlarına göre ileri çalışmalar için önerilerde bulunulmuştur.

anahtar kelimeler; *gıda atıkları, malzeme deneyimi, malzemelerin deneyimsel karakterizasyonu, malzeme denemeleri, Kendin-yap malzemeler, kakao çekirdeği kabuğu, çöven otu ekstraktı*

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LIST OF ABBREVIATIONS

CBS..Cocoa bean shell

CNC... Computerized Numerical Control

DIY Materials..Do it yourself Materials

ICCO... The International Cocoa Organization

Ma2E4 ....Materials-to-Experiences at four levels

CHAPTER 1
INTRODUCTION

Considering our world's limited resources, the linear economy model that operates as take- make- dispose is not sustainable anymore. There is a need to find new ways of doing business and managing resources. In recent years, this problem gained the attention of many scholars, companies, and governments. The food industry also started to focus on this problem since it has been reported that we waste one-third of our food (FAO, 2011). Utilization of this food waste is a significant problem both economically and environmentally. It is important to stop seeing it as waste and consider it a resource. Cocoa bean products are US $ 10 billion dollars valued industry (Market Data Forecast, 2022). Turkey is the eighth at the top importer countries of cocoa bean shells in the world (“List of importers”, n.d.). Cocoa bean shells [CBS] are one of the main byproducts of this industry. Companies search for ways of utilizing their CBS waste (Nieburg, 2013). One of the most suggested ways is using it as a food ingredient because of its rich content (Balentić et al., 2018; Hernández-Hernández et al. 2018; Okiyama et al., 2017; Redgwell et al., 2003). But some cocoa bean shells may consist of heavy metals, and it is a problem for consumption of it (Vītola & Ciproviča, 2016). So, there is a need for additional treatment before using it for food products. Another option for utilizing is using it as a materials ingredient. In recent years, there has been growing attention to the utilization of byproducts through material development by designers (Cecchini, 2017). Even though they lack technical knowledge, designers started to get into the material development process with the help of open sources and the democratization of production techniques (Rognoli & Ayala-Garcia, 2018). A material is experienced not only with its technical properties but also with the features perceived by the users. Therefore, while developing materials, designers pay attention to both technical and experiential characteristics of products to create meaningful experiences for users. In light of this, the study aims to contribute to the utilization of cocoa bean shells through material development. It seeks to answer how users experience the materials developed using cocoa bean shells. The study will first familiarize with materials and practice-led research using methods such as Material Tinkering (Parisi et al. 2017). Then the two developed materials will be evaluated using Materials-to-Experiences at four levels [Ma2E4] toolkit developed by Camere and Karana (2018), who argue that we experience materials at four levels; performative, sensorial, affective, and interpretive. The reason for choosing this toolkit is that it lets evaluate individual levels of experience and their relationships, resulting in a more comprehensive understanding of materials. It also allows comparing different materials according to their properties. One of the materials has soapwort extract as an ingredient. Soapwort extract is derived from the roots of the plant *Gypsophila* which is grown in various Anatolian cities (Özçelik & Yıldırım 2011). It is mostly used in the food industry as an ingredient for tahini halwa and Turkish delight. It has saponin content which gives it a foaming property in aqueous solutions. Using soapwort extract as a materials ingredient is a novel approach.

The thesis structure can be summarised as literature review, material development, understanding the materials, and discussion. Chapter two discussed the relationship between materials and the main components of the study waste, designers, and users. For the relationship between materials and waste, different economic models and growing attention for utilization of waste products were mentioned (Ayres, 1994; Bocken et al., 2016; Franklin & Till, 2020; Matrec, 2015; McDonough & Braungart, 2002; Rognoli et al., 2021). Then to showcase the importance of cocoa bean production, the production numbers and the sectors were mentioned (Grand View Research, 2019; ICCO,2021; Industry Research, 2021; Market Data Forecast, 2022). A literature review of the utilization of cocoa bean shells was discussed according to the different ways they could be used (Balentić et al., 2018; Battegazzore et al., 2014; Hernández-Hernández et al. 2018; Olumide et al. 2014; Rojo- Poveda et al., 2020; Romanczyk & McClelland, 2004). Then the relationship between designers and materials and how it evolved were discussed (Antonelli, 1995; Ashby & Johnson, 2002; Ayala-Garcia, 2019; Rognoli & Levi, 2005). Change of designers' role from material selection to material development was emphasized, and conditions that prepared this situation were discussed (Anderson, 2014; Bettiol & Micelli, 2014; Rognoli & Ayala-Garcia, 2018; Rognoli et al. 2021; Tanenbaum et al., 2013). New approaches such as Do it yourself Materials [DIY Materials] and Material activism were mentioned with examples (Lee, 2015; Humier, 2012; OpenMaterials, n.d.; Ribul, 2013; Rognoli et al., 2015). Their common features were summarized. Then Material Driven Design (Karane et al., 2015) methodology and its Material tinkering (Parisi et al. 2017) step were explained. The relationship between materials and users was discussed through the materials experience concept and its four levels (Giaccardi & Karana, 2015). Then the tools developed for studying materials experience were mentioned (Bang, 2007; Hasling, 2016; Karana, 2009; Ravnløkke & Bang, 2016; Rognoli, 2010; van Kesteren et al., 2007; Zuo, 2003; Zuo et al. 2004; Zuo, 2010). Ma2E4 toolkit, which was used for the study, was explained (Camere & Karana (2018). Chapter three explains the materials used for the study, recipe development process, material demonstrators, experimental characterization map, data collection, and data analysis methods. The results of recipe development, technical, experiential characterization, similar products, and usage suggestions were discussed in Chapter four. General discussion and suggestions for future studies were made in Chapter five.

CHAPTER 2
RELATIONSHIP WITH THE MATERIALS

2.1 Materials and waste

Resources of our world are limited, but the needs of humans are unlimited. We need to manage how we use limited resources and prioritize our needs. Today, most of our production is based on the linear economy model that operates as *take- make-dispose.* If we do not change our current practices, we would need two more planets by the half of the century to live as present (United Nations, n.d.). There is a need for a more sustainable approach for our ways of production and consumption as United Nations Sustainable Development Goal 12 focuses on this problem. With their increased attention to the problem to find solutions, scholars, companies, and governments started to look for ways of finding new resources and new ways of doing business. One of the solutions suggested is Circular Economy (European Union, 2020). Although it is a more popular term recently, circular economy concept has its roots in industrial ecology in the nineties (Ayres, 1994; Bocken et al., 2016). Ayres (1994) connects living bioorganisms and industry by using metabolism metaphor with common grounds of flow of free energy, self-organizing systems, and life cycle. In order to have closed cycle system for the long term, he argues recycling and reuse, or dissipative loss are possible ways for waste materials. Another concept similar to industrial metabolism is Cradle-to-cradle developed by McDonough and Braungart (2002) with three principles; seeing everything as resource including wastes, using clean energy and celebrating diversity. They argue we need to change our system from Cradle-to-grave to Cradle-to-cradle which emphazise closing the technical and biological loops. Based upon these works, Ellen

McArthur foundation conteptualise the circular economy model which suggests two circular directions; technical (reuse without returning to nature) and biological (return to nature) (Rognoli et al., 2021). Similar to this, Franklin and Till (2020) suggest changing our systems to *make–waste–make* instead of *take–make–waste.* European Commission (n.d.) proposes a waste hierarchy scheme (Figure 1) for how to utilize waste from the most preferred option to the least; (1) prevention; (2) preparing for re-use; (3) recycling; (4) other recovery, e.g., energy recovery; and (5) disposal.

Figure 1: Waste hierarchy according to Waste Framework Directive (European Commission, n.d.).

By-products are substances or objects that are created as a result of a manufacturing process that does not have the primary goal of producing that item. Generating value from things usually defined as by-products or waste in linear business model is called closing loops (Bocken et al., 2016). Extending resource value (creating new values) and industrial symbiosis (utilization as raw material for other processes) are two of the strategies for closing loops (Bocken et al., 2016). Since it is reported that we waste one-third of our food (FAO, 2011), utilization of food waste and byproducts is a significant problem both economically and environmentally through closing loops. Materials are one the options for closing the loops of food waste which started to gain attention in recent years (Matrec, 2015). There are now commercial materials developed by using pineapple leaf waste (Piñatex textile), orange peels (Orange Fiber yarn), and milk waste (Qmilk fibers).

2.1.1. Cocoa production

Cocoa beans, the main material of chocolate production, are seeds of a plant called *Theobroma cacao*. The climate of the cocoa belt countries, located within 20° of latitude from the Equator, is suitable for the cultivation of cocoa trees. While Côte d'Ivoire and Ghana meet most of the world's cocoa production needs, Ecuador, Cameroon, Nigeria, Indonesia, Brazil and Papua New Guinea are also among the leading producers (Shahbandeh, 2022). The International Cocoa Organization (ICCO,2021) estimated world cocoa bean production as 5.175 million tonnes for the Cocoa Year 2020/21. In 2022, global cocoa bean market size is worth US $ 10 billion, and it is expected to grow 7.3% in five years (Market Data Forecast, 2022). In 2021, Turkey imported 124,494 tons of cocoa beans valued 340,007 USD from Côte d'Ivoire (65.8%), Ghana (19.2%), Cameroon (7.2%) and the rest from various countries including Nigeria, Ecuador and Dominican Republic (“List of supplying markets", n.d.). Turkey is ranking 8th in the world cocoa imports accounting for 3.5% of the imports ("List of importers", n.d.) (Figure 2).

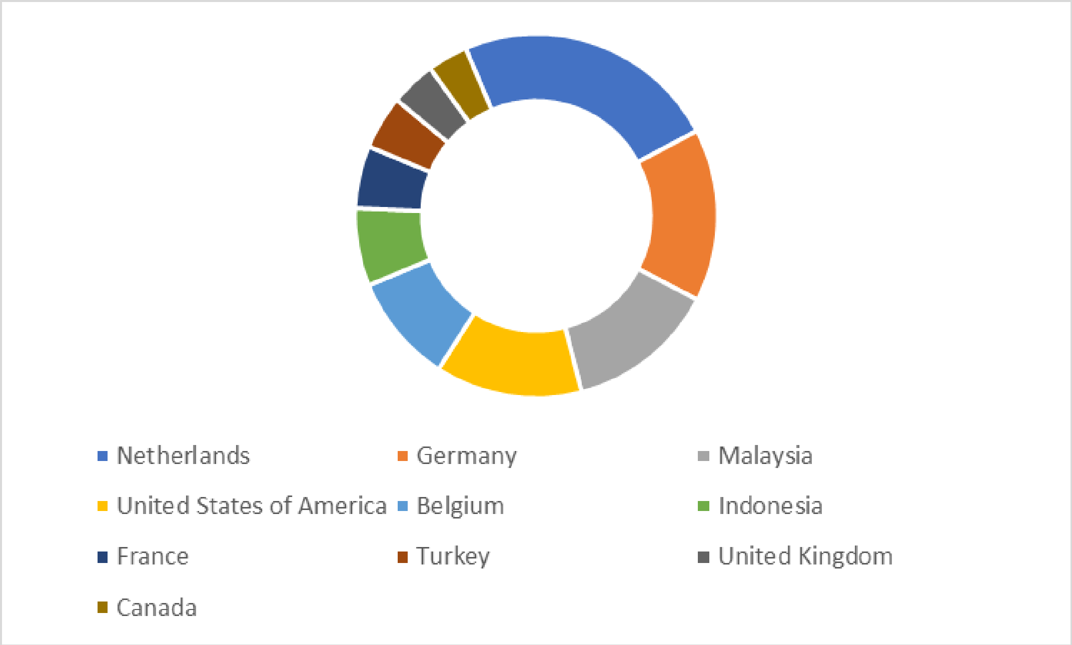


Figure 2: Top 10 importer countries of cocoa beans ("List of importers", n.d.).

Grinding numbers published by ICCO show cocoa consumption. It is expected that there will be an increase in the amount of grindings, which decreased due to the effect of COVID-19, as a result of the recovery of the economies and return to their previous levels (ICCO, 2021; Food Turkey, 2021). (Figure 3).

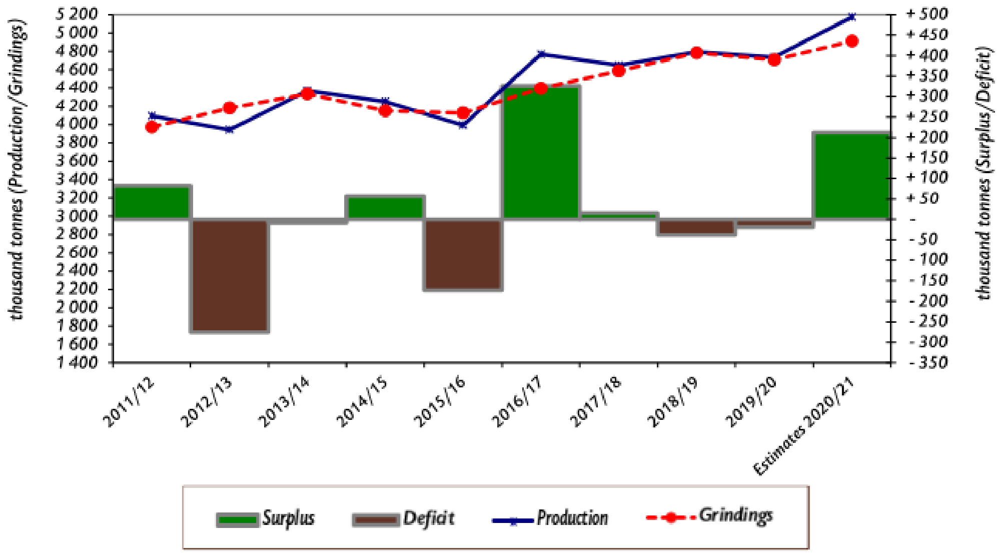


Figure 3: World cocoa bean production, grindings, and stocks. (ICCO,2021)

Cocoa production starts with harvesting. On the trunk and branches of the cocoa tree, both flowers and ripe fruits can be seen at the same time. Since the ripening period of the pods can differ from each other even on the same tree, the ripe fruits must be collected individually and manually by cocoa farmers. Early harvest affects aroma and flavor formation negatively, whereas late harvest cause germination. Farmers specialize in understanding the fruits of the cocoa varieties in their fields that reach the optimum ripeness for harvesting. After harvesting, farmers cut pods open by using a machete or hitting them a sharp surface to take the beans out from the pods. A cocoa pod contains about 30- 40 cocoa beans inside. Cocoa pods are covered with white colored sugary mucilage called cocoa pulp. Cocoa pods and cocoa pulp are byproducts that occur in the cocoa farms (Figueroa et al., 2020). Wet cocoa beans are put inside wooden boxes covered by banana leaves for fermentation. After a few days, they are left to dry under the sun. This reduces their moisture levels. Then, the beans are packed and ready to ship to companies. Cocoa beans are used to produce various products such as cocoa powder, cocoa butter, cocoa liquor, and chocolate (Figure 4). Although they are mostly used in confectionery with a rate of 55.42%, functional food & beverage, pharmaceuticals, and cosmetics are also markets for cocoa beans (Grand View Research, 2019, Industry Research, 2021).

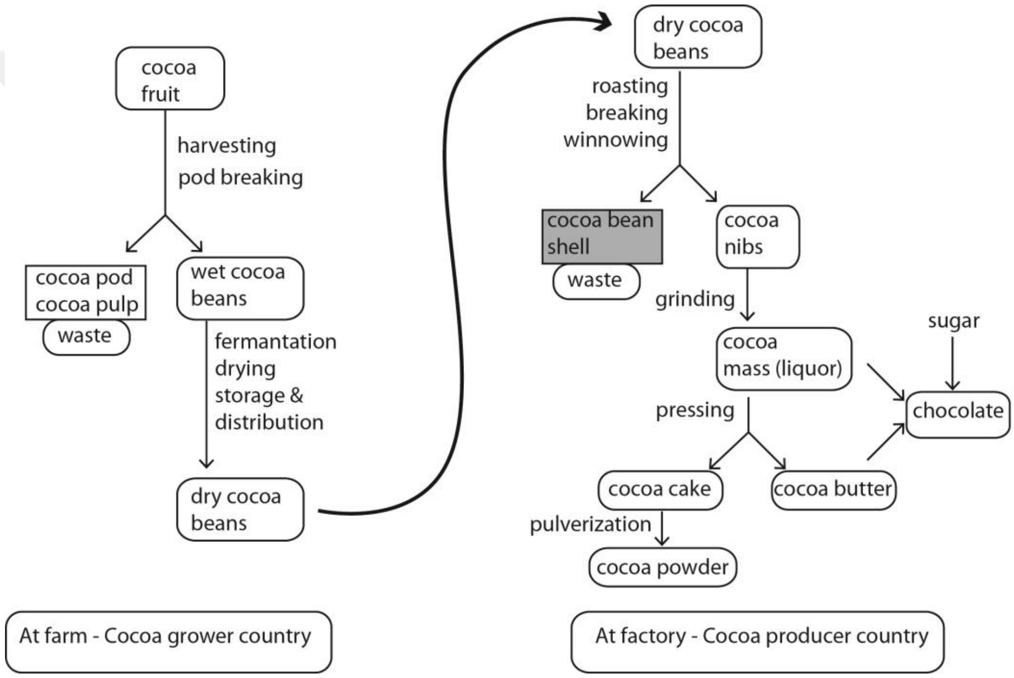


Figure 4: Production steps of cocoa bean products

Chocolate companies are one of the main customers of cocoa beans. There are two types of chocolate companies; chocolate makers and chocolatiers. Chocolate makers produce the chocolate raw materials (cocoa powder, cocoa butter, cocoa liquor, and chocolate) and chocolatiers buy them and use for their productions. Chocolate makers start the raw material production from cocoa beans. Other than industrial producers, there are also small companies which call themselves as craft chocolate makers who source cocoa beans and produce chocolate.

2.1.1.1. Cocoa bean shells

Cocoa beans have shells accounting for about 10%- 17% (Hashimoto et al. 2018; Zhao, 2014) (Figure 5). Chocolate makers remove the shells by roasting and a procedure called winnowing. The shells are underutilized byproducts that the chocolate makers and the cocoa bean processing industry needs to deal with regularly (Redgwell et al., 2003). Researchers and companies try to find ways to utilize their waste since it has economic value and environmental impact (Rojo-Poveda et al., 2019). Utilization areas of cocoa bean shell in literature can be categorised as food ingredients, agriculture, feedstuff, biofuels, absorbents for pollutants, activated carbon, natural dye for fabric, biofunctionality, and material ingredient (Balentić et al., 2018; Rojo-Poveda et al., 2020).

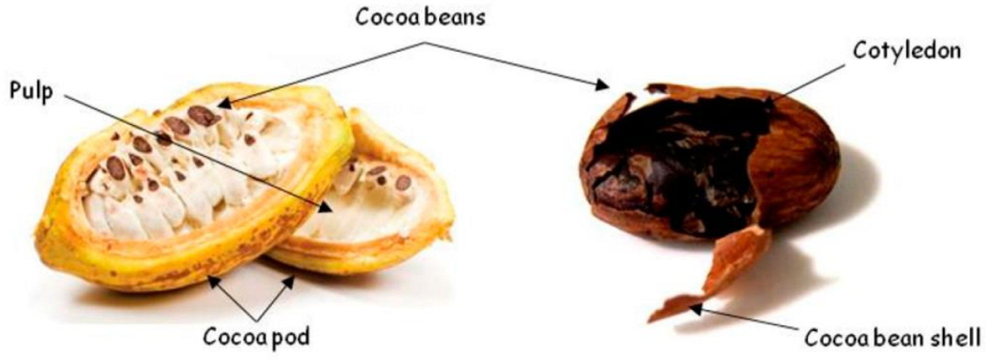


Figure 5: Cocoa fruit and its parts. (Rojo-Poveda et al., 2020).

Utilization as food ingredients

At several stages of production, such as fermentation, roasting, and alkalizing, nutritionally valuable substances of cocoa beans have been found to migrate to cocoa bean shell (Hernández-Hernández et al. 2018). Cocoa bean shell has rich content that consists of phenolic compounds, flavanols, insoluble fibers, polysaccharides, fats, methylxanthines, protein, cell wall lignin, minerals, vitamins, and ash (Balentić et al., 2018; Hernández-Hernández et al. 2018; Okiyama et al., 2017; Redgwell et al., 2003). These contents make it a good resource for a wide range of applications in industries such as food, cosmetics, and pharmaceuticals (Hernández-Hernández et al. 2018; Romanczyk & McClelland, 2004). It has been studied in the food industry to use as food enrichment (Altin, 2016; Handojo et al., 2019; & Martínez et al., 2012), fat replacer in muffins and functional cakes (Martínez-Cervera et al., 2011; Öztürk & Ova, 2018), ingredient for beverages (Cantele et al., 2020), and functional snack products such as cookies and corn puff snack (de Barros et al., 2020; Jozinović et al, 2019; & Rojo-Poveda et al., 2020). A German startup named Spoontainable developed an alternative to plastic cutlery using cocoa bean shell as an ingredient for their edible gluten-free and vegan spoons and stirrers (Figure 6). Some craft chocolate makers sell their shell waste as cocoa tea since it can be brewed. Also, others collaborate with other craft makers such as brewers for fermenting beer using cocoa bean shells. Because some cocoa bean shells may consist of heavy metals, there is a need for additional treatment before using them for food products (Vītola & Ciproviča, 2016).

Figure 6: Cocoa bean shell-based edible spoon and stirrer (Spoontainable, 2021 & 2022)

Utilization as Feedstuffs

Even though it is known that its theobromine content is toxic to some animals (Drolet et al. ,1984; European Food Safety Authority, 2008), cocoa bean shell is used as feedstuffs for animals such as poultry, pigs, fishes, ruminants, and rabbits (Amin & Cahyono, 2016; Ayinde et al., 2010; Bamba et al, 2014; Magistrelli et al., 2016; Oduniyi, 2015; & Olumide et al. 2014). This utilization way is also a preferred option in Turkey, as stated by a local chocolate maker company that they sell their waste from the daily production of five thousand tonnes of cocoa beans as animal feed (S. Yilmaz, personal communication, May 13, 2020). Another company that had R&D projects with universities also stated they utilize their waste as animal feed (G. Yilmaz, personal communication, April 13, 2020).

Utilization as material ingredients

There are several studies that uses CBS for material development such as bioelastomers (Tran et al., 2017a), biofilament (Tran et al., 2017b), poly(lactic acid) and poly(propylene) (Battegazzore et al., 2014), and paper packaging (Nieburg, 2013). By using cocoa bean shells, Badalotti (2014) developed a bio-polymer-based composite that has organoleptic properties and appearance similar to chocolate. PriestmanGoode developed a concept food-delivery system with designers that used cocoa bean shells-based bioplastic containers (Hitti, 2020) (Figure 7). An example of industrial symbiosis mentioned in closing the loops is the collaboration between packaging producer Favini and chocolate maker company Domori. Favini (2020) used cocoa bean shells waste from the production of Domori and produced a packaging material called Crush Cocoa to be used by Domori for their chocolate products.

Figure 7: A concept food-delivery system with cocoa bean shells-based bioplastic containers. (Priestmangoode, 2020).

Other usages

Cocoa bean shell-based activated carbon can be used for the adsorption of pollutants such Ni(II) ion (Kalaivani et al., 2014) and dyes in industrial textile effluents (Ribas et al., 2014).

2.2 Materials and the designers

2.2.1. From material selection to material development

Throughout the history, relationship between designers and materials were changed and evolved. Expressive-sensorial properties of materials were part of design education for one of the first design schools, the Bauhaus (Wick, 2000). The school had different laboratories for materials such as metal and ceramics, and students were required to connect with the materials to understand their technical and expressive-sensorial properties (Rognoli and Levi, 2004). Design has its roots in craft practices in which creating things with hands and connecting with the materials are important. But with the industralization, designers and materials started to distance themselves from each other. Mass production changed the variables of design into assembly lines, joint materials, and molding technologies. Materials characteristics were also shifting as Antonelli (1995) argues that the technical properties, production methods and usage areas of ceramics, glass and plastics materials changed and expanded over time by the help of grand scientific developments. He uses the analogy of mutants for materials that can be shaped and behave like other materials and be used in place of them. For example, mutant characteristics provided plastics to look and behave like wood. Rognoli and Levi

(2005) mention surrogate materials that are cheap alternatives for other materials. According to Ashby and Johnson (2002, pp 73), a material is “like an actor, it can assume many different personalities, depending on the role it is asked to play”. As Manzini (1989) points out, a "material of invention" is the one that has specially calculated and engineered qualities instead of being a "found material." Antonelli (1995) claims that customization and variety are at the heart of this new material culture in which materials became translators of the aims of engineers and designers instead of being their supporters. There are different forces that drive material development; (1) developing high tech materials for solving technological issues of military, medicine and aerospace without financial limitations producing in small quantities, (2) finding cheaper options for existing commodity materials for more profits in large quantities; (3) renewable and biobased materials that focus more on the sustainability and environmental impact (Lindström et al., 2008; Lindström et al., 2014; Rognoli & Ayala-Garcia, 2018). Until recently, materials development was dominated by engineers and scientists. There was a linear approach in which engineers or scientists developed the material, and designers used these materials and found new application areas. For example, autarchy period designers found new applications for materials (Ayala-Garcia, 2019). Also, a material developed for the military could be used by designers in a new way and product that can bring it to the domestic life-usage. The linear approach resulted in designers being material selection experts that are not part of the material development process. Rognoli and Ayala-Garcia (2018) argue that the idea of designers having insufficient technical knowledge and the system based on material selection are the main reasons for designers to be omitted from material development. So, designers did not have the chance to manipulate the material properties. In addition to this, the tools available for material selection were mostly developed for engineers to select the best material for a product according to the technical requirements. These tools were insufficient for designers since they did not cover the intrinsic values and intangible characteristics (Karana et al., 2008a), which are essential variables for designers in materials selection (Figure 8). While engineering is focused on functionality and usability, designers also focused on creating the personalities for materials that will result satisfaction for users which is crucial for successful materials development (Ashby & Johnson, 2002; Ashby 2014).

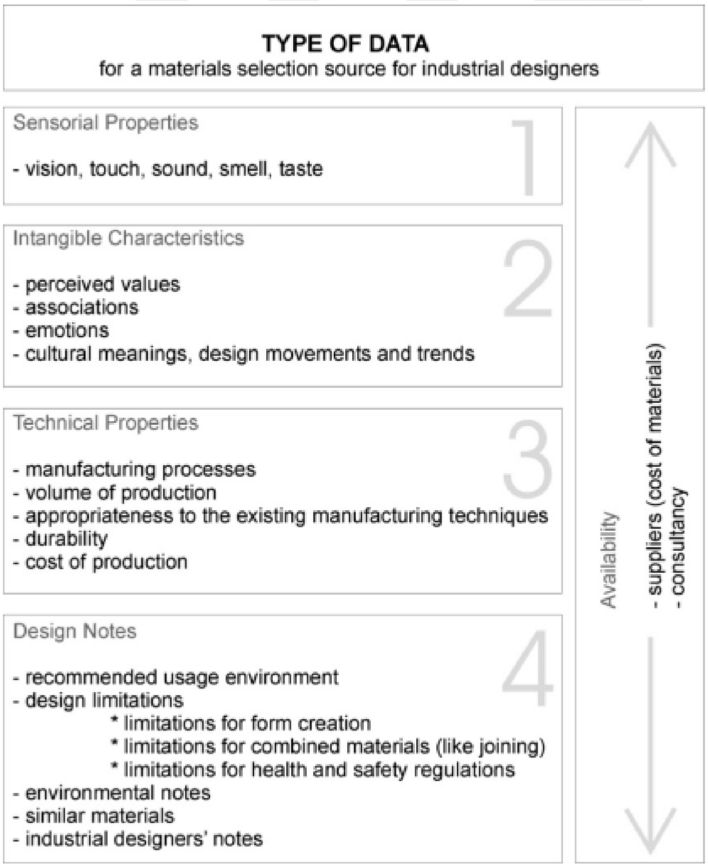


Figure 8: Materials selection sources for industrial designers (Karana et al., 2008a).

For a long time, designers' only interaction with materials was selecting them through tools such as materials libraries that includes material samples from mass production but this started to change with the desire of designers to take part in the development of the materials (Rognoli & Ayala-Garcia, 2018). This desire was the outcome of various factors such as democratization of production and technologies, do-it-yourself practices, open sources and ease of access to information through internet, and new admiration of artisan (Anderson, 2014; Bettiol & Micelli, 2014; Rognoli & Ayala-Garcia, 2018; Rognoli et al. 2021; Tanenbaum et al., 2013). Inspired by these movements, designers started developing and producing their own materials because they wanted to go back to their roots and connect with the materials again. Rognoli et al. (2015) call this practice DIY materials mainly made with low technologies using ingredients that are easy to find and celebrate the imperfect qualities of self-production. These materials can be either a new material or an updated version of an existing material (Rognoli et al., 2015). Even though these new design practices put existing manufacturing processes and material classification systems to the test, they offer a chance to rethink and modify them to create new material experiences (Asbjørn Sörensen & Thyni, 2020; Rognoli et al., 2015). They also take the material development out from the laboratories to kitchens (Rognoli & Ayala Garcia, 2018). The desire for creating new materials and experiences can originate from various sources. Ayala-Garcia (2019) summarizes motivations and conditions for designers to develop new materials as; material source (source and the origin of the material), driving source (particular interest of designer such as solving a problem), technology source (techniques and practices), inspirational source (material concept, aesthetics or materials experience), and craft source (creating with hands). Ayala-Garcia et al. (2017) classify DIY materials into five kingdoms based on their sources and origins;

1. Kingdom Vegetabile (plants and fungi)
2. Kingdom Animale (animals and bacteria)
3. Kingdom Lapideum (minerals such as stones and sand)
4. Kingdom Recuperavit (waste)
5. Kingdom Mutantis (technology i.e. industrial, interactive or smart)

The boundaries between kingdoms are blurred since some of the materials fall under more than one kingdom (Ayala-Garcia et al., 2019).

Another concept similar to DIY materials is material activism, first used by Ribul (2013). In her book, she shares recipes she developed through open sources, low-tech production methods for finding alternatives to traditional processes. Other than sharing recipes, she also suggests ways for molding and shaping. According to Rognoli and Ayala-Garcia (2018), a material activist wears many hats; he or she is an alchemist, an artisan, or a chef depending on the process. They mention three material activists that pave the way for new approaches for designers. The first one is Jenny Lee (2015), who wrote the book Material Alchemy. She thinks that just like an alchemist, a designer aims to turn things into a more valuable state. She emphasizes the designer's role as a systems thinker looking for solutions from a range of viewpoints instead of being merely an artifact creator (Rognoli and Ayala-Garcia, 2018). Another activist is Laurence Humier (2012), who combines design, material physics, and molecular gastronomy in her book Cooking material. She makes a connection between the kitchen and material development. She suggests using culinary methods as an inspiration and point of departure for ingredients other than food. She shares recipes such as making caramel using boric acid and silicone oil and chantilly from beeswax and water. Ayala-Garcia (2015) also suggests designers can learn culinary crafts to help them produce things. The last activist to mention is social scientist Catarina Mota who started OpenMaterials project in 2009 with Kirsty Boyle (OpenMaterials, n.d.). OpenMaterials aims to share resources and how-to videos and tutorials, create a database on materials, tools, and techniques, and document experiments on these. She seeks to encourage materials as an open resource that can be investigated and shared in a public emphasizing collaboration with inspiration from open source and DIY movements. Rognoli and Ayala-Garcia (2018) indicates that these activists can be seen as extention of DIY Materials. In light of this, we can sum up the main features of material designers that practice DIY materials and material activism approach as;

- Supporting the independence of designers by creating things even without required technical knowledge by hacking things and processes
- Changing things seen as invaluable into valuable
- Adopting the methods of other disciplines such as gastronomy into material development
- Creating expressive- sensorial experiences
- Knowledge sharing through platforms and open sources.

2.2.2. Material Driven Design

With the growing interest of designers in material development, a need to develop a methodology for designing material experiences whose starting point is materials has emerged. Karana et al. (2015) developed the Material Driven Design methodology to help designers not only focusing on the material itself but its ability to do, express, elicit and make someone do something. They mention three scenarios for point of departure for design; (1) well-known material to develop new applications, (2) unknown material to settled meanings and (3) semi-developed material to material development. They present four steps of the method as; (1) understanding the material (2) creating materials experience vision, (3) manifesting materials experience patterns, (4) designing material/product concepts (Figure 9). The designer can follow all the steps or can use only the required ones. At the first step, it is important to understand the materials properties both technical and sensorial. Various methods such as material tinkering, material benchmarking, and user studies are used at this step. At the second step, Materials experience vision is created by envisioning the materials purpose, place, and interaction in a changing context of society and planet while considering the results from material characterization. By using metaphors and moodboard, designer creates a vision for the material. Then at the third step, the similarities and differences between the envisioned interaction and how people interact with the material needs to be explored. It lets articulating the relationship between product properties and created envision. At the final step, all the findings are used for designing material concepts and products.

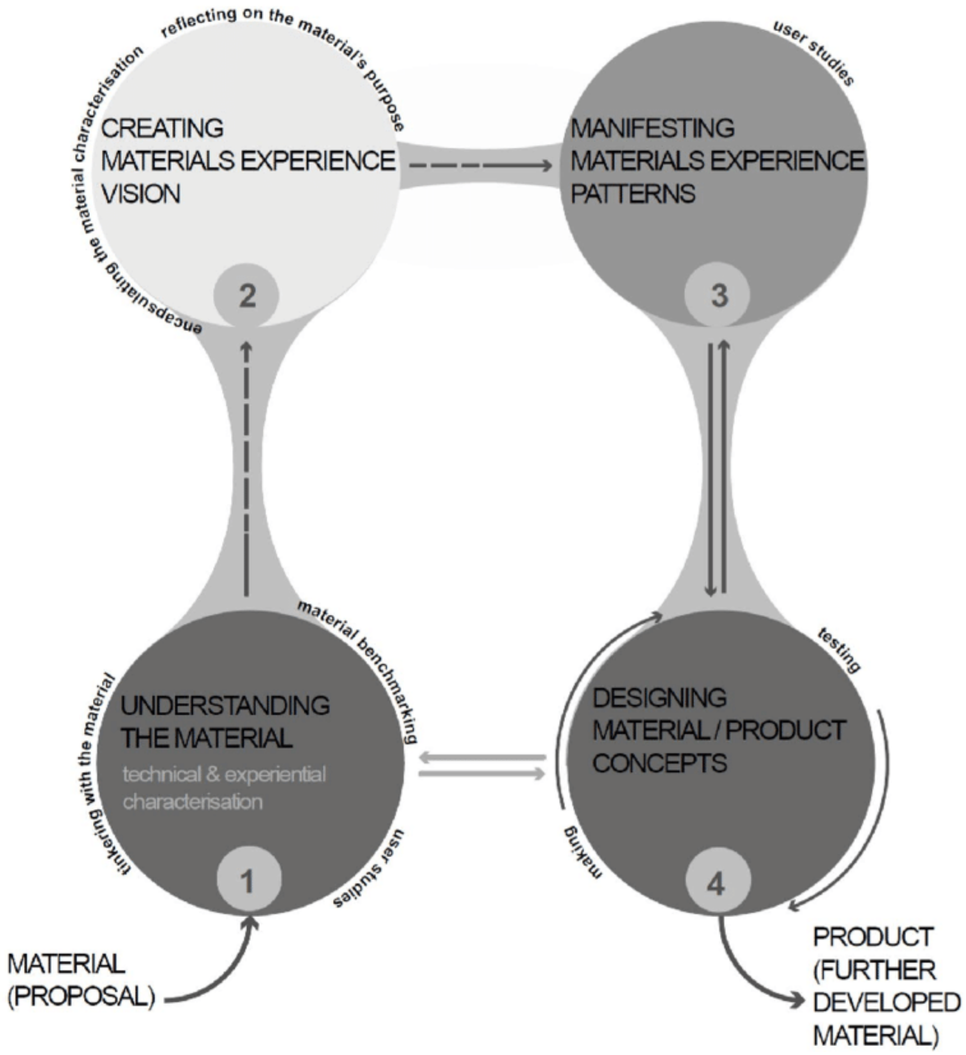


Figure 9: Steps of Material Driven Design methodology (Karana et al., 2015)

2.2.2.1. Material Tinkering

Understanding the technical and sensorial charecteristics of a material is the first step of Material Driven Design. At this step, tinkering with the material is crucial for the designer. Through tinkering, the designer learns about the constraints and strengths of a material and how it behaves under particular situations. Material tinkering is a method based on experiential learning (Smith, 2001, 2010) that encourages experimenting with the materials in a direct, creative, and iterative way that was first used by the Human-Computer Interaction community as Tinkering (Parisi et al., 2017; Wilson & Petrich, 2014). By directly manipulating the material, the designer creates a relationship with the material through trial and error and develops it into an intended result similar to Darwinian evolution (Santulli & Rognoli, 2020). Tinkering starts with a formulation that gets inspiration from other disciplines, such as culinary science. Then with the developed formulation, various samples are produced and treated by different processes such as coloring, water resistance, etc. During these processes, experiments are done by changing variables such as time, temperature, and shaping techniques. These experiments let the designer understand the technical characterization of the material. The main technical properties, constraints and opportunities, and suitable manufacturing processes are researched during technical characterization (Karana et al., 2015). The designer needs to understand experiential qualities (sensorial properties, meanings it is associated, emotions it elicits, and actions and performances it makes us do) of the material through user studies, focus groups, online questionnaires, and interviews. Also, the material associations to similar products and materials can be studied.

2.3 Materials and the users

Materials are part of our daily lives through the products they are embedded in (Rognoli et al., 2016). They act as an interface between us and the products. They have an impact on our ways of doing and feeling things (Giaccardi & Karana, 2015). They give meanings to the products we use (Karana, 2009). We experience materials through our senses. Materials have both technical and experiential characteristics. Technical characteristics are mostly studied by engineers and scientists. Designers want to also study the experiential properties of materials and products through a more holistic approach creating more meaningful material experiences for users. Materials experience is a term first proposed by Karana et al. (2008b), describing our experiences with and through materials. According to Wilkes et al. (2016), material experiences are outcome of interactions between various elements such as technical and sensorial properties, cultural and historical associations informed by materials science, psychophysics, design research, and anthropology (Figure 10).

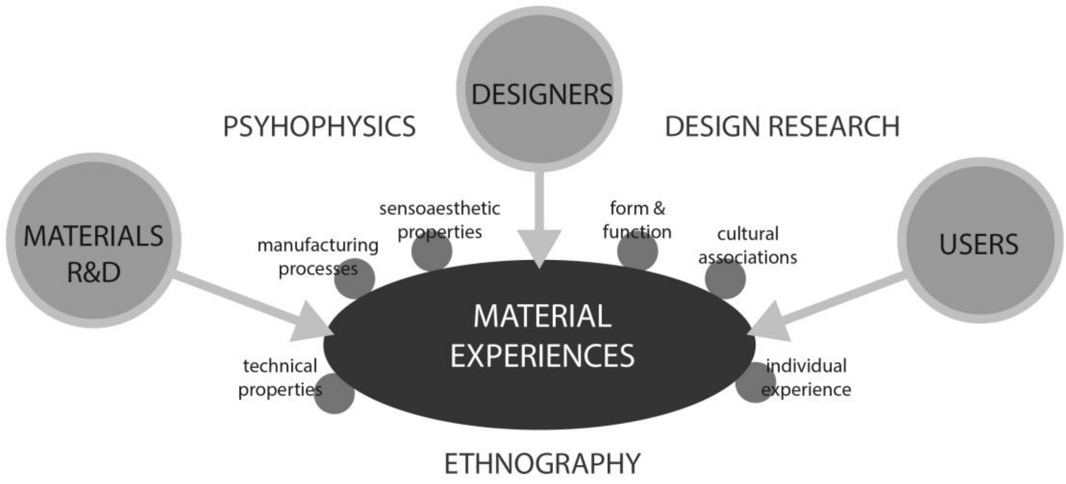


Figure 10: Domains informing material experiences (Wilkes et al. 2016)

Giaccardi and Karana (2015) describe the situational whole we experience materials which consists of materials, people, and practices that interact through encounters, performances, and collaborations (Figure 11). They explain encounters as experiences that happen at the moment of first interactions and performances that are repeat encounters with a material, and collaborations that result in material changes through repeat performances as experiences happen over time. They argue that we experience materials in four experiential levels: sensorial, interpretive, affective, and performative affecting one another unordered fashion.

Sensorial level; the experience we have through our five senses at the moment of first interactions that are affected by material properties.

Interpretive level; describes the meanings and associations we give to the materials after we sense them. For example, we can describe a material as “toy-like” because of its flexibility and color.

Affective level; describes the emotions a material evokes such as surprise or disgust through material properties or our ideas and assumptions.

Performative level; describes how we respond to the materials and what they make us do. Different sensorial characteristics, meanings, and emotions can trigger us to perform and interact with the material. In addition to these four levels, Parisi et al. (2018) added fifth level; the connective level for non-human relations for Interactive, Connected, and Smart Materials.

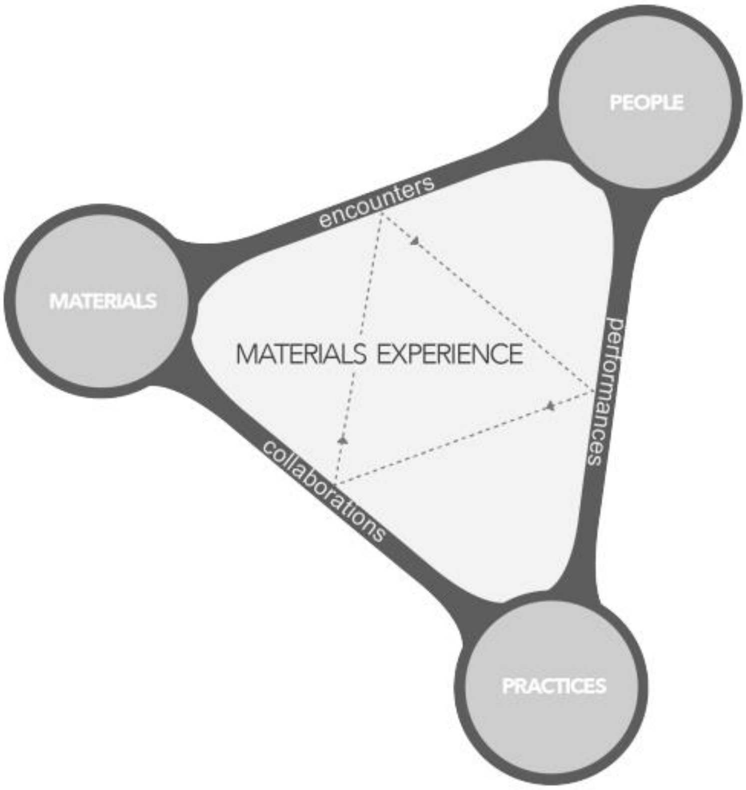


Figure 11: The materials experience framework (Giaccardi & Karana, 2015)

There are various tools developed for studying experimential levels of materials. Rognoli (2010) developed Expressive-Sensorial Atlas to help designers and students to understand the link between subjective qualities and objective properties of materials. It includes sensorial maps (light/heavy, cold/hot, and soft/hard) and theoretical charts (texture, touch, brilliancy, and transparency) that can be used to sort and compare different materials. The Materials in Products Selection (MiPS) tools developed by van Kesteren et al. (2007) focus on materials' sensorial properties, emphasizing user interaction with materials in the early phases of design through instruments such as a picture tool, a question tool, and a sample tool. Karana (2009) developed the Meanings of Materials (MoM) tool that aims to help designers to understand and manipulate the meanings of materials in their materials selection processes by considering the expressive dimensions of them. Created by Zuo (2003), the Material-Aesthetics Database uses four dimensions to describe material textures: geometrical, physical-chemical, emotive, and associative. The tool is intended to discover the factors that influence human perception of materials and to serve as a database that designers can access during material selection to investigate the interrelationships between these factors (Zuo et al. 2004; Zuo, 2010). Bang (2007) investigates tactile and visual sense of fabrics, as well as people' emotional experiences with textiles, using Repertory grid models. It is also used to demonstrate the relationship between personal taste, aesthetic preferences, and feelings of well-being and use frequency of textiles (Ravnløkke & Bang, 2016). The physical-experiential scale of material attributes model developed by Hasling (2016) for design education emphasizes the co-existence and interrelating nature of physicality and experientiality of material attributes. Properties such as compositional, technical, and sensorial and characteristics as associative and emotional are among the attribute categories on the scale.

Since all of the four levels of materials experience are strongly linked and experienced simultaneously in a situational whole, impacted by one another as well as other elements like time and context of use, it is essential to study them with a holistic approach that helps to understand their relationships (Camere & Karana, 2018; Giaccardi & Karana, 2015; & Karana et al., 2014). The mentioned tools mostly focus on particular level of materials experience and do not involve the performative level of it (Camere & Karana, 2018). To solve this problem, Camere and Karana (2018) developed the tool Ma2E4 (Materials-to-Experiences at four levels) that helps designers with both data collecting and data analysis about different characteristics of materials and lets them compare and relate different levels of the experiences. The tool provides information on three layers; the experiential qualities, the mode it is experienced, and the underlying relationship between (Figure 12). The tool consists of a manual of instructions for the designer on using the toolkit, the facilitator's guide to help designers on which questions they need to ask and activities they need to carry out, and the experiential characterization map to collect data from participants. Also, there are sets of words for both affective and interpretive levels. For the interpretive level, there is also an accompanying picture set. The experiential characterization map has five parts; (1) the performative level in which the designer observes how users touch, move, or hold the material by free exploration, (2) sensorial level, the users scale the materials on, (3) affective level, where users reflect on emotions elicited by the material, (4) interpretive level where users describe the meanings associated by the material, and (5) final reflection part for the most pleasant, disturbing and unique qualities of the material.

	sensorial	interpretive	affective	performative
quality	rough	elegant	surprised	caressing
mode	very rough	elegant like a luxury palace	negatively surprised	gentle/ repetitive caressing
relationships	the material is very surprising because it looks rough but feels very smooth.			

Figure 12: Three layers of information provided by experiential characterization tool. (Camere & Karana, 2018).

Through the literature review, the relationship between materials and the main components of the study (waste, designers, and users) was discussed. Food waste can be used as a material ingredient that will help both close the loop and utilize it. The study uses cocoa bean shell waste as its point of departure for material development through Material Driven Design and Material Tinkering methods. Material Tinkering methodology connects designers and materials with a hands-on approach through active learning and experimenting. Since the importance of considering both technical and experiential characteristics of materials to create meaningful experiences for users was emphasized in this chapter, the developed materials for the study were evaluated using Ma2E4 toolkit for a more comprehensive understanding of the materials.

CHAPTER 3

METHODOLOGY

3.1. Material

A literature review was made on open sources that share recipes for materials development. Then readily available and possible ingredients are listed and supplied from the kitchen of the Gastronomy and Culinary Arts department of Ozyegin University, local stores, and companies. Cocoa bean shells were supplied from Altınmarka in İstanbul, Turkey. Soapwort extract was supplied from İstanbul Tarım in İstanbul, Turkey. The ingredients used in the experiments are cocoa bean shells, glycerin (Balen Chemistry), agar agar (Dr.Gusto), gelatin powder (Dr.Gusto), soapwort extract, sodium alginate, sugar, vinegar, corn starch, rice flour (Dr.Oetker), chickpeas for aquafaba, citric acid, wheat (all purpose) flour, powdered sugar, salt, baking powder, vegetable oil, milk, and potato starch. For applying the steps of the recipes, kitchen utensils such as a whisk, stove (BOCD T 6510 ES, BEKO, Turkey), oven (LX-9645, Luxell, Turkey), cooking pot, sieve, spoon, mixer (3 MIX 4000, KRUPS, Germany), blender (BL 3500, Balance, Germany), kitchen scale (Metaltex, Chineese), kitchen thermometer (TP101, OEM, Chineese), and food dehydrator (Excalibur, USA) were used (Figure 13).

Figure 13: Kitchen scene

3.2. Recipe development

Figure 14 summarizes the formulation procedure applied. The procedure had two phases; pilot experiments and main experiments. The experimentation, elimination, and recipe development were conducted simultaneously. Starting point of experimentations were the recipes in literature and open sources. No recipes that utilizes cocoa bean shells were found in the literature. Therefore, the recipes that were found suitable were modified to be used with cocoa bean shell. The existing recipes were modified by adding cocoa bean shells, replacing other wastes with cocoa shells or changing the amounts of some ingredients. New recipes were also developed by experimentation and practicing do it yourself material development procedure. A total of twenty-three recipes created this way with various combinations and different amounts of ingredients were experimented to understand how ingredients behave and react to each other. Table 1 shows resources, ingredients, and process of these recipes sorted in order of trial. Thirty-four materials were produced for pilot experiments using the recipes. Considering the materials which showed good forming potential, dried without moulding and were not brittle, six recipes (three carbohydrate-based and three protein-based) were chosen to be further developed. Then these recipes were divided into four categories according to their binding agents: (1) gelatin-based, (2) agar agar-based, (3) starch-based, and (4) sugar-based recipes. For the main experiments, one starch-based recipe, two sugar-based recipes, three agar agar-based recipes, and twelve gelatin-based recipes were created and evaluated. At the end of the recipe development process, two recipes were chosen among main experiments to be used for material demonstrators' production. The selection criteria for these two recipes were the ability to be shaped by various procedures, drying without molding, not being brittle, and having different sensorial properties. The selection criteria were created with an exploratory bottom-up approach. All the recipes and their processes were noted, and the resulting materials were photographed using a smartphone (Mate 10 Pro, Huawei, Chineese). The photos were taken regularly during processing such as after they were cooked, and they were fully dried. All these data were kept like a diary in a Word document with photos.

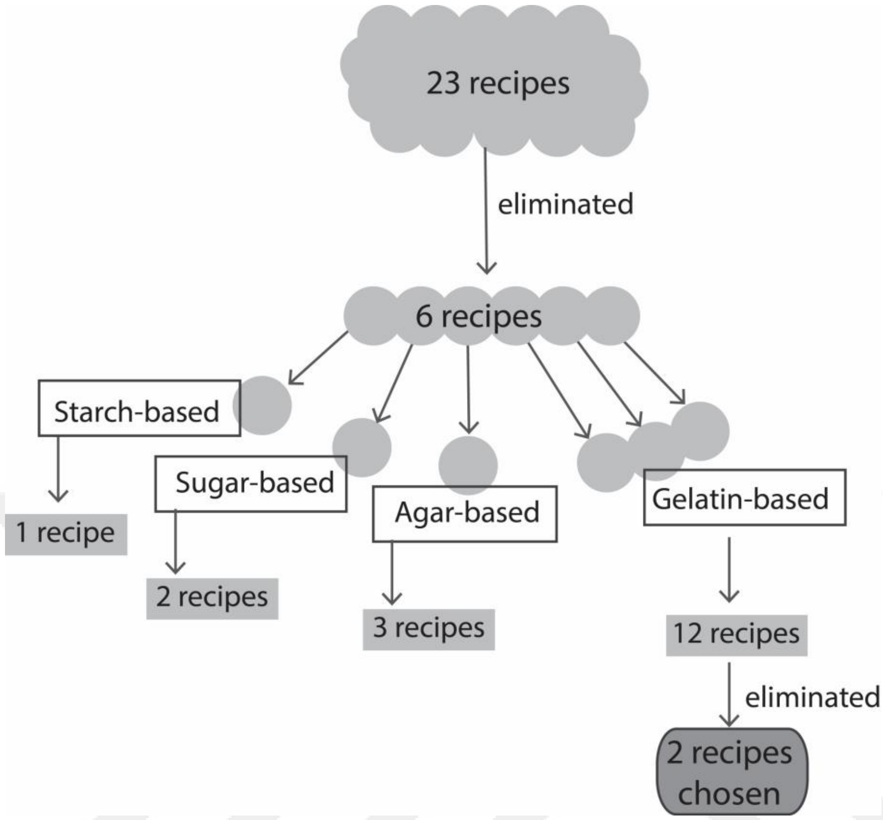


Figure 14: Recipe development procedure

Table 1: Resources, ingredients, and process of first 23 experiments

Recipe No	Resource of the recipe	Ingredients	Process
1	Gillies and CSM BA Textile Design (n.d.)	Glycerin + Water + Gelatin + Cocoa bean shells	Mixing Cooking until it thickens
2	Pavez (n.d.).	Glycerin + Water + Potato starch + Vinegar + Cocoa bean shell	Mixing Cooking until it thickens
3	Bañados et al. (n.d.)	Glycerin + Water + Agar agar + Sodium alginate + Cocoa bean	Mixing Cooking

Recipe No	Resource of the recipe	Ingredients	Process
		shells	until it thickens
4	Developed at the labaratory	Aquafaba + Sugar + Cocoa bean shells	Whisking Mixing Oven baking at low heat
5	Termtanasak & CSM BA Textile Design (n.d.)	Corn starch + Warm water + Rice flour + Cocoa bean shells	Mixing Kneading Oven baking at 165 °C for 15 minutes
6	Termtanasak & CSM BA Textile Design (n.d.)	Corn starch + Warm water + Rice flour + Glycerin + Cocoa bean shells	Mixing Kneading Oven baking at 165 °C for 15 minutes
7	Habashneh (n.d.)	Glycerin + Agar agar + Water + Cocoa bean shells	Mixing Cooking until it thickens
8	Perales (n.d.)	Water + Gelatin + Cocoa bean shells	Mixing
9	Cook With Parul (2021)	All purpose flour + Sugar powder + Salt + Baking powder + Cooking oil + Milk + Cocoa bean shells	Mixing Cooking on pan on low heat
10	Follert et al. (n.d.)	Agar agar + Glycerin + Boiling water + Gelatin + Cocoa bean shells	Mixing

Recipe No	Resource of the recipe	Ingredients	Process
11	Dunne (2018)	Glycerin + Water + Gelatin + Soapwort extract + Cocoa bean shells	Mixing Cooking until it starts boiling Whisking until it thickens and whitens
12	Developed at the labaratory	Water + Sugar + Sodium alginate + Soapwort extract + Cocoa bean shells	Mixing
13	Dunne (2018)	Glycerin + Water + Agar agar + Soapwort extract + Cocoa bean shells	Mixing Cooking until it starts boiling Whisking until it thickens and whitens
14	LABVA et al. (n.d.)	Sugar + Water + Agar agar + Soapwort extract + Cocoa bean shells	Mixing Cooking until it starts to boil
15	Besoain et al. (n.d.)	Water + Vinegar + Sodium alginate + Cocoa bean shells	Mixing
16	Bolumburu (n.d.)	Water + Glycerin + Sodium alginate + Cocoa bean shells	Mixing
17	Developed at the labaratory	Water + Sodium alginate + Cocoa bean shells	Mixing
18	Dunne (2018)	Glycerin + Water + Gelatin + Soapwort extract + Cocoa bean shells	Mixing Cooking until it starts

Recipe No	Resource of the recipe	Ingredients	Process
			boiling Whisking until it thickens and whitens
19	Gerede TSO, 2020	Water + Sugar + Soapwort extract + Citric Acid + Cocoa bean shells	Mixing Cooking until it reaches 140 °C Whisking until it thickens and whitens
20	KWMC: The Factory (2021)	Water + Glycerin + Agar agar + Cocoa bean shells	Mixing Cooking until it thickens
21	Living Matter Lab (2022)	Water + Glycerin + Agar agar + Cocoa bean shells	Mixing Cooking until it starts boiling
22	FabTextiles and Davis (n.d.).	Water + Glycerin + Gelatin + Cocoa bean shells	Mixing Cooking until it reaches 95°C
23	Dunne (2018)	Glycerin + Water + Agar agar + Soapwort extract + Cocoa bean shells	Mixing Cooking until it starts boiling Whisking until it thickens and

Recipe No	Resource of the recipe	Ingredients	Process
			whitens

Gelatin-based recipes

Twelve different versions of the selected three gelatin-based recipes were modified into more recipes by systematically changing the amounts of ingredients to compare the results, as shown in the Table 2. For example, changes were made by keeping the amount of glycerin constant for two trials but changing the amount of gelatin or vice versa. Also, the effects of the addition of different ingredients were evaluated. Process for Recipe 24 and 25 were mixing hot water and gelatin, then adding cocoa bean shells. Then the mixture was shaped by hand or put inside a mold.

Process for Recipe 26, 27, 28, and 43 started by mixing water, gelatin, and glycerin inside a pot. Then they were cooked on the stove while constantly mixing until the mixture began to boil. Next, the heat was turned off, and the cocoa bean shells were added to the mixture and mixed until they were combined homogeneously. Then the mixture was poured onto a surface or inside a mold.

Process for Recipe 29, 30, 35, 40, 41, and 42 started by mixing water, gelatin, and glycerin inside a pot. Then they were cooked on the stove while constantly mixing until the mixture began to boil. Then the heat was turned off, and the soapwort extract was poured inside the mixture. Next, the mixture was whisked by a hand mixer until it whitened and thickened. Finally, the cocoa bean shells were added to the foamed mixture and whisked for ten seconds. Then the mixture was poured inside a mold.

Table 2: Ingredients, amounts, and process of the gelatin-based recipes

Recipe No	Water (mL)	Cocoa bean shell (g)	Gelatin (g)	Glycerin (mL)	Soapwort extract (mL)	Process
24	20	10	5	0	0	Mixing
25	20	15	5	0	0	Mixing
26	40	10	5	6	0	Mixing Cooking
27	40	10	8	6	0	Mixing Cooking
28	40	10	5	2	0	Mixing Cooking
43	40	11	7	4	0	Mixing Cooking
29	36	10	24	0	6	Mixing Cooking Whisking
30	36	10	12	13	6	Mixing Cooking Whisking
35	36	10	12	9	6	Mixing

Recipe No	Water (mL)	Cocoa bean shell (g)	Gelatin (g)	Glycerin (mL)	Soapwort extract (mL)	Process
						Cooking Whisking
40	36	6	10	10	6	Mixing Cooking Whisking
41	36	6	18	10	6	Mixing Cooking Whisking
42	36	6	10	15	6	Mixing Cooking Whisking

Agar-based recipes

Three different recipes were tried as shown in the Table 3. The effects of glycerin and the amount of CBS, and cooking times were evaluated.

Process for Recipe 31, 32, and 39 started by mixing water, agar agar, and glycerin inside a pot. Then they were cooked on the stove while constantly mixing until the mixture began to boil. Then the heat was turned off, and the soapwort extract was poured inside the mixture. Next, the mixture was whisked by a hand mixer until it whitened and thickened. Finally, the cocoa bean shells were added to the foamed mixture and whisked for ten seconds. Then the mixture was poured inside a mold.

Table 3: Ingredients, amounts, and process of the agar agar-based recipes

Recipe No	**Water (mL)**	**Cocoa bean shell (g)**	**Agar agar (g)**	**Glycerin (mL)**	**Soapwort extract (mL)**	**Process**
31	40	4	2	0	6	Mixing Cooking Whisking
32	40	6	2	5	6	Mixing Cooking Whisking
39	40	3	2	5	6	Mixing Cooking Whisking

Sugar-based recipes

The effect of combining agar agar + sugar and gelatin + sugar was evaluated with the recipes in Table 4. By whisking same amount of soapwort extract and water (10ml+10ml), soapwort foam was obtained and used for both recipes.

Process for Recipe 36 started mixing water and sugar inside a pot and cooking them until it reached 140 °C. Then gelatin was added and cooked until it dissolved. Next, the mixture was taken off the heat, and soapwort foam was added. Then the mixture was whisked by a hand mixer until it whitened and thickened. Finally, it was poured inside a mold.

Process for Recipe 37 was the same as Recipe 36, only with the difference of using agar agar instead of gelatin.

Table 4: Ingredients, amounts, and process of the sugar-based recipes

Recipe No	Water (mL)	Cocoa bean shell (g)	Gelatin (g)	Agar agar (g)	Sugar (g)	Soapwort foam (mL)	Process
36	20	4	5	0	50	4	Mixing Cooking Whisking
37	20	4	0	3	50	4	Mixing Cooking Whisking

Starch-based recipes

One recipe was evaluated as shown in the Table 5.

Process for Recipe 38 started mixing water, potato starch, glycerin, and the vinegar inside a pot and cooking it until it thickens while constantly mixing. Next, the mixture was taken off the heat, and cocoa bean shells were added and mixed. Then, the mixture was poured inside pastry piping tool and piped onto a surface.

Table 5: Ingredients, amounts, and process of the starch-based recipe

Recipe No	Water (mL)	Cocoa bean shell (g)	Potato starch (g)	Glycerin (mL)	Vinegar (mL)	Process
38	50	11	7	6	5	Mixing Cooking

3.3. Material Demonstrators

Two gelatin-based recipes (26 and 41) were chosen as final formulations for producing material samples to be studied. In the remainder of the study, the material which were produced with using recipe 26 will be called as Material A (Material

Brown) and recipe 41 as Material B (Material White). Each of the two selected materials was manufactured in two replications, and thus a total of four demonstrators were manufactured (Figure 15). All four were cooked and produced separately using the same two recipes. In literature, flat rectangle shape is the most used shape for material studies with a minimum dimension of fifteen square centimeters so that it can be touched by the whole hand (Veelaert et al., 2020). Material A demonstrators were produced by pouring onto an acetate sheet and cutting with an X-Acto knife and scissors into a rounded rectangle with dimensions of 14 cm x 17 cm. Material B demonstrators were produced by pouring them into plastic foam food containers with the same dimensions and shape. Material A had both rough and smooth surface because of its production technique. The surface which interacted to the acetate resulted smooth while the other was rough. The rough surface was the front surface of the material to be scaled by the participants. Also, for Material B, the surface interacted with the plastic foam was considered as front surface to be scaled.

Figure 15: Material A (on the left) and Material B (on the right).

3.4. Technical Characterization

To understand the main technical properties of the material, several experiments were made. Different manufacturing processes to form the materials were tried such as CNC (Computerized Numerical Control) machining, molding, laser cutting, and extruding for 3D printing. Both materials were poured inside plastic molds to experiment molding. CNC machining and laser cutting trials were made at OpenFab at Özyeğin University. Laser cutting and etching were done on both materials by using laser cutter (Helix 24, Epilog, USA). CNC machining was done by using a desktop milling machine (MonoFab SRM-20, Roland, Japan). For experimenting CNC machining, thick samples were produced for both materials. 3D printing was experimented by pouring the mixture of Material B inside pastry piping tool and were piped by hand onto an acetate sheet.

Both materials were produced as a sheet material and they were cut by using scissors. Then, they were weaved to experiment different joining techniques. Also, the materials were stitched with sewing machine (Tipmatic 1019, Pfaff, Germany). Coloring studies were made using red beet and blue food dye for Material B. The coloring was done by coloring the water used for the recipe before using it. After coloring the material blue, it was cut into pieces and put inside a mold randomly. Then, the original white colored material was produced and poured onto these pieces to experiment producing terazzo material. It was not possible to color the Material A.

To test water resistant of the materials, two glasses were filled with 100 ml distilled water and two centimetres squares of both materials were cut and put inside these glasses. They were photographed for several days to evaluate their durability to water.

3.5. Data collection

3.5.1. Experiential characterization setup

Experiential characterization setup can be summarised as in Figure 16. Four physical material demonstrators were used. Interaction modalities included all five senses; touch, vision, smell, taste and sound. Dependent variables were sensorial, interpretive, affective and performative. Independent variables were technical, product aspects, and user aspects. Methods were scaling, discrimination, and free exploration. Thirty randomly selected voluntary respondents participated to the study.

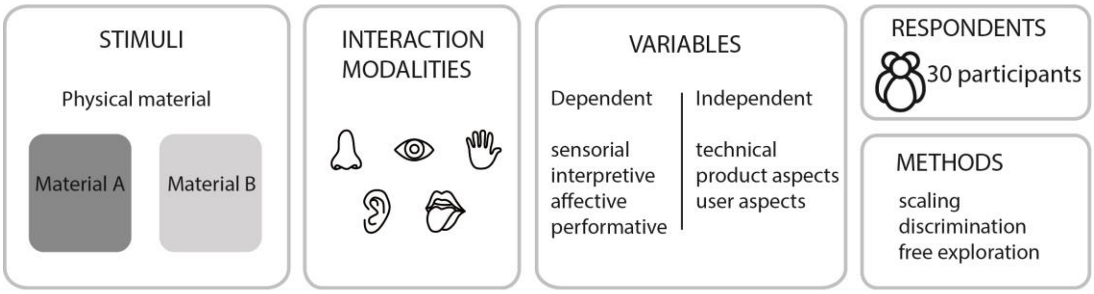


Figure 16: Experiential characterization setup of the study. Adopted from Veelaert et al. (2020).

3.5.2. Ma2E4 toolkit

To understand the materials' experiential characterization, the study used the Ma2E4 toolkit (Camere & Karana, 2018) to demonstrate all four levels and their relationship (Figure 17). Experiential characterization map was used to collect data from the participants. There were some changes made to the map. It was translated into Turkish. The sensorial attributes were arranged from negative to positive, low to high, and low impact to high impact on five-point hedonic scale. For example, one meant very soft on the soft-hard scale, three meant neither soft nor hard, and five meant very hard. Since both study materials did not have reflection properties, not reflective-reflective scale was removed from the sensorial scale. Grids were added to the three-axis diagram for easier data analysis at the affective level. For the interpretive level, every meaning had five corresponding pictures that helped participants describe their choices better. Numbers were added to the pictures for easier data collection and analysis. Separate forms were provided to each participant and each material for experiential characterization map, the affective level meanings list, interpretive level emotions list, and an additional sensorial scale page.

Figure 17: Materials-to-Experiences at four levels (Ma2E4) toolkit (Camere & Karana, 2018).

3.5.3. Procedure

The study was conducted with 30 participants (18 Female and 12 Male) average age of 27, chosen randomly at Ozyegin University Çekmeköy Campus in three days. In the remainder of the study, participants had been anonymized and numbered as P1, P2, and P3 etc. Informations of the participants such as age, gender, occupation, department (for students and lecturers) were collected before the sessions were started. Fourteen of the participants were students, nine of them were lecturers and the rest were university staff (Table 6).

Table 6: Demographic information of participants

Participant No	Gender (Female/ Male)	Age	Job	Department
1	F	25	Food Engineer	
2	F	32	Kitchen staff	
3	F	25	Food Engineer	
4	M	35	Lecturer	Gastronomy
5	M	19	Student	Computer Engineer
6	M	18	Student	Electric and Electronic Engineer
7	M	35	Managing Director	
8	F	41	Lecturer	Fashion design
9	M	22	Student	Electric and Electronic Engineer
10	M	21	Student	Electric and Electronic Engineer
11	M	29	Manager	Finance graduate
12	M	22	Intern	Finance graduate
13	F	20	Student	Architecture
14	F	20	Student	Architecture
15	F	20	Student	Gastronomy
16	F	21	Student	Civil engineer
17	F	22	Student	Law
18	F	25	Student	Law
19	F	42	Lecturer	Gastronomy
20	F	22	Student	Food engineer
21	M	42	Entrepreneur	
22	F	48	Lecturer	Gastronomy
23	M	23	Student	Gastronomy
24	F	27	Lecturer	Gastronomy
25	F	36	Lecturer	Gastronomy
26	F	31	Lecturer	Gastronomy
27	F	21	Student	Architecture
28	M	21	Student	Computer Engineer
29	M	29	Lecturer	Mechatronics Engineer
30	F	29	Lecturer	Industrial Design

The sessions took approximately 20 minutes per participant on average and were voice recorded. Participants were first asked to freely explore the first demonstrator of Material A with all their senses, and how they interacted with the material was observed and noted on the map (Figure 18). Also, their interactions throughout the sessions were noted. Then they were asked to scale the sensorial attributes of the material on the map. Small pieces of scraps were given to participants who wish to test tearing, bending or pulling the materials. For the affective level, participants chose and marked three emotions that were elicited by the material from the list of emotions that were shown to them. Then they were asked to put those emotions on the three-level axis diagram according to their intensity and pleasantness. Participants chose and marked three meanings that could describe the material for the interpretive level. Then the corresponding interpretive level pictures were shown to them, and they were asked to choose one picture that described what they meant by the word they chose and write its number down on the map. Then they were asked about the most pleasant, the most disturbing, and the most unique quality of the material and write them on the map. As final reflection, the participants were asked to explain their meaning and emotion choices. They were asked questions such as “Which attribute made you feel surprised?” to understand the relationship of levels. Participants were asked to mention if there is any similar product or material that resemble the material of the study. Later, they were asked about their suggestions for the material’s possible usage areas. Then they were asked to scale only the sensorial attributes of the second demonstrator of Material A. The procedure was repeated for Material B.

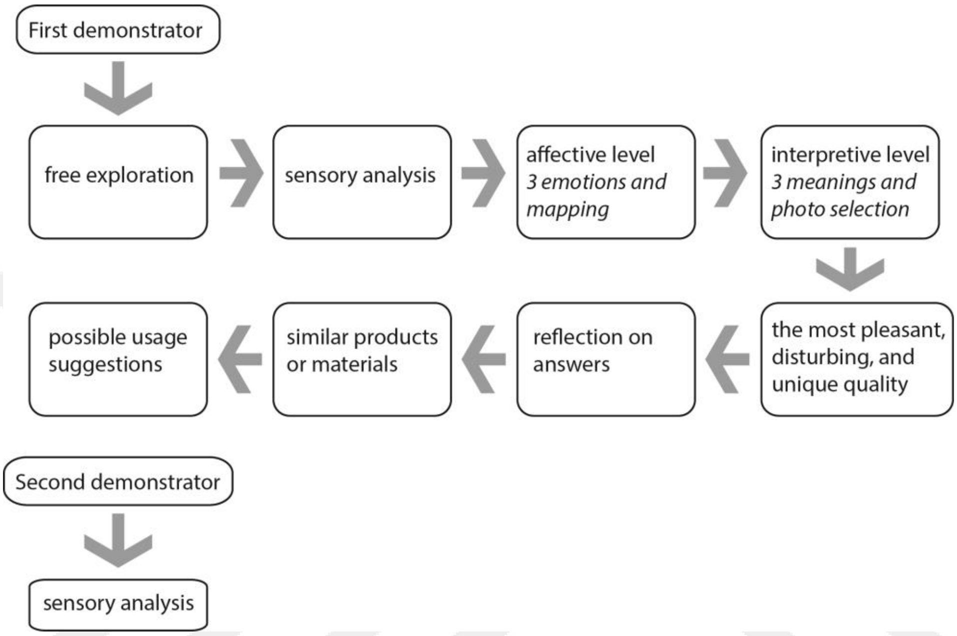


Figure 18: Procedure applied for experiential characterization.

3.6. Data analysis

All data gathered from the four levels of experience were analyzed seperately and correlatively. Since the sessions were voice-recorded, initial data processing was made through transcription of comments and insights from the participants and observation notes taken during the sessions. These insights were used to find correlations between different levels and to understand underlying reason for their choices. All data gathered were entered into an Excel workbook for data analysis. For sensorial level, descriptive statictics were used for calculating mean values of two replicates of both materials and standart deviation.

For both of affective level and interpretive level, frequency of choices was analyzed. For affective level, the emotions were numbered according to their value on the map for plesantness and intensity. Then for the most selected three emotions, mean value of plesantness and intensity levels were calculated. For interpretive level, photos for the most selected three meanings were analysed with frequency of choices. The most pleasant, disturbing and unique qualities were transcribed, listed, and grouped by their similarities. The most common answers were evaluated to understand weak and strong qualities of the materials. Also, the same was done for material suggestions and similar material choices.

CHAPTER 4

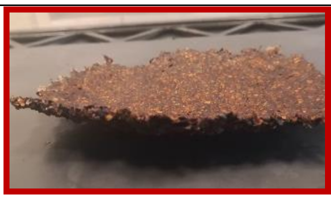
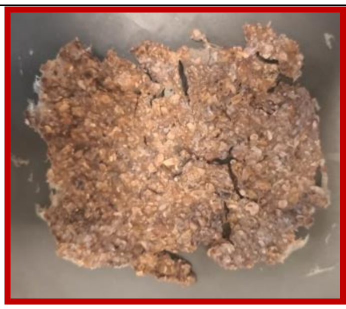
RESULTS

4.1. Formulation

4.1.1. Pilot experiments

Considering the materials which showed good forming potential, dried without molding, and were not brittle, six recipes (numbered 1,2,8,13,18, and 19) were chosen to be further developed. Photos, ingredients, and observations of the first twenty-three recipes can be found in Table 7 with the photos of the chosen recipes framed by red. When the recipes required CBS to be cooked with other ingredients, it gave unplesant odor to the mix. Visible mold growth was observed on some samples. Using sifted or non-sifted CBS affected the texture and sensorial attributes of the materials.

Table 7: Ingredients, photos, and observations of the pilot experiments

Recipe No	**Ingredients**	**Photos**	**Observations**
1	Glycerol Water Gelatin Cocoa bean shell		Hard, deformed shape. It did not thicken during cooking in contrast to the original recipe.
2	Water Cocoa bean shell Glycerol Potato starch Vinegar		Cracked, brittle. It did not bubble while cooking in contrast to the original recipe.

Recipe No	Ingredients	Photos	Observations
3	Agar agar Glycerol Water Sodium Alginate Cocoa bean shells		Cracked, brittle. Off-odor formation during cooking with CBS.
4	Aquafaba Sugar Cocoa bean shells		Brittle. After baking in the oven, it reduced its volume and became thin like a caramel flake.
5	Corn starch Warm water Rice flour Cocoa bean shells		Hard. It cracked after baking in the oven. It sticked to the mould.
6	Corn starch Warm water Rice flour Glycerin Cocoa bean shells		Hard. Baked with silicon mold. Color differences are resulted between outside and inside surfaces.
7	Glycerin Agar agar Water Cocoa bean shells		Cracked, brittle. Off-odor formation due to cooking with CBS. It was dried with food dehyrator.
8	Water Gelatin Cocoa bean shells		Hard but elastic. It was hard to mix the ingredients properly because it started to stabilize so quick.

Recipe No	Ingredients	Photos	Observations
9	All Purpose Flour Sugar Powder Salt Baking Powder Cocoa Shells Cooking Oil Milk		It sticked to the surface of the cooking pan. The recipe did not work.
10	Agar agar Glycerin Boiling Water Gelatin Cocoa bean shells		Brittle. Most of the water evaporated and resulted very thin brittle particles.
11	Glycerin Water Gelatin Soapwort extract Cocoa bean shells		Hard. It started drying while pouring into the mold so it resulted with an amorphous shape. It was whisked by hand.
12	Soapwort extract Water Sugar Sodium alginate Cocoa bean shells		Deformed, ductile but tears up easily. After drying, it had very unpleasant odor.
13	Glycerin Water Agar agar Soapwort extract Cocoa bean shells		Cracked, brittle, and hard. It was whisked by hand.

Recipe No	Ingredients	Photos	Observations
14	Sugar Water Agar agar Soapwort extract Cocoa bean shells		Cracked, semi-brittle, and deformed. It had mold spots after drying.
15	Water Vinegar Sodium alginate Cocoa bean shells		Thin and brittle. Alginate and vinegar did not react to each other in contrast to the reference recipe.
16	Water Glycerin Sodium alginate Cocoa bean shells		It did not dried properly and mold growth on the surface was noted
17	Water Sodium alginate Cocoa bean shells		Cracked, mold growth, and highly brittle.
18	Glycerin Water Gelatin Soapwort extract Cocoa bean shells		Hard but ductile. It was whisked by a hand mixer and poured into a plastic mould.

Recipe No	Ingredients	Photos	Observations
19	Water Sugar Soapwort extract Citric Acid Cocoa bean shells		Sticky surface. It did not dried and became like a melted candy. Some of the CBS sinked to the bottom.
20	Water Glycerin Agar agar Cocoa bean shells		Shrinked, deformed, and mold growth.
21	Water Glycerin Agar agar Cocoa bean shells		Shrinked, deformed, and mold growth.
22	Water Glycerin Gelatin Cocoa bean shells		Hard and shiny surface, deformed. When poured thin, it was semi-transparent.
23	Glycerin Water Agar agar Soapwort extract Cocoa bean shells		Sticky, mold growth. Whisked with a hand mixer. Some of the foam was deflated while drying.

4.1.2. Main experiments

Ingredients, photos, and observations of the main experiments can be seen in Table 8. Glycerin makes it easier to mix gelatin and water. The higher the amount of glycerin, the more flexible the resulted material. At the same time, the higher gelatin amount resulted harder and less flexible material. Changing material thickness affected the properties of materials produced by Recipe 26 and 27. The thinner they were, the more flexible they became. Just as it did in sugar confections, soapwort extract whitened the recipes it was used in. Also, with its foaming properties, it increased the volume of the resulted materials. It was possible to produce various hardness levels with gelatin and soapwort-based recipes from very soft to very hard. Both Recipe 31 and Recipe 32 cracked after they dried. As Dunne (2018) pointed out, when the water was not evaporated sufficiently, agar-based recipes had tendency to crack. So, Recipe 39 were cooked more to evaporate more water and the resulted material did not crack. Recipe 26 and Recipe 41 were chosen to produce materials to be used for the study for technical and experiential characterization. They were chosen because of their sensorial properties and their ability to be shaped by different methods and to dry without molding. Material A was produced by using Recipe 26 while Material B was produced by using Recipe 41.

Table 8: Ingredients, photos, and observations of the main experiments

Recipe No	**Ingredients**	**Photos**	**Observations**
24	Water Cocoa bean shells Gelatin		Ductile, rough surface. It was hard to combine ingredients without cooking so more water was added. It had mold growth before it dried properly.

Recipe No	Ingredients	Photos	Observations
25	Water Cocoa bean shells Gelatin		Ductile, rough surface, and mold growth. When ingredients were mixed, lump formed. It was shaped manually into a mold in order to hold its shape.
26	Water Cocoa bean shells Gelatin Glycerin		It shrinked after taking out of the mold. When it was poured thinly, it was deformed.
27	Water Cocoa bean shells Gelatin Glycerin		Deformed, rough surface.
28	Water Cocoa bean shells Gelatin Glycerin		Deformed, mold growth, rough surface.
43	Water Cocoa bean shells Gelatin Glycerin		Hard, deformed, rough surface.

Recipe No	Ingredients	Photos	Observations
29	Water Cocoa bean shells Gelatin Soapwort extract		Hard, deformed, and mold growth. The amount of water was increased to prevent lump formation. Some of the CBS sinked to the bottom surface.
30	Water Cocoa bean shells Gelatin Glycerin Soapwort extract		Ductile, rough surface. Some of the CBS sinked to the bottom surface.
35	Water Cocoa bean shells Gelatin Glycerin Soapwort extract		Ductile, rough surface. Some of the CBS sinked to the bottom surface. It was shrinked after drying.
40	Water Cocoa bean shells Gelatin Glycerin Soapwort extract		Foam-like soft texture. It holds its shape after pushing.
41	Water Cocoa bean shells Gelatin Glycerin Soapwort extract		Hard but ductile, smooth surface.

Recipe No	Ingredients	Photos	Observations
42	Water Cocoa bean shells Gelatin Glycerin Soapwort extract		Foam-like soft texture. It was deformed while taking out from its mold.
31	Water Cocoa bean shells Agar agar Soapwort extract		Cracked, brittle, moulded, sand-like texture.
32	Water Cocoa bean shells Agar agar Glycerin Soapwort extract		Cracked, moulded, sand-like texture.
39	Water Cocoa bean shells Agar agar Glycerin Soapwort extract		Soft, ductile. It was shrinked after it was dried.
36	Water Cocoa bean shells Gelatin Sugar Soapwort foam		Sticky, glue-like texture.

Recipe No	Ingredients	Photos	Observations
37	Water Cocoa bean shells Agar agar Sugar Soapwort foam		Hard, macaron-like texture inside. Smooth surface on top but bottom surface was sticked to the mold.
38	Water Cocoa bean shells Starch Glycerin Vinegar		Brittle, hard. It was shaped by pastry piping tool. The material did not join well.

4.2. Understanding the materials

4.2.1. Technical characterization

When put inside a glass full of water, Material A sank to the bottom while Material B floated on top (Figure 19). On the fifth day, Material B was fully dissolved, and some of the cocoa bean shells were sunk to the bottom. On the other hand, even though the water was blurred, Material A still held its shape.

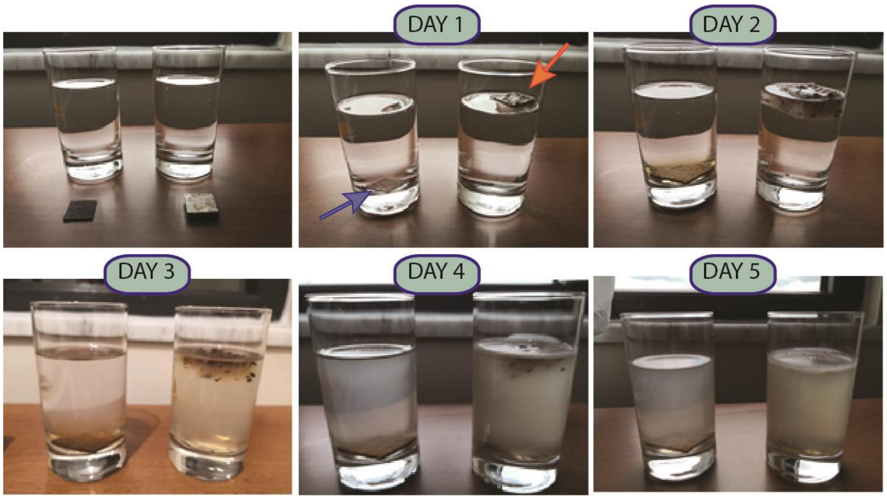
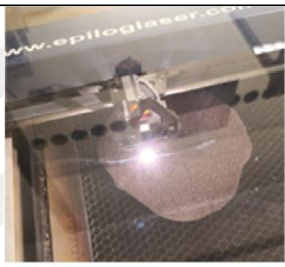
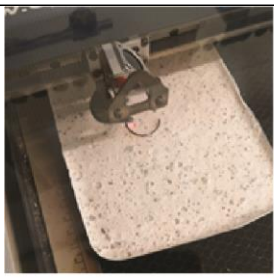
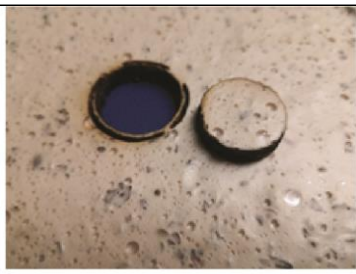
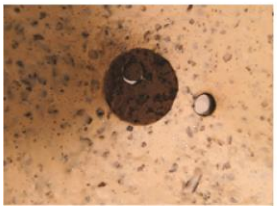


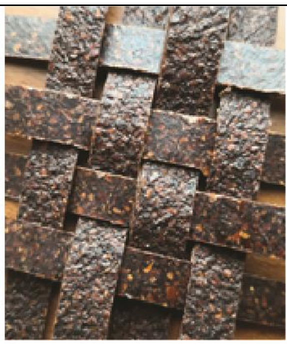
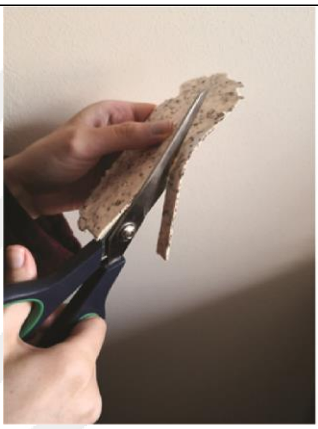
Figure 19: Water resistant test for the materials.

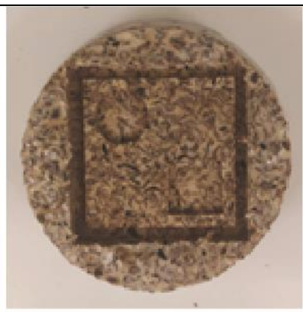
Experimented processes and their results can be seen in Table 9. Both materials are suitable for molding, laser cutting, CNC machining, cutting, and stiching with sewing machine. Material B is suitable for 3D printing and coloring.

Table 9: Results of different production, joining, and shaping studies

Process / Material / Observations	**Photos**
Coloring / Material B Coloring with beetroot did not yield good results. It almost had no effect on the color of the material. On the other hand, it was possible to color it by using blue food coloring.	 
Terrazzo / Material B The produced blue material was used for terazzo experiment. Because of its sticky surface, it was easy to fix the pieces into the mold. Even though there were air pockets at some places, the results show that the material can be shaped into terrazzo.	   

Process / Material / Observations	**Photos**
3D printing / Material B It was possible to extrude the material through the nozzle and make a few layers. But after some point, the material started to solidify, and it was not possible to continue extruding.	 
Laser cutting and etching / Material A It was suitable for both processes. The visibility of the etching was low.	  
Laser cutting and etching / Material B It was suitable for both processes.	  

Process / Material / Observations	**Photos**
Cutting and weaving/ Material A It can be cut by scissors and X-acto knife. The strips produced this way can be weaved.	 
Cutting and weaving/ Material B It can be cut by scissors and X-acto knife. The strips produced this way can be weaved.	 
Sewing/ Material A It can be stiched by sewing machine.	 
Sewing/ Material B It can be stiched by sewing machine.	 

Process / Material / Observations	Photos
CNC machining / Material A It was suitable for CNC machining.	  
CNC machining / Material B It was suitable for CNC machining.	  

Process / Material / Observations	**Photos**
Molding / Material A It was suitable for molding. After taking out from the mold and drying fully, it shrinked.	  
Molding / Material B It was suitable for molding. After taking out from the mold and drying fully, it shrinked.	 

4.2.2. Experiential characterization

Performative Level

The sensorial qualities of both materials such as flexibility, surface, texture, and odor affected the performative level. Most of the participants smelled both materials. Only one participant tasted the materials.

Performances done by participants with Material A can be seen in Figure 20.

For material A, P2 said “I liked it a lot. It has a stress relief effect.” while playing with it constantly. Some participants held the material at their hand throughout the whole session. Performances consisted folding, caressing, grabbing, bending, pulling, weighing, and smelling.

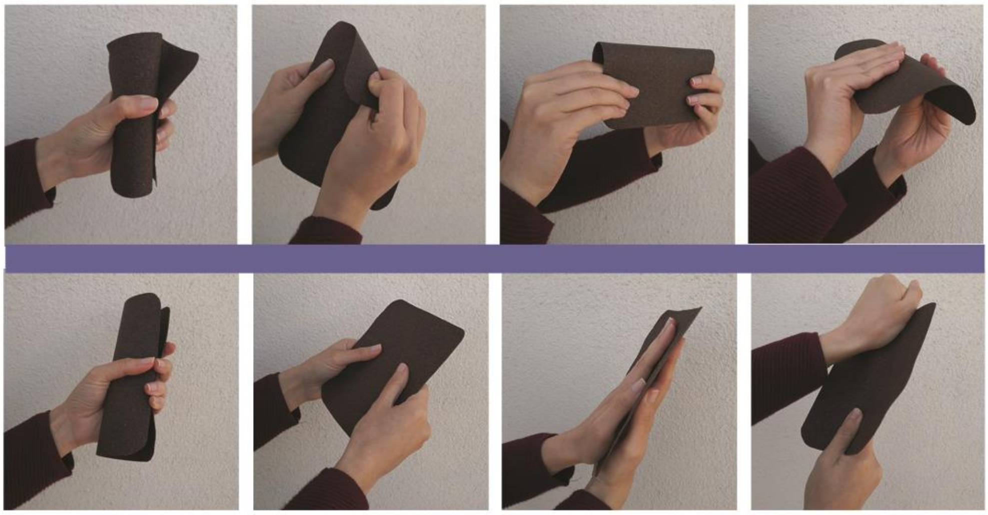


Figure 20: Performances with Material A.

Performances done by participants with Material B can be seen in Figure 21. Most of the participants repeatedly pressed the material with their thumb. Some of the participants got anxious about when they bend the material and asked before whether they could do it. Performances consisted pressing, caressing, grabbing, bending, scratching with nails, weighing, and smelling.

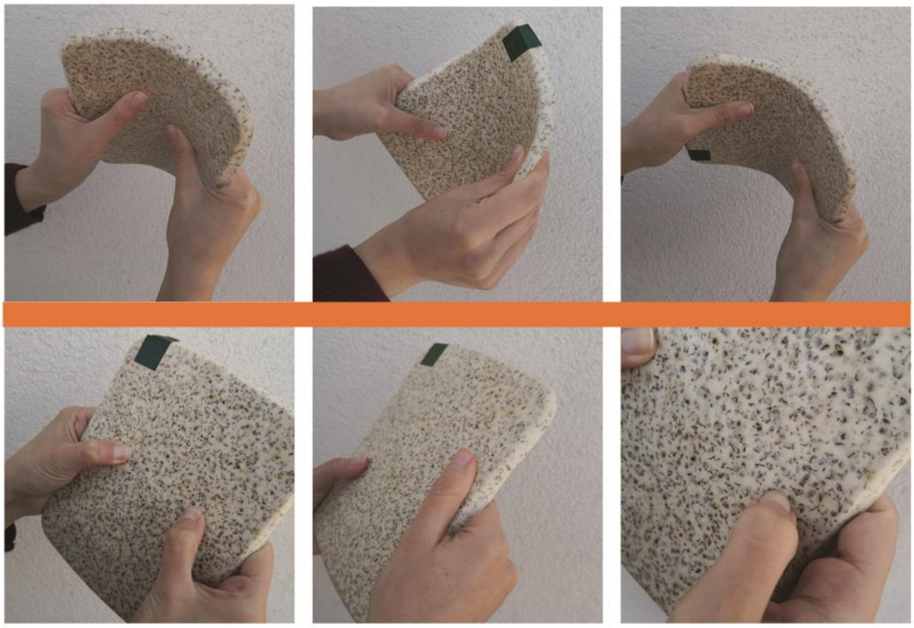
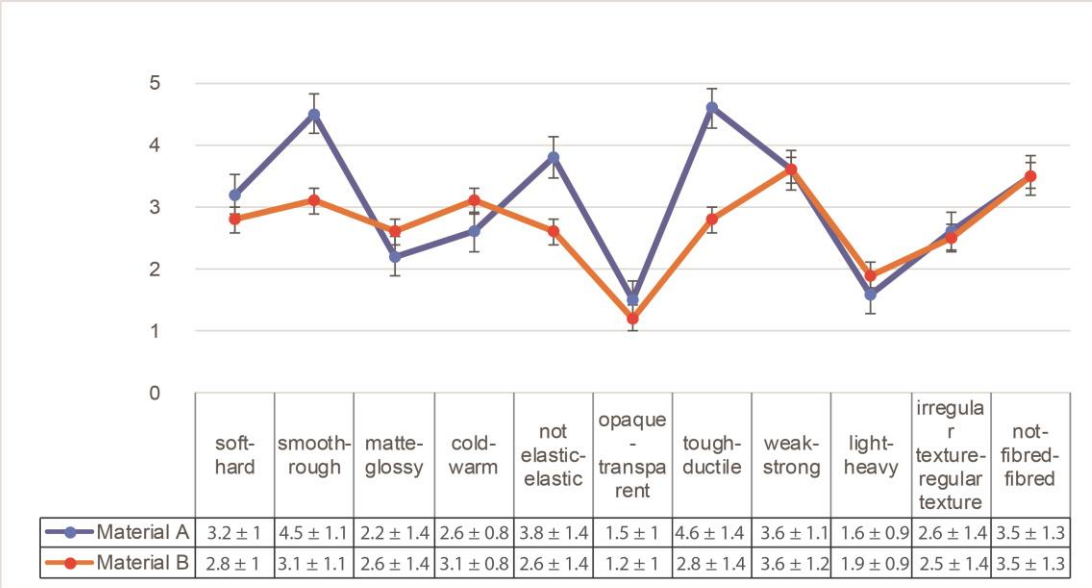


Figure 21: Performances with Material B.

Sensorial Level

Results of the sensorial level of the materials can be seen in Figure 22. Smoothness, elasticity, and flexibility were the qualities most differed for the two materials on the sensorial scale. Material B was found glossier and warmer. Material A was easy to tear but had resistant against pulling. It was also a higly flexible material. On the other hand, participants found Material B less durable to bend.



	soft-hard	smooth-rough	matte-glossy	cold-warm	not elastic-elastic	opaque-transparent	tough-ductile	weak-strong	light-heavy	irregular texture-regular texture	not-fibred-fibred
Material A	3.2 ± 1	4.5 ± 1.1	2.2 ± 1.4	2.6 ± 0.8	3.8 ± 1.4	1.5 ± 1	4.6 ± 1.4	3.6 ± 1.1	1.6 ± 0.9	2.6 ± 1.4	3.5 ± 1.3
Material B	2.8 ± 1	3.1 ± 1.1	2.6 ± 1.4	3.1 ± 0.8	2.6 ± 1.4	1.2 ± 1	2.8 ± 1.4	3.6 ± 1.2	1.9 ± 0.9	2.5 ± 1.4	3.5 ± 1.3

Figure 22: Results of sensorial level of the materials. Data are the mean value of two replicates ± standart deviation.

Most of the responses for most pleasant, disturbing, and unique qualities were about sensorial qualities of the materials. The results included attributes such as odor, taste, color and apperance of the materials that were not included at the sensorial scale.

For Material A, the most pleasant qualities were its flexibility and natural, unprocessed texture feeling. The most disturbing qualities were odor and rough surface. “It looks as if it will smell good, but it does not” (P14). On the other hand, some participants liked the odor and suggested product ideas about it. The unique qualities were its elasticity and having two opposite surface qualities (rough and smooth) simultaneously.

For Material B, the texture, color, and pattern on its front surface were the most pleasant qualities. Also, participants found its ability to take its shape back after it was manipulated to be a pleasant quality. Similar to Material A, the odor was one of the most disturbing qualities for Material B. In addition, participants found the probability of being fragile and sticky surface feeling to be unpleasant. They found the material's appearance and texture qualities to be unique properties.

P30 wanted to taste Material A by asking, “Is there a small piece that I can bite?” and after tasting, she said “It does not have much taste. It feels like eating paper, but it has a little taste”.

Affective Level

For affective level, each participant chose three emotions elicited by the material. Some participants found it hard to fill the map as P8 said, “It's challenging to describe the feeling, you say it's fun when you look at it, but I don't know why it's fun, the things that come to my mind are actually fun.” Also, P27 said, “These feelings vary a lot depending on where I see the materials.”

The frequency of choices results of affective level for both materials can be seen in Figure 23. Out of 22 emotions, none of the participants chose feminine and unsexy for Material A and aggressive for Material B. For both materials, how the materials were made, what their ingredients were, and where they would be used were the main reasons that evoked curiosity among participants. Curiosity about the ingredients and process also confused some participants, including regarding surface qualities. The pleasantness and intensity levels of curiosity and surprise were higher for Material A among participants (Figure 24).

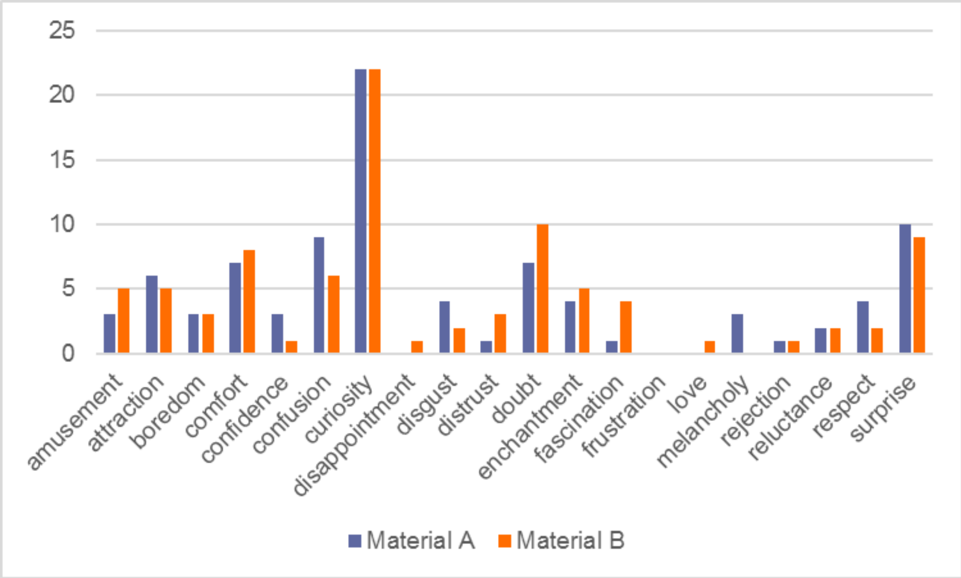


Figure 23: Results of affective level of the materials

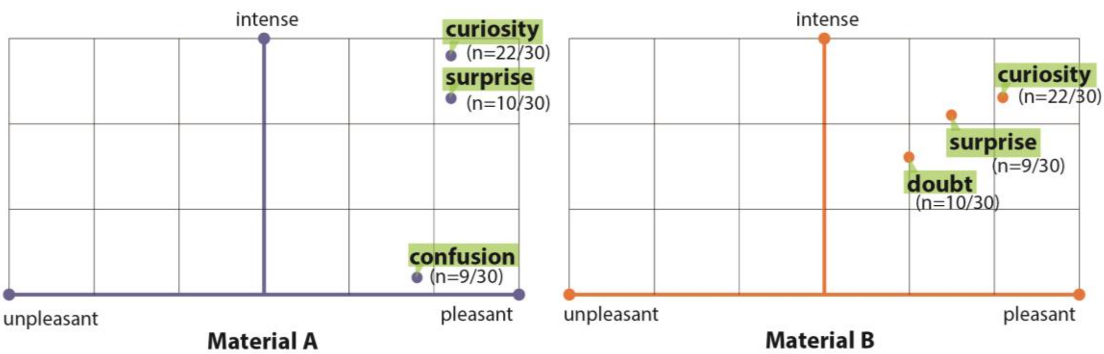


Figure 24: The pleasantness and intensity level of the top emotions for materials.

The numbers in parentheses indicate how many participants chose the emotion. Curiosity (22), surprise (10), and confusion (9) were the most common emotions elicited by Material A, followed by comfort (7), doubt (7), and attraction (6). Sensorial qualities of Material A, especially the rough surface, surprised some participants. “I have not seen plastics with the rough surface before” (P28). On material ingredients, P30 said, “If you said I made it by using sawdust, it would not be surprising for me. But it is surprising that it was made from cocoa bean shells” Because of the rough surface, some participants felt doubt about the material. Material A had attraction and amusement to touch and play with the material, giving participants comfort. “It is fun to play with hand” (P23). “You want to keep playing with it” (P22). The odor of Material A resulted in negative emotions such as disgust, reluctance, and rejection for a few participants.

Material B elicited curiosity (22), doubt (10), and surprise (9) among participants, including comfort (8), confusion (6), attraction (5), enchantment (5), and amusement (5). While explaining her choice for curiosity, P18 said, “This material reminds me of human personality. There is always something different in the light, such as there are different colors such as brown etc. on this white material. Every person has different urges inside, so it reminded me of that”. Doubt was the result of not understanding what exactly the material was and also the possibility of breaking the sample while bending it, as pointed out by P3 “It looks like as if something is going to happen, but actually not so”. P29 also doubted “I thought I may damage it with my hand”. Participants were surprised about Material B being a plastic material and its ingredients as P25 said “It is surprising that it was made by soapwort. Its foaming property really attracted me”. While explaining her choice about comfort, P8 pointed out she used the word for describing the space she imagined the material was situated in “..as if it was part of a place where you feel comfortable, safe and have fun in a friendly environment in an entertainment space”. The color and the resulted pattern through cocoa bean shells elicited amusement, enchantment, and fascination.

Interpretive Level

The frequency of choices results in interpretive level for both materials can be seen in Figure 25. Out of twenty meanings, none of the participants chose dissapointment, love and frustration for Material A, and melancholy and frustration for Material B. Participants knew the fact that both materials were produced by natural ingredients. While Material A was highly perceived as natural among participants (natural: 14 and unnatural: 6), the choices for Material B were mixed (unnatural: 8 and natural: 7). For hand-crafted, participants chose a picture with a craftsman for Material A and a picture with an artistic ceramic bowl for Material B (Figure 26). For cozy meaning, two pictures were most chosen by participants for Material B. Participants chose the same picture for strange meaning for both materials. The corresponding photos at the interpretive level were not suitable for some participants. They said they could not find the proper photo they want to mean with the word they chose.

“Vulgar is none of the photos. I want to mean vulgar as sackcloth” (P4).

"When I say vulgar, I mean a raw material. What I mean does not fit the photos" (P22).

“Toy-like photos are not suitable. If there were a play dough picture, I would choose it because of its flexibility" (P11).

“By natural I mean leather because it looks like leather…I expected there to be a picture of leather" (P26).

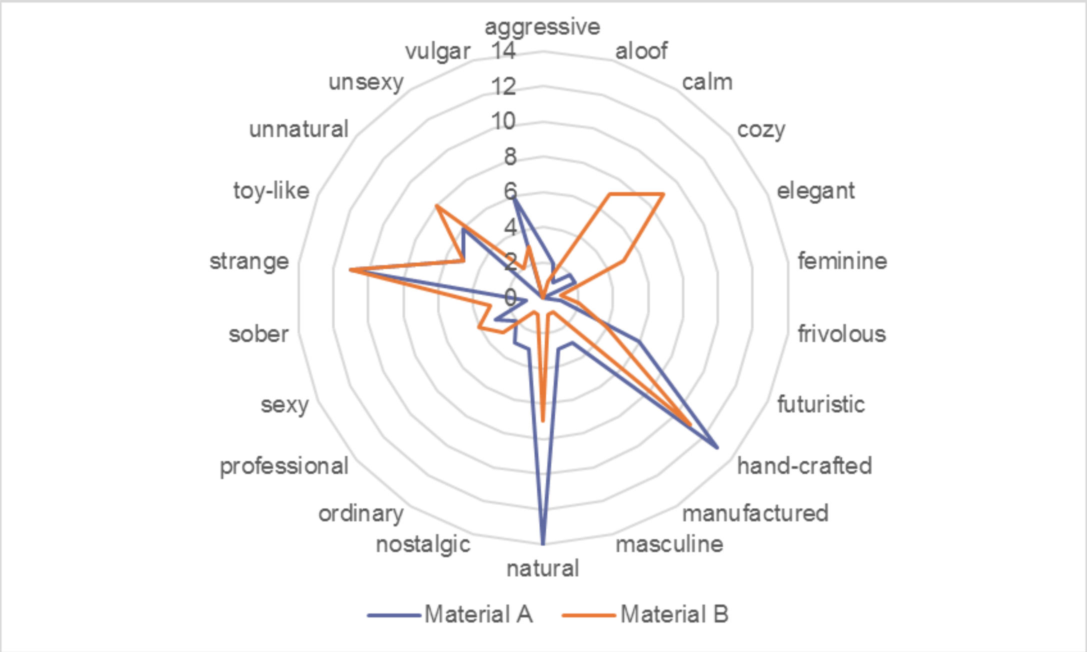


Figure 25: Results of interpretive level of the materials

Figure 26: Corresponding pictures chosen by participants for the interpretive level

The numbers in parentheses indicate how many participants chose the meaning. Natural (14), hand-crafted (13), and strange (11) were the top meanings selected by participants for Material A at the interpretive level, followed by futuristic (6), unnatural (6), vulgar (6), and toy-like (5). Participants chose natural because of the materials natural feeling that it gives to hand, and its ingredients being natural. “It is reassuring. It is not chemical. You can feel that it is natural” (P7). Because of its irregular and imperfect surface qualities, the material gave participants the impression of hand-crafted material. The material's flexibility made it to be defined as a toy-like and unnatural material. The rough surface created an expectation among participants that the material would not be flexible. But when they started to move it with their hand, they saw it was a very flexible material. “It is a material as if it will tear when I bend it with my hand; it is strange that it can be this flexible even though it has particulate texture” (P27). Also, the fact that the material had two opposite surface qualities (rough and smooth) made participants define it as a strange material. Since it was a semi-developed material, some participants found the material futuristic. Vulgar, unnatural, aggressive, and nostalgic were related to color, texture, and odor.

For Material B, the top choices were strange (11), hand-crafted (11), and cozy (9), followed by unnatural (8), natural (7), calm (7), toy-like (5), and elegant (5). Participants highly appreciated the appearance of the material. Still, on the other hand, the texture made some participants find the material strange as P16 said, “The strange thing is that it is a plastic”. “What kind of plastic is this?” (P28). Participants perceived the light color of the material as cozy, calm, and elegant. P8 commented on the hardness of the material and said, “It would be better if it were a little softer. Because it would be more suitable for the elegance of the material”. P30 imagined a cozy environment for the material ” I would take my MacBook, which had a cover made from this material, and my coffee with me. That was why I chose the picture with coffee. It is something natural, it has a warm feeling”. The material seemed natural but felt unnatural for some participants. So, the choices between natural (7) and unnatural (8) were close. The foamy texture of the material made it feel like an unnatural material. On the other hand, this in-between texture of being hard and soft gave the material a toy-like attribute. Similar to Material A, being the material for future usage made participants choose futuristic meaning.

4.2.3. Similar materials and usage suggestions

For both materials, participants said they look like edible materials. When participants were asked if there is any other material or product similar to Material A, the most common answers were *pestil* (traditional fruit leather), mousepad, coaster, track flooring for walking, sandpaper, wallpaper and wall covering, and leather. Material suggestions for Material A were products related to heat and heat protection such as *nihale* (table mat), accessories for the kitchen, and products for the kitchen with the tactile surface through the rough surface of the material. It was suggested that it can be used as part of interior design as covering material for decoration on surfaces and walls or can be used as a flooring or insulation material. Accessory suggestions were made such as laptop case, watchband, textile products such as bag and wallet because of the material's leather-like texture. Participants also suggested packaging and carrying, and products that can be used for its odor were aroma therapy scents.

Similar materials for Material B mainly consisted of food products. Participants associated the material with food such as a white chocolate bar with pistachio, nougat, tahini halwa, white chocolate ice cream, moldy cheese, and *yayla çorbası* (a Turkish yogurt soup made with different herbs and rice). Other than food, play dough, foam plates, styrofoam containers and insulation materials, marble kitchen counter, and terrazzo materials were mentioned by participants. Suggestions for Material B included products that have protective features such as packaging, cases for laptop, or eyeglasses. Because of its color and pattern, it was also suggested to be used as decorative element for products such as glasses or plates, accessories for home such as vase. Similar to Material A, insulation and covering material suggestions were also made. Because of its foamy texture, children's toys, memory foam, foam for sports or children's playgrounds, and pinboard were suggested.

CHAPTER 5
GENERAL DISCUSSION

The study aimed to contribute to the utilization of cocoa bean shells through material development. The study started with the recipe development process using Material Tinkering, a method emphasizing active learning and experimenting while doing and practicing. Even though there are several sources for guiding designers on do-it-yourself materials, there is still a lack of information. Most recipes do not include tips and tricks. Also, they do not give information on substitutes or how to modify recipes according to different needs. There is no methodology available that guides designers while tinkering. Which recipes to choose and continue developing depends on mainly the designer. Because of this limitation, the study created its own exploratory elimination criteria based on a bottom-up approach. These criteria included the ability to be shaped by various procedures, drying without molding, not being brittle, and having different sensorial properties. There is a gap in the literature on this subject and a need to develop criteria and guidelines that will help designers during the elimination of the materials for exclusion and inclusion procedures. Future studies can be made on this subject for creating a set of elimination criteria. The study of Asbjørn Sörensen and Thyni (2020) focuses on problems with DIY materials. They argue when the designers have prior knowledge of production and consider technical and experiential properties from the beginning, it affects the quality of results of studies. So, they point out the need for a methodology that will guide designers during different steps of the process.

After developing two recipes, rectangle shaped material demonstrators were produced to use for the study. The shape of the material demonstrators affects how the participants perceive the materials. As Veelaert et al. (2020) point out in their literature review, there is a literature gap that studies in-between forms that do not resemble other products that encourage users to interact with materials. So, in future studies, different shapes and their effect can be studied.

Next phase of the study was understanding the materials through experiential characterization map. There are some points that the experiential characterization map can be developed. Since they were chosen randomly, some participants were unfamiliar with words on sensorial scale, such as fibred. So, a guide can be designed to help them understand these unfamiliar words or the participants can be informed on the sensorial qualities and how to scale them before the sessions. Also, additional sensorial qualities can be added to the scale such as color and odor. The matrix of the affective level was also confusing for some participants since it required them to scale according to both pleasantness and intensity. During the sessions, the participants were given Material A first, then Material B to evaluate. This may have created a novelty effect for Material A which can be related to the result of the affective level which showed higher pleasantness and intensity levels for curiosity and surprise for Material A. In future studies, the materials can be given to the participants in different orders to counterbalance and to see if this effect can be reduced.

Interpretive level pictures were not suitable for some participants since they were mostly based on visuality and tangibility limiting the different modalities to be explored. Meanings associated with the materials can vary depending on culture and people. So, a new set of pictures can be developed for further studies considering Turkish culture and different modalities.

The participants of the study were chosen randomly. In future studies, the choice of participants can be diversified in different categories such as those who have experience about the materials and those who do not. Also, the study can be repeated with respondents chosen according to the customer segmentation of possible users of the materials.

During the sessions, the perception of people changed before and after they interacted with the materials. They got to know the materials more and interact with them at every level. When the expectation from the experience from a distance did not match the experience from a close-up, it resulted in emotions such as surprise, curiosity, confusion, and attraction among participants. These differences can be a subject of a future study to understand the differences between expectations and authentic experiences.

The experiential characterization map was used to collect data on the developed materials. The relationship between different levels of experiential characterization of Material A can be seen in Figure 27. The rough and smooth surface qualities of Material A make it a weird material. But this also gives it a natural feeling and comfort. It is a toy-like, highly flexible material that is also durable at the same time. Its most unpleasant property is its odor. Future studies can be made to make its odor more pleasant or lighter. It is suitable for shaping by CNC machining, molding, laser cutting, and joining by weaving and stitching.

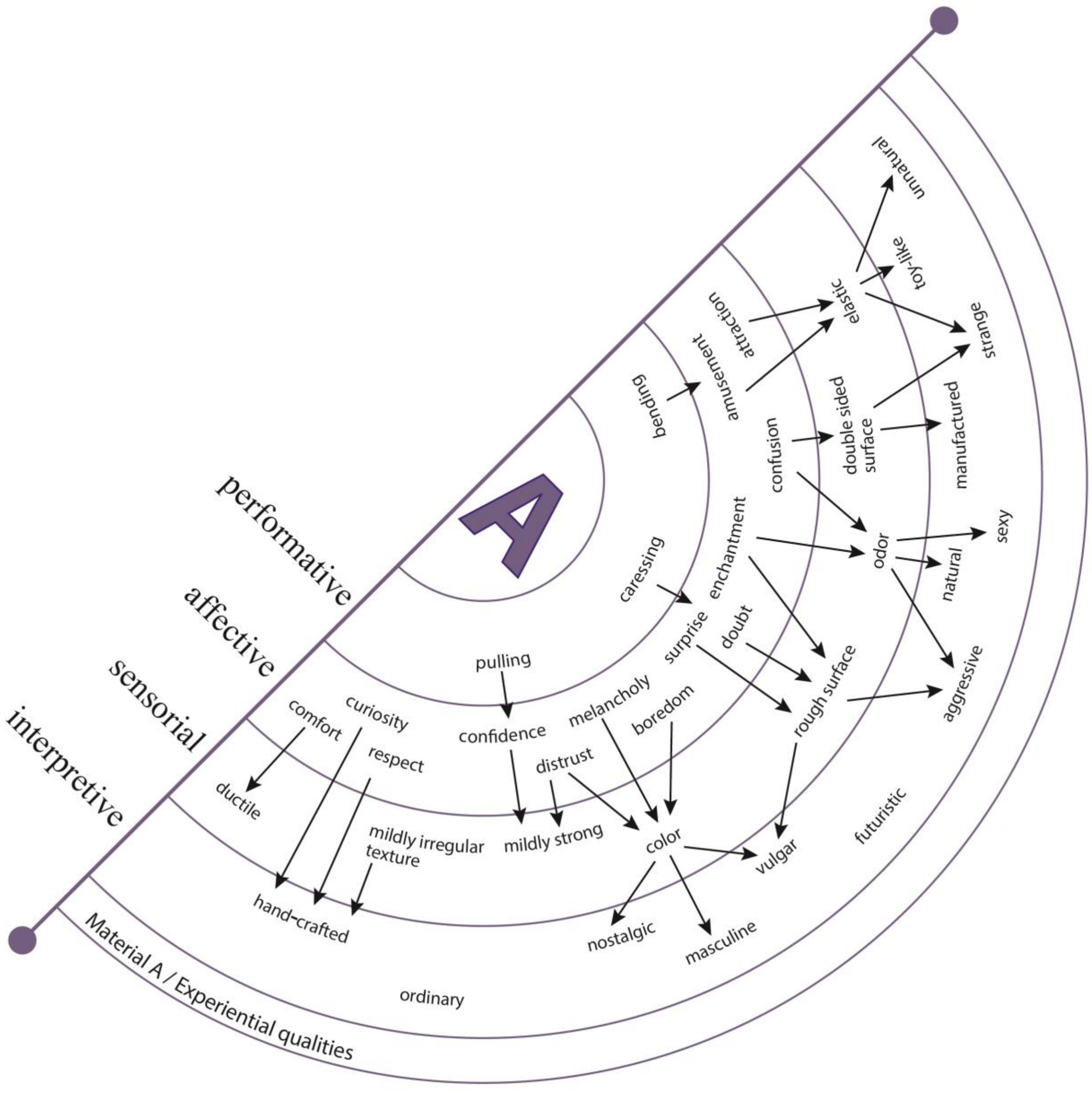


Figure 27: The experiential qualities of Material A on the basis of four levels of materials experience and their relationships. Adopted from Camere and Karana (2018).

The relationship between different levels of experiential characterization of Material B can be seen in Figure 28. Material B has a surprising white color, giving it a calm and cozy feeling. The brown particles on the white surface create amusement, enchantment, and fascination. The foamy texture makes it a toy-like and fun material. The unpleasant property of the material is the doubt feeling for its flexibility. It can be shaped by various processes such as CNC machining, molding, laser cutting, extruding for 3D printing, and joining by weaving and stitching. It can be colored by food coloring, and different textures can be achieved by molding. The front and back of both materials had different sensorial properties. Participants were required only to scale the front surfaces of the materials. In future studies, they can be scaled separately. More technical analysis can be done for materials such as fire resistance and tear test. Using the study's technical and experiential characterization results, a product vision can be created to turn these materials into products in future studies.

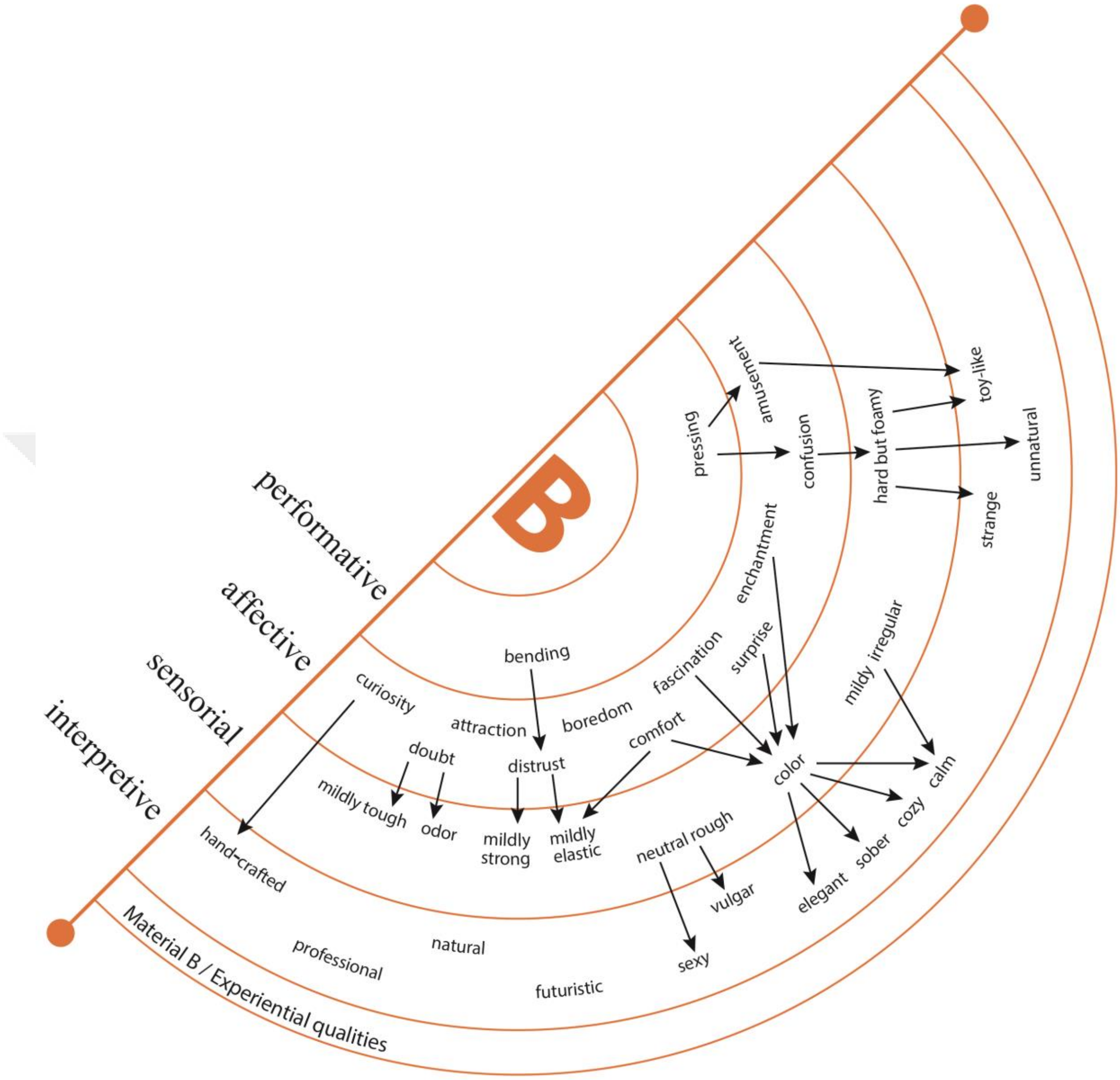


Figure 28: The experiential qualities of Material B on the basis of four levels of materials experience and their relationships. Adopted from Camere and Karana (2018).

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APPENDICES

APPENDIX A

Consent form

ÖZYEĞİN ÜNİVERSİTESİ

Gönüllü Katılım Onay Formu (Form B)

Projenin Adı: Utilization of cocoa bean shell

Proje yürütücüsünün adı ve iletişim bilgileri: Sevda Kaya Email: sevda.kaya@ozu.edu.tr

Proje bütçesine katkı ile ve/veya diğer şekillerde projeyi destekleyen kuruluşlar: Yok

Projenin amacı: Projenin amacı, yüksek lisans tezi kapsamında geliştirilen biyoplastiklerin kullanıcı deneyimlerinin araştırılmasıdır. Kullanıcıların farklı malzelere nasıl tepki verdikleri ve algıları araştırılacaktır.

Süreç: Serbest zaman dilimlerinde gönüllü olan katılımcılardan duyusal analiz için izin istenecek ve kabul eden katılımcılarla görüşme yapılacaktır. Katılımcıların analiz öncesi bir onay formu ile hem çalışmadan haberdar edilmesi hem de ön bilgilendirme yapılması hedeflenmektedir. Yapılacak deneyim araştırmasında kullanıcılara farklı biyoplastik örnekleri gösterilecektir. Kullanıcıların plastikleri ellerine alıp incelemeleri ve daha sonra malzemelerle ilgili düşüncelerini araştırmacılarla paylaşmaları istenecektir.

Gizlilik: Katılımcıların kimliği ve cevapları anonim olarak kalacak, çalışmada toplanan bilgiler başka kimse ile paylaşılmayacaktır. Sonuçlar araştırmacılar tarafından sadece veri girişi ve analizi yapılırken görülecektir. Böylece başka bir amaç dâhilinde kullanılmayacaktır.

Gönüllü Katılım: Bu projeye katılım tamamen gönüllülük temelindedir. Projeden herhangi bir zamanda çekilme hakkınız vardır ve katılımı reddetmek herhangi bir zarara yol açmayacaktır. Serbest zaman dilimlerinde gönüllü olan katılımcılardan duyusal analiz için izin istenecek ve kabul eden katılımcılarla görüşme yapılacaktır.

Bu formda anlatılan araştırmanın etik yönleriyle ilgili soru veya görüşleriniz varsa lütfen Özyeğin Üniversitesi Etik Kurulu ile (216) 564 9846 numaralı telefondan temasa geçiniz.

Yukarıda sözü geçen "Utilization of cocoa bean shell" isimli araştırma projesinin detaylarını okudum ve bu proje ile ilgili sorularım cevaplandı. Bu çalışmaya gönüllü olarak katılıyorum.

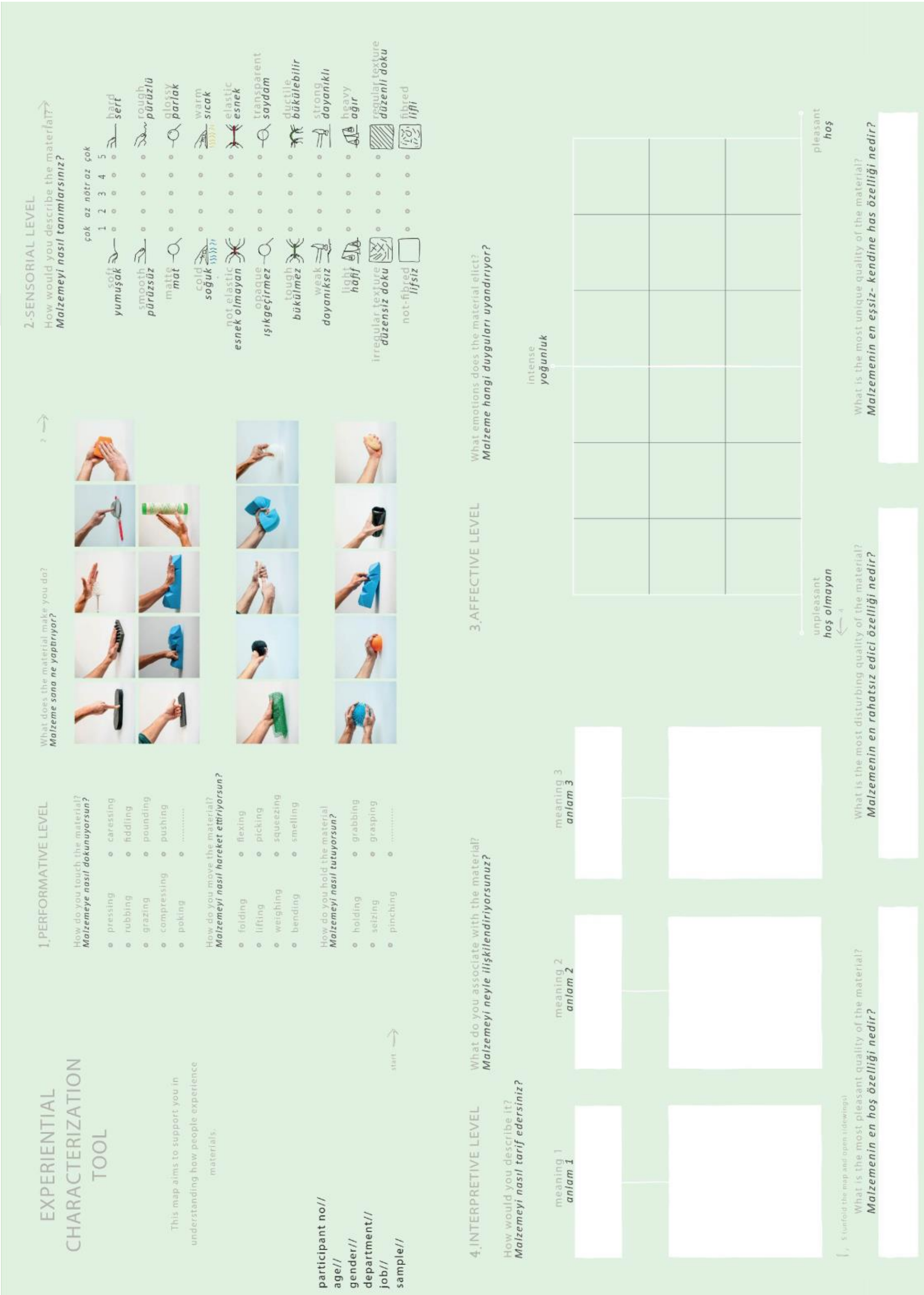
____________________________ ____________________________

İsim Soyadı Tarih

∗ İşaretli başlıkların detayları açık ve günlük dille, katılımcı bakış açısından ve kısaca anlatılmalıdır.

APPENDIX B

Experiential Characterization Tool



APPENDIX C

List of words for the affective level

AFFECTIVE LEVEL

(list of emotions)

frustration *boşa çıkma*	love *sevgi*
boredom *can sıkıntısı*	amusement *eğlenme*
disappointment *hayal kırıklığı*	surprise *beklenmedik*
reluctance *isteksizlik*	confidence *güven*
confusion *kafa karışıklığı*	enchantment *cezbetme*
rejection *reddetme*	respect *saygı*
disgust *iğrenme*	attraction *çekim*
melancholy *melankoli*	curiosity *merak*
distrust *güvensizlik*	fascination *büyüleyici*
doubt *tereddüt*	comfort *rahatlık*

APPENDIX D

List of words for the interpretive level

INTERPRETIVE LEVEL

(set of meanings)

OR

aggressive *agresif*	calm *sakin*
cozy *rahat*	aloof *soğuk*
elegant *zarif*	vulgar *kaba*
frivolous *uçarı*	sober *ölçülü*
futuristic *fütüristik*	nostalgic *nostaljik*
masculine *erkeksi*	feminine *kadınsı*
ordinary *sıradan*	strange *garip*
sexy *çekici*	not sexy *çekici olmayan*
toy-like *oyuncak gibi*	professional *profesyonel*
natural *doğal*	unnatural *yapay*
hand-crafted *el yapımı*	manufactured *seri üretim*

APPENDIX E

Photos for the interpretive level

APPENDIX F

Sensorial scale