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Crafting Materials During COVID-19: The Locked-Down Material Lab

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Abstract
Lately, designers have become deeply interested in the materials generation process. With an approach of transforming unconventional elements into possible materials, they discover many possibilities with new characteristics ready to explore. This article discusses a study proposing concepts of materials generation, focusing on self-production in a pandemic context of domestic isolation and resource limitations. It follows the Do-It-Yourself Materials approach to create homemade samples (organic waste-based) and the experience-based method called Material Driven Design (to search for new insights in the material samples) as a framework. The research presents some tools to measure and understand possible new materials. It evaluates the materials experience generated in users when using unconventional sources for their creation and shares some information to get a more straightforward path when choosing to work with an experimental approach to developing alternative materials.

Keywords
Materials design
DIY-Materials
Materials Experience
COVID-19

Introduction

It is an established fact that designers also participate in generating proposals for new materials. Often, these material ideas suggest more sustainable alternatives to traditional choices, proposing to be developed using broadly available raw materials, such as scraps or waste from other cycles, processed with simple and inexpensive tools.

This article discusses a study of material generation based on a *Do-It-Yourself (DIY) Materials* approach (Rognoli & Ayala, 2021; Rognoli et al., 2015). In short, *DIY-Materials* are created through individual or collective self-production practices, applying novel techniques and processes. The study adopted this approach to create samples using organic waste as a source, to analyse limits and possibilities, and to discover their technical, physical, and experiential characteristics. Despite the restrictions imposed by Italy's first COVID-19 pandemic lockdown, the study still obtained exciting insights, and *DIY-Materials* demonstrated that it could adapt to crises and states of emergency. The *Material Driven Design (MDD)* method was used as a framework for the journey; it supports designers in designing for experiences when a particular material is a starting point in the design process (Karana et al., 2015). However, the method has been customised with regard to the limits provided by the context and nature of the project. Because of this unique setting and approach, the method emerges as relevant and exciting, to be shared with the design community, while encouraging readers to customise the steps in the method when the journey of experimentation requires it. This article describes the study through the following content: (2) Background of the study, an overview of the general context, motivations, and approaches; (3) Proposing waste as a source, introducing the choice of raw material; (4) The experimental journey, explaining the method in greater detail and suggesting new activities; (5) Results, describing new tools and adaptations; (6) Discussion and conclusions.

Background of the Study

Innovative materials are increasingly important to respond to the world's technical, economic, social, and sustainable challenges. Nevertheless, the creation and production of materials is complex and has demonstrated an unstable domain, constantly changing, with dynamics that depend on discoveries, availability, prices, policies, and other factors.

Materials have been categorised in terms of different dimensions. The range of classification today is vast, and includes biomaterials, nanomaterials, 3D printed materials, composites, etc., within an extensive variety (Brownell, 2017; Peters & Drewes, 2019). It is possible to see how new categories emerged from a mix of science and design.

The growth of general interest in sustainability, the circular economy, self-sufficiency, and global environmental awareness has been driving alternatives to petrol, fostering a renaissance in the diversity of raw material sources (Elvin, 2015). Furthermore, the crisis caused by COVID-19 has helped to increase the environmental sensibility that drove emergent new flows of research to find opportunities for sustainable materials development.

A wide range of speculative materials has been created, highlighting the use of unique resources where waste, natural assets (e.g., algae), and dust can be considered as raw materials (Franklin & Till, 2018). In this context, researchers, designers and makers have pushed their ideas in the field of materials, opening a world of new material possibilities (Brownell, 2017; Franklin & Till; Peters & Drewes, 2019; Solanki, 2018). Many actors, including designers and makers, have chosen DIY-Materials to demonstrate their experiments with local resources, elaborate their transformation processes and develop creative solutions in response to the creators' different needs (Clèries et al., 2021).

DIY-Materials afford an experimental approach based on self-production and tinkering. *Material Tinkering* is defined by Rognoli and Parisi (2021) as "the art of manipulating the material creatively for discovery and learning purposes" (p. 20). This process includes exploration to play with the ingredients and create material samples, combined with a trial-and-error approach in which the documentation of the process and its results become vital to understanding them. *DIY-Materials* are produced with local ingredients, fostering sustainability, reducing costs, presenting an emotional connection with users and creators, and an aesthetic of imperfection due to the production method (Parisi et al., 2016). The results are probably unfinished but present insights for further development or research, such as this study.

Methods and tools have been created for designers to push materials generation and find new insights and properties (e.g., expressive properties, sensory qualities), from different perspectives such as the *Expressive-Sensorial Atlas* by Rognoli and Levi (2004); the *Meaning of Materials* model by Karana (2009); *Material Driven Design (MDD)* by Karana et al. (2015), highlighting the incorporation of the materials user experience for product design. This study implements the *MDD* tools and steps for materials experience exploration with this background. It has been chosen because of its exciting focus on the *Materials Experience* (focusing on the role of materials as both technical and experiential) (Karana et al., 2008).

Proposing Waste as a Source

It was decided to start with a *DIY-Materials* approach for the experimentation. The choice was to use organic waste as a source of raw material and rudimentary kitchen tools for manufacturing. Furthermore, simple techniques were used for a rough analysis of the properties. These choices were principally shaped by the context.

This study was developed during the first lockdown caused by COVID-19 in Milan, Italy (Livingston & Bucher, 2020), constrained and inspired by the situation due to the global emergency. The context imposed many limitations regarding access to information (universities and libraries) and experimentation (access to laboratories, shops for buying ingredients and elements, and the impossibility of meeting people to perform user studies). The general situation prompted the use of organic waste as a source (easy to produce in-house). It motivated the use of the *DIY-Materials* approach recognised by the democratisation of information, processes and practices and the use of low-technologies in different circumstances (extensive online dissemination, e.g., Materiom, 2018; Humier, 2012).

Waste has an unknown value which gives rise to further research; the identity of the materials has been found to vary and is not yet defined with solid characteristics.

The Experimental Journey

The journey started with *Material Tinkering* (Rognoli & Parisi, 2021). An experimental process was undertaken to gain knowledge about the materials, the ingredients, and the method, freely encouraging creativity. The exploration was open to an intuitive mixture of ingredients, carried by a hands-on attitude, following some online recipes (e.g., Ribul, 2014) and trying everything that suggested a material outcome. Organic waste was selected and introduced in 'bioplastics' recipes (bioplastic is a form of plastic derived from renewable biomass sources) (Rognoli et al., 2011). Generally, basic DIY bioplastics were made using a biopolymer (e.g., starch), a plasticiser (e.g., glycerine) and water (Kretzer & Mostafavi, 2021).

It was a stage that led to unexpected discoveries, errors, and positive outcomes. Nevertheless, it was decided to use the *Material Driven Design* (Karana et al., 2015) method to frame and guide further activities; this method encourages materials design, focusing on exploring new material experiences in users (Giaccardi & Karana, 2015). It was used to understand the creative processes of materials, identifying the best possibilities to create meaningful material experiences. The method proposes a journey from tangible to abstract (from materials to a vision of material experience) and from abstract to tangible (from a vision of material experience to a physically or further developed idea), suggesting that it concludes with a product or a more evolved material (Karana, 2015). This method presents four main steps: (1) Understanding the Material, (2) Creating a Materials Experience Vision, (3) Manifesting Materials Experience Patterns, and (4) Designing Material/Product Concepts.

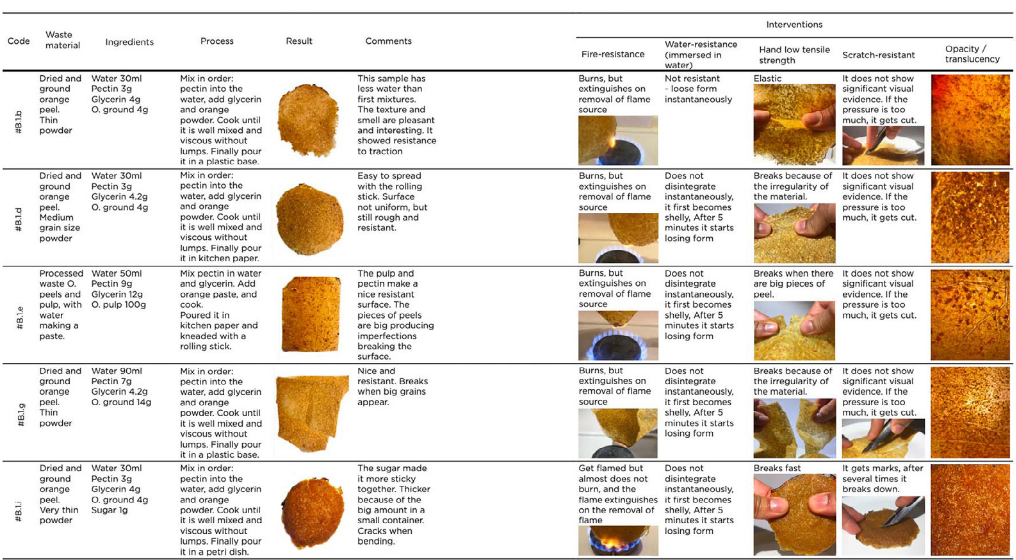
This journey was not focused on following the four phases and reaching a product concept, but on the first phase (Understanding the Material) to learn from each tool, to evaluate and propose new adaptations regarding the limits presented by the context of isolation, to gain insights into materials. The following paragraphs will describe the activities suggested by the authors to proceed with the first phase of the method, and how this study was carried out.

Understanding the Material

The first step of the *MDD* is defined by the technical and experiential characterisation of the material or proposal. It suggests developing three activities simultaneously to understand this initial phase better: *Tinkering with the Material*, *Material Benchmarking*, and *User Studies*.

Tinkering with the material is a hands-on approach to get information on what it offers, its technical/mechanical properties and how it can be moulded or incorporated into products. The tinkering process is extensive and creates much information through two types of actions; this activity includes taking notes of steps and ingredients when making a material for later replication, to make it better, or change outcomes.

This study began with three different organic wastes and many possible bioplastic outcomes. A tool called the *Abacus of Tinkering* was incorporated to organise the ingredients and processes. It is a data sheet composed of a sample code, the elements and quantities of production, the process to achieve it, an image of the outcome, interventions, and some additional comments. Possible tests include fire resistance, water resistance, hand low tensile strength, scratch resistance and opacity/translucency. These are neither mandatory nor the only ones. This tool shows the *Technical characterisation of the materials* (Karana et al., 2015), typified by modifications in the material preparation and testing of their qualities. They can vary depending on the availability of tools, requirements, or desired properties to discover. Those interventions were selected for this study due to the possibility of realisation in a simple kitchen during the lockdown. Fig. 1 The suggestion is to combine it with an *Archive of Samples*, where pieces are displayed, showing the code that links the material with the abacus. The sample's production date is also required to understand the characteristics over time (Parisi et al., 2016).



Code	Waste material	Ingredients	Process	Result	Comments	Interventions				
						Fire-resistance	Water-resistance (immersed in water)	Hand low tensile strength	Scratch-resistant	Opacity / translucency
#B.1.b	Dried and ground orange peel. Thin powder	Water 30ml Pectin 3g Glycerin 4g O. ground 4g	Mix in order: pectin into the water, add glycerin and orange powder. Cook until it is well mixed and viscous without lumps. Finally pour it in a plastic base.		This sample has less water than first mixtures. The texture and smell are pleasant and interesting. It showed resistance to traction	Burns, but extinguishes on removal of flame source	Not resistant - loose form instantaneously	Elastic	It does not show significant visual evidence. If the pressure is too much, it gets cut.	
#B.1.d	Dried and ground orange peel. Medium grain size powder	Water 30ml Pectin 3g Glycerin 4.2g O. ground 4g	Mix in order: pectin into the water, add glycerin and orange powder. Cook until it is well mixed and viscous without lumps. Finally pour it in kitchen paper.		Easy to spread with the rolling stick. Surface not uniform, but still rough and resistant.	Burns, but extinguishes on removal of flame source	Does not disintegrate instantaneously, it first becomes shelly, After 5 minutes it starts losing form	Breaks because of the irregularity of the material.	It does not show significant visual evidence. If the pressure is too much, it gets cut.	
#B.1.e	Processed waste O. peels and pulp, with water making a paste.	Water 50ml Pectin 9g Glycerin 12g O. pulp 100g	Mix pectin in water and glycerin. Add orange paste, and cook. Poured it in kitchen paper and kneaded with a rolling stick.		The pulp and pectin make a nice resistant surface. The pieces of peels are big producing imperfections breaking the surface.	Burns, but extinguishes on removal of flame source	Does not disintegrate instantaneously, it first becomes shelly, After 5 minutes it starts losing form	Breaks when there are big pieces of peel.	It does not show significant visual evidence. If the pressure is too much, it gets cut.	
#B.1.g	Dried and ground orange peel. Thin powder	Water 90ml Pectin 7g Glycerin 4.2g O. ground 14g	Mix in order: pectin into the water, add glycerin and orange powder. Cook until it is well mixed and viscous without lumps. Finally pour it in a plastic base.		Nice and resistant. Breaks when big grains appear.	Burns, but extinguishes on removal of flame source	Does not disintegrate instantaneously, it first becomes shelly. After 5 minutes it starts losing form	Breaks because of the irregularity of the material.	It does not show significant visual evidence. If the pressure is too much, it gets cut.	
#B.1.i	Dried and ground orange peel. Very thin powder	Water 30ml Pectin 3g Glycerin 4g O. ground 4g Sugar 1g	Mix in order: pectin into the water, add glycerin and orange powder. Cook until it is well mixed and viscous without lumps. Finally pour it in a petri dish.		The sugar made it more sticky together. Thicker because of the big amount in a small container. Cracks when bending.	Get flamed but almost does not burn, and the flame extinguishes on the removal of flame	Does not disintegrate instantaneously, it first becomes shelly, After 5 minutes it starts losing form	Breaks fast	It gets marks, after several times it breaks down.	

Fig. 1
The *Locked-Down Material Lab, Abacus of Samples*. Ph. by the Authors.

Fig. 2
The *Locked-Down Material Lab, Archive of Samples*. Ph. by the Authors.

Experiential Characterisation

The *Experiential Characterisation of the Material* is another essential step. The authors first suggested that designers reflect on their own regarding the experiential qualities of the samples: meanings, emotions, actions, and performances. Following that they should explore how other people perceive these materials. These reflections are critical to understanding the potential material experiences and their relation to their properties.
This journey started with the designer's reflection upon the qualities of the samples, where six (pectin-based) bioplastics were selected. Next, taking into consideration the constraints of the pandemic, an *Online User Studies* was designed based on a survey to evaluate people's answers and perceptions of the samples. In force majeure, they were a handy tool for generating insights.

The *Online User Studies* was a descriptive self-administered web-based survey (Gray, 2004) showing high-quality videos and audios of the materials being moved, folded and wrapped. It was a mix of qualitative and quantitative questions that reached almost 100 people of different ages and backgrounds in 3 days.

The questionnaire with 30-second videos motivated interviewers to perceive the materials and describe them. Some words (open and with no imposed meanings) were suggested to express the feelings and memories the materials produced. Interviewers were classified and entered into a data record to organise the information graphically (e.g., excel graphs). This data was later analysed and contained in mind maps.

Material Benchmarking

Mapping potential areas of application by classifying information is called *Material Benchmarking*. Positioning the material with similar ones will help designers understand which issues are expected and which strategies or values are successful. The activity began by selecting three bioplastics charged with orange, banana, and coffee waste parts. They were positioned in three different benchmarking tables with similar materials and products describing their application, limitations, production scale, future impact, commercial readiness, experimental qualities, and emerging issues. This information is just an example of what can be used depending on the project requirements.

Benchmarking Orange by-products

	Orange Fiber	Venn Reactor	Bio-Peel	Apeel	Repulp	Feel the Peel	Agrumiscela
Content:	Citrus juice byproducts	Orange Peel & Pulp	Orange Peel & Pulp	Waste citrus peel	Orange Peel	Orange waste from juice	Skin of the lime, lemon, clementine and orange.
Application:	Textile	Lamp, stool, table and smaller products.	Packaging	Versatile	Cup	Filament	Panels
Type/Size:	1m x 1,35m - 1m x 1,5	Small batch.	Small.	Versatile	Small	On demand	Small batch
Enviornmental:	Local resources	Local resources	Local resources	Natural resources	Local resources	Local resources	Local resources
Limitations:	-	Physical and mechanical.	HandMade aesthetic	Currently small production	Produced in small scales.	Weak - single-use.	Fragile
Future Impact:	Incentivate to other industries/products.	Multiporpose application.	Replace single-use plastic.	Develop of novel method of production.	Incentivate to other industries/products	Replace single-use plastic	Fostering local production
Commercial readiness:	●●●●●	●○○○○	●○○○○	●●○○○	●●●●●	●○○○○	●○○○○
Scale:	Patented material, commercialized.	On exploration Lab made	Student exploration HomeMade	Patent-pending Design Studio	Commercialized. Semi-industrial	Prototype	Experimental HomeMade
Contact:	www.orangefiber.it	www.manny-melo.squarespace.com	Denny Handley	www.studioarp.uk	www.repulp.fr	www.carloratti.com/	Román I, Qianni C, Beatriz T, Danfeng G.
Experimental qualities & emerging experiential issues							
Natural colour	Conceal	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed
Imperfections	No	Yes	Yes	Yes	No	Yes	Yes
roughness	No	Yes	Yes	Yes	No	Yes	Yes
Scent intensity	Traditional textile	High	High	High	High	High	High
Visible Fibres	None	Yes	Yes	Yes	Yes	No	Yes
Standard unique	Not visually perceived	Yes	Yes	Yes	Yes	Yes	Yes
Temporal (change over the time)	No	Yes	Yes	Yes	Yes	Yes	Yes
Authenticity	Low	High	High	High	High	High	High
Naturalness	No	Yes	High	High	High	High	High

Fig. 3
The *Locked-Down Material Lab, Material Benchmarking*. Ph. by the Authors.

New Activity

By this point, designers should have an idea of potential areas of application, and clarity regarding the technical and experiential qualities of the materials. Designers should begin a new phase (2) *Creating Materials Experience Vision*. However, this study proposed a new activity, expecting fewer errors in future stages before going ahead.

Scientificity to Tinkering was introduced to enhance the selected materials, where more specific knowledge, for example, about matter and its molecular interaction and reaction, had to be incorporated.

The scientific approach to tinkering proposes a stage dedicated to collecting essential information about each element that makes up the sample, to understand its function within the composition. It is suggested that the practice should be reinforced in a laboratory using specific tools within knowledge integration from expert sources. The recommendation is to search for scientific papers and books, and to interview specialists to guide the approach. In this phase, the material ingredients and quantities must be justified and measured to understand the changes from one sample to another, avoiding unexpected results.

Once the material has been broadly understood, the following phases of the *MDD* may be performed. (2) A summary of the results provides critical points to help define a meaningful vision. (3) Define the pattern of formal qualities and the expressive-sensorial characteristics, linking them to the material and making them coherent with the vision. (4) Integrate the findings into a design phase.

Results

Various tools and one activity have emerged from the first phase of the applied method, proposing an organisation and adding knowledge to the journey. By producing more than a hundred samples (Duarte P., 2020) and some technical characterisations, it has been possible to analyse materials while applying different treatments or varying the recipes. Focusing on the pectin-based samples, it is possible to say that many variables influenced the aspects and properties: The quantities of ingredients in the production (e.g., glycerine made them more flexible or rigid), the production time (cooking period), the shaping techniques (stretched or 3D moulded, pressure and disposition), the addition of filler matter (grains, dimension, type, colour) and the drying technique (applying heating or fresh air and the time of exposure). All of them lead to different results and give rise to different features. They were mainly characterised by imperfection, the visibility of the fibres and the moulding textures. The technical properties were compared through homemade tests to understand which techniques achieve better results. New tools made the analysis easier.

The *Online User Studies* made it possible to understand peoples' perception of the materials. The users did not know that the material samples came from waste, and they could hardly imagine it. They described the characteristics as "rough", "flexible" and "resistant", as well as "light" and "malleable". Many interpreted them as "natural", "innovative", and "imperfect", while the more daring interpretations used the words "sustainable" and "ecological". The materials were associated with " textiles" or "leathers" because of their shapes and finishing.

The benchmarking helped to identify the main problems with these materials, making space for proposals to improve some aspects. There is no fixed strategy for presenting waste-based materials on the market. There is a lack of definition and application, so that many materials remain primarily conceptual. The characteristics are ill-defined, and the scale of production is generally poor.

The *Scientificity to Tinkering* process provides space for researching specific information to generate the materials, considering the science of the ingredients. Interviews with professionals made it easier to understand the reactions and quantities, leading to the development of advanced samples.

The Customised *MDD*

The study described above was developed in a context of crisis and uncertainty, which prompted a significant reflection about sustainable materials, stopping waste production, the circulation of materials, and the regeneration of nature (Ellen Macarthur Foundation, 2013).

Against this background, the *MDD* method was used as a guide and a valuable set of tools. It has been graphically updated, inspired by the graphics of *The Krebs Cycle of Creativity* by Neri Oxman (2016). Within a structure that considers domains to be synergetic forms of thinking and making, the output from one becomes the input of another, and the transitions between fields generate impressive results in terms of knowledge and information. Users are invited to perform the method depending on the project, dividing the phases equally, or giving more space to specific steps.

All the tools may be found within each phase. Furthermore, the graph displays two circular bands. One represents the context that must be kept in mind in any project. The other represents the *Material Tinkering* that should be developed throughout the project; there will always be space for later discoveries and modifications.

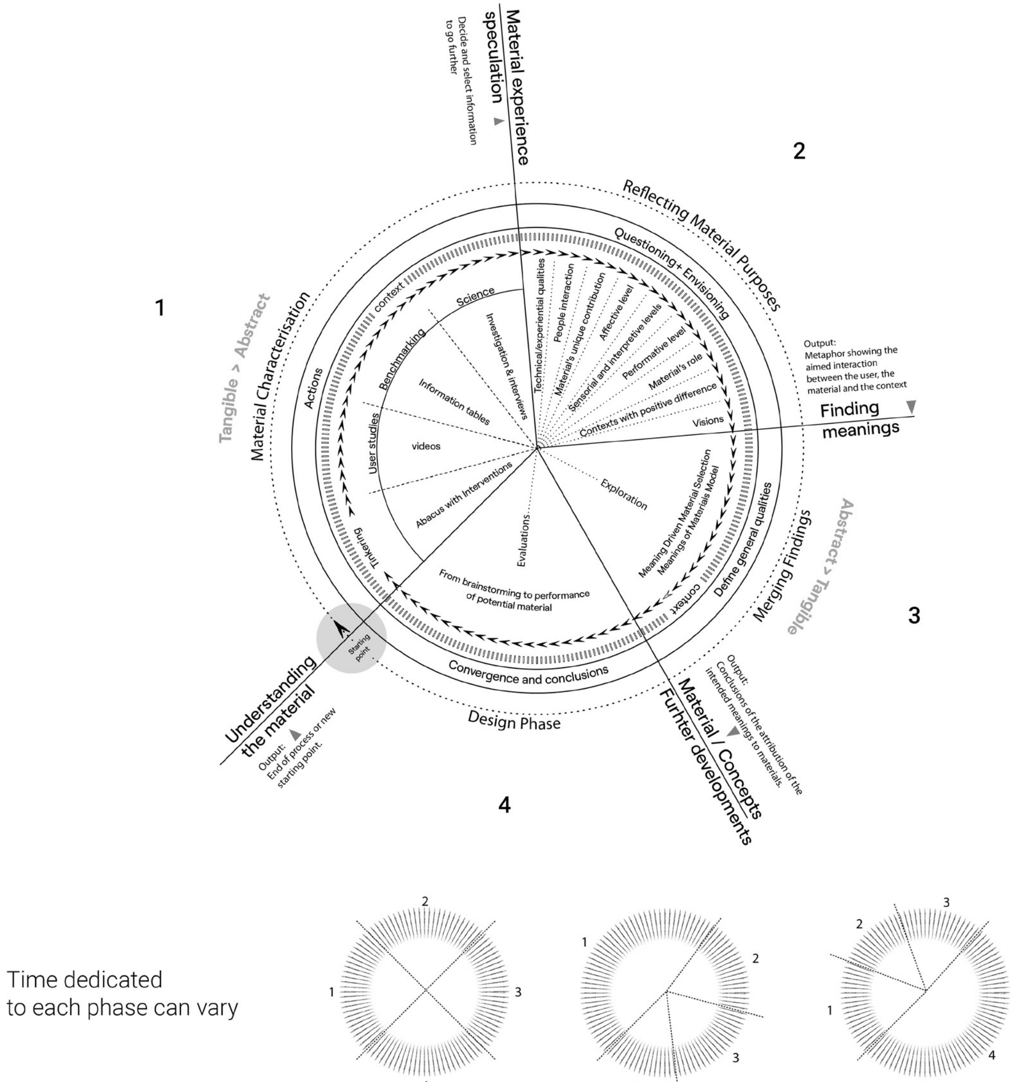


Fig. 4
The ***Locked-Down Material Lab updated graphic method*****. By the Authors.**

Discussion

This paper has presented a journey of exploration into self-producing materials, mixing *DIY-Materials* (Rognoli et al., 2015) with *Material Tinkering* (Rognoli & Parisi, 2021) and the *Material Driven Design (MDD)* method (Karana et al., 2015).

The study suggested how alternative uses of food waste, such as orange peels, can be used as a raw material to avoid waste production, aiding in the construction of a circular economy. It is essential to highlight that the COVID-19 pandemic pushed and encouraged this journey of self-production under conditions of isolation, leading to reflection and new insights. Designing, researching, and fabricating during a pandemic brought with it constraints and opportunities. Indeed, the context characterised the methodology, starting with the identification and collection of resources (i.e., household food waste and leftovers) and equipment (from cooking equipment and digital fabrication technologies, to the execution of socially distanced user studies, through videos and online forms instead of physical samples and paper questionnaires). During the pandemic, the spread of video conferencing software and online platforms fostered interaction and exchanges with professionals, allowing the research to be funnelled into a science-based exploration of the materials. In addition, the context that we have experienced as a society has been an interesting point to reflect upon and discuss the complexity of the current ecosystem, sustainable consumption and the exploitation of resources.

Thanks to the different results, it could be demonstrated that *DIY-Materials*, *Material Tinkering* and the *MDD* method are useful in limited contexts. The experimentation was perfect for introducing the *Abacus of Tinkering* and the *Archive of Samples*, tools that help to organise the production process, while *Scientificity to Tinkering* gave space for a more scientific approach to the materials. Furthermore, the graphic changes proposed for the *MDD* seek to provide a more fluid perception. The phases of the method are synergetic forms of thinking and making, where content is generated, some is consumed, other is released, and new content is formed (Oxman, 2016).

In further research, the *MDD* method could be updated for more conscious production patterns, providing tools whereby the concept of circularity can be more easily understood. The lack of certain tools or steps can be seen as a limitation for creating materials in more complex scenarios; this can be the starting point for a new method update.

It is expected that further publications could propose a materials recipe book, the content of which could be available as open-source, which might also suggest and discuss the optimisation and application of the materials.

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