DEVELOPMENT OF AGAR BASED ORGANIC MATERIALS AND THEIR USES IN DESIGN FIELDS WITH DO-IT-YOURSELF (DIY) APPROACH

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DEVELOPMENT OF AGAR BASED ORGANIC MATERIALS AND THEIR USES IN DESIGN FIELDS WITH DO-IT-YOURSELF (DIY) APPROACH

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ABSTRACT

DEVELOPMENT OF AGAR BASED ORGANIC MATERIALS AND THEIR USES IN DESIGN FIELDS WITH DO-IT-YOURSELF (DIY) APPROACH

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The material is the essence of everything and when it comes to designing and production, it becomes the foundation of productivity and manufacturing. According to requirements and aesthetics, novel materials have been invented and altered. As today's biggest problem is environmentally hazardous materials, avoid such materials scientists and designers are looking for various possibilities. New materials are emerging through do-it-yourself (DIY) approach encouraged by the open and shared platforms. This study aims to develop a sustainable and organic DIY material that can be easily developed through easy production methods with natural materials. The study is conducted to contribute in resolving environmental issues. A DIY material formula is developed to attain a sense of responsibility and craftsmanship experience. Furthermore, this study investigated new identities of DIY material, designed and developed through the creative use of natural substances. Agar agar is used as the main material, which is used in food industries for thickening and gelling purposes. The agar-based DIY material is developed through various experimentations by combining other daily substances and observing their compatibility. Material Driven Design (MDD) method is used to evaluate the material to identify its qualities, adverse effects and possible uses through user studies. User studies are conducted with students from Design, Culinary Art and Food Engineering and other departments to understand the aesthetical and practical usage of agar based DIY materials in the design field. Agar based materials have shown some similar properties with plastics and silicone, suggested that they can be used as substitute materials in design fields.

Keywords: Agar agar, DIY, DIY Materials, Material Development, Material Driven Design, Self-production, Organic Material, Sustainable Design, Edible Films

ÖZET

AGAR TABANLI ORGANİK MATERYAL GELİŞTİRİLMESİ VE TASARIM ALANLARINDA KENDİN YAP (DIY) YAKLAŞIMI İLE KULLANIMI

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Malzeme birçok ürünün özüdür. Tasarım ve üretim söz konusu olduğunda malzeme, verimlilik ve üretimin temelini oluşturur. Gereksinim ve estetiğe göre, yeni malzemeler geliştirilmiş ve mevcut malzemeler değiştirilmiştir. Günümüzün en büyük problemi çevreye zararlı malzemeler olduğundan, bu tür malzemelerden kaçınmak için bilim insanları ve tasarımcılar çeşitli olasılıkları değerlendirmektedirler. “Kendin Yap’’ (Do-It-Yourself- DIY) yaklaşımı ile ortaya çıkan yeni malzemeler, paylaşım platformları tarafından teşvik edilmektedir. Bu çalışma, doğal malzemelerle kolay üretim yöntemleri aracılığıyla kolaylıkla şekillendirilebilen, sürdürülebilir ve organik bir DIY malzeme geliştirilmesi amaçlanmaktadır. Sorumluluk ve ustalık deneyimi kazanmak için, bir DIY malzeme formülü geliştirilmiştir. Ayrıca bu çalışma, doğal maddelerin yaratıcı kullanımı yoluyla tasarlanmış ve geliştirilmiş DIY malzemesinin yeni kimliklerini araştırmaktadır. Agar agar, gıda endüstrisinde kıvamlaştırma ve jöle yapımı amaçlı ana malzeme olarak kullanılır. Agar esaslı DIY malzemesi, diğer günlük maddeleri birleştirerek ve uyumluluklarını gözlemleyerek çeşitli deneyler aracılığıyla geliştirilmiştir. Malzemeye Dayalı Tasarım (Material Driven Design-MDD) yöntemi, malzemenin özelliklerini, yan etkilerini ve muhtemel kullanımlarını tasarımcı ve amatör deneyimler yoluyla değerlendirmek için kullanılmaktadır. Kullanıcı çalışmaları, tasarım alanında agar esaslı DIY malzemesinin estetik ve pratik kullanımını anlamak için, Tasarım, Mutfak Sanatları, Gıda Mühendisliği ve diğer öğrencilerle agar esaslı malzemeler kullanılarak anket yapılmıştır. Agar esaslı malzemelerin bazı polimer ve elastomerlere benzer özellikler gösterdiği anlaşılmıştır, dolayısıyla bunların yerine geçmesi olasılığı bulunmaktadır.

Anahtar Kelimeler: Agar agar, DIY, DIY Materyalleri, Materyal Geliştirme, Malzemeye Dayalı Tasarım, Kendinden Üretim, Organik Materyal, Sürdürülebilir Tasarım, Yenilebilir Filmler

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CHAPTER 1

INTRODUCTION

1.1 Introduction

When moving from a conceptual sketch to a physical object in the design process, one of the main factors to consider is the material. The material is the key component which transforms a virtual shape into the form of a product or a component. Without materials, the design remains just a concept. To turn a concept into a tangible product, the designer needs a suitable material. Selection of the proper material is crucial to the success of a product. For a designer, architect, or even an artist, the right material selection is one of the most important factors. The material has a significant impact on physical appearance, performance, and user experience. The meaning, use, and experience changes depending on the material selection. Suitable material selection for a particular product dictates the designer to consider multiple design criteria like a manufacturing process and its limitations, availability of the material and its cost, shape and use in design. It is also important to consider characteristics, meaning, association, emotions, and cultural aspects before selecting a final material for design (Karana, Hekkeret, and Kandachur, 2009). Furthermore, optimal material selection is a responsibility towards the society and the environment.

The material trend has changed over the past decades. Now users are getting more aware gradually about the after effects of materials; they are also concerned about the global, environmental and health issues apart from their comfort level. As it has been observed scientifically, climatic conditions of the world are deteriorating with the passage of time and causing global warming. One of the predominant reasons behind this situation is pollution; the pollution we cause due to production, transportation, use, and discarding products (Papadimitriou, 2004; Gruijl and Leun, 2000). A typical landfill today consist of old furniture, outdated electronics like; television, telephone handsets and radio, clothing, and a huge portion of plastics in various forms. All these products end up in landfills or marine debris due to multiple reasons like a change of trend, design failures or becoming useless. Change of trend encourages people to discard their belongings such as clothing, furniture, or other antiquated objects. Design failures usually happen due insufficient knowledge on the behaviour of materials and components under different environmental conditions. Once used, many plastic products like plastic wrappers and water bottles often come in the category of useless items as they were designed for single use. It is a statistically recorded fact that only in the USA every second 1500 plastic water bottles are consumed, and 80% of them end up in landfills, despite widely offered recycling campaigns and programs and growing awareness of pollution hazards (Scholtus, 2009).

Plastics were one of the most amazing inventions during the industrial revolution, which excited both designers and producers because of their good properties, ease of manufacturing and low cost. Many designers adopted plastics because of the possibility of mimicking qualities of the natural materials like wood and leather (Karana, Rognoli, Barati, and Laan, 2015; Dormer, 1990). However, in the 21st century plastics became one of the major alarming materials because of their non-sustainable and non-biodegradable qualities. Many other adverse health side effects have been observed, which made material engineers develop sustainable and biodegradable materials over the last couple of decades. The trend of sustainability started and urged designers to design in more ethical ways, considering sustainability and biodegradability issues during the design process.

For a designer, designing a product with new materials is much more difficult and challenging than selecting from existing materials. Therefore, during the development of new materials, scientists and material engineers started to collaborate with designers. Engineers do not perceive materials the way designers do and anticipate their possibilities in products. Material development has become a multidisciplinary field in which biologists, scientists, material engineers and designers, all contribute their best to develop materials and their practical applications in the real world.

The situation has changed after the trend of open design and open culture. With the help of open platforms, knowledge becomes accessible to all. Professionals or amateurs can share their research or knowledge openly, which can be prolific to others and lead towards the do-it-yourself culture (DIY). Traditionally, materials are developed in laboratories and mass produced. However, through open platforms and DIY processes; materials can be self-produced with the help of freely accessible websites and video. Bio-plastics are one of the common examples of

DIY material on open source. From different websites to YouTube videos, easy recipes are available which can be easily reproduced by anyone. The concept of DIY materials is still new, and it needs an appreciable amount of further development. In the DIY material culture not only biologists, scientists, or material engineers are contributing; also many designers have started to develop new materials and promote them through open platforms. Designers play a significant role to contribute to society from solving social issues to promoting a safe environment. DIY material development not only promotes a safe environment but also gives a new sense of experience and craftsmanship to the designer.

DIY material development for designers is a relatively new field. To contribute in this field, it is aimed to develop an original and organic material that can help to resolve environmental, ethical, sustainable and health issues, with the means of accessible organic materials from nature. The material is developed through an easy DIY recipe that can be prolific to both amateurs and professional designers to design and self-produced organic products instead of non-sustainable materials. To develop a new DIY organic material, multiple experiments, considerable manufacturing and material knowledge are needed to explore how to develop a simple, easy formula, to produce organic materials with the means of accessible and low-cost materials. The DIY material should be understandable, simple, and easy instead of necessitating complex procedures. Such a material can be further reproduced by designers or even amateur material producers. That formula will help the designers to get a sense of responsibility, achievement, and craftsmanship experience and facilitate them to produce their own products through a self-produced material. A material can be self-customised according to the need of the particular project or customer request.

The main aim of this thesis is to develop a formula that can be further customised by designers and become easily accessible to them. The concept is influenced by the DIY and open design philosophy to provide an easy-to-use formula and method that interests amateurs, students, and young designers. Furthermore, this study aims to investigate new identities of DIY material designed and developed through the creative use of natural substances, which can give rise to new identities to existing materials. The main substance is agar agar. This substance is used in food industries as a vegetarian gelatine substitute for thickening and gelling purposes. This study intends to develop agar based DIY material through various experimentations, combining other daily substances and observe their compatibility. The material Driven Design (MDD) method is used to evaluate the material the qualities, adverse effects, and possible uses of agar based materials through the designer and amateur experiences. The MDD guides the designer through the process of discovering a material added value, meaning, user experience and how a material can support user practices. User experience was investigated by the surveys conducted with design, culinary art and food engineering, and random students to understand the aesthetical and practical usage of the DIY material in the design field.

CHAPTER 2
DIY CULTURE

2.1 Introduction

DIY is an abbreviation of Do-It-Yourself. DIY is defined as creating, modifying or repairing of objects without the help or guide from a paid professional or an expert. DIY has been practised and recorded in history for human survival ability to repair, redesign and restore objects through basic tools and materials. DIY has changed the trend of depending on professionals for more than a century; people have been repairing water leaks, restoring furniture, remodelling and redesigning their homes and interiors without the help of professional plumbers, architects or designers. Modern societies oppose the concept of self-reliance with mass- production and consumer economy, as it is easy, cheaper and more convenient than DIY. Tangible things can be bought easily; professionals can be hired to build and repair effectively, designers and artists can be employed to decorate or customise with sophistication. However, people continue to practise DIY to create, design, modify and develop objects, stitching clothes, fix gadgets, generate music and develop software (Wolf and McQuitty 2011).

DIY depicts as a practice where people connect with raw or primary materials and segment parts to deliver, change, or reproduce objects, including those drawn from the natural habitat, e.g. bonsai making. DIY conduct can be activated by different inspirations like; financial advantages, an absence of item accessibility and item quality, a requirement for customisation and character improvement such as; craftsmanship, strengthening or uniqueness (Wolf and McQuitty 2011).

Subsequently, DIY refers to the broader range of self-driven and self-directed skills of various disciplines, including science, arts and craft, design, maker culture and self-published media (social audio and video networks). The term “amateur” used in DIY culture referred to the young skilled user, who uses his/her skills as profession or entrepreneur. Over the past few decades, social media and computer networking integration have increased such as social computing, online sharing tools, and other human-computer interaction (HCI) technologies. These technologies have transformed new interest and broader adoption of DIY cultures and practices through affordable or free tools and the emergence of new sharing mechanisms (Kuznetso & Paulos, 2010).

2.2 DIY Cultures

The arts and craft movement was the initial stage of DIY consumer culture, emphasising the need for on self-satisfaction. Subsequently, multiple cultures and movements emerged from DIY. From 20th century handcrafted ornament to 21st century 3D printed items, trends and cultures have grown in different sorts of fields (arts and craft, design and architecture, science and technology, etc.). A brief history, cultures, movements and communities associated with DIY are explained in this chapter.

2.2.1 Historic Overview:

Alvin Toffler (1980) described societies in three waves. The first wave is the agricultural age; the second is the industrial age based on mass production and mass consumption; the third wave is the post-industrial society, also called as the information age (Gardien et al., 2014). In the same way, DIY is also divided into three waves; the first wave is the subsistence DIY, the second wave is industrial DIY, and the third wave is the new DIY (Fox, 2014). The first wave of DIY is the era of agriculture age, where people used to grow what they eat and make what they need by themselves without regular purchase from the outside source. For example, people used to build their own homes with local and natural materials, and women used to make clothes and craft for themselves and their families.

The term "do-it-yourself" came to existence in the second wave since 1912 in the domain of arts, craft, and design as a hobby, need or requirement; like home improvement and maintenance (Gelber, 1997). During 1920’s and 1930’s women magazines popularised arts and crafts. Colourful visual transformed tips, kits, patterns and step-by-step instructions for knitting, sewing and home craft features were the prominent and popular component of women consumer’s magazines in British and American society. Woman’s Weekly (British) and Good Housekeeping (American) were two of the famous magazines of 1920’s which are still being published (Hackney, 2006). These magazines were helping women to work in a better way with the DIY approach based on craft and home maintenance, as we can see from 1920’s magzine covers in Fig 2.1.

Fig 2.1 Woman's Weekly of 1920 and Good Housekeeping of 1926

(Source: Google images)

During industrialisation, men and women had separate working spheres. Men were working and earning money, from that money wives used to run the household. Men were more into masculine home chores, like household construction, repair and maintenance. There were separate do-it-yourself magazines for men, about constructing and repairing things. The household craft was more like a hobby for many men. Handicraft (British), Popular Mechanics (American) and The Craftsman (American) were some of the famous magazines during 1920's and 1930's (examples shown in Fig 2.2). They had illustrated (Fig 2.3) do-it-yourself templates for making, repairing and maintaining indoor and outdoor households for amateur hobbyists (Gelber, 1997).

Fig 2.2 Men magzine covers from Handicraft of 1934 and Popular Mechanics of 1920 (Source: Google images)

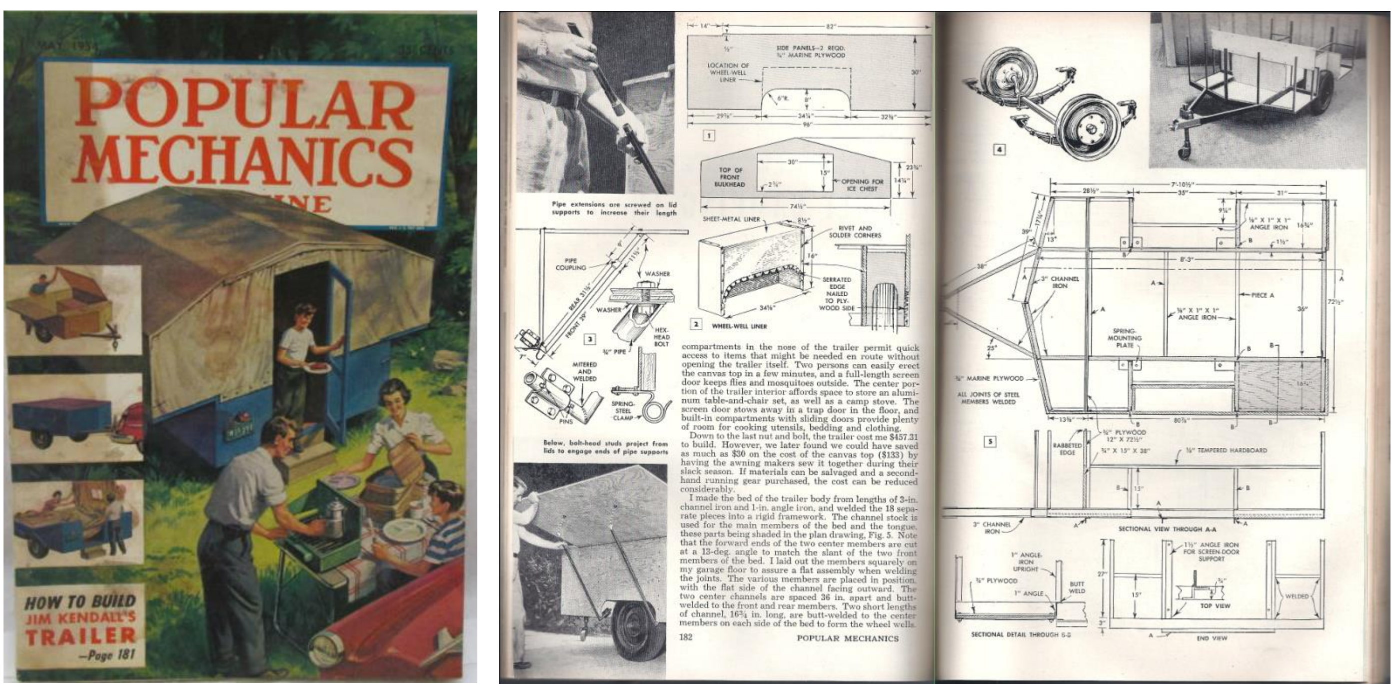

Fig 2.3 Popular Mechanics of May 1954, with detailed illustrated drawing to make DIY picnic trailer. (Source: Google images)

DIY promoted self-sufficiency on a functional and economic level. DIY also allowed people from a different range of backgrounds to live and build better homes with modernist design principles without employing expensive architectural advisors. DIY has encouraged self-preservation and self-expression, as an intrinsic part of the material culture of everyday life (Atkinson, 2006). DIY has formed the concept of an amateur craftsman, artist, designer, carpenter or musician based on interest. DIY handbooks and magazines for repairing, building and construction increased interest levels as a hobby and to improve the level of living. Magazines like Popular Mechanics opened up minds and gave technical knowledge and interest in technology and innovation. Second World War resulted in self-expression and rebellious attitude among the youth towards the society and politics. During the late twentieth century DIY subcultures generated self-produced and originated projects like DIY media and punk subculture. DIY media become the platform of self-expression in the formation of rock music (punk subculture), private radio among amateur hobbyist and DIY punk zines to express themselves. In the late 1980's, computer hobbyists formed communities to create, explore and exploit software systems, resulting in the Hacker culture (Kuznetsov & Paulos, 2010; Moran, 2010).

Today's DIY cultures reflect the anti-consumerism, rebelliousness, and creativity of earlier DIY initiatives, supporting the ideology that people can create rather than buy the things they want. The Third Wave or today's modern DIY draws upon the read/write functionality of the Internet, and digitally-driven design/ manufacture, to enable ordinary people to invent, design, make and sell goods (Fox, 2014; Kuznetsov & Paulos, 2010).

2.2.2 Modern DIY Cultures and Communities:

Modern DIY or New DIY started in the 21st century during the boom of Web 2.0. When the internet became available to everyone, people began interacting and collaborating with each other in social media as creators and contributors of user-generated online communities. Web 2.0 online communities became places for people to reaffirm their identity through creative expression by sharing knowledge and skills (Gardien et al., 2014). Advancement and innovation in technology resulted in the emergence of amateur professionals. Anyone from anywhere could document and showcase their DIY projects to the large audience. New technology and tools permit enthusiasts, hobbyists, amateurs and professionals to conceptualise, develop and collaborate their work online. This accessibility has enabled many communities to form around and transfer DIY information, attracting others who are curious, passionate or heavily involved in DIY work. Today thousands of DIY communists exists on almost every subject from arts to science; varying in size, organisation and project structures. DIY is revolutionary for both individuals and communities for innovation and for entrepreneurship (Kuznetsov & Paulos, 2010).

DIY has been a tool for hobbyists in early days, today it is used to innovate, create and develop tangibles and non- tangibles as innovation, entrepreneurship and contribution towards society and environment. Multiple cultures, movements and communities have been developed, depending upon the subject, cause or requirement of individual or a community, some are listed bellow;

- DIY crafts culture
- Maker culture
- DIY bio culture

2.2.2.1 DIY Craft Culture: Art and crafts (movement) are one of the earliest topics of DIY. In the start of 20th-century women used to do embroidery, stitching and decor for their homes with the help of DIY kits, stencils and step by step instructions given in the magazines like *Good Housekeeping* as a hobby, need, saving money or improving their lifestyles. Today arts and crafts is no more gender or age oriented, anybody at any age can start doing arts and crafts work as a hobby, need or for entrepreneurship. DIY craft can be practised based on self-knowledge and skill or outer resource knowledge (printed, online or workshop) (Fox, 2014). Outer source for knowledge depends on the interest and availability. People use to and still practise DIY based on instructions given in books and magazines or through stencils as printed resource. Online resources are one of the most common after the boom of the internet to gain knowledge because of endlessly availability of outer source knowledge. Free websites and videos tutorials, free or low cost online printable stencils and blueprints, and easy to practice or implement outer source knowledge can be transformed into a tangible DIY craft.

DIY crafts used to be described as artistic practices within the family for functional, utilitarian and decorative products through materials such as wood, clay, ceramics, glass, textiles, and metal. However, trends and needs have changed, and sources of information have increased from

20th to 21st century. DIY crafts are being practised as a hobby, need, entrepreneurship and also as solving environmental issues by making recycled and upcycled crafts.

As hobby or pastime is one of the oldest and most practised media of DIY craft. Old age citizens, adults, youngsters and even children can practise DIY craft as productive leisure. DIY craft has no age limit. Today there are unlimited DIY projects, ideas, stencils about hundreds of topics available in magazines like; *Craft Beautiful*, *Kids Craft* (Fig 2.4) and *DIY* magazine. Websites like *Pinterest*, *Instructables*, *doityourself.com*, *Crafster* and *Youtube* offer unlimited instructions, images, and videos on DIY crafts.

Fig 2.4 DIY craft magzines for adults *Crafts Beautiful* for adults and *Kids Craft* for childeren. (Source: Google images)

New DIY changed the trend, and it converted a hobby into business and entrepreneurship. New DIY encouraged hobbyists to learn, make, share, promote and sell their crafted goods through open platforms. DIY craft hobbyist can earn money by posting pictures and videos for promotion of their DIY craft goods on social media like *Facebook*, *Twitter*, and *Instagram* and open platforms and communities like *Etsy* for amateurs. Etsy is self-described as an "online marketplace for buying & selling all things handmade" striving to empower DIY enthusiasts financially. Projects are thus posted as catalogue items with images, descriptions, and prices (Kuznetsov & Paulos, 2010). Platforms like Etsy gave new hope to those who love to create a craft and can earn money through their hobby and passion towards crafted items. Fig 2.5 shows hand knitted woollen blanket made by DIY craft hobbyist and entrepreneur. For young learners who want to make it themselves, they can even buy and download patterns at *Etsy* or learn it for free from other open source websites like *Pinterest* and *Youtube*.

Fig 2.5 Handkniteed blanket by the DIY craft enterpernur for sale at Etsy.
(Source: Etsy.com)

DIY craft culture has a big contribution towards solving environmental problems in the form of recycled and upcycled goods. Upcycling is known as creative reuse materials and products by transforming products, waste materials, useless, or unwanted products into new materials or products for the betterment of the environment. There are numerous ideas and projects available online for free regarding recycling and upcycling old items into new and interesting products. These environmental friendly DIY crafts can used as functional, utilitarian and decorative products through different medium likes old textiles, paper, metals, wood and plastics (examples given in Fig 2.6). Websites like *Crafting Green World, Pinterest, Instructables* and *wikihow* can be sources of instruction and inspiration to create DIY crafts for both adults and children. These websites encourage people to practise DIY themselves and also to introduce small sustainable projects to educate and attract the interests of kids. Upcycled and recycled crafts can help to protect the environment while saving money and give sense of responsibility towards the environment and society.

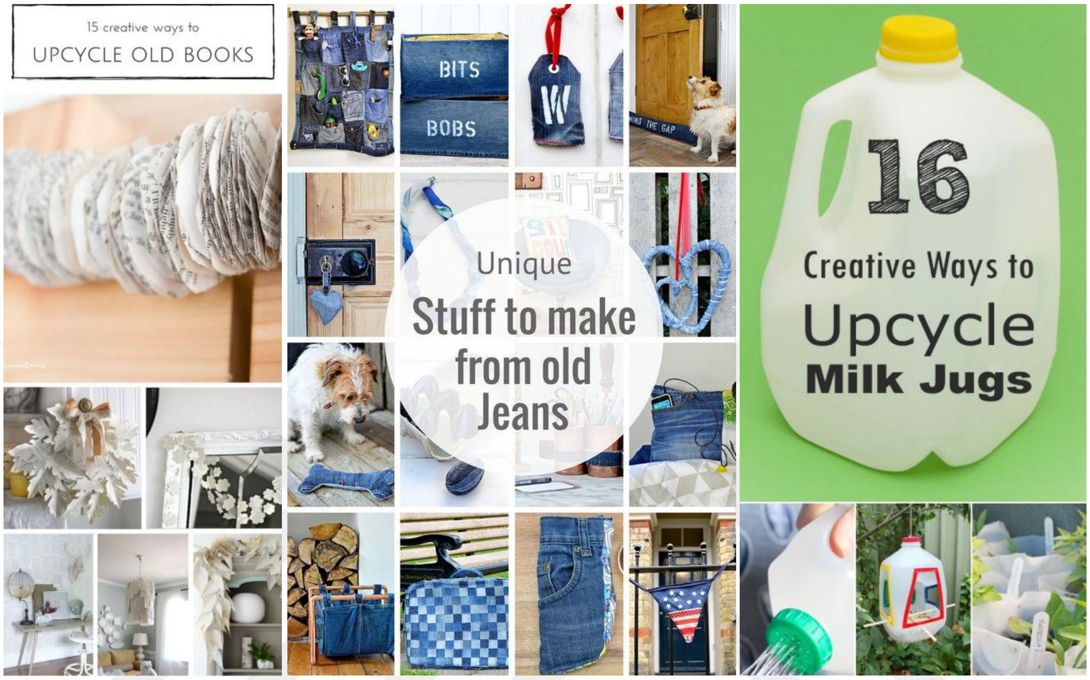

Fig 2.6 Pinterest upcycling examples of paper, textile and plastic.

(Source: Pinterest)

Social media have increased the interest of DIY craft among social communities and users. According to *Statista* the statistics portal, as of 2017 there are 2 billion active *Facebook* users from worldwide. Among 2 billion (Statista, 2017), 44 million are followers of *5-Minute Craft* (Facebook craft page). There are many other craft pages like *Nifty* which has 30 million followers within Facebook. In addition to Facebook; Instagram, Snapchat, Twitter and Pinterest are popular social media networks among internet users. Among the traditional and modern DIY craft tends, technology and interest has fused the craft traditions with modern technologies into a new movement knows as hyper craft (Van Abel, 2011). Hyper-craft have broadened the perspectives of DIY design and crafts. Hyper-craft is a practice of *maker culture*, where production methods include latest technologies like 3D printers and design patterns available for all, based on open design. Maker culture promotes new technologies for layman, amateurs and professionals as new concept of DIY craft, design, science and technology. Maker Culture is another perspective of New DIY cultures.

2.2.2.2 Maker Culture: Maker culture is the subculture and extended version of DIY. The maker cultural movement is a social movement which gave rise to amateurs with artisan spirit through digital fabrication. Maker culture or maker movement supports the concept of open design, where mean of production are based on latest technologies from open source hardware and software. Open design encourages layman, amateurs and designers to use open software create a 3D design on computers with the help of free platforms like *Thingiverse*. A DIY user can also develop the design or product and share it on *Priate Bay*. For the local digital manufacturing or open distribution services can proceed through *Shapeways* or directly sell it on *Etsy* like websites, where people start their small business too. (Van Abel, et al. 2011).

A user can learn, create or design products with the help of open communities like *Instructables*, *Shareable* to share or download designs openly, *hackerspaces* and *Fablabs* (digital fabrication laboratories) to print or produce design and to sell open platforms are available like *Etsy* and similar websites. Hackerspaces are community-operated physical places where people share their interests in tinkering with technology, work on projects, meet and learn from each other. Hackerspaces organisation is an informal volunteer network of such spaces, maintaining community services. Hackerspaces allow individuals with similar interests to share ideas, tools, and skill sets (hackerspaces, n.d). A Fablab is a technical prototyping platform for innovation and invention and encourages local entrepreneurs. Fablab is also a learning and innovation platform, a place to create, learn, help, to teach and to invent. Fablab connects a global community of learners, educators, technologists, researchers, makers and innovators. It is a knowledge sharing network that spans 30 countries and 24 time zones as of 2017 (Fig 2.7). Because all Fab Labs share common tools and processes, the program is building a global network, a distributed laboratory for research and invention (fabfoundation, n.d).

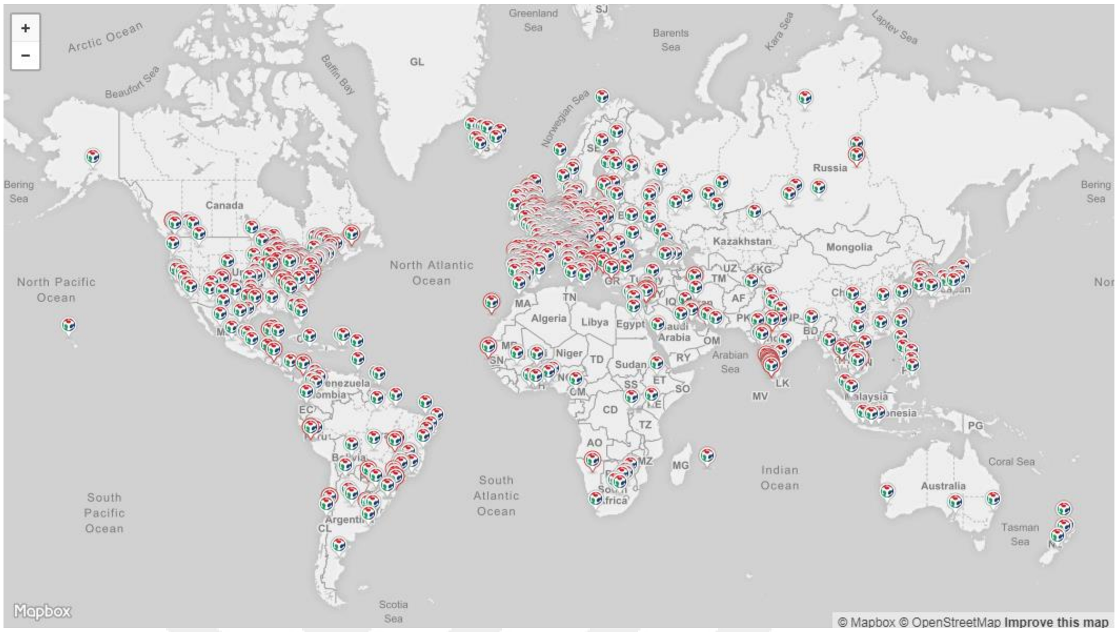

Fig 2.7 Map of the FabLabs located around the worldwide.

Source: (fabfoundation, n.d).

Makers act as interaction designers, crafters and engineers. It is about creating their important tangibles, sharing their projects and supporting each other in the web communities. Makers also design, program, construct and engineer technically enhanced artefacts. The Internet offers a vast amount of easily accessible resources and assistance, which in the offline world, would be much harder to access. It also opens opportunities for people with special interests, who may find no people with similar interests in their local area. DIY and maker projects showcased on the Internet are often very trendy, aesthetical, and stylish. Maker culture or DIY maker movement often appears as a lifestyle. Factors such as self-expression in mass culture seem to play a role in such cultures. The crafts activity is no longer dominated only by professionals, but many amateurs who share their ideas and works can be expressed as a doing and making culture. (Katterfeldt, et al., 2014)

Maker culture encourages active learning through technological advancements in the social environment by informal, formal, networked and shared learning. It encourages to explore novel applications of technologies and intersection of technology within traditional domains like woodworking, knitting, music making, or computer programming. Communities interact and share and exchange ideas through social media tools, websites and technological networks. These communities can develop, produce or re-produce designs through shared spaces, Fablabs or at personal spaces through affordable and easy to use technological tools like Maker Bot's Cupcake CNC kit. Maker culture promotes and opens up opportunities to contribute and create new pathways to learn and share knowledge on relevant topics (Niemeyer & Gerber, 2015).

The digital and technical revolution after web 2.0, Wired and Make magazines (Fig2.8) and Make, Instructables, and Thingsiverse websites became popular among DIYers interested in digital DIY. Digital artefacts or 3D models require basic programming skills and while handicraft skills is becoming less important to create artefacts.

Fig 2.8 Maker culture DIY magazines *Wired* and *Make:*

(Source: Google images)

As maker culture becomes more popular, hackerspaces like Fablabs are becoming more common in universities and public spaces. Many countries have started the fully open makerspaces for public among the agencies like Fablabs (Nascimento, & Pólvora, 2016). The rise of maker culture has increased the number of hackerspaces, Fablabs, Techshops and other common maker spaces. In Europe the popularity of the Fablabs is more prominent than in the US: about three times more labs exist there. Hackerspaces like TechShop and Fablabs provides all kind of technical facilities and knowledge depending on interest of individuals and common users (fabfoundation, n.d).

In today's society, knowledge and skills about digital media are essential. Furthermore, environmental aspects are considered to be more important. Therefore, the usage and re-usage of recyclable materials should be considered. Based on the new relationship between design and production, a new DIY culture of digital innovation has arisen. Active members of the maker movement and open design cooperate in open community labs, incorporating elements of machine shops, workshops and studios; where activists come together to share resources and knowledge to build and make things. Inexpensive rapid manufacturing technologies in open local communities like Fablabs are enabling to print out new 3D products. (Katterfeldt et al., 2014). High tech devices are becoming graspable to commoners (non-professionals). Many of the commoners like to download some prefabricated designs from *Thingiverse* (website) and just print it out. DIY culture in the creative environment of Fablabs experiments with new forms of design and manufacturing on a personal level.

Digital fabrication started by the advent of 3D printing for prototypes and mock-ups of architecture, design and medicine declining cost. Broad adoption has opened up a new sphere of innovation. The cost has become effective by the technological advancement in rapid prototyping, and this approach is depicted as a personal fabrication for personal items. Typical interests of maker communities are mostly engineering based tools such as computer numeric control (CNC) machines, 3D printing, laser cutting, robotics and electronics. They also support traditional craftsmanship like metalwork, woodwork and textiles (Chalifoux, 2016). The maker culture supports the concept of copy, paste (and edit depending on the interest), print or produce approach of open design to standardised technologies and encourages re-use of downloadable designs published on websites and maker-oriented publications (Macmillan, 2012) like *Thingiverse*, *Sharable* and *Instructables* (Fig2.9). These communities focus on using and learning practical skills and applying them to reference designs available online. Professionals (designers, engineers, etc.) are being encouraged to document their designs (blueprints) on open platforms which can be freely distributed, approachable and modified or copied by enthusiastic users, designers or amateurs. Maker movement became an influential trend in the world which allowed for designing or creating, sharing and innovation together. Through maker movement and open design audiences like design professionals, students, critics and amateur enthusiasts can contribute to the development of open DIY practice. Movement opens up possibilities to young design professionals and amateurs to flourish and contribute easily. Open design works on creative common (CC) license, in which the intellectual property belongs to the creator and gives freedom to creative people to deploy copyright flexibly. It allows and eases designer to share their work or designs without the fear of copyright issues. The main agenda of open design is the transparency in design and its responsibility whether it is about the production of a chair or political agenda of service design related to the government (Van Abel et al. 2011). Through open design, designing becomes friendly, innovative and playful as it is not about just designing a product but giving s whole new DIY maker culture experience.

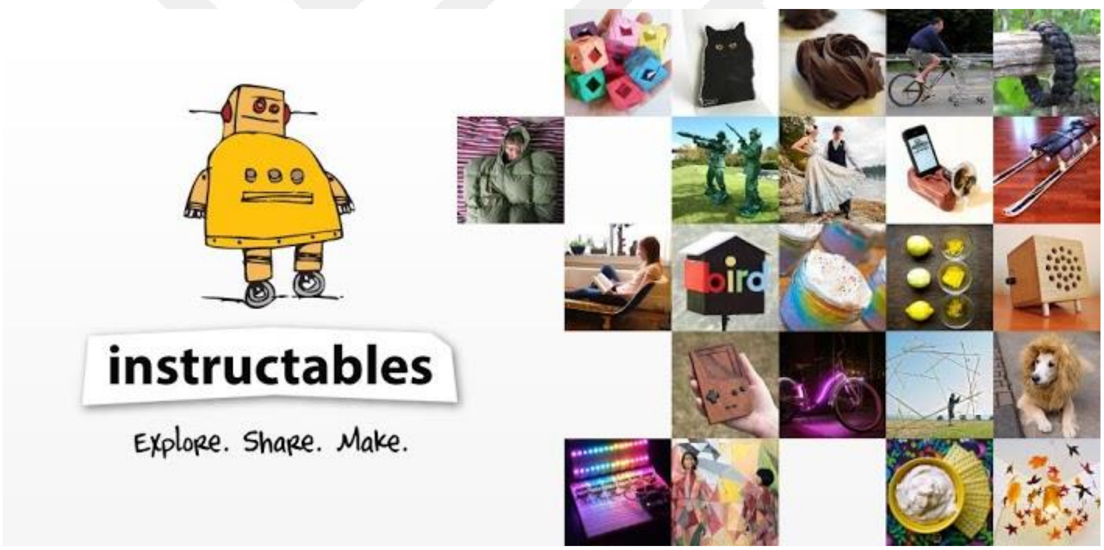

Fig 2.9 Instructables is all about to exploring, sharing and making in DIY maker culture. (Source: www.instructables.com)

Science and technology (engineering and robotics), design (hyper crafts, products, textiles) and architecture works are being practised and promoted in open design and maker culture. Websites like *Shapways* and *Ponoko* (Fig2.10) encourage to buy or upload, edit or design, print and sell or use personalized products through the same website instead of going to the hackspaces like *Fablabs* and *Techsops*. CAD files available to edit designs or upload files for amateurs, hobbyists and interested users to enjoy ethical and sustainable products with zero waste production. Books, Magazines (*Make* and *Wired*), Websites (*Instructables*, *Thingsivers* and *Make*) and social media encourage and develop interest among people (laymen, amateurs and professionals) to learn, create, participate and produce within maker communities.

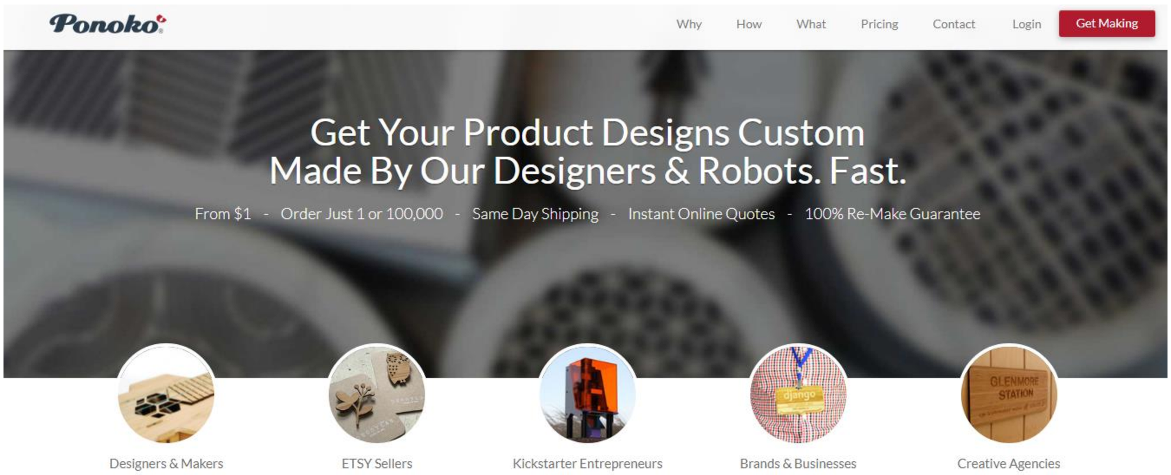

Fig 2.10 Screen shot of the main webpage Ponoko.

(Source: Ponko.com)

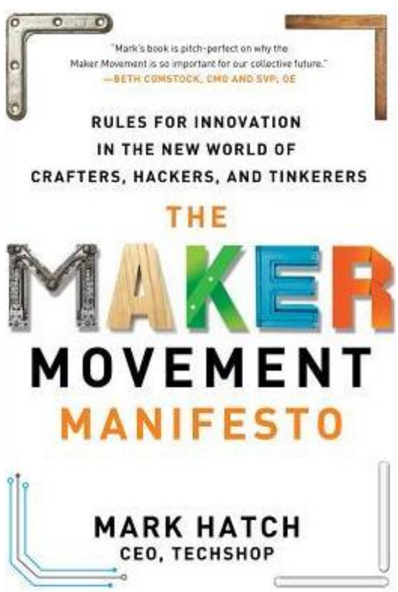

Fig 2.11 Book cover of The Maker Movement Manifesto by Mark Hatch.

(Source: www.books.google.com)

DIY maker culture and open design's interesting feature is that through the open platform a single person can start a one-person show from design, production to entrepreneurship or it be a group of people from around the world can create joint venture. Professional designers have adopted and promoted commercially who supports the concept of transparency in design and do not have copyright fears or issues towards their concept. Ronen Kadushin's Hack Chair (Fig 2.12 and Fig 2.13) is one the earliest and famous example of open design adaptation in the furniture industry. His chair is designed and produced by lasering cut from a single metal sheet. He publishes his design in the form of CAD file on the Internet so anybody can download the file, edit it as desired produce it from anywhere around the world. His concept was DIY open design for everyone, and that was the reason he named it Hack which means that it can be copied or hacked by an average person. In that way young designer, amateurs, non-professionals get an opportunity to see professional work, edit it, re-design it and share it (Troxler, 2011).

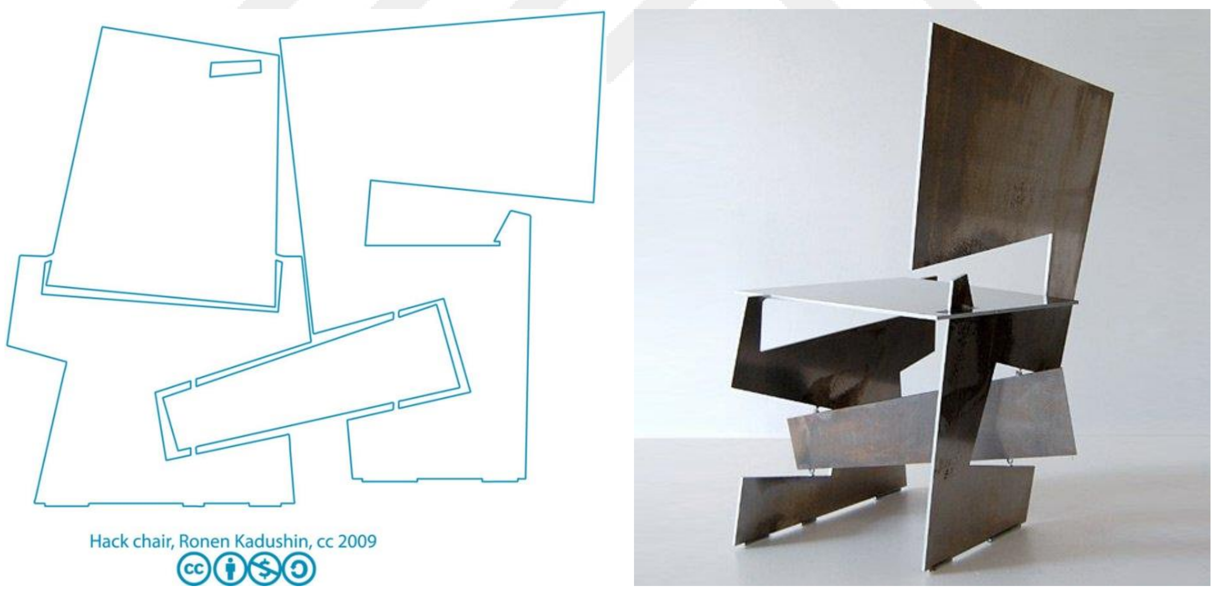

Fig 2.12 Hack chair; open and free template (left) and hack folded one piece metal chair (right).
(Source: Dezeen/ hackchack-chair-by-ronen-kadushin)

Fig 2.14 Hack chair; instructed steps to fold chair from single metal sheet.
(Source: Dezeen/ hackchack-chair-by-ronen-kadushin)

Digital manufacturing and open platforms with open and shared designs gave a whole new perspective to the design field, primarily to product design where people can produce almost anything with the help of 3D printers. Professionals, amateurs and people with no design background can also design, create or innovate, produce, and promote it on platforms. Maker culture based on open design; where designing, production and even distribution made it open and transparent. Maker culture made things accessible to those who did not even imagine it before that their work can be produced cheaply and distribute efficiently. It opened the close gates for those who could not afford copyrights and patent and wanted to produce their work affordably.

2.2.2.3 DIY Bio Culture:

DIY biology or DIY bio is a growing biotechnological social movement and culture. Individuals, communities, and small organisations study, work and innovative methods in biology. DIY bio is practised by professionals, amateurs and enthusiastic hobbyists. Professional individuals usually have extensive proper academic research knowledge and training from corporations, to mentor and guide other amateurs and hobbyists with no prior formal training. It allows large numbers of small organisations and individuals to participate in research and development, by spreading knowledge to a higher priority than making profit. DIY bio gave rise to technical innovations, and sharing mechanisms encouraged hobbyists to learn, innovate and experiment with organic materials. DIY bio expanded science practice beyond professional level into hackerspaces, art studios and homes (Kuznetsov et al., 2012).

Human-computer interaction (HCI) development in technology and research started a new range of opportunities and concerns in science and biology. The increment in HCI research explored inhabitant science methods and applications to enable general public members to collect, analyse and work on scientific data efficiently. Health support, personal care and food production made innovative DIY tools and low-cost technologies support emerging science by non-experts (Kuznetsov et al., 2012).

DIY bio is involved with various open source developments in biomedical, bioengineering, material development and food technology within the fields and subfields of biology. Open bio organisations such as OpenWetWare, Registry of Standard Biological Parts and International Genetically Engineered Machine competition, they have enabled broader access of scientific information and materials in synthetic biology (Kuznetsov et al., 2012). OpenWetWare is an organisation with a wiki-style collection of data protocol, which promotes sharing of information, knowledge and insight amongst individual researchers and communities who are working in biology and biological fields. It also fights to prevent and patent the living matters, such as DNA (De Mul, 2011).

DIY bio inspired by the concept of openness and transparency of open design and applied it to biology. DIY bio started open and affordable laboratories with fully equipped tools for hobbyists, amateurs and professionals. Genespace, Indie Biotech and Manchester DIYbio are some of the prominent DIY bio-labs for professionals, amateurs and public (Kuznetsov et.al, 2012). Open source platforms have opened up possibilities for DIY bio groups and DIY bio-labs (hackerspaces) where scientists, engineers and doctors can also access research, perform and produce their projects on an open scale (Kennedy, 2011).

DIY bio culture ranges different topics and projects carried by the scientists, engineers, biologists, and doctors and from other fields interested hobbyist citizens. Topics like biosensors, genetic modification of organisms, artificial limbs development, organic food development and experiments with foods and organisms to create material development. Artists and designers have started to incorporate science, technology and organic materials into various projects to discover the relationship between biotechnology and humans (Kuznetsov et al., 2012). Some of the prominent works include bio artist Adam Zaretsky's work with transgenic organisms about cutting and pasting genes from one organism into another (Ramsak, 2016), Anna Dumitriu's (Fig 2.14) infective textiles with DIY microbiological processes by exploring the notion of infection control (Braun, 2016). Suzzan Lee of Biocouture's (Fig 2.15) DIY microbial leather (Chua, 2015) and the Critical Art Ensemble's performative genetic experiments about genetically modified food in the global food trade (critical art, 2004).

Fig 2.14 Anna Dumitriu's infective textiles

Source: (Braun, 2016)

Fig 2.15 Suzanne Lee's open DIY microbial leather recipe and process
(Source; Chua, 2015)

DIY bio culture is a forum supported and initiated by diybio.org (Fig2.16), where people can learn, meet, teach and publish with openness and safety. There are almost 2000 members from enthusiastic hobbyists, scientists, amateur biologists to professional biological engineers and scientists. DIY bio organisation is dedicated to making biology accessible and shareable for all. It is an open bio forum to discuss issues from the practical (project related queries) to philosophical questions like ethical issues related to materials harming nature. DIY bio cultural forums like biohacking and garage biology practices are similar to some of the previously studied DIY communities such as craft culture or electronics group (part of maker culture). These forums are based on hacking, tinkering, playing, and reconfiguring with materials and systems. Materials worked with living- organisms, bio-electronic configurations and even parts of the human body are introduced to lead toward new challenges and opportunities for HCI research. These include novel techniques for ‘crowdsourcing’ biological experiments and visualising data, bio-electronic configurations for working with organic materials, and design explorations to discuss the surrounding bioethical issues (Kuznetsov et al., 2012). Motivation, innovation and technological advancement have developed open source hardware with microcontrollers like RepRap and Maker Bot 3D printers, Arduino and low-cost DIY scientific instruments like Open PCR (polymer chain reaction) and Thermocycler Machine (Kuznetsov et al., 2012; Pearce, 2012)

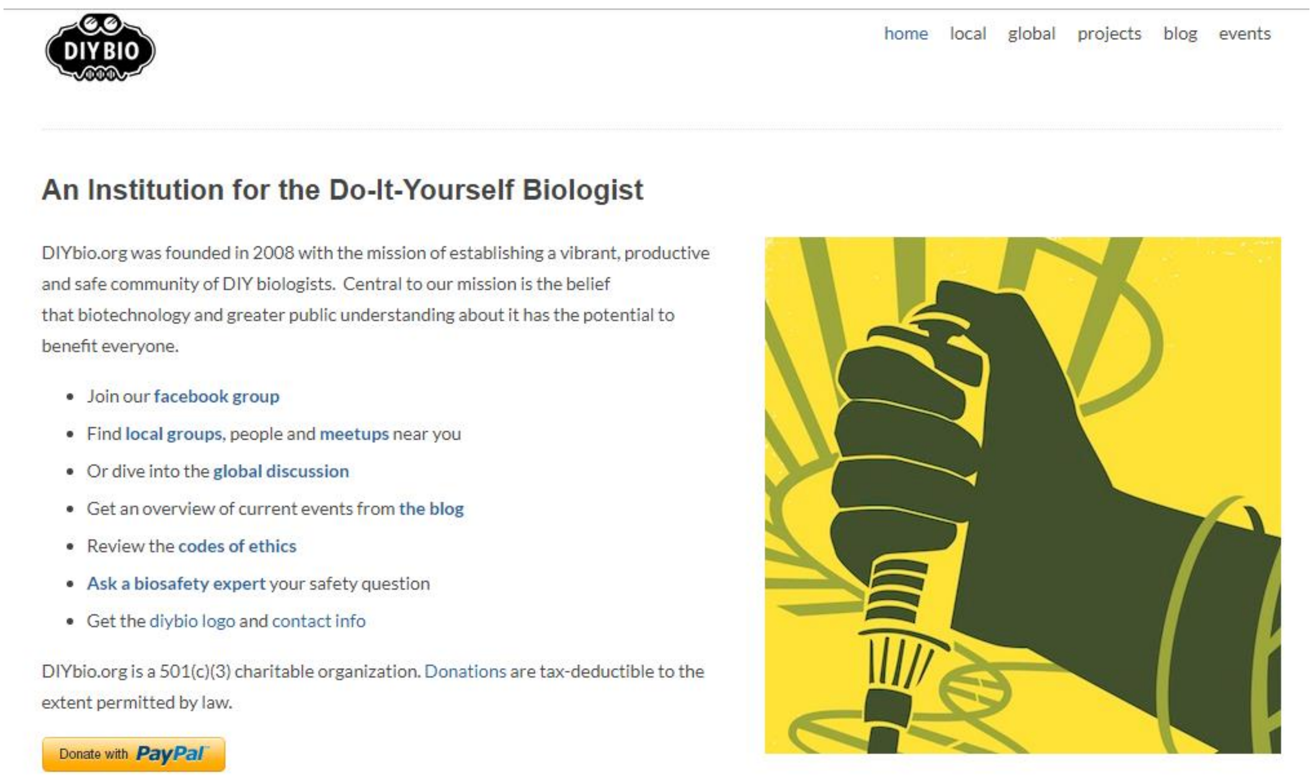

Fig 2.16 DIY bio organisation web page.

(Source: DIYbio.org)

3D printing technology and innovation also made it easy to develop a complicated design and fast production in the food industry, which has created a whole new trend in the food world. (Pettis, 2011) The 3D printer can print food and it can customise designs, shape colour and taste according to the specific needs. Now there is even an open platform which can be accessed by chefs and culinary artists can to create food through digital fabrication in the food world. Bocusini is an open source German digital food fabrication company which provides open source design and services related to 3D food printers, but they also have easy to use DIY printers in which being a professional is not necessary. Bocusini's example (Fig 2.17) shows the innovation and DIY culture implemented in the food the industry. (Team Bocusini, n.d.)

Fig 2.16 Bocusini's DIY food printer.
(Source; kickstarter.com)

DIY bio encouraged and gained the interest and use of science and biology by artists and designers. From DIY bio, DIY materials have emerged in which designers have started developing materials independently or with collaboration of biologists. Suzanne Lee and Anna Dumitriu are one of the designers who have worked with microorganisms to develop DIY materials. DIY material is another subculture of DIY and fusion of other DIY subcultures which includes craft, science and maker properties. DIY materials are separately discussed in the next chapter.

CHAPTER 3
DIY MATERIALS

3.1 DIY Materials

The material has been the primary summit of practice and research issues in design. Materials research has constantly developed new and alternatives materials to replace other environmentally harmful materials (like many polymers). Usually innovative materials are developed by engineers and scientists in laboratories and mass-produced for the industry. The design community has taken a new challenge and developed possible solutions to reduce non-sustainable products and materials. In the last decade, new phenomena have emerged where designers have started taking an interest in the development and design of new materials. Materials which are developed and created based on individual or collective self-production practice are often processes and techniques of the designer's own creativity and invention. The phenomenon of self-produced materials is known as do-it-yourself (DIY) Materials. DIY materials can be new or modified materials. These materials can be a source of richness concerning perception and aesthetics in design (Rognoli et al., 2015; Ayala and Rangnoli, 2017).

3.2 Emergence of DIY material

The DIY material phenomenon comes under the new wave of DIY culture. DIY is largely based on digitally driven design /manufacture to enable common people and amateurs to make, invent, design and sell their goods through online platforms (Fox, 2014). However, advances in mass production technologies helped the emergence of new approaches to the relationship between designers and new technologies, production processes and materials. This novel approach is the fusion of the DIY culture based on making, crafting, and personal fabrication (Kuznetsov, & Paulos, 2010). DIY material highlights the craftsmanship of design and self-production trough combination of advanced and digital manufacturing technologies like 3D printing. Mass customisation and personalisation has grown among the society which resulted in companies and industries to provide and satisfy the emerging demand of users through unique products with novel materials. Customized product users have shown interest in the design process and production. The new DIY culture revaluated the crafts culture and opened up the opportunity for self-production supported by democratic technological practices. These technical practices are based regarding common production labs (like Fablabs), low cost and accessible fabrication tools (available at hackerspaces and open printable services like Shapeways), and open and shared knowledge about production processes (like Instructables). Abundant information is available on the internet about materials and manufacturing processes. For example, material libraries diffuse news of maker-labs for prototyping and experimentations. Fablab Amsterdam, Design for Craft and, DIYBio Labs are some of the prominent examples which enable citizens to participate and form open source science. This way, scientific data related to physics, chemistry, biology, and medicine are available for scientists, professionals and amateurs interested in DIY materials and self-production (Rognoli et al., 2015).

Open platforms like Instructables give guidelines for creating useful tools to facilitate the self-production of PLA filament for 3D printing. Crowdfunding are platforms funded by alternative sources which revert to open calls to the public (generally via the Internet). These open platforms resulted in public interests in materials like the case of a project named Polymakr. Polymakr is a hackerspace to learn and share knowledge about 3D printing materials. It is also possible to find DIY material recipes on the internet about how to prepare natural-based materials. The creation of repositories of self-produced material is the first explicit evidence of this process. Open Materials is a website sharing information over 100 materials are available and accessible knowledge. A research group is dedicated to open investigation and experimentation with DIY production methods. The wiki platform called Material WikiProject is also a material platform which provides an opportunity for design professionals and students to share their material research and find collaboration opportunities through Fablabs, DIY Labs or personal labs.

DIY labs can be accompanied by blogs and websites which can be imagined as future spaces, by enabling new forms of open and self-created materials. DIY practices encouraged and led the common users and designers to develop new materials for the sake of customisation, innovation and solution to face mounting environmental problems. DIY material practise is also popular because of the desire for unique material expression and as a reaction towards mass production. Self-produced materials provide an opportunity for reconsidering features of some of the disadvantages of existing industrialised materials and manufacturing processes (Rognoli et al., 2015).

3.3 DIY Material Development

DIY materials can be an alternative to costly materials science development procedres. DIY material development by designers is unlike scientific approach is more a primary thought and exploration process. DIY materials are developed based on personal or collaborative self-production practice. Usually, techniques and procedures are designer's self-invention. DIY materials can be a totally new material or developed versions of existing materials. DIY materials can be designed through the creative use of substances as material ingredients, like material made from dried fruit peels, blended and fused with natural binders (Fig3.1) (Rognoli et al., 2015).

Fig 3.1 Apeel by Alkesh Parmar
(Source: www.apeelmaterials.com)

New identities for conventional materials can be focused on new production techniques, which can give rise to new identities for existing materials for example recycled materials like plastics and metals (Fig3.2). The development new DIY identity trend in the sphere of materials and design has enabled personal and self fabrication technologies, because of a growing desire among individuals to have personalised products. DIY materials propose immense opportunities to positively contribute to design through material experimentation, distribution and shared or collective production process. Designers' knowledge of materials and production dimensions enables them to develop new materials or create a process to change the value of the material or by modifying the tools that perform simple production operations (Rognoli et al., 2015).

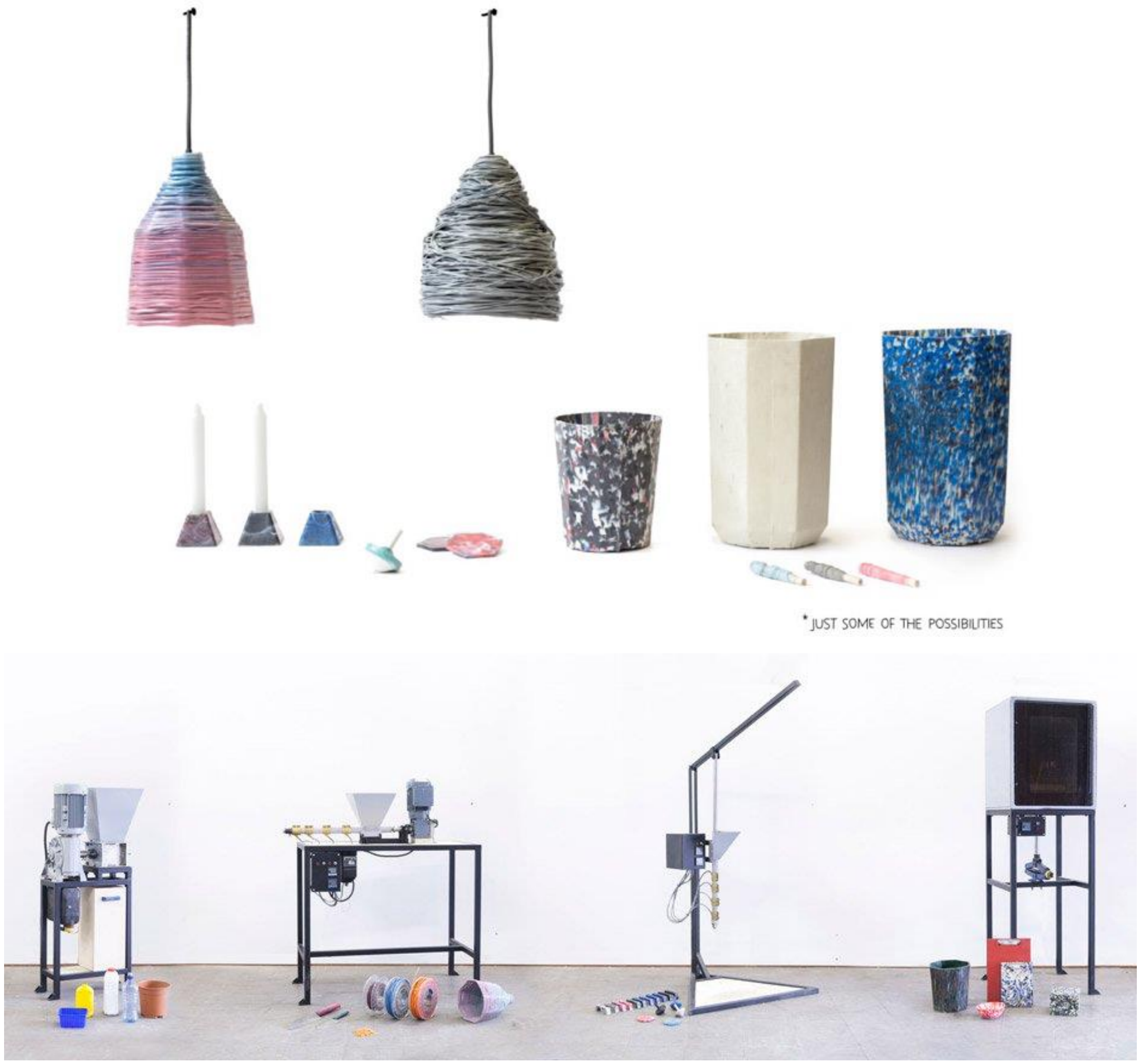

Fig 3.2 Precious plastic by Dave Hakkens

Source: www.preciousplastic.com

Designers try to outline the meaning and identify the sample material by characterising them through an expressive sensorial point of view (Rognoli, 2010) and defining the outlines of the experimental qualities (Karana et al., 2015). DIY-Materials usually derive from the transformation of unconventional sources (e.g., material derived from vegetables, animals, minerals and modified). DIY materials respond to a critical purpose (like tackle a wicked problem, make a particular statement or go beyond the mass customised solutions), through inspirational and innovative solutions concerning a novel material (Rognoli et al., 2015).

The source of DIY material is an essential element for establishing a "new class" in the DIY materials culture. Recent studies suggest an original categorisation of DIY materials based on different kingdoms like to their primary unconventional sources (Ayala et al., 2017).

3. 4 DIY Material Kingdoms

DIY material practices are characterised by the renaissance of craftsmanship (Bardzel et al. 2012). They are empowered by democratic technologies and practices of combining, making, and crafting (Kuznetsove and Paulos, 2010). DIY practices shaping on knowing action relying on experimental knowledge obtained through making materials. The outcome of this process is often a self-produced material by thinking about the material at hand (Nimkulrat, 2012).Thus the process of making materials by hand can be identified as a way of thinking intellectually (Sennet, 2008 pp. 149-153). In other words in DIY practice is a dynamic learning process of understanding through experience with materials (Karana et al., 2015). According to Ashby and Johnson (2002) classification is the first step for bringing order to any scientific achievement. The founders of biology, zoology and geology were those who created the classification systems. Classification segregates an initially disordered population into groups that in some way have significant similarities (Ayala, et al 2017).

DIY materials are analysed in different kingdoms based on the source of the material. Similar groups of similar items were classified into one kingdom. DIY material kingdoms are classified under the inspiration by the first biological classification done by the Swedish botanist, zoologist and physician Carolus Linnaeus. He named this classification as Systema Naturae (Linnaeus, 1758). Linnaeus published biological classification of the earth now known as Linnaean taxonomy (Fig 3.3). He divided the earth based on a hierarchical classification of the natural world divided into three main kingdoms namely; plant, animal and minerals (lapideum) (Ayala, et al 2017).

Fig 3.3 Linenean Taxonomy to DIY Material Taxonomy (DIY-M Kingdoms)
Source: Five kingdoms of DIY Materials for design (Ayala, et al 2017).

The DIY material kingdom was inspired by the Linneaen taxonomy, dividing the materials into five kingdoms based on the analysis of 150 DIY material cases. Animale, Vegetabile, Mutantis, Recuperavit and Lapideum are kingdoms of DIY material taxonomy (Ayala, et al 2017).

Fig 3.4 Graphical representation of five kingdoms of DIY Materials for Design
Source: (Ayala, et al 2017).

3.4.1 Kingdom Vegetabile: When the primary source for DIY Material is derived from plants and fungi, it is categorised under the material under the kingdom Vegetabile. Traceability of the origin is possible by observing and recognising traces of the main constituents (like plant leafs, fibres, fruit skins and so on). Materials under this kingdom differ from other materials; substantially because of their primary source derived by growing or farming techniques. Designers who develop or create materials under this category might have to collaborate with farmers or biologists. A prominent characteristics of DIY-Materials (Fig 3.5) belonging to the Kingdom Vegetabile is the imperfection of the surfaces and possible macro textures, concerning the touch and sight perception. These materials display uneven and rough features in the object made from that particular material (Ayala, et al 2017; Ayala & Rognoli, 2017).

Fig 3.5 Examples of products made from DIY materials from the Kingdom Vegetabile; Harvest by Asif Khan (left) and Artichair by Kizis Studio (right)
(Source: www.asif-khan.com/project/harvest and www. kizisstudio.com/artichairs)

3.4.2Kingdom Animale: DIY-Materials that belong to the Kingdom Animale refer to all material sources derived from animals and bacteria. DIY materials in this kingdom can be developed by collaborating with living organisms or by using a particular part or parts of the animal like skin, bone or hair (Like Hair Highway by Studio Swine in Fig 3.6). Noticeable attributes include rough and uneven surfaces with high malleability and flexibility. Animal skin, fur, horns and shells (Like Coleoptera by Agje Hoekstra in Fig 3.6) have been used as the primary material for products by several civilisations. They used to represent particular status or the achievement of a specific goal. It is probable that materials from this category still inherit such cultural insight (Ayala, et al 2017; Ayala & Rognoli, 2017).

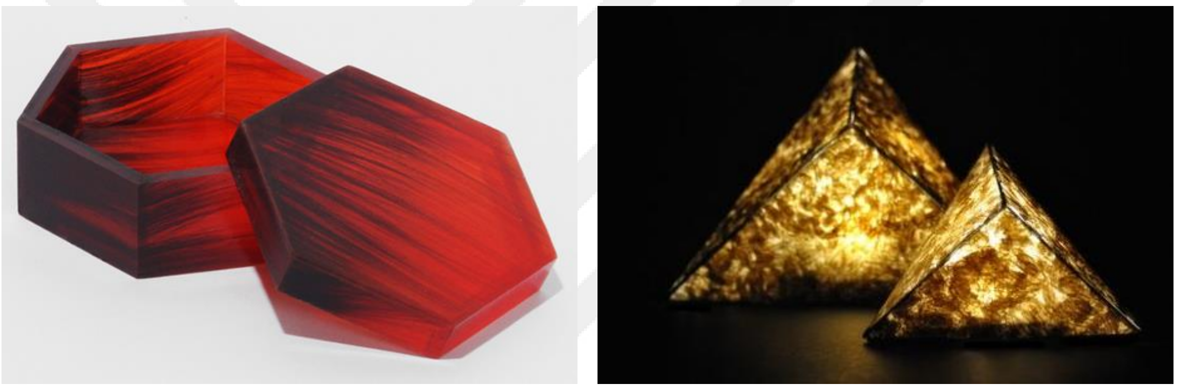

Fig 3.6 Examples of products based on materials from the Kingdom Animale; Hair Highway (made out of human hair) by Studio Swine (left) and Coleoptera (made out of beetle sheels) by Agje Hoekstra (right).

(Source: -www.studioswine.com/work/hair-highway and-www.aagjehoekstra.nl/coleoptera)

3.4.3 Kingdom Lapideum: It contains all DIY materials which come from minerals; stones, sand, ceramics, clay etc. Some current cases combine sources from the other kingdoms such as wool or cotton fabrics, but in a lower percentage as compared with the first material. Kingdom Lapideum and previous two kingdoms show the natural appearance of their main ingredients and sources. However in this kingdom, irregularities in shape of surface texture diminish because of presence of corrosion (due to use of machinery), stains and random coloured surfaces from materials (Fig 3.7). Materials in this category need the use of machinery and instruments, even if they are simple modification. This kingdom has an active link to crafts probably because these types of materials have a long tradition in our material culture (Ayala, et al 2017; Ayala & Rognoli, 2017).

Fig 3.7 Examples of products based on materials from the Kingdom Lapideum: Colour casting concrete by Ungyon Iwarhura (left) and Improvisation machine by Annika Frye (right). (Source: www.localdesign.com.au/colour-casting-concrete and www.annikafrye.de)

3.4.4 Kingdom Recuperavit: It comprises all sources that modern society considers as waste. Most waste can be transformed into a valuable resource. They often come from plastic, metal or organic waste, sometimes as side products of industrial production. It is at the moment the most prominent kingdom by the number of cases observed. Inside this kingdom the designer's intention towards a more ethical, conscious, and sustainable future is evident. Different recycled sources like industrial excess, pieces of plastic, dust and leftovers of food are being investigated and used by designers. These DIY materials usually carry their aesthetical qualities of the original state of their sources. For example, plastic particles exhibit their vivid colour of smooth surfaces in (Fig 3.8) and coffee grains maintain their original colour and texture (3.9) The fusion creates a fascinating appearance and gives a possible new scenario of use for such materials (Ayala, et al 2017; Ayala& Rognoli, 2017).

Fig 3.8 Polyfloss by Polyfloss Factory
(Source: www.thepolyflossfactory.com)

Fig 3.9 Decafe by Raul Lauri
(Source: www.raullauri.com)

3.4.5 Kingdom Mutantis: DIY materials from this kingdom are created from different technological mixtures of smart, interactive and industrial sources. They are the combination of different material sources, which may be from different kingdoms but evolve in particular process with the help of any technology. According to biology, mutations play a role in both standard and abnormal biological processes of life including evolution. Mutantis refers to all cases where transformation occurs with the aid of technology (Fig 3.10). This transformation represents a significant change in the material's nature and behaviour in comparison to another kingdom. Some of these materials are smart, and their body or surface respond to particular stimuli or invite a specific kind of interaction. Futuristic, artificiality and modernity look of this kingdom materials gained popularity among DIY materials. High reflective surfaces, luminescent parts and translucent components are similar to smart materials developed by the professional scientists and engineers. This Kingdom differs from the previous four because of production these materials depends on adavanced machines technologies. Mutantis can be associated to engineered materials of the science domain (Ayala, et al 2017; Ayala & Rognoli, 2017).

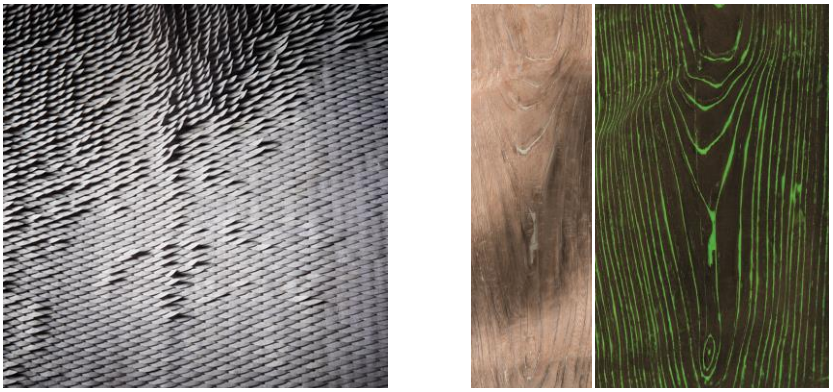

Fig 3.10 Examples material samples from the Kingdom Mutantis: Transformation Paper by Florian Hundt (left) and Interactive Wood by Johhanes Wohrlin (right).
(Source of both pictures is from: www. material.nl)

The DIY kingdoms are helpful to understand what kind of source a designer or amateur may use as a starting point for material development. It has been observed by the developers of DIY kingdom that designers who prefer a self-production process for development of their material usually select elements from the world of plants, animals or minerals. It has also been discovered that many designers use waste, in particular scraps from industrial processes as raw sources. Obtaining DIY materials from a wide variety of sources is possible. It should be emphasized that although five kingdoms of DIY materials have been presented, many cases fall into two or more different kingdoms (Fig3.11). Borders between kingdoms are not strict but loose (Ayala, et al 2017; Ayala & Rognoli, 2017). For many DIY projects, the material kingdom may not be as long as the desired product features are attained. However, knowledge of the type of the material can be helpful in estimating possibilities of use and sensorial qualities. Furthermore, issues such as compatibility of multiple materials or reinforcing one material with other, one may be based on the simple classification as practical guide.

Fig 3.11 some cases can fall under two or more categories
Source: (Ayala, et al 2017).

3. 5 DIY Case Studies based on DIY Kingdoms

3.5.1 Autarchy
(Kingdom Vegetabile)

Autarchy is a project by Netherland based the Studio Formafantasma. Autarchy was presented in the form of installations for Milan design week 2010 by the Dutch-based Italian designers Andrea Trimarchi and Simone Farresin. "Autarchy' the vessels are displaced in the form installation to encourage and acknowledgement to simple, easy and uncomplicated, average life. The hidden message behind the installation is the unusual and unearthly way of producing products and goods. It gives a speculative sketch, where society adopts a serene, where nature makes to cultivate, harvest and process to feed and develop goods to serve human needs and necessities (Chin, 2010).

Fig 3.12 Autarchy by studio Formafantasma

(Source: www. formafantasma.com)

Organic, natural and sustainable design connects craftwork and the industry. The collection of these earthy vessels combines low-impact materials with old traditional techniques to create functional and durable objects. The designers presented the project as a manifesto about a possible way to develop products with zero waste production. Autarchy suggests that it is possible to create objects with the aid of inherited knowledge from other disciplines. It will ease and help the designer to develop sustainable and uncomplicated solutions. Autarchy collaborated with Italian broom maker Giuseppe Brunello and the renowned French bakery Poilâne to join in the development of the installation. With the assistance baker, Formafantasma developed vessels with DIY natural material composed of flour, agricultural excess and natural limestone. Natural dyes were selected to give a colour palette for different samples (Ayala, et al 2017; Chin, 2010).

Fig 3.13 Autarchy basic biomaterial ingredients; lime stone, agricultural waste and flour.
(Source: www. formafantasma.com)

Autarchy Vessels are handmade containers created using only natural materials and plant-based dyes that are cooked at low temperature. Biomaterial consists of 70% flour, 20% agricultural waste and 10% limestone. Food was the source behind gorgeous the palette of containers; they were obtained from natural dyes derived from coffee, cinnamon, paprika, beetroot and spinach (Chin, 2010).

Fig 3.14 Autarchy's natural colorants; coffee, cinnamon, paprika, beetroot and spinach.
(Source: www. formafantasma.com)

A surface like a pie achieved from another baking necessity; eggs were used to add some shine and coating to the containers' surface. Crafty yet durable, the vessels have a natural waterproof coating that plays with the designers' Italian roots (Chin, 2010).

Fig 3.15 Autarchy's baking technique experiments with egg wash coating.
(Source: www. formafantasma.com)

The cereal sorghum was used to work as a link between these crafts – the vessels and brooms. The production process was without waste, by harvesting cereal and using it to create tools, vessels and food.

Fig 3.16 Sorghum cereal details used in vessels and brooms designed by Giuseppe Brunello
(Source: www. formafantasma.com)

Autarchy is an open source where knowledge is being shared through the installation. It displays the different steps of research, explaining the material and its production. The furniture used in the installation is to display the products, which were used for the manufacturing and drying processes products by featuring a drying oven and mill (Chin, 2010).

Fig 3.17 Autarchy's installation displaying vessels and brooms with tools and materials.
(Source: www. formafantasma.com)

Autarchy is an example of showing and embracing an alternative way of producing goods with the use of inherited knowledge from artisans and their traditional DIY techniques from the Renaissance times to find sustainable and uncomplicated solutions (Chin, 2010).

3.5.2 From Insects
(Kingdom Animale)

Fig 3.18 From Insects by designer Marlène Huissoud - www. marlene-huissoud.com
(Source: www. marlene-huissoud.com)

From Insects by designer Marlène Huissoud showed the potential of insects as an innovative future material ingredient. With a beekeepers family background, she is interested in utilising insects and their waste streams to create future craft artefacts. She primarily used insects as co-partners in the design process, -instead of consuming insects directly; she showed interest to work with them directly and explored their natural waste streams into the production of valuable craft artefacts. She worked with two insects from her farm; honeybees and Indian silkworms. Honey bees produce propolis, a natural bio-degradable resin, and silkworms discard their hard cocoon when they reach maturity (Howarth, 2014).

Fig 3.19 Marlène Huissoud's beekeeper father working at his farm.

(Source: www. marlene-huissoud.com)

In particular, she worked with propolis, a glossy black variant that is extracted from rubber plants and has comparable look and feel to glass. The designer also created a material she calls wooden leather using silkworm cocoons, which are made from hundreds of metres of silk threads (Ayala, et al 2017; Howarth, 2014).

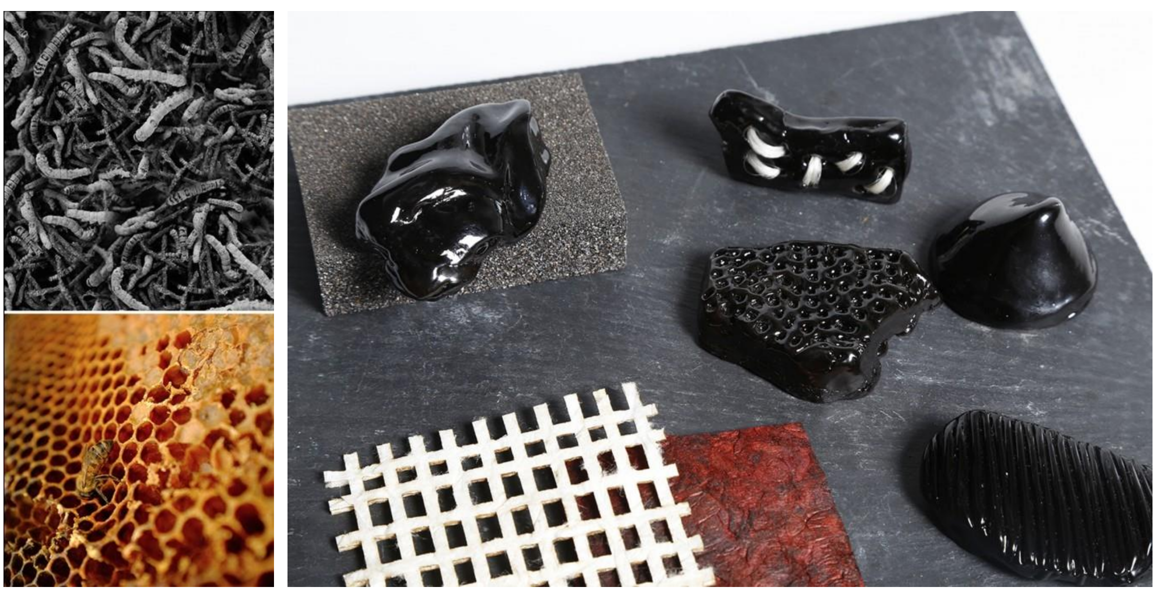

Fig 3.20 Silkworm's cocoon and honeybees hive propolis samples.

(Source: www. marlene-huissoud.com)

Propolis: It is a biodegradable resin which is collected by honey bees from trees to use as a sealant for their hive. Once a year the beekeeper removes a bit of the propolis to extract the honey from the frames of the beehive. A bit of propolis means minimal quantity, which is less than 100 grams per hive per year. Thus, it is a precious and unique material. The colour of propolis is dependent on the sources (forests, trees and so on) used by the honey bees during collection. The most common colour is brown, but there are plenty of variations in colours and properties. Huissoud chose to work with a black propolis from rubber trees (Howarth, 2014).

Fig 3.21 Marlène Huissoud collecting propolis from the honeybee hive.

(Source: www. marlene-huissoud.com)

Primarily propolis is a mixture of 50 to 150 different components like wax, balsams, resins, pollen and essential oils. For a pure sample of the material, propolis was cleaned by heating all the substances together in a large bowl of water. At the boiling point, the wax, and all other substances come up at the surface of the water; this was the primary process used to extract the propolis from its natural stage (Howarth, 2014).

Fig 3.22 Propolis extracted samples

(Source: www. marlene-huissoud.com)

Propolis Vessels: Huissoud has made a collection of vessels from propolis using different glass making techniques because the black propolis is similar to glass. She developed a way of blowing propolis using the same basic technique used with glass to produce great black shiny vessels (Howarth, 2014).

Fig 3.23 Propolis blow moulded and hand carved vessels.
(Source: www. marlene-huissoud.com)

She wanted to develop her materials through traditional techniques. She went to work in a glass workshop to learn from a specialised craftsman. She worked with different glass techniques including Venetian techniques, glass blowing and engraved glass. For example, she tried many Venetian techniques, which makes explicitly long stripes from a material. Although it worked, unfortunately, it was much too fragile to be considered for the making process in this instance. After many experiments, she succeeded in blowing the propolis, by using the same basic technique as with glass to produce exceptional, beautiful black vessels. Overall the process took a long time because a kiln, had to be developed specially for the propolis as its melting point is 100° C which is far much lower than 1200°C for glass (Howarth, 2014).

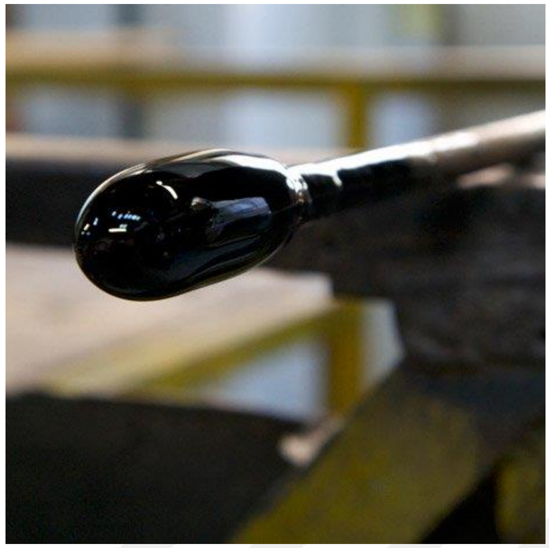

Fig 3.24 Propolis Vessel blow moulding.
(Source: www.marlene-huissoud.com)

She chooses to make vessels because vessels are one of the most common products from glass that we know as an industrial material. She used many engraved techniques which she developed throughout the project. By using the engraved glass techniques, she depicts the source of the material by replicating specific textures found in the insect's world (Howarth, 2014).

Fig 3.25 Marlène Huissoud hand carving her vessels.
Source: www. marlene-huissoud.com

Wooden Leather: The silkworm cocoons are composed of raw silk threads which are around 300 to 1000 meters; it represents hundreds of layers of fibres. The cocoon can be cut into two parts, and the fibres can be extracted one by one (Howarth, 2014).

Fig 3.26 Fibre extraction from silkworm cocoons.

(Source: www. marlene-huissoud.com)

The wooden appearance of the material came from combining tens of thousands of fibres into silkworm's paper. Fibers are combined with a natural glue contained a by the fibre itself called Sericin. The glue is the resinous substance in nature which are linked the silk fibres and bind them firmly in the raw stage of the sericulture. This natural glue is activated by spraying water and heating the fibres. The outcome of this process is the creation of a novel paper. A varnish with propolis was applied on top of the paper to change its natural state and give strength to the material. Varnished paper resulted as “wooden leather” (named by the designer) like material which has surface texture like leather with appearance like wood (Howarth, 2014).

Fig 3.27 Wooden leather varnish procedure and result from Sericin.
(Source: www. marlene-huissoud.com)

The wooden aspect of the material developed through combining thousands of fibres into the silkworm's paper. This new material can be used in different ways and various applications in the form of furniture design, fashion design and surface design (Howarth, 2014).

Fig 3.28 Wooden leather applications.
(Source: www. marlene-huissoud.com)

3.5.3 Marwoolus

(Kingdom Lapideum)

Fig 3.29 Marwoolus by Marco Guazzinni

(Source: www. marcoguazzini.com)

Italian designer Marco Guazzini developed Marwoolus by merging two predominant materials, marble and wool. The theme of the project is Mediterranean Landscape. Marwoolus is wool-infused marble representing the textile legacy of Prato; town creativity, innovation and hard work. Waste cuts marble was used from Pietrasanta, where Michelangelo selected marble for his masterpiece David (Grieco, 2016).

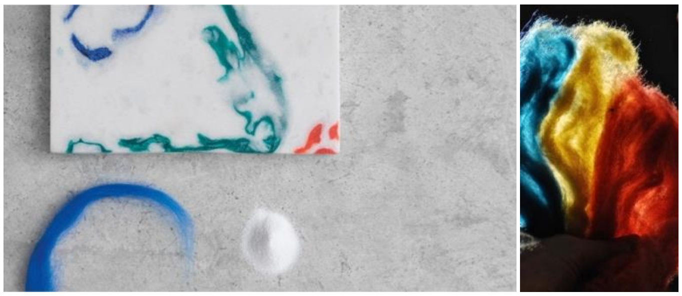

Fig 3.30 Marwoolus ingredients (marble + wool)

(Source: www. macroguazzini.com)

Marble cuts were melted into liquid and then fused with dyed with rainbow hues yarns. Mixture liquidised marble paste with yarn was poured into the moulds of the desired shape. Wool fibres floated within the liquid marble until it hardened into the solid material. Wool infused marble slabs were cut into the desired product applications like tiles, tapestries and table surfaces (Ayala, et al 2017; Grieco, 2016).

Fig 3.31 Marwoolus slabs in production

(Source: www. macroguazzini.com)

Designers composed wool fibre patterns casually to give the material a natural coloured streak marble look. Coloured woollen strings with the contrast of white or black marble gave the main characteristics. These colourful pieces are unique with both expressive and expressive sensorial qualities based on the designer's cultural connections with material sources (Grieco, 2016).

Fig 3.32 Marco Guazzini's creative implementation to his material Marwoolus.

(Source: www. macroguazzini.com)

3.5.4 Sea Chair
(Kingdom Recuperavit)

Fig 3.33 Sea Chair by Studio Swine

(Source: www. studioswine.com)

Sea chair is a collaborative project by Studio Swine with designer Kieren Jones. Sea chair is a seating designed and made entirely from the floating plastic waste particles from the oceans. Sea chair is an environmental project to emphasise of the Pacific garbage patch which was discovered in 1997. Plastic is one of the major ingredients of marine debris which is harming marine life and environment because of its non-biodegradable character. Recent studies have estimated almost 46,000 plastic particles per square kilometre in world's oceans. Studio swine decided to embark on a quest for the different plastic waste particles that float on the surface of the ocean and transform them into seating furniture (Mikocki, 2013).

Fig 3.34 Sea Chair's material process; plastic sorting, chipping and melting in furnace.

(Source: www.designboom.com)

The ‘sea chair’ re-purposes plastic waste from oceans through DIY and open source method of making. The chair is designed by collecting waste from debris, separating plastic from it, melting it and shaping into seating (Ayala, et al 2017; Mikocki, 2013).

Fig 3.35 DIY furnace for Sea Chair by Studio Swine

(Source: www.designboom.com)

The plastic material collected from debris soup is separated and organised according to colour. Fragmented plastic is melted into the DIY furnace at 130°C. Melted mixture is compressed between two heavy metal or stone slabs to form a recycled material. The material is cooled and solidified by the sea water. The waste turned into recycled material shaped in the formed seat and moulded into three legs, tided and assembled into the sea chair (Ayala et al. 2017; Mikocki, 2013)

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Fig 3.36 Debris collected plastic Sea Chair

(Source: www.designboom.com)

The open-source design has given instructions, precautions and manual to use readily available materials with necessary DIY skills. DIY furnace and mould plan are provided to enable the creation of a sea chair. The designers have released a manual so that others can also build the chair with the help of DIY tools and kits (Mikocki, 2013).

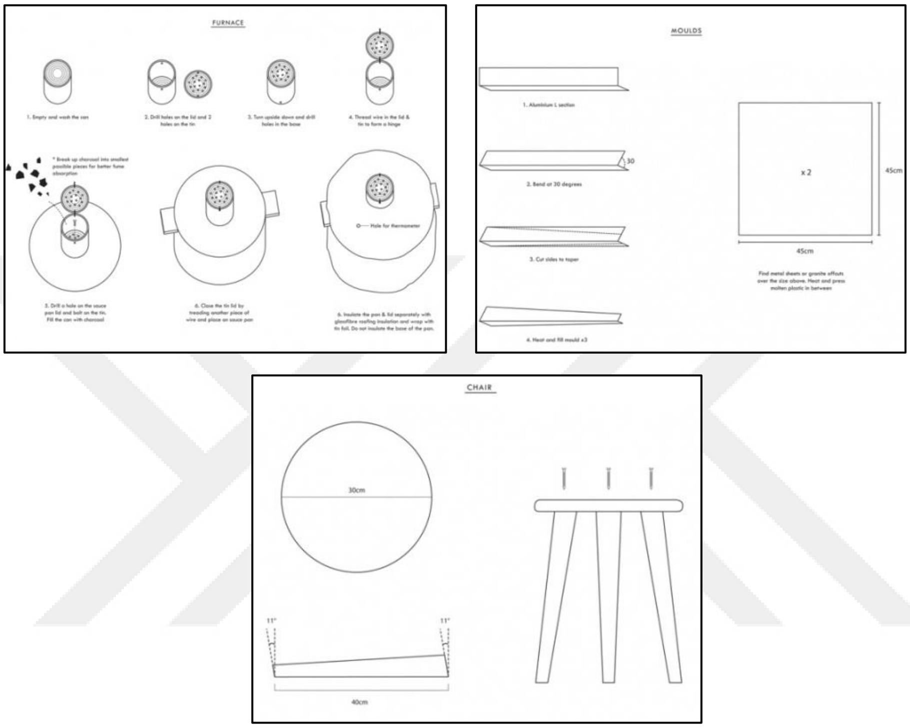


Fig 3.37 Open source DIY templates of furnace, chair mold and chair assembly

(Source: www.designboom.com)

Although the shape of the object may not be aesthetically pleasing, it is interesting that tag with the coordinates where plastic pieces were collected adorns it. Sea chair has transformed a waste material into something valuable (Mikocki, 2013).

Fig 3.38 Debris collected plastic coordinated Sea Chair Tag

(Source: www.designboom.com)

3.5.5 Magnetic Fabric

(Kingdom Mutantis)

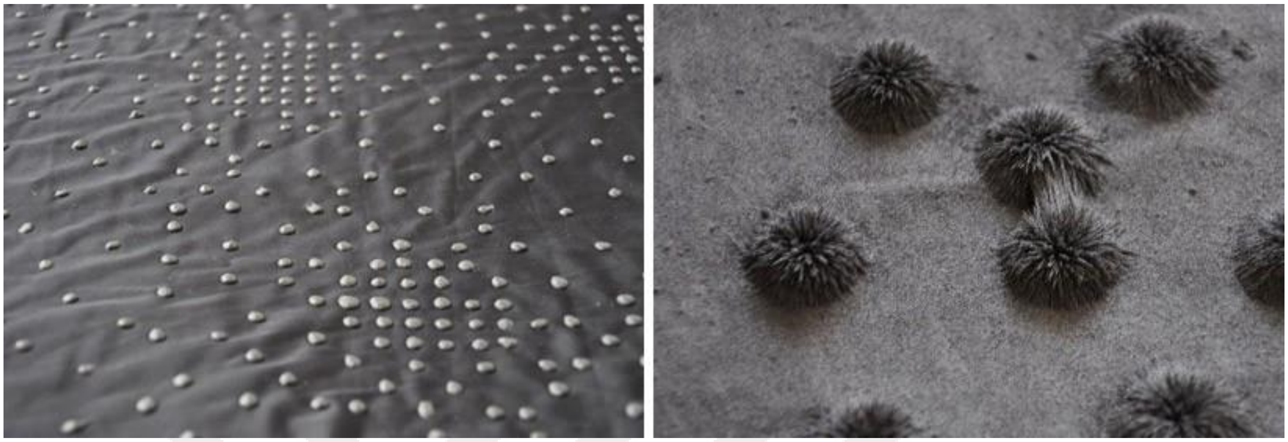


Fig 3.39 Magnetic Fabric by Lilian Dedio at Material Xperience 2016
(Source:www.mateialxperience.com/magnetic-fabrics-lilian-dedio)

Magnetic Fabric is designed by Lilian Dedio. It was presented in the exhibition "Future is Here" by Material Xperience 2016. The exhibition h was based on three themes: New Techniques, New Materials and New Energy Sources (materia.nl, 2016).

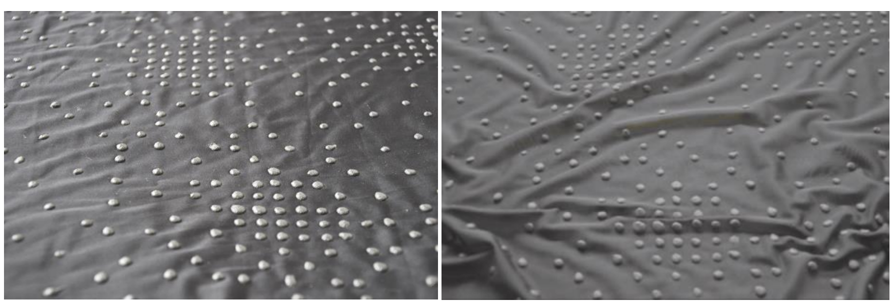


Fig 3.40 Magnetic Fabric static and moved form
(Source:www.mateialxperience.com/magnetic-fabrics-lilian-dedio)

Dedio developed the new material and explored its new limits of textile by incorporating magnetic components through further developing familiar features of magnetic dynamics. The designer arranged magnetic constituents in various patterns inside the traditional fabrics. By doing so, the material became alive with the help of electronics. Te fabric moves and creates the active and dynamic behaviour, due to stimulus reaction of magnets (materia.nl, 2016).

Fig 3.41 Magnetic Fabric movements in reaction to stimulus.
(Source:www.mateialxperience.com/magnetic-fabrics-lilian-dedio)

Dedio also added and arranged pattern with visible magnets. With the combination of visible and hidden magnets methodologically arranged causes unique and aesthetical mechanical accumulation of material. It changes over and over and makes the material alive through entire material movement (materia.nl, 2016).

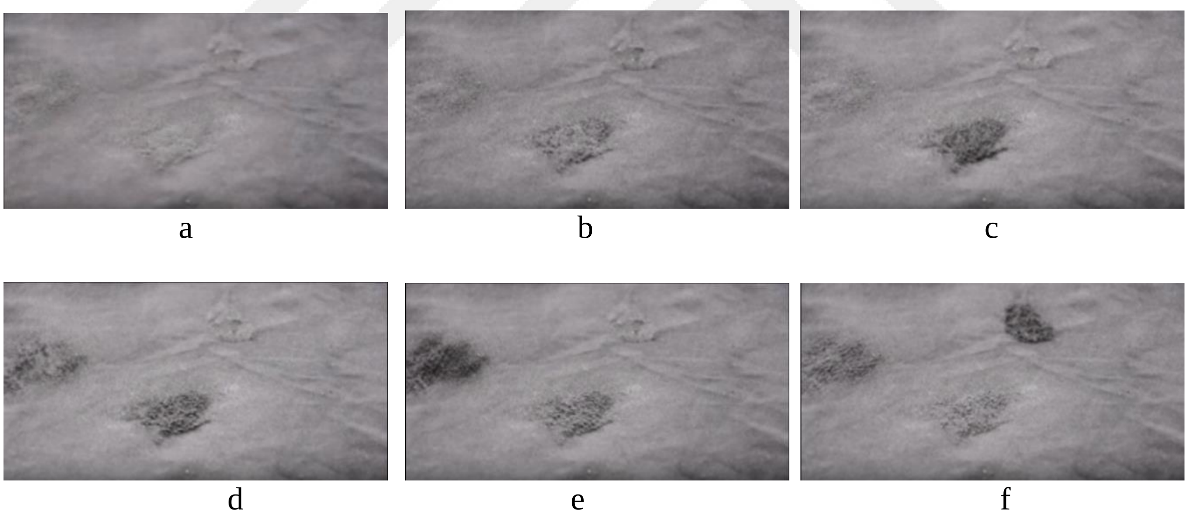


Fig 3.42 Visible magnets movements video screen shoots from “a” to “f”.
(Source: Youtube/ magnetic fabric)

Unique and surprising motions create a new set of innovative aesthetics of textile. Magnetic fabric shows the new and interesting relationship between media and shapes through its unique motion sequences (materia.nl, 2016).

CHAPTER 4
METHODOLOGY

4.1 Methodology

This study aims to develop a sustainable and organic DIY material that can be easily produced through simple production methods with natural materials. The study aims to contribute to resolving environmental issues because of most synthetic plastics possess non-sustainable properties. To substitute some of the harmful materials, a DIY material formula was developed to attain a sense of responsibility and craftsmanship experience. That formula can be easily reproduced and self-customised by designers and amateurs based on the need for a particular project or customer request.

Practice-led experimental research was adopted to develop a DIY material. Materials were selected based on literature review and practical experimentations. Experiments were performed both in systematic and casual ways. Firstly, a pilot study was carried out, in which trial and error based experiments were performed to select materials, on the basis of their properties and compatibility with agar. During the second phase, experiments were performed systematically under controlled laboratory conditions. Through pilot experiments, observation, and with the support of literature review, agar was selected the base material to develop a DIY organic material. After the pilot study, a whole series of experiments were executed with agar as the central substance which comes under the vegetable kingdom from the DIY materials classification (Ayala Garcia., Karana and Rognoli, 2017). Agar is an extracted form of seaweed, usually used as vegetarian gelatine and a substitute to animal-based gelatine for vegetarian and vegan meals. It is prominently used in Asian kitchens as a gelling agent and a key ingredient in desserts. It has a natural gelling property with a higher melting point (85˚C) compared to animal-based gelatine (which is usually 37˚ C) (McHugh, 2003). Agar is bio based, organic and abundant in nature therefore to develop an organic-based DIY material with the simple procedure; agar was selected as the main substance. Other additives were also selected through pilot phase and literature review to support the aim of the research. After the phase of pilot experiments, a series of experiments were performed with agar and selected additive materials; namely water, sugar, glycerine, and cornstarch as comparative bio-based material. Some coloured and textured samples were produced. Natural colourants were also used to observe possible organic coloured and textured variations.

Usually, engineering materials are evaluated scientifically, based on technical and physical properties like tensile strength and chemical resistance. For designers physical and technical properties are important; however, sensorial properties are also essential to incorperate material in physical design. To experience the material and its tangible and intangible characteristics, Material Driven Design (MDD) is the most suitable approach to evaluate material in a designerly way. MDD helps to understand how the material behaves under different circumstances and how it responds when subjected to different making techniques or manufacturing processes (Karana et.al, 2015). Therefore, the MDD approach was selected to evaluate the agar-based DIY material, to understand and experience the bigger picture of the material.

The aim of the thesis is not just to develop a DIY material but also its practical implementation in the design fields. To understand its practical implementation in design fields, a qualitative study was conducted with design and culinary arts and food engineering students (19-26 yrs old). Apart from the field related students, a third group was also selected to conduct user studies, this was a random group of people, selected as random students at Izmir University of Economics from age 19- 26 yrs. User studies were conducted through a questionnaire, that consist of open and close ended questions to understand the material, its sensorial properties and further possible usage in design fields. The questionnaire was designed and evaluated based on MDD approach, as user studies are a part of the MDD evaluation process of the material, which helps to evaluate the material starting from understanding material to design implementation proposal. The sample questionnaire designed for this study is given in the Appendix-1

This chapter further describes a detailed process of experiments with material selection phase and how agar based materials were developed through multiple experiments. The evaluation section describes how material samples were evaluated through the MDD approach, and a complete picture is describes what a MDD approach is and how it will work in the evaluation of the agar-based material.

4.2 Experimentation

Experiments were done in two phases. Firstly, pilot experiments were done to select a feasible material by understanding material properties and their response to other constituents. The second phase consisted of multiple experiments using selected materials through pilot experiments. Second phase experiments were done in a more precise and scientific way to develop an agar-based material instead of general procedures.

4.2.1 Pilot Experiments: Multiple random experiments were done with various substance materials on a trial and error basis to develop an organic material. The primary purpose of pilot experiments was to create a material with the help of existing substances from our surrounding which are accessible and affordable. During this phase, food grade materials were selected and used as key ingredients in experiments such as flour, rice flour, raw rice, corn starch, and agar agar powder. Other substances were also selected from the daily kitchen materials like sugar, tea and tea waste, coffee ground, and vinegar to develop a composite material. After multiple experiments, agar agar and cornstarch were selected as key components to develop DIY materials. Experiments were done through a simple procedure by combining dry ingredients and water and cooking that mixture on a stove at medium heat. After the mixture became thick like a paste, it was spread on a sheet and left for a week or two to dry. As pilot experiments were based on a trial and error approach, some experiments involved baking in an oven for about half an hour with both cooked and uncooked mixtures of dry and wet ingredients. Based on literature review and research on DIY materials, glycerine was incorporated as an additive to yield more elasticity.

To understand the properties of the selected materials and their reaction with other substances various ratios were applied during the pilot phase. For example, at first agar: sugar: glycerine ratio was 2 teaspoon (tsp): 2 tsp: 2tsp. However, instead of equal ratio the amount of glycerine was increased by using 2 tsp: 3 tsp: 2tsp in later experiments to increase material elasticity. It was observed that adding vinegar increases the hardness and stiffness of agar and starch based films.

Through pilot experiments, the basic two types of results were observed in the form of hard samples and soft and flexible samples. Hard samples were without glycerine whereas glycerine was used as a plasticizer to give elastic property (Palviainen, et al. 2001; Wang & Rhim, 2015).

Multiple experimentations with household equipment and food grade materials yielded some encouraging results that were further carried out in a more precise way with better-controlled procedures.

4.2.2 Main Experiments: After the pilot experiments, agar was selected as the base material while other substances were water, glycerine, sugar and vinegar. Cornstarch was selected as a comparative material to agar. During the second phase, experiments were done to understand easily available agar types and their separate reactions to other substances. Three types of agar were selected to perform experiments which are commonly accessible;

i. Bacto™ Agar(agar powder) by Becton, Dickinson and company used as bacterial growth and solidifying agent in laboratories (agar type 1).
ii. Food grade agar powder used in food industry as vegetarian gelatine substitute for animal-based gelatine (agar type 2). Two types of powder were used, one food grade agar powder bought in Italy (Type 2a) and second agar powder bought in Turkey, named as Agar Agar by Tito with E code E-406 (Type 2b).
iii. Food grade white agar flakes/strips also used as vegetarian gelatine as well as a food ingredient in Japanese and Chinese cuisines (agar type 3). The food grade agar strips were bought from Chinatown, Italy.

Food grade synthetic or white vinegar, cornstarch and sugar (both brown and white sugar) were bought from the local grocery store, which are used in daily household items. Laboratory grade glycerine (Glycerol for analysis by EMSURE®) was used. Experiments were done in a precise manner to minimise errors and calculate ratios with proper units instead of spoons and cup measurements. Since the pilot phase measurements did not measure the amounts in grams or millilitres and the appropriate temperature was not noted during the experiments, to maintain the accuracy of the variables; temperature, quantity and shape were kept constant through the second phase of experiments.

Simple tools were used in all of the experiments; a standard saucepan to cook, a hot plate for heating it and a stirrer or spoon to stir the mixture. A measuring scale was used to measure the dry ingredients accurately and a measuring cylinder was used for liquids. To maintain the shape and quantity of the sample and to observe the shrinkage of size and thickness during the drying period, Petri dishes were used.

A basic procedure to develop a DIY material was used in phase 2, which was similar to pilot experiments. The procedure consisted of four steps;

i. Precise measurement of the ingredient weights.
ii. Combining dry and liquid ingredients in a saucepan.
iii. Placing the saucepan on a hot plate at 240- 260°C and heat the mixture until it becomes homogeneous (agar flakes melts at 90°C) and thick in consistency like honey.
iv. Pouring the mixture into the Petri dish (93 mm x 7 mm) and let it dry at room temperature for a week

Quantity and ratio remained constant through the whole period of experiments of the second phase, which was 2:2 ratio with 50 ml water. For the basic recipe, 2 g of agar was used with 2 ml glycerine and 50 ml of water. The ratio was kept the same for all samples.

Three types of agar were used in this phase to compare them and their material development possibilities. Basic experiments were done with hard and soft films comparing agar types with and without cornstarch since both agar and corn starch are edible and bio-based materials. Through literature review, it has been observed that cornstarch based bio-plastics are available and edible films which are in the process of the practical development. To compare and understand cornstarch properties, a series of experiments were done using cornstarch and different types of agar. Glycerine, vinegar, and sugar were used as basic substance during basic experiments. Table 4.1 describes the basic combination of agar with other substances and cornstarch as a comparative material. Detailed compositions of basic experiments with types of agar, quantity and proportions are given in Table 4.2.

Table 4.1 Basic Material Combinations

Agar	Starch	Agar &Starch
agar	starch	agar + starch
agar+ glycerine	starch+ glycerine	agar+ starch+ glycerine
agar+ glycerine+ sugar	----	----
agar+ glycerine+ vinegar	----	----
agar + vinegar	----	agar + starch+ vinegar
agar + vinegar+ sugar	----	----
agar+ sugar	----	agar+ starch+ sugar

* All initial solutions contain 50 ml water.

Table 4.2 Compositions of Solutions Used for Base Materials

Sample No	Agar Type	Agar (g)	Water (ml)	Glycerine (ml)	Sugar Type	Sugar (g)	Vinegar (ml)	Starch (g)
2	Type 3	2 g	50 ml					
3	Type 2a	2 g	50 ml					
13	Type 1	2 g	50 ml					
24	Type 2b	2 g	50 ml					
4			50 ml					2 g
5	Type 3	2 g	50 ml					2 g
6	Type 2a	2 g	50 ml					2 g
14	Type 1	2 g	50 ml					2 g
24	Type 2b	2 g	50 ml					2 g
12	Type 3	2 g	50 ml	2 ml				2 g
11	Type 2a	2 g	50 ml	2 ml				2 g
10	Type 1	2 g	50 ml	2 ml				2 g
27	Type 2b	2 g	50 ml	2 ml				2 g
7			50 ml	2 ml				2 g
8	Type 3	2 g	50 ml	2 ml				
9	Type 2a	2 g	50 ml	2 ml				
15	Type 1	2 g	50 ml	2 ml				
26	Type 2b	2 g	50 ml	2 ml				
16	Type 3	2 g	50 ml	2 ml	brown	2 g		
17	Type 3	2 g	50 ml	2 ml	brown	1.5 g		
18	Type 3	2 g	50 ml	2 ml	brown	1 g		
19	Type 3	2 g	50 ml	2 ml	brown	0.5 g		

Sample No	Agar Type	Agar (g)	Water (ml)	Glycerine (ml)	Sugar Type	Sugar (g)	Vinegar (ml)	Starch (g)
20	Type 2a	2 g	50 ml	2 ml	brown	2 g		
21	Type 2a	2 g	50 ml	2 ml	brown	1.5 g		
22	Type 2a	2 g	50 ml	2 ml	brown	1 g		
23	Type 2a	2 g	50 ml	2 ml	brown	0.5 g		
29	Type 2b	2 g	50 ml	2 ml	brown	2 g		
30	Type 2b	2 g	50 ml	2 ml	brown	1.5 g		
31	Type 2b	2 g	50 ml	2 ml	brown	1 g		
41	Type 3	2 g	50 ml	2 ml			2 ml	
32	Type 2b	2 g	50 ml	2 ml			2 ml	
43	Type 3	2 g	50 ml				2 ml	
34	Type 2b	2 g	50 ml				2 ml	
45	Type 3	2 g	50 ml		white	2 g	2 ml	
33	Type 2b	2 g	50 ml		brown	1.5 g	2 ml	
40	Type 3	2 g	50 ml				2 ml	2 g
38	Type 2b	2 g	50 ml				2 ml	2 g
42	Type 3	2 g	50 ml		brown	2 g		2 g
39	Type 3	2 g	50 ml		brown	1.5 g		
44	Type 3	2 g	50 ml		50 ml	2 g		
28	Type 2b	2 g	50 ml		brown	2 g		
45	Type 3	2 g	50 ml		white	2 g	2 ml	

After the basic experiments with different types of agar, agar flake (type 3) was selected as a preferable raw material to continue the new phase of experiments. This phase consisted of coloured and textured samples using natural and organic additives. Coloured samples were developed using food colours, fruit peels and juice, and spices from an Asian kitchen. Different types of herbal teas and coffee ground were also used to give colour and texture to samples. For coloured and textured samples two types of films were adopted to perform experiments;

i. Agar + water + colour
ii. Agar + water + colour + glycerine

Table 4.3 Composition Used for Coloured Samples

Sample No	Agar (g)	Water (ml)	Glycerine (ml)	Colourant Type	Colour Qty (g/ ml)
59	2 g	50 ml		Cinnamon powder	0.5 g
60	2 g	50 ml		Red chilli powder	0.5 g
61	2 g	50 ml		Turmeric powder	0.5 g
58	2 g	50 ml		Rosehip tea	0.5 g
62	2 g	50 ml		Hibiscus tea	0.5 g
66	2 g	50 ml		Orange zest powder	0.5 g
67	2 g	50 ml		Lemon zest powder	0.5 g
63	2 g	50 ml		Green food colour	few drops in water
64	2 g	50 ml		Black food colour	few drops in water
65	2 g	50 ml		Blue food colour	few drops in water
46	2 g	50 ml	2 ml	Red chilli powder	0.5 g
49	2 g	50 ml	2 ml	Cinnamon powder	0.5 g
50	2 g	50 ml	2 ml	Turmeric powder	0.5 g
52	2 g	50 ml	2 ml	Hibiscus tea	0.5 g soaked in water
57	2 g	50 ml	2 ml	Rosehip tea	0.5 g
68	2 g	50 ml	2 ml	Green tea	0.5 g
70	2 g	50 ml	2 ml	Turkish coffee ground	0.5 g
55	2 g	50 ml	2 ml	Orange zest powder	1 g
55 a	2 g	50 ml	2 ml	Orange zest powder	0.5 g
56	2 g	50 ml	2 ml	Lemon zest powder	0.5 g
47	2 g	50 ml	2 ml	Cherry	3 cherries boiled in water for coloured water
48	2 g	50 ml	2 ml	Cherry Juice	2 ml
51	2 g	50 ml	2 ml	Red food colour	few drops in water
53	2 g	50 ml	2 ml	Green food colour	few drops in water
54	2 g	50 ml	2 ml	Blue food colour	few drops in water
69	2 g	50 ml	2 ml	Onion skin (grounded)	0.1 g

Agar with water and colouring material was used to obtain coloured samples while glycerine was used to get flexible and softer samples. The ratio and quantity remained constant as in the basic experiments. The quantity of colourant materials varied in experiments depending on the shade of colour and texture required. Quantities and types of colorants are given in Table 4.3, whereas the overall procedure remained the same as the basic experiments.

4.3 Evaluation

Material Driven Design (MDD) method was selected to evaluate the agar-based material samples. MDD is a method developed for designers to understand and create a material experience for designing a product. As the main aim of the thesis was to develop a DIY material formula that can give the sense of responsibility and craftsmanship experience. MDD does not only understand a material by as asking for what it is, but also for what it does, what it expresses to us, what it elicits from us, and what it makes us do. MDD method can be applied to three scenarios based on the requirement of the designer (Karana et al., 2015):

i. *Designing with a relatively well-known material,* to explore new application areas, elicit novel meanings and exclusive user experiences.

ii. *Designing with a relatively unknown material*, accompanied by a fully developed sample such as novel smart materials like thermochromic materials, to define application such as by introducing their distinctive user experiences, identities and new meanings to the material.

iii. *Designing with a material proposal* with semi-developed or exploratory samples (e.g., DIY materials like food waste composites, living materials made of bacterial cells, etc.).

Since the material is semi-developed or a new composite material proposal (like the case of agar based DIY material) its properties need to be defined through process in relation to a selected application area, also to generate feedback for further materials development. Furthermore, since the material is new, the designer has to propose meaningful applications through unique user experiences and meanings through MDD approach. The agar-based material comes under the third scenario, because of novelty as it is developed through multiple experiments. For a novel or semi- developed material, it is difficult to understand, recognise and propose meaningful applications through which unique experiences and meanings will be elicited (Karana et al., 2015). Understanding the material is a more a process of exploration and experimentation, which requires knowledge and skill development through hands-on experience of properties such as softness, hardness, glossiness, colouring, texturing and sometimes smell (Van Bezooyen, 2013). Agar-based material properties were observed and explored through experimentations (tinkering with other additive materials), their observed time-dependent changes and user material experiences (user studies through a questionnaire) based on MDD action steps.

4.3.1 Evaluation Steps: It is important to understand steps and procedures of MDD to evaluate a material. MDD method based on multiple main action steps starting from understanding the material to product concept. In case of novel materials (the third scenario), the process starts after the material proposal and ends with a developed material. Figure 4.1 illustrates the MDD method with its four main action steps presented sequentially:

1. Understanding the material: Technical and Experiential Characterization
2. Creating materials experience vision
3. Manifesting materials experience patterns
4. Designing material/ product concepts

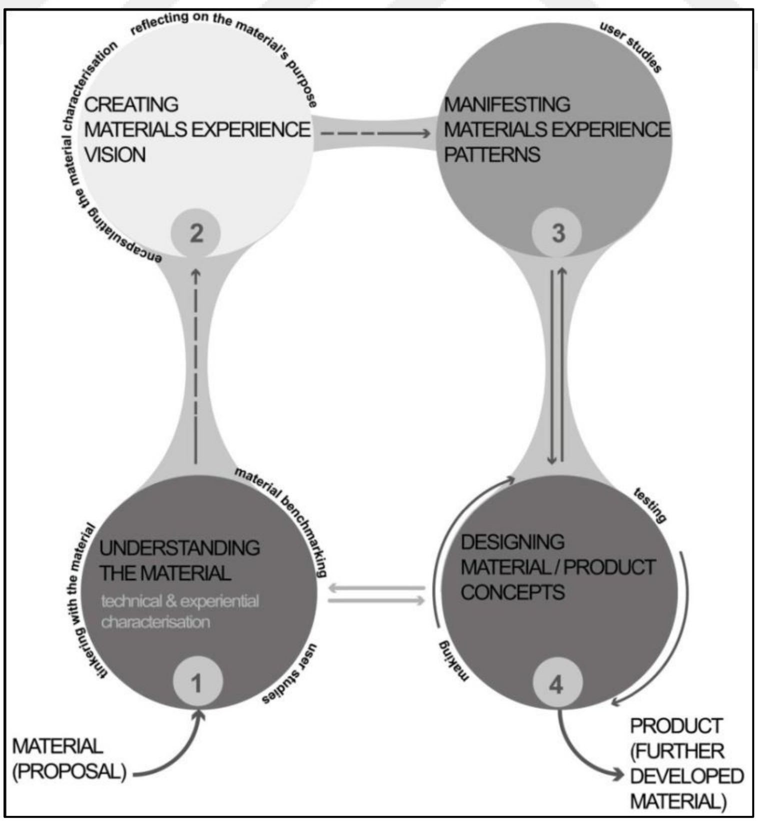


Fig 4.1 Material Driven Design (MDD) method.
Source: Karana et al. (2015).

The MDD method emphasises the journey of a designer from tangible to abstract (i.e., from a material to a materials experience vision), and then from abstract back to tangible (i.e., from materials experience vision to physically manifested, further developed materials/products) (Karana et al., 2015). Agar-based material samples are evaluated and further developed through the steps of MDD. Detailed evaluation of agar-based materials through MDD is described in chapter 6.

CHAPTER 5
TIME DEPENDENT CHANGES

5.1 Time Dependent Changes

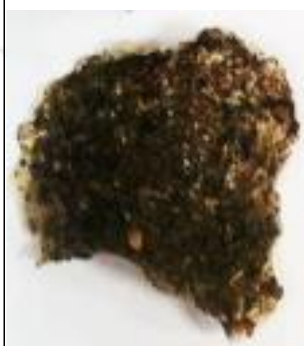
During and after the experiments, some noticeable changes have been observed over the period of time. Experiments were in two major phases, pilot phase and the main experimentation phase. The pilot phase was main an observatory phase, as the key material (agar agar) and other additive materials were selected from the changes observed from the pilot phase of experiments with the support of literature review. The pilot phase was based on trial and to evaluate various options for suitable substances and processes to develop a DIY organic material. The main experimental phase observation led towards the selection of agar type, quantity and preferable DIY material sample for the evaluation and practical implementations.

5.1.1 Pilot experiments observations: The pilot phase consisted of numerous experiments with multiple key ingredients varied from food grade agar powder to daily use pasta flour. Pilot phase experiments were random in quantity, choice of additives and process. Different materials and processes were tested to obtain an appropriate DIY material sample. Multiple primitive changes were observed during the pilot phase such as hard, soft, rough, dry, sticky, etc. Table 5.1 shows the detailed observed time-dependent changes of pilot experiments (experiment details are given in the previous chapter 4)

Table 5.1 Pilot Experiments Observations

S.No	Sample Picture	Ingredients	Process	Observation
1		• Agar Powder • Orange Peel • Water	Cooked	• Hard • Dry • Rough • Brittle
2		• Agar Powder • Orange Peel • Water	Cooked then Baked	• Hard • Dry • Rough • Brittle
3		• Agar Powder • Rice Flour • Orange Peel • Water	Baked	• Hard • Dry • Rough • Cracked • Brittle
4		• Agar Powder • Green Tea • Orange Peel • Water	Baked	• Hard • Dry • Rough • Brittle
5		• Agar Powder • Date Seeds • Orange Peel • Water	Baked	• Hard • Dry • Rough • Cracked • Brittle
6		• Agar Powder • Coffee Ground • Orange Peel • Water	Baked	• Hard • Dry • Rough • Brittle

S.No	Sample Picture	Ingredients	Process	Observation
7		• Agar Powder • Green Tea • Orange Peel • Water	Dry mixed ingredients	• Hard • Dry • Rough • Cracked • Brittle
8		• Pasta • Salt • Carton • Water	Cooked	• Hard • Dry • Rough • Cracked • Brittle
9		• Pasta • Salt • Carton • Water	Cooked then Baked	• Hard • Dry • Rough • Cracked • Brittle • Colour changed
10		• Agar Flakes • Coffee Ground • White Flour • Salt • Water	Cooked then Baked	• Hard • Dry • Rough • Brittle
11		• Agar Flakes • Coffee Ground • White Flour • Rice • Water	Cooked then Baked	• Hard • Dry • Rough • Brittle

S.No	Sample Picture	Ingredients	Process	Observation
12		• Agar Flakes • Black Pepper • White Flour • Rice • Water	Cooked then Baked	• Hard • Dry • Rough • Cracked • Brittle
13		• Agar Flakes • Black Tea • Water	Cooked then Baked	• Hard • Dry • Rough • Broken • Brittle
14		• Agar Flakes • Glycerine • Orange Peel • Brown Sugar • Water	Cooked	• Soft • Sticky • Flexible • Rough • Tearable
15		• Agar Flakes • Glycerine	Cooked	• Soft • Cold • Flexible • Rough • Tearable

S.No	Sample Picture	Ingredients	Process	Observation
17		• Agar Flakes • Glycerine • Cornstarch • Brown Sugar • Orange Peel • Honey	Cooked	• Soft • Sticky • Flexible • Rough • Tearable
18		• Agar Flakes • Glycerine • Brown Sugar • Green Tea	Cooked	• Soft • Dry • Flexible • Rough • Stretchable • Tearable • Strong
19		• Agar Flakes • Glycerine • Brown Sugar	Cooked	• Soft • Dry • Flexible • Smooth • Stretchable • Tearable • Strong
21		• Glycerine • Cornstarch • Brown Sugar • Orange Peel	Cooked	• Soft • Cold • Flexible • Rough • Tearable

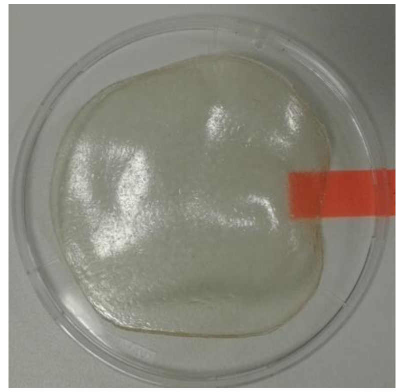
S.No	Sample Picture	Ingredients	Process	Observation
22		• Agar Flakes • Glycerine • Cornstarch • Green Tea	Cooked	• Soft • Dry • Flexible • Smooth • Strong • Tearable • Stretchable
24		• Agar Flakes • Glycerine • Brown Sugar • Golden Leaves	Cooked	• Soft • Dry • Strong • Flexible • Rough • Stretchable • Tearable
25		• Agar Flakes • White Vinegar • Brown Sugar • Red Leaves	Cooked then Baked	• Hard • Dry • Smooth • Broken • Brittle
27		• Agar Flakes • White Vinegar • Brown Sugar • Turmeric Powder	Cooked	• Hard • Dry • Rough • Broken • Brittle
28		• Agar Flakes • Potato Starch • White Vinegar • Brown Sugar • Turmeric Powder	Cooked	• Hard • Dry • Rough • Brittle

S.No	Sample Picture	Ingredients	Process	Observation
29		• Agar Flakes • Glycerine • Brown Sugar • Cinnamon	Cooked	• Soft • Dry • Strong • Flexible • Rough • Stretchable • Tearable

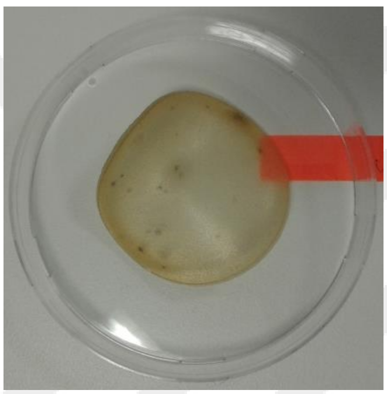
Varied time-dependent changes were observed during the pilot experiments, which led to select an appropriate sample with favourable features to further explore its possible characteristics through systematic and precise experiments. Some interesting features came out that helped to understand agar in a better way for next phase of experiments. Agar is a versatile material that reacts differently to other materials. It has been observed that by adding glycerine; agar becomes flexible and stretchable. In contrast vinegar makes it hard and brittle. The detailed property changes as a function of time are listed in Table 5.1, showing some similar features between agar and cornstarch, reactions to other additives and some captivating attributes. These observations helped to select agar as a key ingredient for the next phase of experiments and cornstarch as a comparative substance to understand similar features to develop organic materials.

5.1.2 Main experiments observations: The main experiments consisted of multiple compositions with agar as the key ingredient and cornstarch as a comparative material. Different types of agar (type 1, 2 and 3) were used to understand properties, similarities and differences within agar types and in comparison to cornstarch. Different time-dependent changes and physical properties were observed within agar types with altered additives materials. Though ratios remained constant (agar 2gm + additive 2gm/2ml+ water 50ml) throughout the second phase of experiments, time-dependent changes were different even within agar types. Prominent changes observed within agar types were the amount of shrinkage, colour, thickness and flexibility.

i, Type 1(Bacto Agar)



ii, Type 3 (Agar Flakes)



iii, Type 2a (Agar powder)

iv, Type 2b (Agar Powder)

Fig 5.1 Observed changes within agar types in basic recipe (agar+ water)

Figure 5.1 shows the observed time-dependent changes within agar types. Samples from agar flakes were white whereas other agar types are yellowish. Both food grade agar powder; type 2a (bought in Italy) and 2b (bought in Turkey) also have some differences and changes are observed such as shrinkage size, colour and deformation. Type 1 deformed during drying and also it is more fibrous than other types. Except for type 3 sample, other samples are non-flexible, less transparent and brittle with higher shrinkage ratio. Though all these four samples in Fig 5.1 contained the same quantity of agar and water, different types of agar showed different change characteristics.

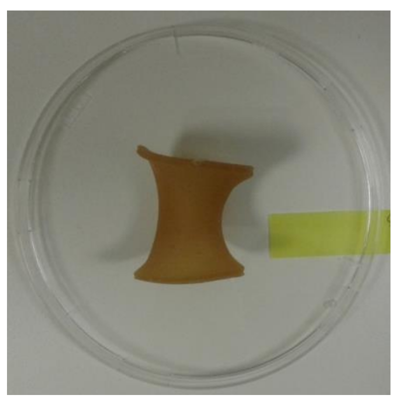
During the second phase of experiments, major changes were observed depending on agar type and use of the different additives. Even though the second phase of experiments were precise and constant in ratio, not all samples came out perfect; some unpleasant samples were also observed with other interesting results. These observed changes are given;

1. Contaminated samples, mold or fungus-like spots

2. Shape changed and deformation during the week of drying.
3. Broken or torn samples
4. Transparent to milky/mistiness
5. Softening of samples
6. Soft surface and flexible samples
7. Hard surface and flexible samples
8. Hard surface and brittle samples
9. Colour changes, and colour differences within agar types
10. Shrinkage and thickness differences within agar types
11. Addition of vinegar can protect impurities like fungus and spots.

Through observed changes, samples can be categorised into the three characteristic types; soft and flexible (S.F), hard and flexible (H.F), and hard and brittle (H.B). These three types are because of agar type, use of glycerine, sugar, vinegar and starch. Use of starch makes the sample hard and gives ponderous effect. Unfortunately, samples containing starch got contaminated. Vinegar (acetic acid) is used in food industry and home cooked products (like jam and marmalade) as a natural preservative from spoilage. For controlling contamination of samples, vinegar was added later into the samples containing cornstarch. Fig 5.2 shows that sample 25 containing starch and agar (type 2b) without vinegar contained black spots but adding vinegar to starch and agar mixture suppressed these spots (sample 38 with agar type 2b) .

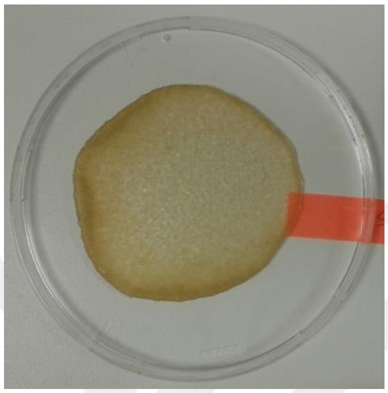
Sample 25 (agar + starch)



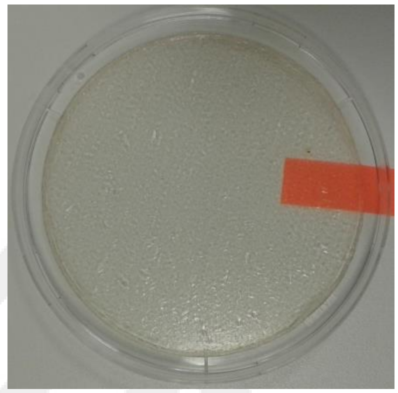
Sample 38 (agar + starch + vinegar)

Fig 5.2 Comparison between samples with and without vinegar, in agar (type 2b) and starch containing sample.

Glycerine used as a plasticiser to give flexibility to materials. Materials containing glycerine falls into the category of soft and flexible (S.F) samples. Samples containing glycerine are strong, flexible and stretchable (Fig 5.3). However without glycerine, samples are usually hard and brittle (H.B).



Type 1(Bacto Agar)



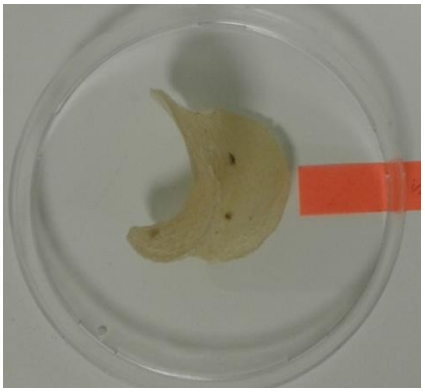
Type 3 (Agar Flakes)

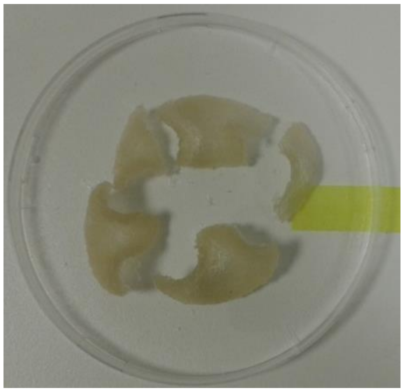
Type 2a (Agar Powder)

Type2b (Agar Powder)

Fig 5.3 Observed changes within agar types in basic recipe (agar+ glycerine+ water)

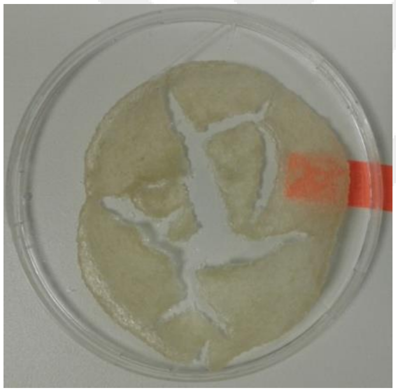
Usually without glycerine samples are in H.B category except few samples that are hard and flexible which contains type 3 agar. Type 3 samples are flexible in nature with hard surfaces. Interestingly Type 3 samples containing water, vinegar and sugar, all resulted in hard and flexible samples, but adding starch makes them brittle (without glycerine).

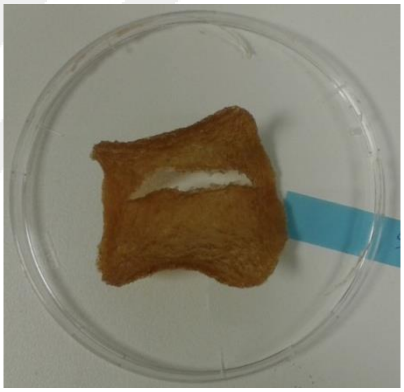




Sample 5 (agar + starch) Sample 40 (agar + starch + vinegar)

Fig 5.4 Comparison of samples with and without vinegar, in agar (type3) with containing starch.

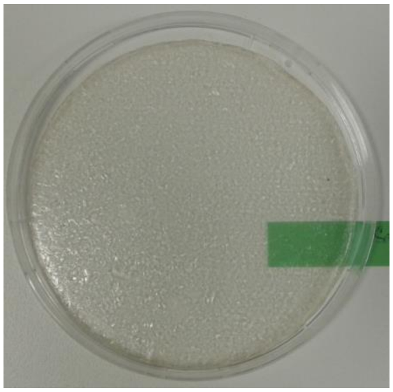




Sample 12 (agar + starch+glycerine) Sample 42 (agar + starch + sugar)

Fig 5.5 Type 3 agar and starch containing samples, using glycerine and sugar as plasticizer.

Through experiments and literature review it has been observed that apart from glycerine, sugar also works as a plasticiser. In fig 5.5 both samples are flexible though sample 12 (type 3 agar) contains glycerine whereas sample 42 (type 3 agar) contains brown sugar. Sugar was used in multiple experiments with glycerine and without glycerine, to understand its plasticiser property. In some cases, sugar did work as a plasticiser and gave flexibility to samples such as sample 44 (type 3 agar) and sample 28 (type 2b) shown in Fig 5.6.

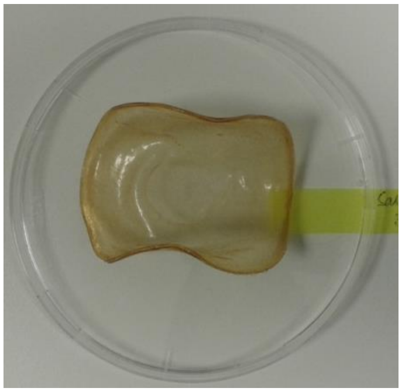


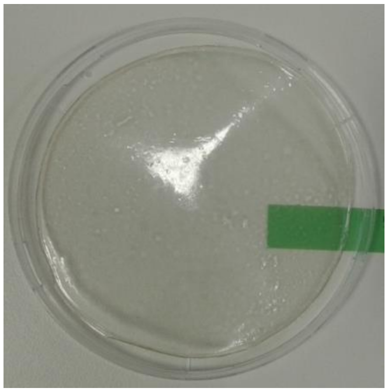
Sample 28 (agar + sugar) Sample 44 (agar + sugar)

Fig 5.6 Use of sugar as plasticizer in type 2b and 3 agar.

Sugar worked as the plasticizer and gave flexibility to agar, but it worked differently towards type 2b and typed 3 agar. White sugar was used in sample 44 with type 3 agar, it has more flexibility and soft surface as compared to sample 28(type 2b) which has the same amount of sugar (brown). After longer period around 6 months, the sample changes into hard and brittle form.

Vinegar was used as an antimicrobial agent to prevent contamination of samples. As samples were developed and dried in a laboratory, some spoiled ones were observed as shown in Fig 5.2 & 5.4. The reason for spoiled experiments is still uncertain, but it might be because of atmosphere or maybe because of a systematic error. Vinegar was added as a preventive to other samples; however interesting results appeared as shown in Fig 5.7. Vinegar gave plasticy and a glossy effect to samples. Sample 43 containing vinegar with type 3 agar is flexible while sample 34 (type 2b) is hard, brittle and distorted.



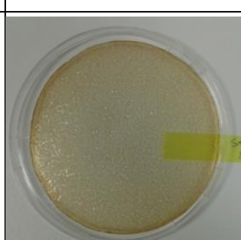


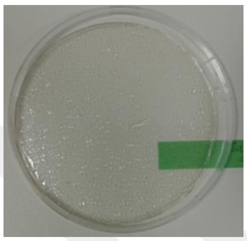
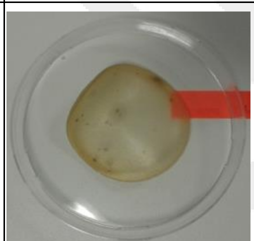
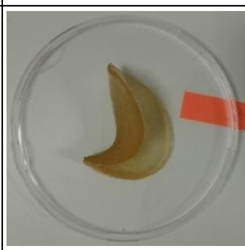
Sample 34 (agar + vinegar) Sample 43 (agar + vinegar)

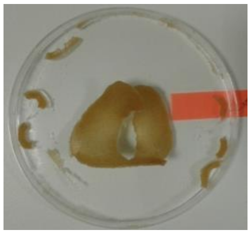
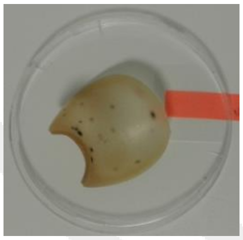
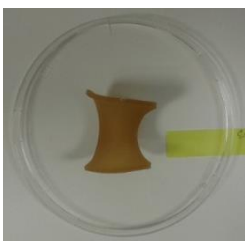
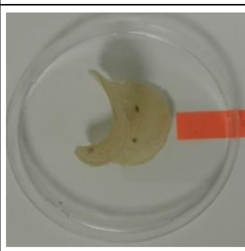
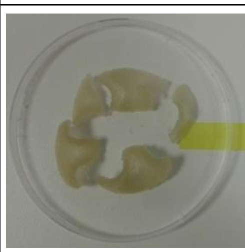
Fig 5.7 Use of vinegar in type 2b and 3 agar.

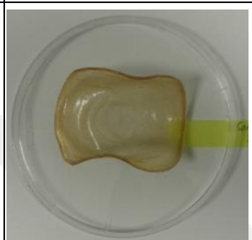
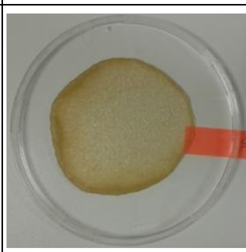
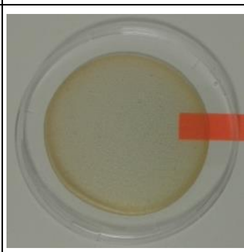
Interesting and multiple changes were observed during the main experiment, depending upon the selection of agar type and additive. Glycerine, sugar (brown and white) and vinegar responded differently toward agar type. Cornstarch was used as a comparative material towards agar types since it is already used in organic materials. Though cornstarch and agar do not constitute same characteristics, it did give ponderous effect to samples, when it was used as an additive material. Detailed changes with description of additives are provided in Table 5.2 based on the three categories observed from the time-dependent changes as; hard and flexible (H.F), soft and flexible (S.F) and hard and brittle (H.B).

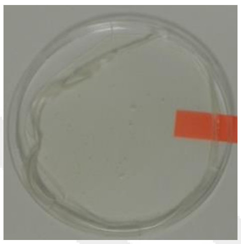
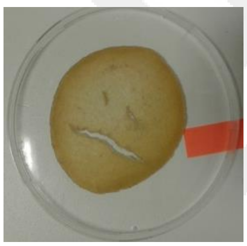
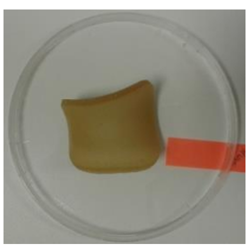
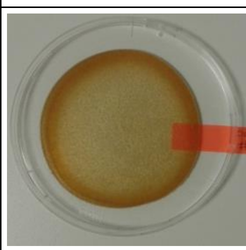
Table 5.2 Observations in the Main Experiments

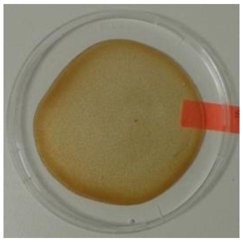
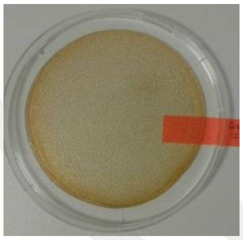
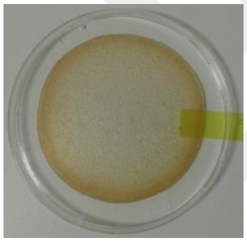
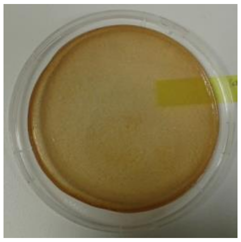
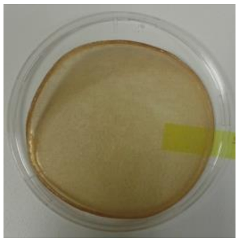
Sample No	Picture	Category	Agar Type	Additives	Observations
2		H.F	3	Water	• Shape changed • Glossy • Smooth • Breakable
28		H.F	2b	water Brown Sugar	• Shape changed • Colour changed • Glossy • Smooth • Breakable
39		H.F	3	water white Sugar	• Colour changed • Matt • Rough • Fibrous
44		H.F	3	water white Sugar	• Matt • Rough • Fibrous

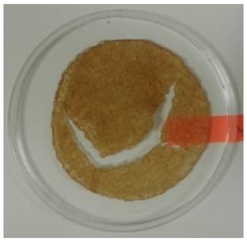
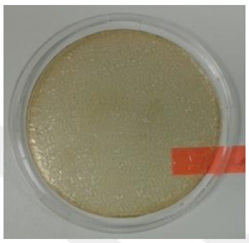
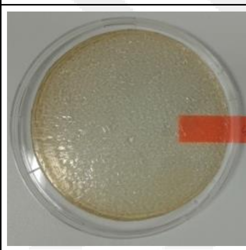
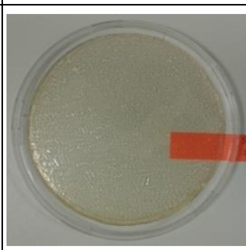
Sample No	Picture	Category	Agar Type	Additives	Observations
43		H.F	3	water white vinegar	• Shape changed • Glossy • Smooth • Fibrous • Breakable
45		H.F	3	water white sugar white vinegar	• Colour changed • Glossy • Rough • Fibrous
3		HB	2a	Water	• Contaminated • Shape changed • Colour changed • Shrinked
24		HB	2b	Water	• Shape changed • Colour changed • Shrinked
13		HB	1	Water	• Shape changed • Colour changed • Shrinked • Rough • Fibrous
4		HB		Cornstarch Water	• Shape changed • Fragile • Shrinked

Sample No	Picture	Category	Agar Type	Additives	Observations
14		HB	1	Water Cornstarch	• Shape changed • Shrinked • Broken • Rough • Fibrous
6		HB	2a	Water Cornstarch	• Contaminated • Shape changed • Colour changed • Shrinked • Smooth
25		HB	2b	Water Cornstarch	• Contaminated • Shape changed • Colour changed • Shrinked • Rough
38		HB	2b	Water Cornstarch White Vinegar	• Shape changed • Colour changed • Shrinked • Rough
5		HB	3	Water Cornstarch	• Contaminated • Shape changed • Shrinked • Rough • Fibrous
40		HB	3	Water Cornstarch White Vinegar	• Shape changed • Shrinked • Broken • Rough

Sample No	Picture	Category	Agar Type	Additives	Observations
42		HB	3	Water Cornstarch White Sugar	• Shape changed • Colour changed • Shrinked • Broken • Rough • Fibrous
34		HB	2b	water white vinegar	• Shape changed • Colour changed • Shrinked • Glossy • Smooth
33		HB	2b	water white sugar white vinegar	• Shape changed • Colour changed • Shrinked • Broken • Glossy
15		SF	1	Water Glycerine	• Shape changed • Colour changed • Shrinked • Rough • Fibrous • Stretchable
9		SF	2a	Water Glycerine	• Colour changed • Shrinked • Matt • Rough • Stretchable
26		SF	2b	Water Glycerine	• Shape changed • Colour changed • Shrinked • Stretchable • Matt

Sample No	Picture	Category	Agar Type	Additives	Observations
8		SF	3	Water Glycerine	• Shrinked • Stretchable • Rough • Fibrous
7		SF		Water Cornstarch Glycerine	• Shrinked • Smooth • Matt • Torn
15		SF	1	Water Cornstarch Glycerine	• Colour changed • Shrinked • Rough • Matt • Torn
11		SF	2a	Water Cornstarch Glycerine	• Shape changed • Colour changed • Rough • Matt
12		SF	3	Water Cornstarch Glycerine	• Colour changed • Shrinked • Rough • Matt • Torn
20		SF	2a	Water Glycerine Brown sugar	• Colour changed • Shrinked • Rough • Matt

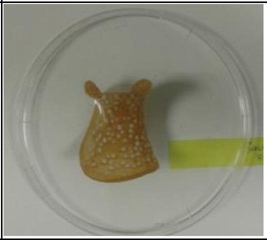
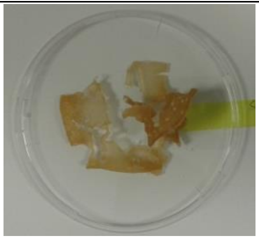
Sample No	Picture	Category	Agar Type	Additives	Observations
21		SF	2a	Water Glycerine Brown sugar	• Colour changed • Shrinked • Rough • Matt
22		SF	2a	Water Glycerine Brown sugar	• Colour changed • Shrinked • Rough • Matt
23		SF	2a	Water Glycerine Brown sugar	• Colour changed • Shrinked • Rough • Matt
29		SF	2b	Water Glycerine Brown sugar	• Shape changed • Colour changed • Shrinked • Smooth • Matt
30		SF	2b	Water Glycerine Brown sugar	• Shape changed • Colour changed • Shrinked • Smooth • Matt
31		SF	2b	Water Glycerine Brown sugar	• Shape changed • Colour changed • Shrinked • Smooth • Matt

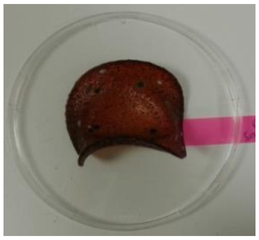
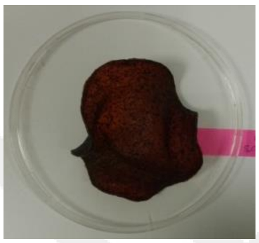
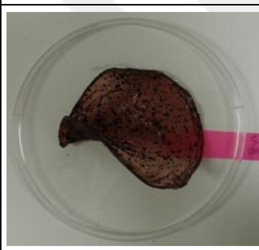
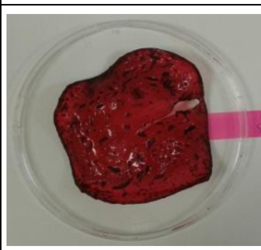
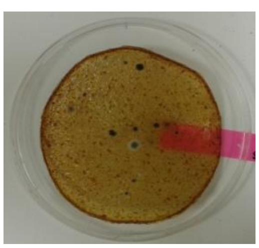
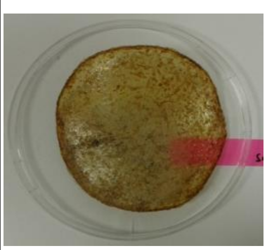
Sample No	Picture	Category	Agar Type	Additives	Observations
16		SF	3	Water Glycerine Brown sugar	• Colour changed • Shrinked • Rough •Torn • Matt
17		SF	3	Water Glycerine Brown sugar	• Colour changed • Shrinked • Rough • Glossy
18		SF	3	Water Glycerine Brown sugar	• Colour changed • Shrinked • Rough • Glossy
19		SF	3	Water Glycerine Brown sugar	• Colour changed • Shrinked • Rough • Glossy
32		SF	2b	Water Glycerine White vinegar	• Shape changed • Colour changed • Shrinked • Smooth • Glossy
41		SF	3	Water Glycerine White vinegar	• Colour changed • Shrinked • Rough • Glossy

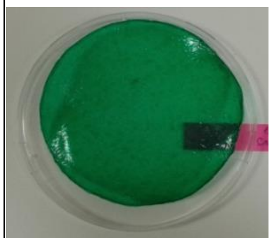
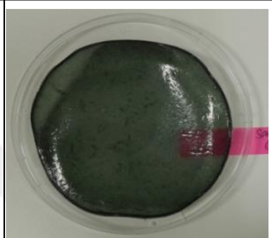
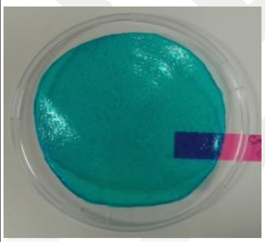
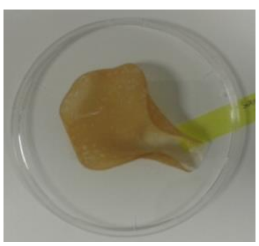
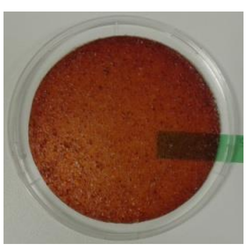
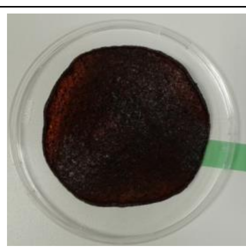
Through the rest of experiments type 3 agar was selected to conduct further coloured and textured samples because of its strong, flexible character. Two basic combinations (**agar + water** and **agar + glycerine + water**) with colourant or textured material were selected to conduct further experiments. Colourants and textured materials reacted differently, and respective changes are given in Table 5.3. Coloured samples are also divided into same three categories based on surface texture (H.F, S.F and H.B) as categorised main experiments in table 5.2. Spices, food colours, fruit peels, herbal tea and coffee were used as colourants. Some of the samples got contaminated, and some of them got broken or torn. These changes appeared during the drying period. Some noticeable factors came out through experiments and literature review support.

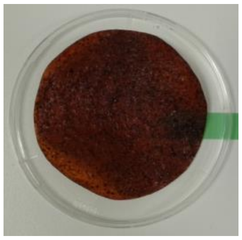
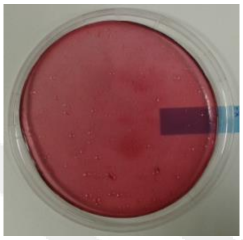
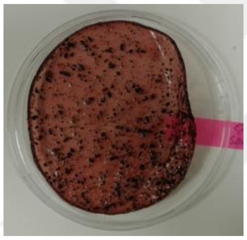
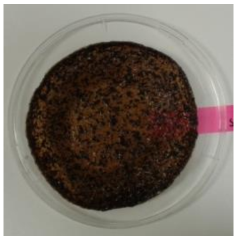
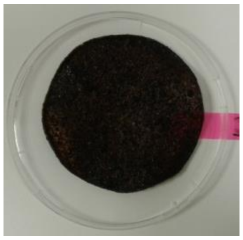
- Spices act as antimicrobial agents such as cinnamon and turmeric (Valencia-Chamorro, et al. 2011).
- Cinnamon gives strength to the material and gives rough fabric like feel with added glycerine.
- The smell of spices and tea disappears by the period of three weeks.
- Addition of food colours does not change the properties of material significantly.

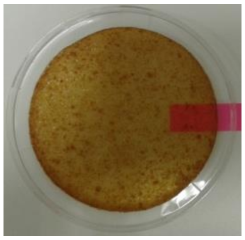
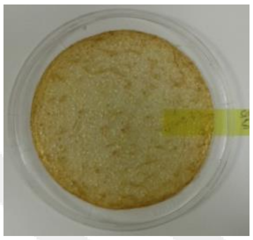
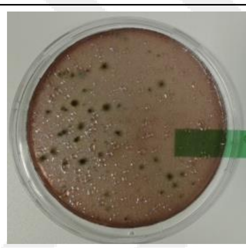
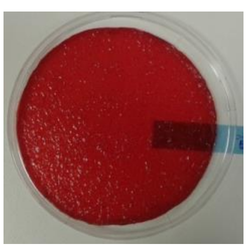
Table 5.3 Coloured and Textured Observed Changes

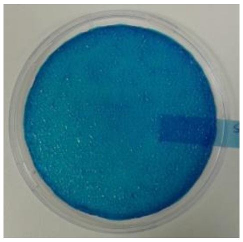
Sample No	Picture	Category	Agar Type	Additives	Observations
35		H.B	2b	Water Sago Seed	• Shape changed • Colour changed • Shrinked • Rough • Textured
36		H.B	2b	Water Sago Seed	• Shape changed • Colour changed • Shrinked • Broken • Rough
59		H.B	3	Water Cinnamon	• Shape changed • Colour changed • Shrinked • Rough

Sample No	Picture	Category	Agar Type	Additives	Observations
60		H.B	3	Water Red Chilli	• Contaminated • Shape changed • Colour changed • Shrinked • Rough • Textured
61		H.B	3	Water Turmeric	• Shape changed • Colour changed • Shrinked • Rough • Textured
58		H.B	3	Water Rosehip	• Contaminated • Shape changed • Colour changed • Shrinked • Rough • Textured
62		H.B	3	Water Hibiscus	• Shape changed •Colour changed • Shrinked • Glossy • Broken • Rough • Fibrous
66		H.F	3	Water Orange Zest	• Contaminated • Shape changed • Colour changed • Shrinked • Fibrous • Rough
67		H.F	3	Water Orange Zest	• Contaminated • Shape changed • Colour changed • Shrinked • Fibrous • Rough

Sample No	Picture	Category	Agar Type	Additives	Observations
63		H.F	3	Water Green Food Colour	• Shape changed • Glossy • Smooth • Fibrous • Breakable
64		H.F	3	Water Black Food Colour	• Shape changed • Glossy • Smooth • Fibrous • Breakable
65		H.F	3	Water Blue Food Colour	• Shape changed • Glossy • Smooth • Fibrous • Breakable
37		S.F	2b	Water Glycerine Sago Seed	• Shape changed • Colour changed • Shrinked • Rough • Textured
46		S.F	3	Water Glycerine Red Chilli	• Shape changed • Colour changed • Shrinked • Rough • Textured
49		S.F	3	Water Glycerine Cinnamon	• Shape changed • Colour changed • Shrinked • Rough • Textured

Sample No	Picture	Category	Agar Type	Additives	Observations
50		S.F	3	Water Glycerine Turmeric	• Shape changed • Colour changed • Shrinked • Rough • Textured
52		S.F	3	Water Glycerine Hibiscus	• Shape changed • Colour changed • Shrinked • Smooth • Fibrous
57		S.F	3	Water Glycerine Rosehip	• Shape changed • Colour changed • Shrinked • Rough • Textured
68		S.F	3	Water Glycerine Green tea	• Shape changed • Colour changed • Shrinked • Rough • Textured
70		S.F	3	Water Glycerine Coffee	• Shape changed • Colour changed • Shrinked • Rough • Textured
55		S.F	3	Water Glycerine Orange zest	• Contaminated • Shape changed • Colour changed • Shrinked • Rough • Textured

Sample No	Picture	Category	Agar Type	Additives	Observations
55a		S.F	3	Water Glycerine Orange zest	• Shape changed • Colour changed • Shrinked • Rough • Textured
56		S.F	3	Water Glycerine Lemon zest	• Shape changed • Colour changed • Shrinked • Rough • Textured
47		S.F	3	Water Glycerine Cherry	• Contaminated • Shape changed • Colour changed • Shrinked • Rough • Fibrous
48		S.F	3	Water Glycerine Cherry Juice	• Contaminated • Shape changed • Colour changed • Shrinked • Rough • Fibrous
51		S.F	3	Water Glycerine Red Food Colour	• Shape changed • Colour changed • Shrinked • Rough • Fibrous
53		S.F	3	Water Glycerine Green Food Colour	• Shape changed • Colour changed • Shrinked • Rough • Fibrous

Sample No	Picture	Category	Agar Type	Additives	Observations
54		S.F	3	Water Glycerine Blue Food Colour	• Shape changed • Colour changed • Shrinked • Rough • Fibrous
69		S.F	3	Water Glycerine Onion skin	• Shape changed • Colour changed • Shrinked • Rough • Textured • Torn

CHAPTER 6

EVALUATION THROUGH MATERIAL DRIVEN DESIGN

6.1 Material Driven Design (MDD)

The approach used to evaluate material samples is the MDD method. It enables the designer thoroughly to understand, analyze and create a material experience. It helps build and understand material specific qualities and enables to understand its design related qualities and application possibilities. The MDD method used here helps to understand the material, find out its added value and design applications through creating material experience. The MDD method is based on four main steps;

1. Understanding the material: technical and experiential characterization
2. Creating materials experience vision
3. Manifesting materials experience patterns
4. Designing material/product

These four steps are further subdivided in order to develop the material. Agar based material was developed, analyzed and its possible applications proposals were achieved through different steps of MDD method. This chapter explains the steps of the MDD methods how they were applied, and how the outcomes were documented.

6.2 Evaluation

The MDD can be applied based on three possible scenarios for a starting point. The first and second scenarios are based on known and unknown materials to evaluate, incorporate or develop design with the particular material. These scenarios accompany fully developed materials while the third scenario is based on a semi-developed material or it starts with a material proposal itself. The third scenario is about development, evaluation and possible material applications through MDD method. For further development the most essential part is to understand the material, to known its technical properties, sensorial qualities and define its character.

6.2. 1 Understanding the Material

This step is about technical and experimental material characterization. To understand the material, three basic steps are defined in the MDD method; tinkering, user studies and bench marking. These steps enable the designer to evaluate, further develop and characterize the material in question.

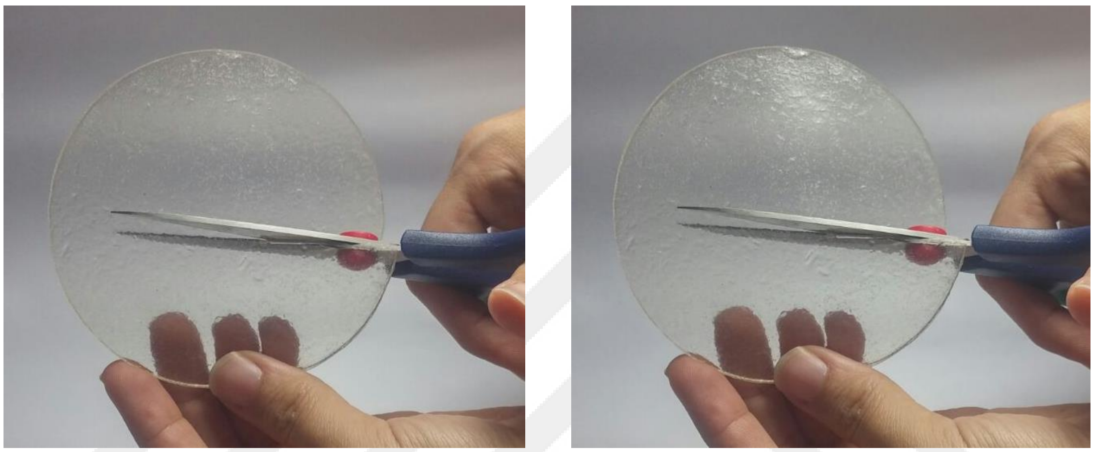
6.2.1.1 Tinkering

To achieve technical characteristics and to further develop a material, tinkering with the material is recommended. Material tinkering is a design practice characterised by specific features, procedures, supportive activities, and goals. Tinkering aims to extract data, understand material properties, understand constraints, and recognise its potentialities. Material Tinkering helps to gain knowledge about materials and to develop procedure (material making) through experiential learning. It allows generating unique and meaningful visions by making and manipulating materials. The Material tinkering process encourages continuous development. The aim of this process is to understand the physical properties, inherent qualities and constraints of a meterial (Paris et al., 2017). Here tinkering with material refers to the exploration of material with multiple experiments like- cutting, bending, burning, smashing or combining with other materials. Direct and creative experimentations on material samples help to formulate ingredients (adding or changing quantities), process (changing variables like temperature) and develop new treatments (colour, surface texture and so on).

In case of agar based material, various experiments were performed to formulate a basic recipe of material to find compatible materials. The experimentation details with multiple ingredients are already described in chapter 4 (methodology)and chapter 5 (time-dependent changes). Water, glycerine, sugar, vinegar and cornstarch were added to find basic key ingredients and observe compatibility with agar. Food colour, spices, teas and fruit peels were added to give colour and textures. These experiments and their observed changes were already mentioned in the previous chapters. From multiple experiments, preferred character samples were selected to further perform technical tests.

On sample 8 (agar + water + glycerine) and sample 2 (agar + water), multiple experiments were performed to explore their technical properties and constraints. Cutting, tearing, heating, burning, stretching, bending, dyeing, water and UV resistance tests were performed with samples.

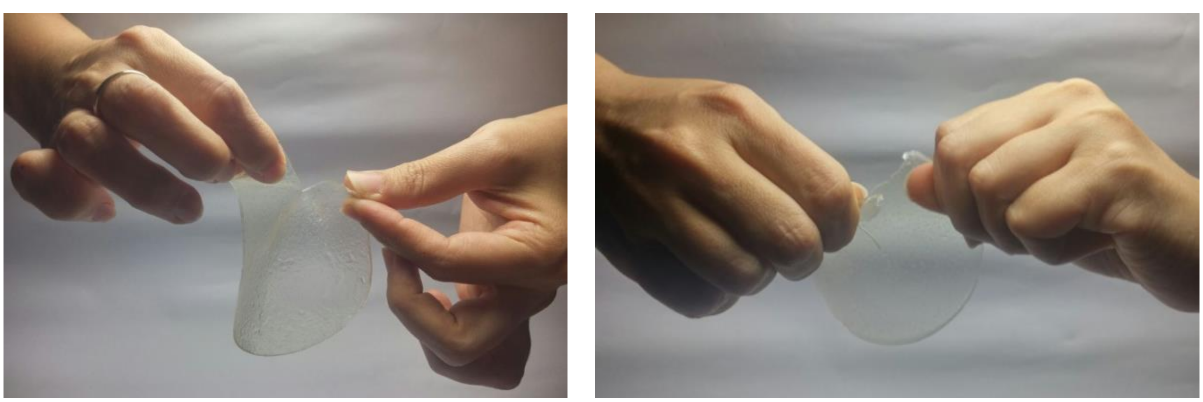
Cutting: Cutting test were performed through cutting both sample 2 and 8 through scissors. Though sample 2 is harder and more like plastic (PET) texture, it can be easily cut into any shape. Sample 8 is soft so there was no problem in cutting it.



Sample 8 Sample 2

Fig 6.1 Cutting test of sample 8 and 2

Tearing: Tearing test was performed by tearing apart both samples. Sample 8 was easily torn apart, however for 2 little force was required to tear it. It was observed that sample 2 is more elastic and flexible.



Sample 8 Sample 2

Fig 6.2 Tearing test of sample 8 and 2

Burning: Neither of the samples are fire resistant: however differences is their burning behaviour. Sample 8 melted, turned black and smelled like burning rubber while sample 2 resulted in white bubbles turned into black when in contact with fire.

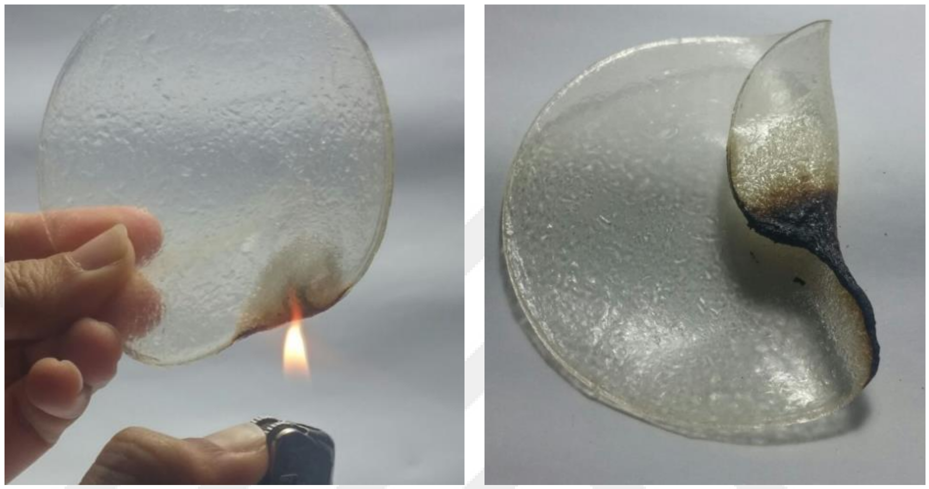


Fig 6.3 Burning test and its resulted sample 8

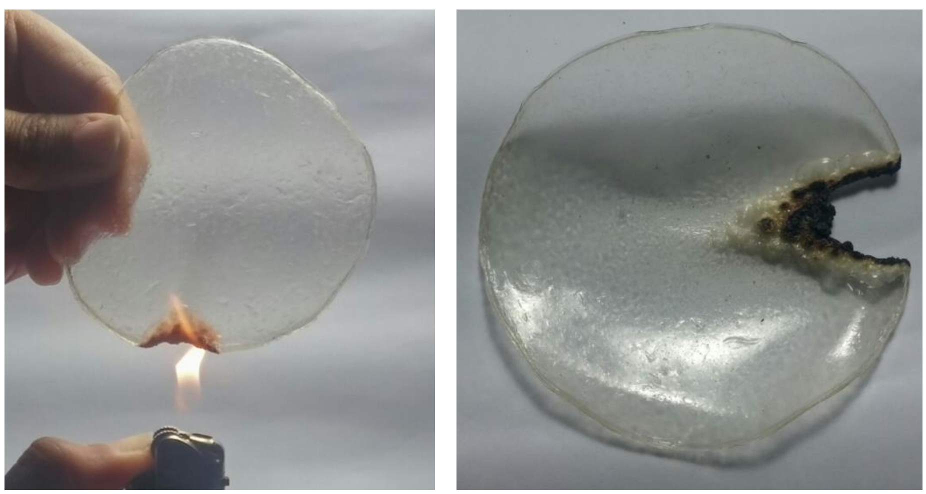


Fig 6.4 Burning test and its resulted sample 2

UV Resistance: Both samples are UV resistant, no change has been observed after exposure to UV for 5 days.

Stretching and Bending: Sample 8 contains glycerine while sample 2 does not. Therefore sample 8 is stretchable and strong. Sample 2 cannot be stretched, however it is flexible and it can easily bend.

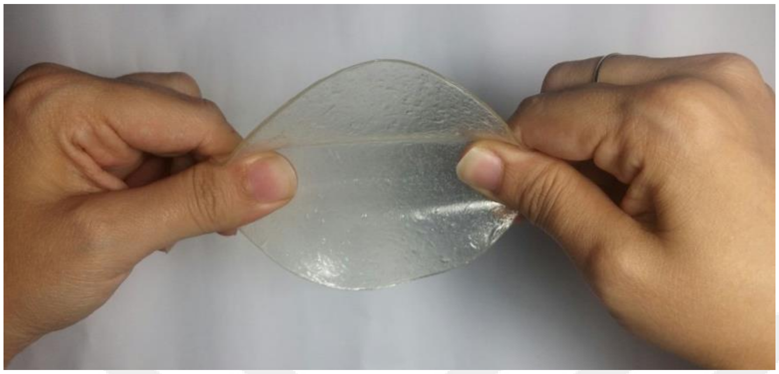



Fig 6.5 Stretching test of sample 8 and bending test of sample 2

Water Resistance: Both samples are resistant to water in a short period. However, when these samples were soaked in water for longer periods (around 30 minutes), they resulted into softer samples, specially sample 2. From hard and flexible it becomes more like sample 8 i.e. soft and flexible like sample 8. Nevertheless sample 8 remains almost the same except it became softer and little weaker.


Sample 8 Sample 2

Fig 6.6 Water resistant of sample 8 and 2

Although sample 2 becomes soft like sample 8, after drying through heating, it becomes hard again like its previous nature.

Fig 6.7 Sample 2 left; wet form after water test and right; dried form after the wet form.

Heat Resistance: Both samples are heat resistant. No change has been observed. Heat resistance test were done by putting samples the on geothermal heaters (around 24℃).

Sample 8

Sample 2

Fig 6.8 Heat resistant of sample 8 and 2

Ironing Test: After the heat resistance test, ironing test was also performed to give shape through heating. Samples were not ironed directly; they were ironed with the help of a cloth. Firstly samples were folded into the desired shape, putting them between a cotton cloth and then they were ironed. Medium level of heat was used for sample 8 but higher heat was need for sample 2 because it is rigid and hard nature. Ironing resulted in constant shape, in case of sample

8 changed into a folded shaped as it was difficult before for sample 8 to be in fold sample 8 because of its elastic nature. In case of sample 2, it has also changed shape but not in folded shape like sample 8.

Sample 8 Sample 2

Fig 6.9 Iron test of sample 8 and 2

Dyeing: Apart from the coloured samples, dying tests were also performed for samples 8 and 2. They were performed to observe external colouring with fabric dye, instead of adding colorants during the production of samples. As these samples are water resistant for short time, their shaped remained and they absorbed the colour of the pigment solution.

Fig 6.10 Dyeing test and its effect on sample 8

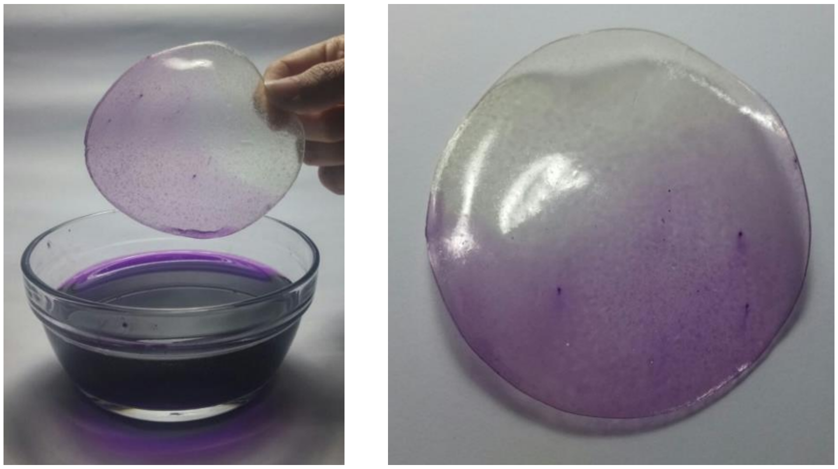


Fig 6.11 Dyeing test and its effect on sample 2

Eating Test: All samples consist of natural and edible materials. In order to check their taste, both sample 8 and 2 were eaten. Both samples were tasteless and edible. Sample 2 is hard so it was difficult to bite and chew while sample 8 is softer and it was more like a tasteless jelly.

Fig 6.12 Eating test; sample 8 (top) and sample 2 (bottom)

6.2.1.2 User Studies

To explore material qualities through sensorial and emotional experience, user studies are suitable. To understand how people perceive the material regarding senses, emotions, meanings and how they interact with it, and to collect inspirations and suggestions from people user studies are suitable. As a suggestion, since it is a novel and unknown material, it could be useful to compare visual expectation and the actual touch and smell experience. Doing user studies like focus groups, questionnaires and interviews using samples of the material, will give insight on how the material is appraised and how it triggers people to use it in a specific manner (Giaccardi & Karana, 2015). The knowledge gained from the experiential characterisation the enables to develop novel material and it is able to perceive the material's suitable applications with experiential levels: sensorial, interpretive, effective and performative.

The questionnaire was developed to achieve sensorial evaluation and material qualities of agar based material samples through user studies (user studies description is given in methodology chapter). Each user was asked to evaluate selected material samples named as A(i) and B(ii) with their coloured samples A (ii, iii, iv) and B (ii, ii, iv) through the combination of qualitative and quantitative questions. Qualitative data was collected by adding open questions at the start of the questionnaire to investigate the material experience. The users were asked to evaluate material samples about their key ingredients, similar materials and possible applications. To obtain quantitative information sensorial evaluation chart was used. The sensorial chart is a combined form of Expressive-Sensorial Atlas (Rognoli, 2010) and Meaning Driven Material Selection (MDMS) Tool (Karana, 2009). The Sensorial evaluation is to sense relevance characteristic like the smell and touch etc to material physical properties like soft, hard and transparency (Parisi et al., 2016).

Samples were categorised into three main groups based on their characteristics already defined in the previous chapter. Two main samples were selected based on their different characteristics. Sample A (i) (sample 8 in Table 4.2, namely is agar + water + glycerine) is soft and stretchable and sample B (i) (sample 2 in Table 4.2, namely is agar + water) is hard and flexible. Coloured samples were also used based on hard and soft samples with same ingredient structures except the addition of the colourant.

- Sample A (ii) is sample 53 and B (ii) is sample 63 with green food colour.
- Sample A (iii) is sample 49 and B (iii) is sample 59 with cinnamon powder.
- Sample A (iv) is sample 50, and B (iv) is sample 61 with turmeric powder

Category "A" Samples **Category "B" Samples**

Fig 6.13 Selected coloured samples of A (ii, iii, iv) and B (ii, iii, iv) for user studies

Qualitative data is about the main ingredient of material samples and their similar materials. Open-ended questions about the key ingredient and similar materials helped to select materials for benchmarking. The “Possible uses” part was used to define design applications of the novel material samples. Users came up with interesting and varied possible applications based on their respective groups, i.e. Design (Industrial, Fashion and Interior Architecture), Culinary Art and Food Engineering and random students. Sensorial evaluation and material characterisation were perceived by the users in a range of seven values between two different characteristics like soft or hard. Qualitative and quantitative data were analysed with the help of tables and visualised into tables, charts and graphs. The questionnaire is given in the Appendix- 1

The first question of the questionnaire was to guess the key ingredient of samples from respected categories. Students guessed as overall key ingredients based on category “A” (soft samples) and category “B” (hard samples). Guessed key ingredient by the students are visualised into table 6.1 and 6.2 based on the common answer percentage by the number of students.

Table 6.1 Overall “A” Category Samples Key Ingredient by User Studies

Category " A"	Percentage		
Key Ingredient	Design	Culinary and Food Eng.	Random
Silicone	33%		
Plastic	47%	13%	40%
Rubber	13%		40%
Cellulous material	7%		
Gelatine		27%	13%
Agar agar		33%	
Organic powder			7%
Starch		27%	

Interestingly, only culinary art and food engineering student guessed agar agar as main ingredient and rest of the groups including, some of the culinary art and food engineering. Students perceived as plastic, rubber or Silicone. Category A (soft samples) were perceived more as Silicone, rubber and plastic. However for category B (hard samples) most of the percentage perceived the samples as plastic, 80% of random group students perceived B category samples as plastic. Some organic materials were also named by the students as main source ingredient of samples like starch, organic powder and gelatine.

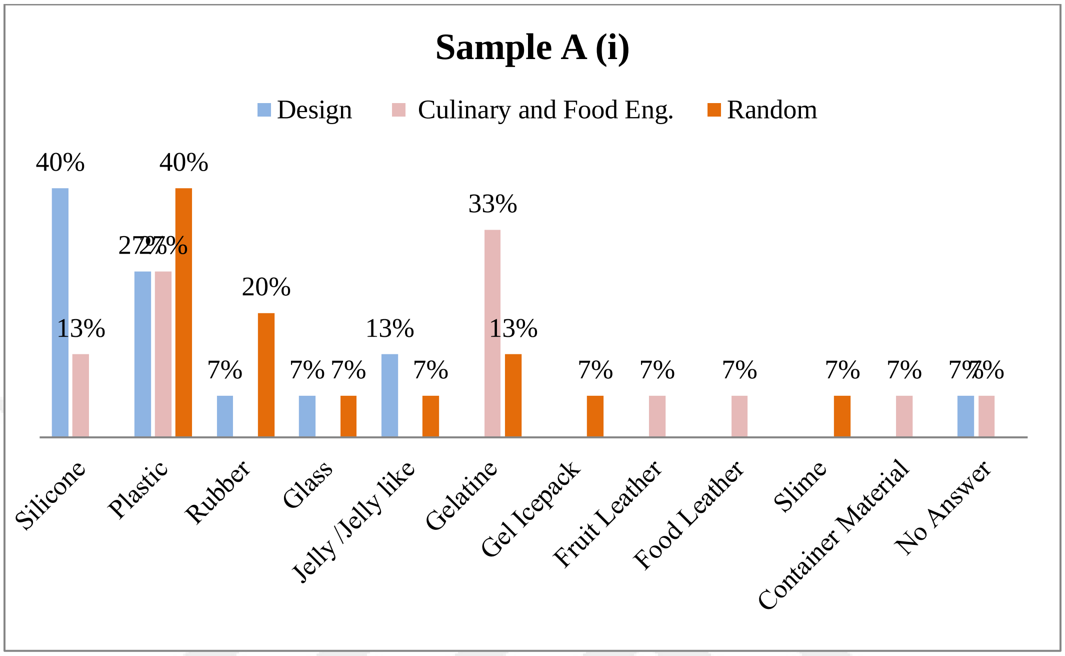
Table 6.2 Overall "B" Category Samples Key Ingredient by User Studies

Category " B"	Percentage		
Key Ingredient	Design	Culinary and Food Eng.	Random
Silicone	7%		
Plastic	67%	60%	80%
Rubber			
Cellulous material	7%		
Gelatine		7%	
Agar agar		27%	
Organic powder			7%
Starch		13%	
Dry glue			13%
Chemical or acid	13%		
Harden nail varnish	7%		

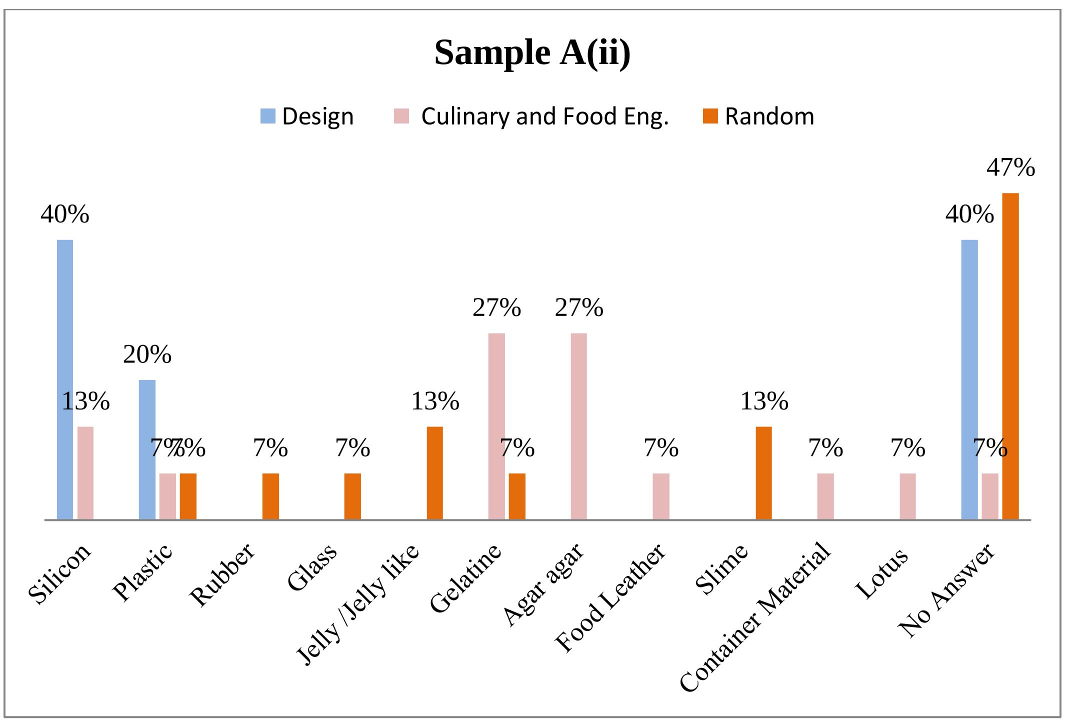
The second question was based on the similar material. Students were asked to answer each sample's similarity with any existing material. Each group gave various answers for category A and B samples. Similar materials for each sample from both categories are visualised into the bar graphs which shows average percentage of the materials named by each group.

For category "A" the mostly mentioned similar materials are silicone and plastic. However Culinary Art and Food engineering students mostly mentioned gelatine and agar agar as one of the most similar material to samples A(i) and A(ii). In the case of other groups, they have mentioned silicone, plastic, rubber and even jelly-like similarities towards A(i) and A(ii). For A(iii) and A(iv) samples, random and various similarities have been mentioned by the students like chips, burnt salami, burnt orange peel, etc. Interestingly some of the students have also mentioned the spice for A(iii), and A(iv) samples and Culinary Art and Food Engineering students have mentioned cinnamon as the most similar material for sample A(iii). The students also used the word fruit leather or dried fruit pulp for sample A(iii) and A(iv), which gives the insights of the possible use of those samples similar to the existing materials.

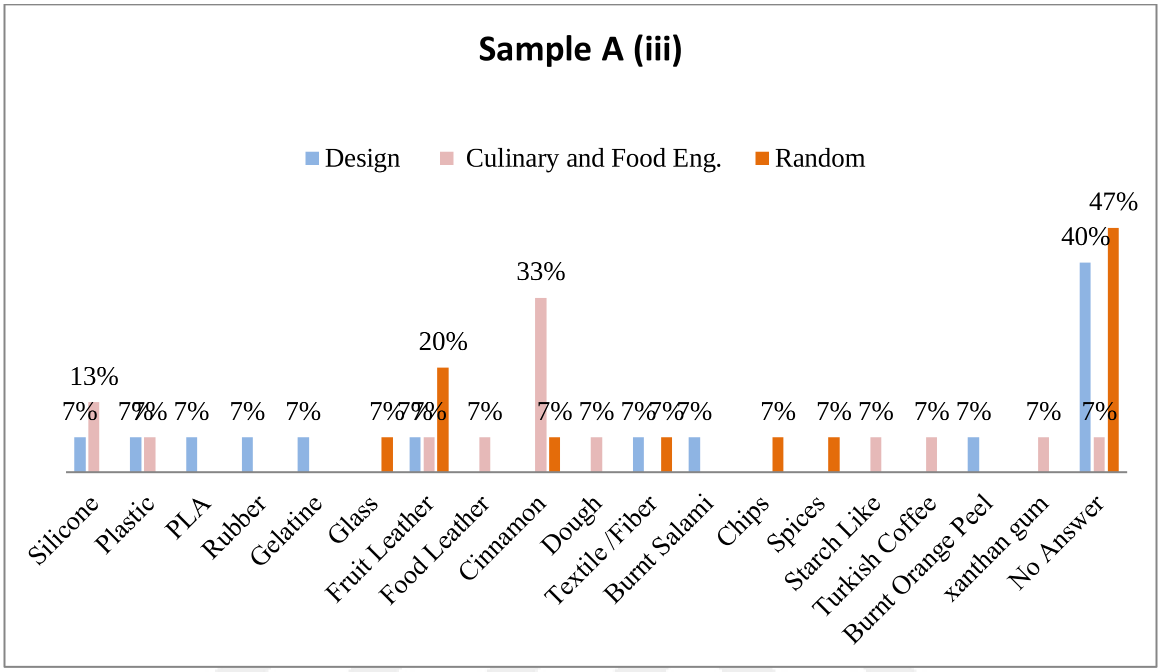
Graph 6.1 Sample A(i) Similar Materials by User Studies



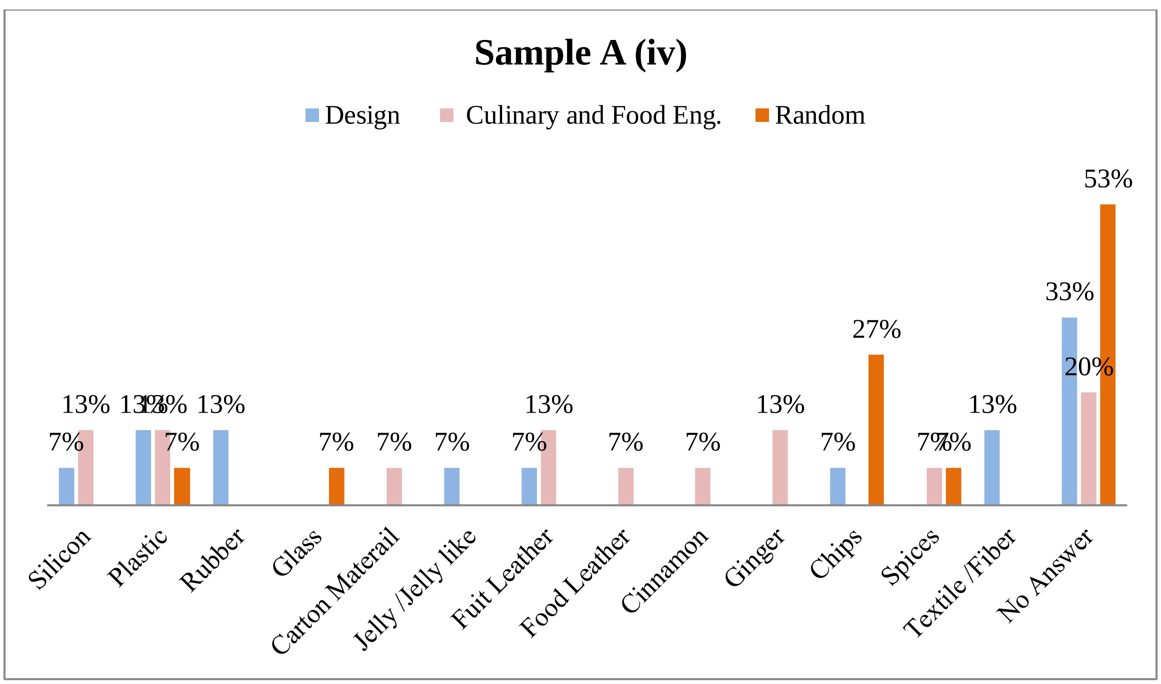
Graph 6.2 Sample A(ii) Similar Materials by User Studies



Graph 6.3 Sample A(iii) Similar Materials by User Studies



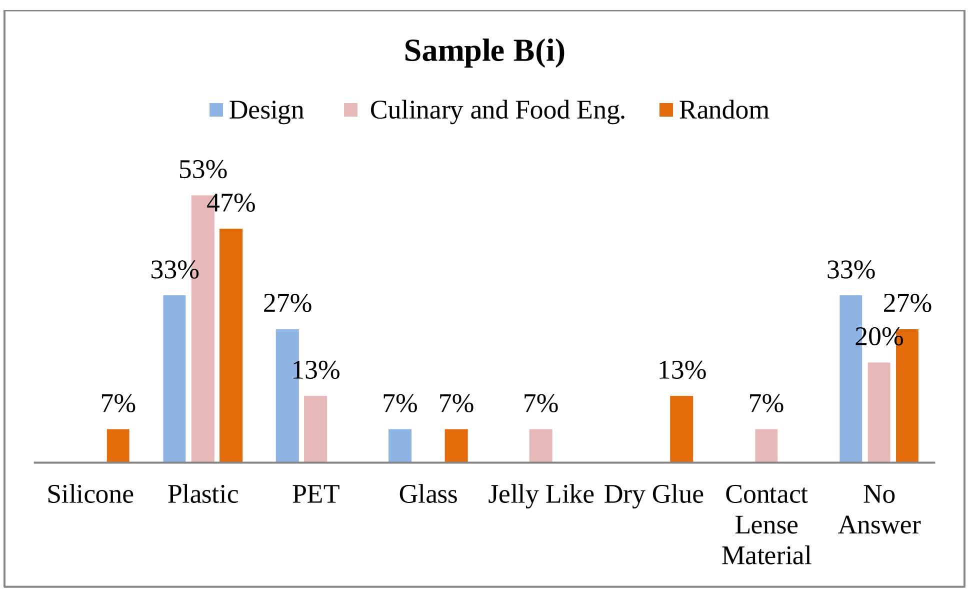
Graph 6.4 Sample A(iv) Similar Materials by User Studies



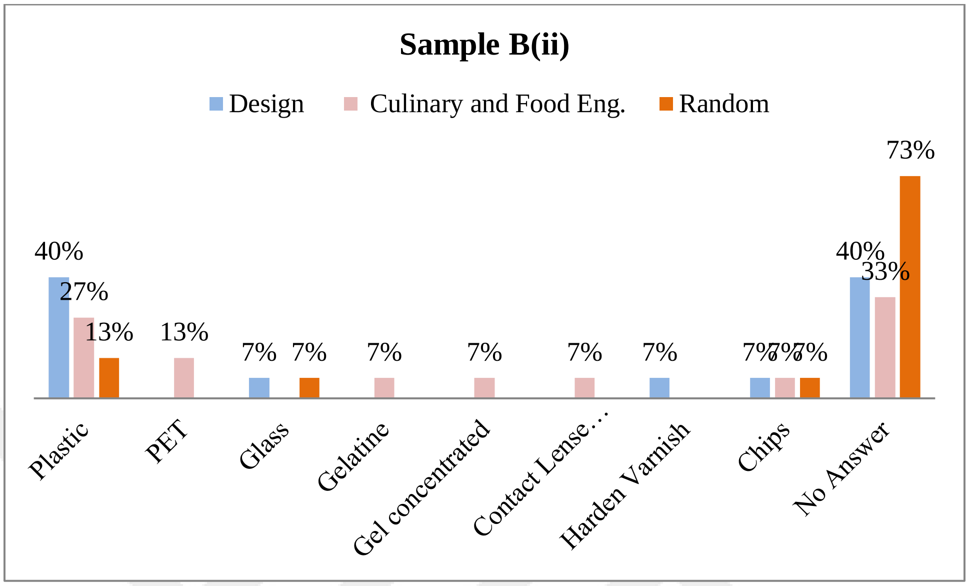
For category “B” the mostly mentioned material overall is plastic as a similar material. Interestingly design students and culinary art and food engineering have actually mention PET as the second most similar material to sample B(i) and some in B(ii) too. Most of the random students and even design students have mentioned chips for samples B(iii) and B(iv). However, instead of chips, culinary art and food engineering students have used cinnamon chips in B category for sample B (iii)**.** Unfortunately there is a big number of students from all groups especially random students who could not understand or were able to find similar material in the B category. For those who have not filled or gave answers, *No Answer* part is given in the data evaluation in the form of the visualized graphs in the text. Percentage of *No Answer* part of each group is given in both categories A and B for each sample.

Both categories A and B results of similar material are based on the existing soft and hard material respect to each category. For both categories most similar materials overall is recorded as plastic. Some of the students have also mentioned as soft and hard plastic with respect to category A (soft samples) and category B (hard samples). For category A many students have mentioned silicone because of the similar nature while in the second category a big number of students have mentioned PET or some as hard plastic

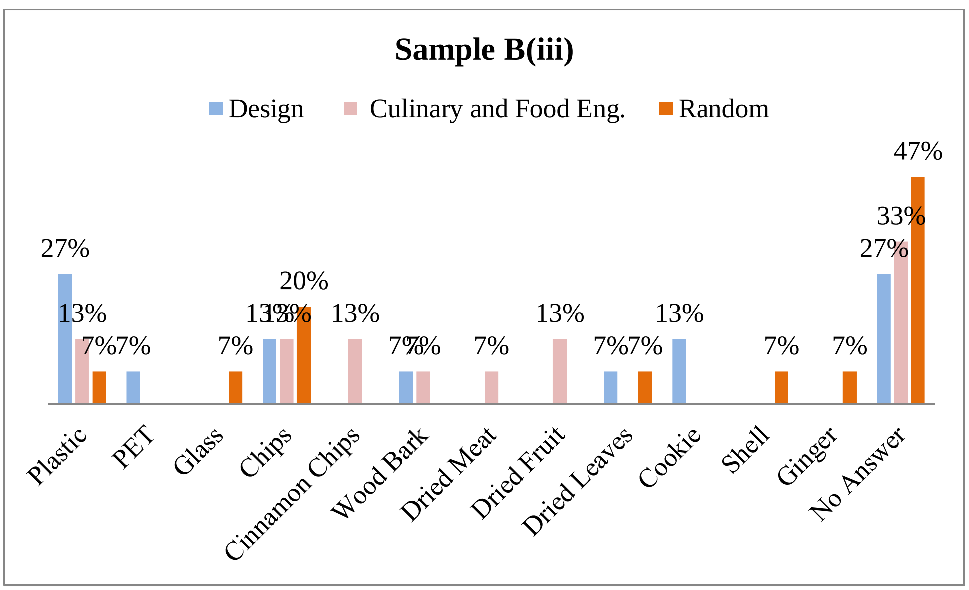
Graph6.5 Sample B (i) Similar Materials by User Studies



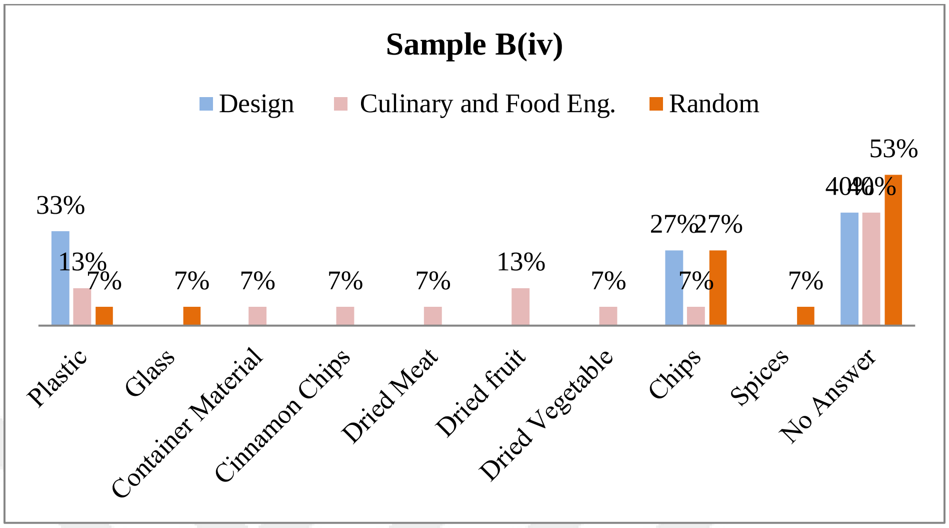
Graph 6.6 Sample B (ii) Similar Materials by User Studies



Graph 6.7 Sample B (iii) Similar Materials by User Studies



Graph 6.8 Sample B (iv) Similar Materials by User Studies



The third question is based on the possible usage of the given samples. Students were asked to suggest suitable and possible applications based on their evaluation. Students gave response in respect to their fields. Culinary Art and Food Engineering students suggested possible applications within respect to food applications while the design students gave more design and product based answers. In case of random students, they gave answers based on existing similar material products. The overall possible uses are visualised into tables in respect to A and B categories based on the soft and hard material samples.

For category A most of the possible applications are based on the similarities to soft materials, like the existing similar materials for example many random students have mentioned plastic bags and plastic table covers. However each group have answered based on their knowledge, experience and perception. Therefore interesting answers have been received by the Culinary Art and Food Engineering students based on their knowledge on materials. As most of students from these fields guessed agar as the source material and some students mention as similar material and guessed gelatine. They have shown up possible applications of the material as a new food packaging material or in the use of food utensils.

Table 6.3 Overall "A" Category Possible Uses by User Studies

Possible Uses of Category "A"		
Design Students	Food and Culinary	Random
Textile use	Food decor	Cup mat
Clothes	Food mat	Bags
Bags	Fake decor	Bands
Mobile cover	Edible packaging	Bracelets
Table mat	Food coating	Jelly slippers
Soft toys	Biodegradable plastic bags	Plates
Undergarments	Baby plates	Plastic bag
Use instead of silicone	Plates	Table plastic cover
Pencil case	Cup mat	
Use in non slip surface	Box making inner coating	
Flexible material coverage	Material for saving fragile objects	
Sneakers		

Table 6.4 Overall "B" Category Possible Uses by User Studies

Possible Uses of Category "B"		
Design Students	Food and Culinary	Random
Cups	Plastic plates	Decoration piece
Accessories	Food art	Plates
Bottles	Cupcake decoration	Food container
Containers	Cup mat	Coke bottle
Stained glass for window	Storage box	Glass cover
Visual material	Home decor	Fixing material
Vase material	Spoons	Massage material
Plastic kitchen utensils	Feeding bottle	Potpourri (dry flowers)
Use in decoration items	Salad decoration	
Pots	Papadum (thin dough crisp)	
Jewellery	Pastry decor	
	Use for toys	

For the case of B category overall, most of the students suggested applications found for hard plastic applications in the food industry like plates, spoon, and kitchen utensils. Some of the culinary art students and food engineering students suggested possible applications as a decorative food ingredient to the dishes, like in the use of salads or cake decor. However overall response and suggestions are interesting and applicable to the design fields which was one of the main of the thesis to find possible applications of the novel material.

For the fourth question, each group of the students were asked to evaluate samples depending on the given sensorial chart. Students were asked to grade each sample between seven scales from -3 to 3 including 0 from two opposite characteristics like opaque and transparent. The sensorial chart is based on physical and sense relevance characteristics, ranging from hardness to pleasant smell of the material. The sensorial charts are evaluated based on each sample into the form of tables. The results are evaluated as whole instead of separating them into each group of students. The tables show the frequency based on the total number of students (45). Each table represents each sample with respective categories.

Table 6.5 Sample A(i) overall students sensorial chart evaluation

SAMPLE A(i)	TOTAL FREQUENCY						
Sensorial Evaluation	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**
subtle colour- vivid colour	29	7	6	1	0	0	2
opaque - transparent	3	1	2	0	0	11	28
matt - glossy	2	1	0	6	9	14	13
non reflective- reflective	5	7	0	12	4	0	17
non fibrous- fibrous	17	1	2	1	12	9	3
regular -irregular texture	11	5	9	4	7	0	9
soft-hard	18	12	5	4	1	2	3
smooth- rough	13	7	5	7	6	7	0
non sticky-sticky	14	7	3	6	7	2	6
dry-wet	19	8	4	6	4	0	4
cold-warm	7	1	7	28	0	1	1
inflexible- flexible	0	0	0	4	2	10	29
fragile-resistant	5	5	2	5	5	8	15
lightweight-heavy	19	7	8	2	4	1	4
odourless-smelly	22	10	1	8	4	0	0
disgusting-pleasant smell	1	0	5	36	1	1	1

Table 6.6 Sample A(ii) overall students sensorial chart evaluation

SAMPLE A(ii)	TOTAL FREQUENCY						
Sensorial Evaluation	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**
subtle colour- vivid colour	3	1	3	17	9	10	2
opaque - transparent	0	2	3	6	14	16	4
matt - glossy	4	1	0	9	5	13	13
non reflective- reflective	7	8	2	14	3	7	4
non fibrous- fibrous	8	2	2	9	10	10	4
regular -irregular texture	4	6	6	5	2	10	12
soft-hard	16	9	8	5	3	2	2
smooth- rough	5	8	5	8	9	8	2
non sticky-sticky	5	14	2	11	6	6	1
dry-wet	17	3	1	15	6	1	2
cold-warm	3	3	1	30	2	3	3
inflexible- flexible	0	0	0	3	8	10	24
fragile-resistant	4	1	4	2	11	3	20
lightweight-heavy	22	6	2	3	6	4	2
odourless-smelly	6	6	1	15	9	5	3
disgusting-pleasant smell	4	4	5	23	7	1	1

Table 6.7 Sample A(iii) overall students sensorial chart evaluation

SAMPLE A(iii)	TOTAL FREQUENCY						
Sensorial Evaluation	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**
subtle colour- vivid colour	4	1	3	0	3	6	28
opaque - transparent	18	12	1	2	2	6	4
matt - glossy	11	7	4	3	7	1	12
non reflective- reflective	16	7	2	13	4	1	2
non fibrous- fibrous	5	6	0	5	6	5	18
regular -irregular texture	3	4	2	3	3	11	19
soft-hard	11	8	4	6	0	10	6
smooth- rough	5	1	6	5	7	10	11
non sticky-sticky	11	11	1	12	1	6	3
dry-wet	21	5	2	10	3	3	1
cold-warm	1	3	3	33	1	3	1
inflexible- flexible	0	0	0	2	4	16	23
fragile-resistant	7	7	5	3	7	5	11
lightweight-heavy	19	8	2	6	1	4	5
odourless-smelly	6	0	1	10	9	9	10
disgusting-pleasant smell	3	4	8	14	5	10	1

Table 6.8 Sample A(iv) overall students sensorial chart evaluation

SAMPLE A(iv)	TOTAL FREQUENCY						
Sensorial Evaluation	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**
subtle colour- vivid colour	2	0	2	1	5	24	11
opaque - transparent	8	14	3	7	6	5	2
matte - glossy	9	6	8	5	5	6	6
non reflective- reflective	10	14	0	9	5	4	3
non fibrous- fibrous	4	2	1	3	11	10	14
regular -irregular texture	2	1	6	4	8	9	15
soft-hard	7	8	3	6	8	4	9
smooth- rough	4	5	6	2	10	6	12
non sticky-sticky	10	10	4	9	4	5	3
dry-wet	14	12	4	10	1	0	4
cold-warm	3	4	4	28	3	1	2
inflexible- flexible	0	0	0	2	7	20	16
fragile-resistant	5	2	4	6	4	6	18
lightweight-heavy	21	2	8	3	3	6	2
odourless-smelly	4	1	2	4	13	10	11
disgusting-pleasant smell	3	4	7	17	7	4	3

Sensorial evaluation of samples is evaluated separately for each sample. For category A it has been observed that Sample A (i) and Sample A(ii) have more similar results except for the subtle colour. Otherwise overall results are similar to each other within respect to overall properties. Both are glossy, flexible, resistant, soft with transparent fibrous textures. In contrast Sample, A(iii) and A(iv) are matte, opaque, rough with vivid coloured samples. Overall all samples from category A are soft, flexible and resistant to nature according to participents. For smell, most of the students have marked as 0. Some of the students have also marked sample A(iii) and A(iv) with a pleasant smell and some with a disgusting smell. However, most of the students remained neutral.

In case of B categories, all samples are being marked as hard and rough. Same as the category A, first two samples B(i) and B(ii) have similar results and other two B(iii), and B(iv) have their similarities in respect to characteristics. First two samples are transparent, glossy, flexible, and resistant while the other two are opaque, matte, rough, fragile and inflexible. The detailed results are mentioned in the form frequency level visualised through given tables in respect to each sample. For smell overall students remained neutral in all samples of category B.

Table 6.9 Sample B(i) overall students sensorial chart evaluation

SAMPLE B(i)	TOTAL FREQUENCY						
Sensorial Evaluation	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**
subtle colour- vivid colour	33	5	2	3	0	1	1
opaque - transparent	0	5	0	0	1	7	32
matt - glossy	8	0	0	0	8	18	11
non reflective- reflective	8	4	0	3	10	5	15
non fibrous- fibrous	18	1	1	3	11	7	4
regular -irregular texture	11	6	3	12	1	6	6
soft-hard	2	1	7	5	5	19	6
smooth- rough	6	1	5	14	7	11	1
non sticky-sticky	9	3	1	20	7	2	3
dry-wet	31	4	0	4	3	1	2
cold-warm	2	1	0	39	0	1	2
inflexible- flexible	0	0	4	4	6	16	15
fragile-resistant	3	15	3	6	2	6	10
lightweight-heavy	27	7	0	7	0	3	1
odourless-smelly	19	3	4	15	2	1	1
disgusting-pleasant smell	1	1	1	41	0	1	0

Table 6.10 Sample B(ii) overall students sensorial chart evaluation

SAMPLE B(ii)	TOTAL FREQUENCY						
Sensorial Evaluation	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**
subtle colour- vivid colour	4	0	4	11	5	16	5
opaque - transparent	1	1	4	3	14	13	9
matt - glossy	5	4	1	4	3	18	10
non reflective- reflective	8	4	4	6	8	5	10
non fibrous- fibrous	8	2	3	6	12	8	6
regular -irregular texture	8	10	1	4	12	4	6
soft-hard	2	0	4	4	14	11	10
smooth- rough	1	2	4	13	12	6	7
non sticky-sticky	15	9	0	14	4	1	2
dry-wet	18	3	1	14	4	2	3
cold-warm	3	3	4	27	2	3	3
inflexible- flexible	1	1	3	2	7	16	15
fragile-resistant	6	9	5	11	5	4	5
lightweight-heavy	24	9	2	5	1	1	3
odourless-smelly	13	6	3	13	4	5	1
disgusting-pleasant smell	0	3	3	33	2	4	0

Table 6.11 Sample B(iii) overall students sensorial chart evaluation

SAMPLE B(iii)	TOTAL FREQUENCY						
Sensorial Evaluation	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**
subtle colour- vivid colour	0	0	2	2	4	10	27
opaque - transparent	15	7	2	1	2	9	9
matt - glossy	22	9	2	1	2	5	4
non reflective- reflective	27	5	1	6	1	0	5
non fibrous- fibrous	5	1	0	1	3	13	22
regular -irregular texture	7	1	0	0	7	6	24
soft-hard	1	0	0	3	4	7	30
smooth- rough	3	1	1	3	5	9	23
non sticky-sticky	22	4	3	5	2	3	6
dry-wet	23	8	1	10	2	1	0
cold-warm	4	2	2	33	3	1	0
inflexible- flexible	24	9	2	7	3	0	0
fragile-resistant	26	9	0	2	1	3	4
lightweight-heavy	26	7	2	4	3	0	3
odourless-smelly	11	2	2	15	11	3	1
disgusting-pleasant smell	0	2	6	31	2	3	1

Table 6.12 Sample B (iv) overall students sensorial chart evaluation

SAMPLE B(iv)	TOTAL FREQUENCY						
Sensorial Evaluation	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**
subtle colour- vivid colour	1	1	1	1	10	13	18
opaque - transparent	12	11	0	7	5	5	5
matt - glossy	17	11	4	5	3	3	2
non reflective- reflective	25	4	4	4	2	3	3
non fibrous- fibrous	5	3	0	3	4	9	21
regular -irregular texture	6	2	2	2	3	9	21
soft-hard	0	0	0	1	3	11	30
smooth- rough	3	0	1	5	2	8	26
non sticky-sticky	22	1	2	5	3	5	7
dry-wet	21	3	2	12	5	1	1
cold-warm	5	2	1	30	3	3	1
inflexible- flexible	25	5	6	4	1	2	2
fragile-resistant	27	8	2	1	0	2	5
lightweight-heavy	20	8	2	9	2	0	4
odourless-smelly	8	5	3	15	8	2	4
disgusting-pleasant smell	0	2	6	28	4	1	4

6.2.2 Overall Material Experience

Material driven design is based on four action steps. After the first main step (understanding material) creating material experience vision and manifesting material experience patterns are the next two steps. Instead of doing separately and following each step of MDD, in the case of agar-based materials, second and third step are combined into an overall material experience. In this part overall results were combined from tinkering to user studies with the help of Elvin Karana's, the Meanings of Materials (MoM) Tool (Karana, 2010). MoM tool is suggested in the MDD method for manifesting material experience step. Here, in this case, this tool is used to summarise the evaluation (user studies and tinkering) for category A and category B samples. Through this tool, information is summarised into meaning, users (demographic information), material properties (technical and sensorial properties from tinkering and user studies), and product regarding novel material (manufacturing process, finishes, function, and shape).

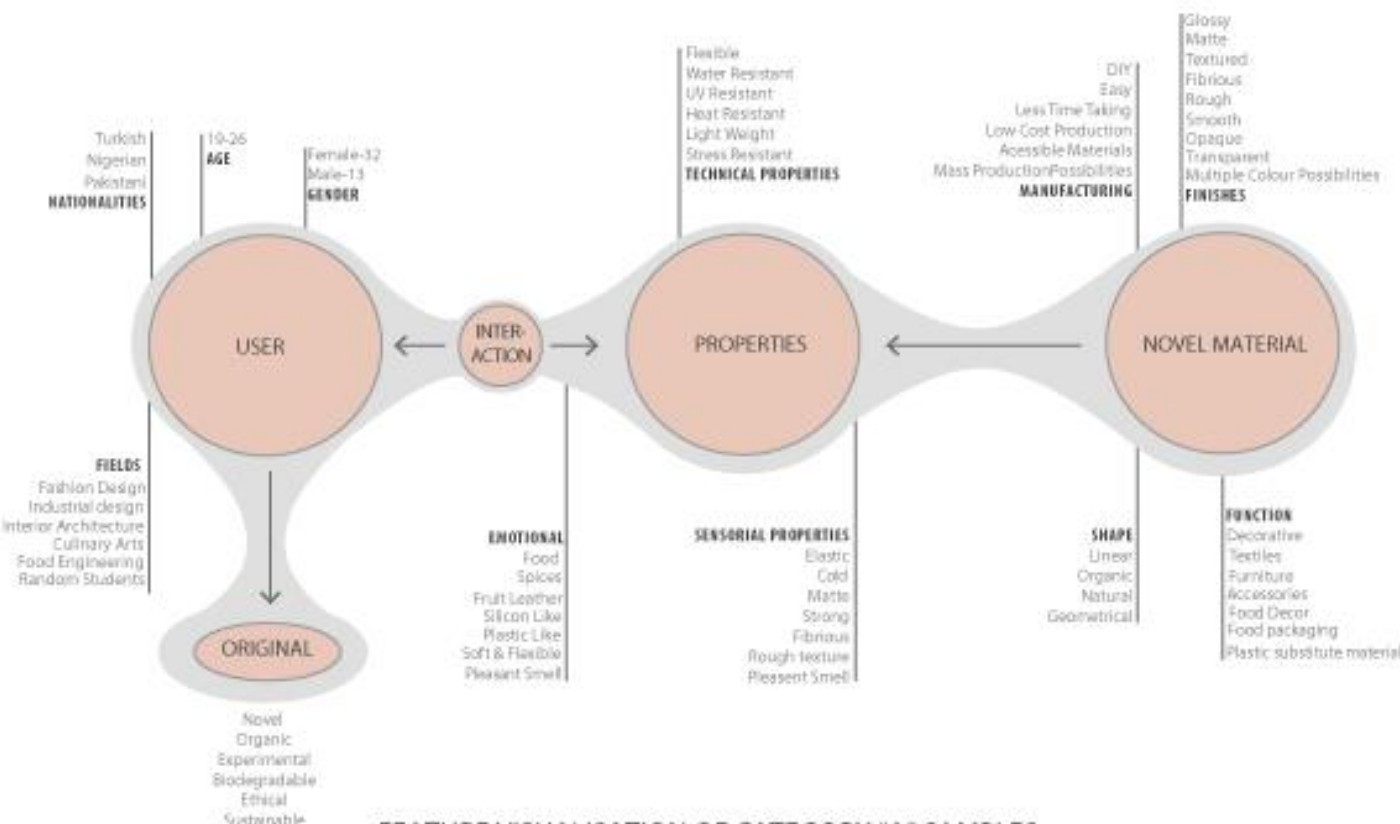


Fig 6.15 Overall material experience of category "A"

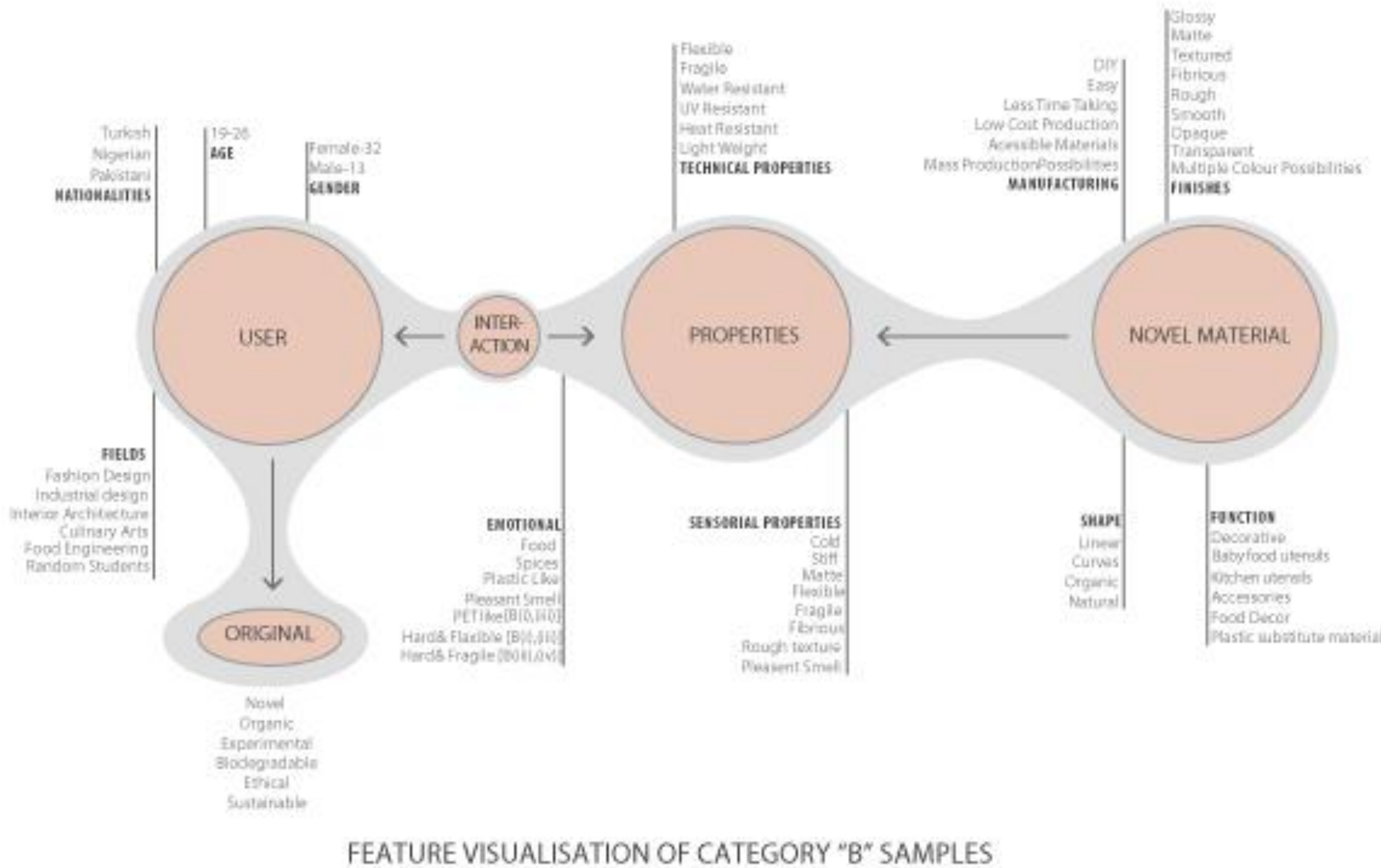


Fig 6.14 Overall material experience of category "B"

Fig 6.13 and 6.14 shows the summarised results of evaluation through MDD approach. User details to possible uses defined by the students are given in the MoM tool in the form of fig 6.13 and 6.14. These figures show an overall evaluation of samples based on their category instead of each sample. Therefore in properties, finishes and emotions (similar material question) both are fragile and hard, matte and glossy, opaque and transparent and so as mentioned. The shape of the material defines the end products visual qualities. As some of the samples were not flat or linear, they come in the curves category because of non-linear appearance. However, with the help of MoM tool overall material experience of the user's study, tinkering and development of the agar-based tangible results are summarised in figures 6.13 and 6.14.

CHAPTER 7
CONCLUSION

From the selection of agar as the main ingredient till the development of samples, multiple steps were used. Designing material/ product is the last step of the MDD in which designers or material developers are expected to apply their novel materials in the form of a product. Since both hard and soft agar-based materials were produced, it is hard to select a specific sample to achieve a final product from the novel material. Instead of conceptual design or application, user studies, technical and sensorial properties and tinkering opens up the possible application ideas. The overall results made possible to define or suggest the specific areas where these categories can be applicable and pragmatic. Category A samples are soft and flexible in nature, with water and stress resistance which made them applicable to the textile industry. Their edible nature and plastic film similarities open up opportunities in the food packaging industry and soft plastic substitute material.

However in the case of category B selected samples are two types, sample B(i) and B(ii) are hard but flexible in contrast sample B(iii), and B (iv) are hard and fragile. It is not easy to define the overall possible application of category B, but they can be defined as hard and flexible samples and hard and fragile samples. In the case of hard and flexible samples they are quite similar to PET and plastic sheets, which can be used as a substitute for plastic products. While in case of hard and fragile samples they are similar to hard plastics but their fragile nature makes them a weaker option. Users have suggested some interesting possible applications, despite at this moment it is hard to suggest. However, its edible property and organic nature open up the opportunity for disposable plastic food utensils. Some of the culinary students suggested using hard and fragile materials in the form of edible food decor, which might be an exciting application apart from the design applications.

Similarities with existing materials like plastic, silicone, fruit leather open up opportunities to further explore the material production techniques based on similar existing material production techniques. Most similar materials named by the users based on the sensorial evaluation are plastic. Therefore agar-based materials might be further produced based on similar plastic production techniques. Plastic has various industrial production techniques ranging from melting of plastic pellets to liquid form processes. In the case of agar-based material, initial liquid form and sheet form has numerous opportunities to convert into industrialised products. From liquid form material (agar based material solution) to the end product multiple production techniques are possible like casting, rotational moulding, injection moulding, compression moulding, extrusion and 3D printing. Whereas resulted samples are in the form of sheets and film (soft) also have further possibilities, which can be further used or converted into different products from various production techniques. Since the present agar-based materials are not thermoplastic, solution-based processes are more suitable for industrial production. In case agar based material sheets and films; thermoforming, vacuum forming, laser cutting (for both soft and hard sheets) and water jet cutting could be possible production techniques. Packing and coating techniques can be applied to the soft films as well.

Agar-based material samples were developed into film forms. To explore its further possibilities in the design fields and achieve various production techniques it is necessary to understand and explore its various forms. Different material forms can be achieved by using different processes, agar concentrations, and mould shapes:

- Solid Blocks
- Thick Sheets
- Plates
- Films
- Fibres

These material forms can be further used in different production techniques depending on the product needs and design areas.

Possible uses of the material samples suggested by the users broaden up the usability in the respected product groups. Many culinary art students have mentioned the use of group “B” (hard) material samples in the use of food décor, while fashion students suggested the use of “B” group material samples as accessory materials. To make it clear and understandable possible uses are categorised into the product groups with their possible products influenced by the user studies and overall material experience based on the material categories “A” (soft) and “B” (hard) samples. These product groups are categorised based on the design field, product category and production sector area. Various groups are formed with possible products depending on the use of material type (i.e. use of hard or soft agar based DIY material). Product groups, possible products and use of suitable materials are described in Table 7.1

Table 7.1 Product Groups With Possible Products of Agar Based Materials

Product Group	Possible Uses	Products	Design Fields	Suggested Material Category
Food Products	Packaging	Food pouches	Service Design	"A"
		Food coatings	Service Design	"A"
		Product coatings	Service Design	"A"
		Food wrappers	Service Design	"A"
	Cutlery	Spoons, Fork , Knife, Chopsticks	Product or Service Design	"B"
	Crockery	Plates, Cups, Bowls	Product or Service Design	"B"
	Mats	Food mats,	Product or Service Design	"A"
		Foldable plates	Product or Service Design	"A"
		Serving mats	Product or Service Design	"A"
	Food Storage Items	Packaging Boxes	Product or Service Design	"B"
		Shopping Bags	Product or Service Design	"A"
	Culinary	Food décor	Culinary art & Food Design	"A" & "B"
		3D printed food ingredient	Culinary art & Food Design	"A" & "B"
Fashion & Textiles	Clothing	Jackets	Fashion Design	"A"
		3D printed clothing	Fashion Design	"A"
		Undergarments	Fashion Design	"A"
	Accessories	Bags	Fashion & Product Design	"A"
		Belts	Fashion Design	"A"
		Jewellery	Fashion Design	"A" & "B"
		Shoes & Sandals	Fashion & Product Design	"A"
	Furniture & Accessories	Furniture upholstery	Interior & Product Design	"A"
		Cushion Covers	Interior Design	"A"
		Throws	Interior Design	"A"

Product Group	Possible Uses	Products	Design Fields	Suggested Material Category
Home Décor	Decorative Use	Pots	Product Design	"B"
		Decorative products like vase	Product Design	"B"
Baby Products	Food Products	Feeding Bottles	Product Design	"B"
		Baby Cutlery & Crockery	Product Design	"B"
	Toys	Building Blocks	Product Design	"B"
		Stuff Toys	Product Design	"A"
		Rattles	Product Design	"A" & "B"
		Teethers	Product Design	"A" & "B"

Different product groups with possible products can be explained through end-user scenarios. Each product group can be illustrated into an exemplary use supported by an end user point of view. The food and baby products are being further explained regarding possible end user scenarios.

Food Products: Disposable crockery and cutlery, and food packaging are some of the most common food product sectors. For example, airlines provide a meal during the flight. The meal varies depending on the flight time. In case of breakfast or evening snack, they give a cup of coffee, an individually wrapped bun or bread with individually wrapped jam, butter and cheese. They provide it in a plastic tray with sealed, wrapped cutlery including knife, fork and spoon. Usually, all these items come in different kinds of plastic. From coffee cup to small butter packets all are aimed for single use, and only for about 5-10 minutes. Instead of these plastic packaging and disposable crockery and cutlery agar- based material would be a better solution. Cutlery can be eaten or thrown after the use; it will make a zero waste scenario.

Baby Product: Baby or toddler products are usually light in weight. From the age of 3-4 months, the baby starts grabbing things. It is a natural habit of toddlers to put things in their mouth, especially when their teeth are coming. It is essential that baby products should be toxin free. If toys are made of agar-based hard materials like blocks or rattles, it would be safer, healthier and an environmentally friendly option. For example, when a child is playing with building blocks it also tries to put them in his mouth. But if that toy is made of plastic and he bites it, it is very dangerous. In case agar based material toys, baby can even bite its toys. It would be possible that rattles or building blocks will come in different flavours that excite the baby while playing and enjoy the taste of toys.

As shown in these scenarios and in Table 7.1 indicating various product groups, possible uses and products, agar based materials offer a wide range of possibilities for designers and different industries. Each of these product ideas deserve more research, development, design, and elaborate analysis in order to achieve environmentally benign alternatives and innovative solutions.

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APPENDICES

APPENDIX-1 SAMPLE QUSETIONNAIRE

QUESTIONNAIRE

I am a design studies student, this questionnaire is for my master's thesis on user studies to evaluate sensorial properties of the given samples namely Sample A (i, ii, iii, iv,) and Sample B(i,ii, iii, iv,) along with their coloured and textured samples. I want you to evalaute these material samples through the given questions.

Name : Age: Sex:

Profession: Department:

1, Here are Sample A (i, ii, iii,iv,) and Sample B(i, ii, iii, iv) , can you tell what are these samples made of?

2, Does these material samples look similar to any other material? If it does, please mention the name of the material and its similaraties.

	SAMPLE 'A'	SAMPLE 'B'
i		
ii		
iii		
iv		

3, Can you suggest any possible uses of these material samples

	SAMPLE 'A'	SAMPLE 'B'
i		
ii		
iii		
iv		

4, Evaluate the given material samples through sensorial evlauation chart

Sensorial Evaluations	Sample 'A'				Sample 'B'			
	i	ii	iii	iv	i	ii	iii	iv
subtle color (-3 -2 -1 ±0 +1 +2 +3) vivid color								
opaque (-3 -2 -1 ±0 +1 +2 +3) transparent								
matte (-3 -2 -1 ±0 +1 +2 +3) glossy								
not reflective (-3 -2 -1 ±0 +1 +2 +3) reflective								
not fibrous (-3 -2 -1 ±0 +1 +2 +3) fibrous								
regular texture (-3 -2 -1 ±0 +1 +2 +3) irregular texture								
soft (-3 -2 -1 ±0 +1 +2 +3) hard								
smooth (-3 -2 -1 ±0 +1 +2 +3) rough								
unsticky (-3 -2 -1 ±0 +1 +2 +3) sticky								
dry (-3 -2 -1 ±0 +1 +2 +3) wet								
cold (-3 -2 -1 ±0 +1 +2 +3) warm								
unflexible (-3 -2 -1 ±0 +1 +2 +3) flexible								
fragile (-3 -2 -1 ±0 +1 +2 +3) resistant								
lightweight (-3 -2 -1 ±0 +1 +2 +3) heavy								
odorless (-3 -2 -1 ±0 +1 +2 +3) smelly								
disgusting smell (-3 -2 -1 ±0 +1 +2 +3) pleasant smell								