Title: Material Tinkering as a Tool to Promote User Empathy and a Subliminal Waste Reduction Strategy

Author: Carlo Santulli

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Material Tinkering as a Tool To Promote User Empathy and A Subliminal Waste Reduction Strategy

CARLO SANTULLI
Università di Camerino

Abstract
In this work, the role of material tinkering using waste, initially from food but then in a more general sense, in a polysaccharidic or proteinic self-produced matrix, is recognized as a producer of renewed empathy first with natural materials then generally with refuse. This moves away from the concept of "bioplastics" as empathic-free materials and allow a better acceptance for the introduction of waste into materials, resulting therefore as a concealed yet real strategy for waste reduction and therefore sustainability. Experiences developed in Università di Camerino are briefly presented as for their empathic content using tentative semantic differential scales and extending over time also to aging and the presence of signs of degradation, such as mold, cracks, unexpected light reflections, etc.

Keywords: DIY materials, materials affection, self-production, senses interaction

The Role Of Material Tinkering

In material designer's curriculum, it is essential to acquire a first-hand experience, creatively interacting with the matter (Rognoli & Parisi 2021). This is defined as "material tinkering", since it apparently starts as an unorganized operation, which only in the passage from the material to a reading of it into a prospective object, acquires the dimension of a design route. This path is based over experimentation, and the metabolization of failure towards the exploration of reasons that caused it, removing which would lead to success. This can be defined as "experimental method" and it is recognized as a way of learning through failure (Huang 2020).

Through this iterative route, by gradually improving materials' design, a physical demonstrator, which can be perceived as a spin-off for a prospective product, is obtained (Veelaert et al., 2022). The principal requirement of the demonstrator is clarifying its suitability for the application, which may be defined from the beginning, in the form of single or multiple function. The idea of providing different functions, for the same physical object, or else to "read" it in various ways, does contribute to its emotional durability. In other words, it prolongs its ability to be used and liked, and, as the consequence, not being discarded ahead of irrecoverable structural failure (Chapman 2012).

The application of a particular material can also be gradually elicited from its very characteristics of the material in a step-like process. In this sense, the demonstrator may have a tentative shape, such as flat, polyhedric or curved according to different laws. This shape can be given using a mold to serve as the model and be subsequently removed. The complete freedom for the respective evaluation of materials would be possibly to be developed moldless. This has recently become the operating mode of additive manufacturing processes, such as 3-D and even more 4-D printing, allowing "on route" correction of the desirable geometry and involving attention to the evolution over time of the material and to its ageing process (Hoa 2017). In the case of material tinkering, taking a moldless approach means fabricating flat shape (sheet or film), arranged so to remove pieces approximately of the same size. This would apparently resemble a show of samples. In this sense, a materials library is already a too much developed and culturally aware system, since it promotes materials and shapes that we are able to associate in our mind, somehow automatically, with different uses. To put it in a more suggestive way, a materials library is a tool to build up the triangle between materials research, design, and user needs (Wilkes and Miodownik 2018). On the other side, from a technical point of view the mold-based approach serves also to better define the pre-structural features of the developed material according to basic questions, such as "may I bend it?", "is it possible to pierce it?", "how much can I control its thickness?", "would it collapse if loaded?", yet also can give some hints about the possible applications. This serves also for a humanistic and educational approach towards materials and therefore to establish also its potential empathic content, and it is definitely adapted to introduce basic concepts of materials science in a school context and to effectively link it to need to make the best possible use of materials to confer them added value also to the user (Santulli et al., 2020). In this sense, giving a shape would assist in the object recognition and in associating it with the material used, especially at a school level, as shown by the example in Figure 1.

The big shift occurs whenever the material demonstrator is brought forward to be possibly adaptable also to a circular economy approach. In this case, the materials tinkering route can be adapted to the use of waste, also referred to as "secondary raw material", into the process. In principle, material tinkering approach can be realized with waste coming from any sector. However, in practice, selecting refuse from the food production does represent a more "ethical" choice since food that cannot be consumed is linked also to other considerations about the survival of the species and therefore the general significance of this operation (Cecchini 2017). The use of waste is also critical from an empathic point of view. A final observation would also be developed further in this work, and concerns the fact that there are "nicer" and "uglier" types of waste, therefore we are not in any way neutral towards refuse, and we necessarily interact with it.

This last observation does concern the fact that we may use materials tinkering to restore empathy with the matter, even after it has become a refuse, and this can be suggested to be a waste management, or even a circular economy strategy for the reason that it confers added value and also additional life to refuse integrated in different ways into materials demonstrators.

Figure 1. Simple objects from materials tinkering formed from a thermoplastic starch (corn starch + glycerol) matrix with eggshell fragments filler and colored with curcumin (yellow samples) and spent ground coffee (brown samples) (Courtesy of Tania Pallottini)

Materials and Feelings

We may prove feelings towards objects and incidentally with regard to materials that constitute them, which is what makes a product or any artifact emotionally durable. These feelings are recognized to be extremely subjective, especially as far as the ageing process is concerned (Lilley et al., 2016). This subjectivity is due to the complex and unique mixture of different perceptions of colors, odors, touch, and possibly even noise associated to the material assembly that constitutes the object with which we interact (Karana et al., 2015). In the case of food design, but not necessarily, also an emotion associated with taste is perceived: recent studies associated a "five senses" emotional map with some categories of food, such as pasta (Altamore et al., 2018). A "five senses" interaction with some materials and objects is possible, even if not always desirable: some examples are even curious e.g., the possibility to improve the self-diet by obtaining selenium by licking stones, one of the paradigmatical categories of materials traditionally used in history (Haug et al., 2007).

This interaction is complex and sometimes very difficult to be elicited and brought to the surface in rational terms, hence, to be quantified. For this purpose, semantic differential scales (SDS) have been developed, to indicate e.g., the limited knowledge of the users about "bioplastics", despite a generally positive, yet quite superficially motivated, perception (Ruf et al., 2022).

The traditional use of plastics, which is prevalently used in design for bare functionality, tends to minimize the interaction with the user, limiting it to the two senses of touch and sight. On the other side, plastics does often enable an easier design of affordance, which is amongst the reasons why it got so diffused in everyday objects (Fisher 2004). For instance, most toys are made by oil-based plastics: however, it is possibly inappropriate to say that there is a real interaction with the material, rather than with the toy function. This also results into not normally proving empathy with the object beyond its very function: moreover, the use of traditional injection molded or extruded plastics has mostly moved away from the user's context the possibility to repair (not to say to fabricate) toys. In this sense, it appears noteworthy that the success of Lego bricks is partly to be attributed to the need for a richer user-object interaction and possibly results in more durable liking and therefore incidentally a longer "active" life for the object. It is no surprise that Lego therapy has been proposed and practiced for improvement of social interaction in case of autism, in view of its immediate empathy with the user and of the wealth of possible "readings" of it (Lindsay et al., 2017). However, here again, Lego bricks' material (ABS) does not really participate into the interaction, it just provides the function.

This represents an example of how, with the introduction of oil-based plastics, our interaction with objects has become quite poor and repetitive, with a limited number of factors that might contribute to the above-mentioned wellbeing. The use of plastic materials (and this also includes composites/resins, such as fiberglass and carbon fiber composites) is reported as contributing to the "efficiency" of our life and our living in "smarter" cities. However, recently also this paradigm has been discussed, bringing to the limelight "empathic" cities, where wellbeing and livability are going to replace the technocentric idea of city, which involves a large consumption of newly produced synthetic materials (Biloria 2021). In this context, materials with continuously renovating five-senses interaction with us can be of interest. In a sense, DIY materials grow old with us, whereas plastics has a sense of eternity, which is not a philosophical or theological one, yet rather a persistent reality, fully linked and complying with the idea of "continuous, infinite, and seemingly inexhaustible source, a source without location or specificity" (Bpetzkes and Pendakis 2013), such as oil.

The introduction of oil-based plastics brought a clear sensation of lightness that was compared with much heavier and substantial objects conceived and used for the same purpose (e.g., a polypropylene bucket compared with a steel one) (Ferrara and Bianco 2023). This lightness and odorless characteristics of plastics was also coupled with hygiene and safety, since it was connected with the limited, if not deemed impossible, contamination of plastics by bacteria and other polluting agents (Paris 2016). However, for further generations using plastics, this kind of reference to previous objects and materials with the same function gradually faded away, together with the sensation of plastic superiority as for cleanliness and safety. The sensation that plastic objects could offer bright colors, offered by the mass-coloration process with dye substances introduced in the masterbatch, remained overtime, but of course allowed a kind of empathic behavior, yet limited to the sense of sight (Sossini et al., 2022). The touch sensation of plastics is a repetitive and uniform smoothness, to the point at surface sanding was required to improve the grip for some applications of plastics. On the other hand, the relation between touch and pleasantness is well established and, as such, it has demonstrated that plastics is more easily recognized by blind eyes experiment: well-known, but most likely not offering no nuances to the touch (Wijaya et al., 2020).

Proto-plastics as precursors of biocomposites

Poor interaction with the user, limited to touch and sight, is thence typical of oil-based plastics and those bio-based ones, which did not modify the paradigm of application, pretending to fabricate the same objects in the same way: a typical example is poly(lactic acid) (PLA), when not processed in additive manufacturing. This only involved growing criticisms also for these "bioplastics" being based on raw materials from the food-producing systems, such as starch, and not on relevant waste (Sabry 2022). In any case, this perception is deemed to bring to absence of feelings towards the plastic object, so to lead to its precocious disposal, even out of the single-use scheme (Heidbreder et al., 2019).

This was not the case for the previous generations of proto-plastics, developed during the 19th century, moldable to various extents, though normally with no use of high pressure. Proto-plastics were treated as sort of "precious" object, though Modernist, therefore even more valuable (Yeung 2020). A pivotal example, very distant from contemporary plastics, was bois durci, a mixture of sawdust and bovine blood, sources of waste from different sectors (Ralston and Osswald 2008). Another material obtained from refuse, namely milk whey and acetic acid (vinegar), then plasticized using formaldehyde, was galalith, which had a longer and more successful history. However, differently from oil-based plastics, it was subjected to sudden failure simply by temperature changes due to day-night-cycles, and the structural limitations represent still an issue in its contemporary formaldehyde-free reprise (Martyn 2023). Galalith does absorb and retain environmental odors, other that specific traces from their production matter, milk whey and vinegar, again both wastes from food sector, in the latter case from wine and spirits production (Jefferson et al., 2020). Thus material can also be interpreted as the substitute for the use of natural protein structures e.g., tortoise shells and bovine horns, in a plasticized form, which was equally diffused at the time (Espinoza et al., 2007).

Another protoplastic, based on sugar derivatives (polysaccharides), and moldable, whose history was even more successful than galalith, was cellulose acetate, which, evolving in the plastic form of cellulose, was able to withstand the passage to oil-based plastics and still marketed and successful. Cellulose acetate can originally be thought of as originated from acetylation of waste from paper production. However, when camphor was substituted in the production of cellulose acetate with plasticizers based on phthalates, or more recently, due to health concerns, with glycerol polyesters of acetic acid (diacetin and triacetin) (Phuong et al., 2014), also the so-called "celluloid odor" tended to fade away (Whelan 1941). The permanence of cellulose acetate as the only "protoplastics" left in contemporary times would perhaps give additional strength to the "odorless-plastic" association.

Synthetic materials and the production of waste

In the materials engineering field, the emotional content embedded in materials is, if any, disregarded. This represents an issue when it comes to creating a durable experience with materials, which is also inherently sustainable. Durability has a deep link with considering sustainability, since more durable materials and objects would lead to lesser production of waste over time. This problem has been investigated in some of the most polluting materials/sectors, such as textiles/fashion (Fletcher 2012) and concrete/constructions (Al-Hamrani et al., 2021).

In the case of polymer-based materials, the production of bioplastics/biocomposites was hailed as a step towards circular economy for the possibility of treating end-of-life materials as composting matter. However, further reflection brought to the idea to escape from the narrow mindedness of single use plastics (SUP), increasingly challenged e.g., by 2019/904 European Commission directive, which eventually came into force on 3rd July 2021. SUP has been proven to have significant environmental impact in a throwaway society, especially in that it does not reduce the amount of materials produced and consumed (Chen et al., 2021). A possible approach is convert end-of-use plastics into value-added materials, therefore into products with some life duration (Sharma et al., 2021).

In itself, SUP's application profile does exclude to even think of any kind of empathy with the object. However, the process for the disappearance of unnecessary single use objects is likely to be long and not linear: hence, discussion about the correct communication of this process has been lately vivacious, including some questioning about the role of scientists in the matter (Krawczyk et al., 2023).

It can be easily suggested that we feel no empathy towards consumables, especially because no "trauma" is experienced from our side at the end of their life, and subsequently no willingness to prolong it e.g., by proposing a repair strategy. In more structured terms, studies about archaeological objects, produced in eras that hardly accepted the concept of end-of-life of objects, evidenced lately that reading the interaction of humans with them by "modern" eyes did not consider the wealth of interactions that were experienced with these in practice (Vindrola-Padrós 2023). These resulted in a kind of "continuous" relationship, the effect of which is reported in Figure 2.

Originally, single use consumables and consequently SUP

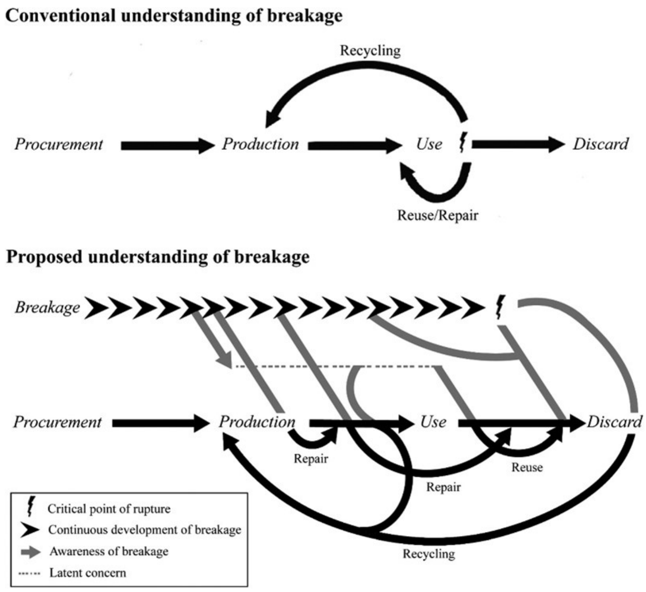

Figure 2. Proposed alternative reading of object breakage in a sense of total sustainability (avoiding until possible its discarding)

were conceived for hygienic purposes: for instance, it would appear senseless and dangerous to re-use non-washable diapers. Also, their environmental impact when disposed is well known: these consumables would therefore be need to be compostable after use. However, the difficulty to apply this measure is given by the fact that this would expose them to bacterial attack and in general terms make them unsafe for use (Mendoza et al., 2019). The question stays open so far, since technical issues in producing compostable and hygienic consumables are still unresolved. Despite this, also to possibly mitigate the sense of guilt generated by "black bag" disposal of these consumables, vividly colored packaging is recently produced for discarded diapers. This might offer some potential for possible empathy so to make it easier and more likeable the process to correctly dispose of the used diaper (Qi and Liu 2021).

Their single-use nature has also an influence on how these objects are designed: along the same line, diapers need to be comfortable and adaptable from an ergonomic and biological point of way, but by no means are designed to appear “nice”. Rather, the studies are concentrated on the effectiveness and reliability of disposal, so that the pollution linked to this kind of consumables is limited (Ntekpe et al., 2020). The characteristic of pleasantness, for non-edible materials, is confined to those objects that are supposed to have some life duration, and on which the fact that they are able to last some time is a factor for appreciation and likeability. In practice, the more you like them the later they become waste: this has a psychological foundation (Bortoleto 2014). This is not different from the concept that if food waste production is going to be reduced, a compromise between likeability, hence taste, of food, and attractiveness, hence sight/smell, and possibly even noise (concepts like crunchiness or fluffiness) needs to be reached, especially among children (Nichols 2014).

However, the absence of empathy has been extended over time to those items that are not single use, such as garments in a “fast fashion” philosophy. This concerns the material used, which is prevalently polyester, hence poly(ethylene terephthalate) (PET), but also an attitude that emphasizes the easy availability and fosters the “instinct” buying, which in turn does not promote the establishment of any empathy relationship between the buyer and the “fast fashion” product. For one, not allowing taking quietly a seat and deciding to buy implies an “unmindful consumption” model (Jha and Veeramani 2021).

The ”bioplastic” empathy-free paradigm

According to what exposed above, increasing the life duration of an object implies also reducing the amount of waste that is produced over time from their disposal. So, in principle, it would be of interest that objects that do not need to be designed for single use on hygienic grounds, are realized for the user to be “sympathetic” with their state and history (Dandavate et al., 1996). These objects will be thus exceeding their pure functionality, in a way to be discarded only when badly damaged. As the consequence, even repair might come back into the picture, which is seldom the case with plastic objects. This might break once and for all the link between product innovation and absence of empathy (Mc Donagh and Thomas 2010).

A good occasion has been the recent replacement of conventional oil-based plastics (described sometimes as “petroplastics”) with biodegradable ones, in most cases bio-based, hence obtained using natural (lignocellulosic/protein) raw materials. Typical examples are offered by poly(lactic acid) (PLA), based on a glucose molecule, then re-polymerized, or thermoplastic starch (TPS), based on the direct plasticization of a polysaccharide. Such replacement took place also in the field of design, with materials produced e.g., by mold-based methods, such as injection molding or extrusion, or else fabricated by additive manufacturing.

This led to an interesting overturning of the significance of biodegradability in materials. When plastic was introduced, its very limited degradation, mainly confined to photo-degradability under very prolonged exposition to sun or other sources of light, was regarded as a resource for a material that was intended as to be eternal. On the other side, as Hawkins (2017) puts it, “The eternal persistence of plastic seems to fuel only apocalyptic visions of ecological disaster”. Unlike marble, eternal but not moldable, and concrete, whose proneness to environmental degradation was not yet revealed at the time, the inalterability yet absence of empathy of plastic stands still as a proof of very long life and is perceived now as an issue rather than an opportunity (Kumar 2021). Unfortunately, and possibly with only economical but not common sense, after the 70s and before the recent limitations due to European directives, SUP objects literally flooded the market.

On the other side, biodegradable and compostable plastics have been perceived as the “good” replacement for conventional plastics, to produce basically any object, even supposed to have a significant life duration. The association of biodegradability, which implies the possibility of the environment to interact, affect and contribute to material aging, with “relative durability”, possibly in a predictable way, is becoming more frequent in literature (Yaguchi et al., 2020). In reality, to foster the appreciation of empathic content, the association of “bioplastics” with animal species e.g., lobster shells for chitin bioplastics, from which the material has been obtained does offer some more significance to the operation (Hudson et al., 2015).

If we want to really go “bio”, the interaction with plastic object needs to be fully modified and occur to the larger extent and with the highest number of senses, and for the longer possible time, therefore departing from what occurs with conventional plastic, where the effect of interaction with environment is virtually nullified. This includes, among other effects, color change, presence and gradual release of odors, surface modification, roughening/smoothing/levelling of the texture/aspect. In a word: ageing. On some very apparent effects that mark patently the difference of bioplastics from conventional undamaged plastics, such as loss of transparency, studies are available already (Baltscheit et al., 2020). Such as in Faust’s myth or even better as it is the case for Dorian Gray in Oscar Wilde’s novel, conventional plastic had been originally designed as not showing any particular sign of time passing by. Plastic has been defined as “simultaneously eternal and eminently disposable, perfect yet utter rubbish” (Boetzkes and Pendakis 2013). At a certain moment, it may simply fail, but this occurs only in case of under-dimensioning, which has been increasingly the case when plastics has been used for packaging. Under-dimensioning, and not plastic itself, has been recognized as one of the principal factors, together with wear, of the increasing effect on the environment of sea littering (Corraini et al., 2018).

At this point, the use of waste in the production of bio-based plastics makes the scene. Waste because it is abundant, while it avoids resource depletion by the use of newly extracted or produced raw materials. On the other side, waste might have a strong personality, being far from odorless, prone to environmental attack, in some cases not completely safe to use. Beyond fact, there is perception: some kinds of refuse are alleged to be nasty, which is some senses they might be too. Yet, if we really want to go “bio”, we

need to accept the coming back of interaction by the five senses and of empathy from the material. So, why not using waste itself (to different degrees of processing, but possibly as received) to make bioplastics, in a sense trying to familiarize with it, maybe starting from food waste (Makhal et al., 2021)? Use of waste represented a possible convergent (yet superposing in the long run) route to DIY material tinkering.

Switching to DIY materials and the search for empathy

The considerations in the above sections pose an essential question of what biocomposites are supposed to be: in general, it is suggested to be defined by the presence in it of some amount of bio-based material, possibly being completely formed of it. Materials originated from nature can be lignocellulosic, such as it the case with plant fibers (from bast, leaf, fruit, seed, bark, roots of a vegetable structure) (Zhang et al., 2005) or more definitely polysaccharidic, such as it is the case with algae or mucilage (Scognamiglio et al., 2020), but also with crustaceous shells (exoskeletons) (Daramola et el., 2020); proteinic, as with animal fibers, such as silk, wool, feathers, horns, etc., (Ilangovan et al., 2022) or mineral, such as it is the case with calcium carbonate structures obtained from shells, or calcium phosphate structures, obtained from fish bones , etc. (Bootklad et al., 2013).

As far as empathy is concerned, this general classification of biocomposites may be only partially helpful. In particular, the bio-fraction in the material can be too limited, which, apart from raising doubts about the possible “green-washing” philosophy followed, might result in a material very close to plastics or resins or traditional composites (e.g., fiberglass) and therefore not only their “empathy profile”, but also their carbon footprint might come to the point to not being discernible from a “synthetic material”. In other cases, may be the bio-fraction might not be that low, but the biocomposite could have been designed as to resemble the material it is supposed to substitute, for example the filler is inserted in an absolutely impermeable and ambient-resistant resin, such as epoxy or acrylic. It is not different from putting a nail work over the real nail. The sensation offered and the possible empathy will be attributed to the superposed material not to the underposed biological one.

Therefore, if the case above is produced, there is nothing specific in being a biocomposite in terms of empathy. It is also fair to say that the commonest cases about biocomposites deal with this kind of substitution process, trying to reproduce the synthetic material with the bio-based one and pretending it has the same properties and the same interactions with the users. This is an uncomfortable question about material substitution (e.g., Styrofoam with mycelium-based materials (Karana et al., 2018, Santulli 2023), or fiberglass with plant fiber composites using the same resin, possibly epoxy) is therefore that they ultimately are presented as the same material as far as sensations are involved. In the case of mycelium-grown foams, the texture may vary and the color is not uniformly white nonetheless, and the nuances of brown and yellow would depend on the very biomass used for feeding the fungi and also the touch might be rougher. Therefore, we can suppose that it might have sense to express likeability and recognizability of one piece with respect to the other, which in Styrofoam we would have much difficulty to do.

The principal reason to deviate from this trend would be to bring back the empathic relation with natural materials, and therefore the five senses interaction with it: this has been prevalently and largely lost by the success of oil-based plastics. However, if we want to bring back local natural materials, it is essential that this global interaction is restored. This is also in the interest of resuming some production systems: a typical example might be the hemp system, which including both food and non-food products, gives to the user a clear sensation of what can be a richer sense interaction (Fike 2016).

Experiences in the production of DIY materials

To make the interaction with biocomposites an empathic experience, the self-production can represent an option: this will detach ourselves from the feeling of being faced with a different type of plastics, just more bio-based. For this, we need a new aesthetic removed from the perfection and pretended eternity of plastics, which has been just transferred into bio-based plastic, as they were able to behave in the same way therefore inappropriately. This new aesthetics classifies DIY materials, which are prevalently based on the revalorization and the refocusing of waste, as the true strategy for sustainability, in five “kingdoms”: vegetable, animal, lapideum, recuperavit, and mutantis (Ayala Garcia and Rognoli 2017). It is from the esthetical characteristics of all these materials that a possible empathic interaction is generate. Self-production, beyond offering more value to a kind of artisanal working, enables to understand what the specific character of each material and relevant product can be, before passing to production. Of course, once accepted departing from the plastics esthetical and empathic concept, it is essential that all possibilities are taken to hinder as much as possible the degenerative processes such as fermentation and generically bacterial attack: this is created mainly from the experience of cuisine and generally cooking tradition.

The experience briefly described as regards the production of DIY materials started from different matrices, inspired to the traditional families of protoplastics, hence polysaccharide (starch, or cellulose based), or protein (e.g., milk whey) based. All DIY need to include some waste and to generate objects that are not intended as fully ephemeral. In particular, a set of twelve materials, produced during the experimentation at Università di Camerino and shown in Figure 3, will be described that have demonstrated a particularly long potential for life, which is essential for possible interaction, and their specific elements and possible empathic content will be summarized in Table 1. All the DIY materials presented have in common the fact to contain at least a type of waste, mainly originated from the food sector, but disrespectful their nature (polysaccharidic, ceramic, or ligneous).

In particular, the main components included in each of the DIY materials are reported in Table 1: when not indicated

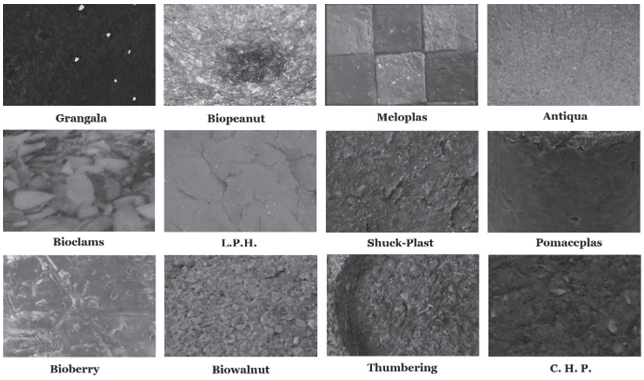

Figure 3. Surface samples of twelve DIY materials

DIY material	Principal waste component	Other characteristics
Grangala (GG)	Exhaust black tea	Expired milk-vinegar matrix
Bioclams (BC)	Clams and other seashells	Gelatin matrix
Biopeanut (BP)	Peanut shells	Lemon juice
Meloplas (MP)	Pomegranate (peel and seeds)	Use of thyme and cinnamon
Antiqua (AQ)	Exhaust ground coffee	Mix with silica (sand)
Bioberry (BB)	Brown berries waste (damaged/rotten)	Infused tea waste
Schuck-plast (SP)	Fruit peel	Added vinegar
L.P.H. (LP)	Ground eggshells	Added blended tomato peels
Biowalnut (BW)	Walnut shells	Expired milk-vinegar matrix
Thumbering (TR)	Exhaust ground coffee + sawdust	Use of cinnamon
C.H-P. (CH)	Grape waste	Use of balsamic vinegar
Pomaceplas (PP)	Oil pomace	Use of curcumin and vinegar

Table 1. Main waste components characterizing each of DIY materials described

otherwise, the basis for the material development is starch (potato/corn) plasticized using glycerol. In some cases, experience of herbs/spices coupled with DIY materials in order to offer scent and stop degradation.Suggestions for empathy, to be developed are offered in the map reported in Figure 4, where the evaluations have been suggested by the author, although they might obviously vary with user's perception. The fact that the materials have an empathic content would also allowing avoiding a single-use strategy. Some duration of life would be needed to be ensured, for this reason the experiments with this DIY materials were intended to be dedicated to some categories of objects, such as personal gadgets, toys or lamps, to which affection is particularly ensured.

From the above considerations, it can be easily revealed that the creation of DIY materials does offer a different and much richer interaction with the user that any plastic material may suggest. These DIY materials were in the past also defined, though possibly in a not completely appropriate way, as "self-produced bioplastics". This is incongruous, since in practice real plastic behavior does seldom occur.

In a strictly technical sense, these bioplastics can be considered as biocomposites, yet they are fabricated, according to a gradually fine-tuned recipe, to offer a specific sensation and experience, according from the self-evaluation by the developers. It can also be noted that the complete divulgation of recipes together with the material produced would allow the reproduction of the material in a tailored way so to enable an as smooth as possible correlation of the properties with what is desired in terms of expressivity and empathy.

A further step is obtained by the progress in the materials, as far as they age and evolve. In that sense this would make acceptable the presence of mold in different forms and geometries, obviously in a less propositional and structural way than it is the case for fungal art (Grunwald 2021). In addition, also the formation of cracks, as well as modifications of their relation with light, can show an empathic significance and value. This is reported in Figure 5.

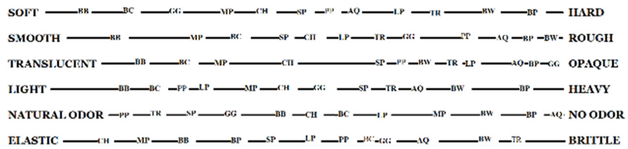

Figure 4. Different characteristics of DIY materials reported on semantic differential scales (SDS)

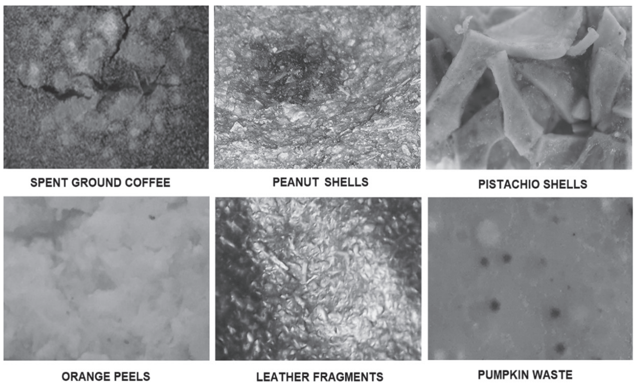

Figure 5. Presence of aging symptoms in waste produced DIY materials

Conclusions

DIY materials production including different types of waste with recipes developed and always modifiable according to an experimental method approach for expressive properties fitting, are able to offer a richer interaction that it is the case for industrial bioplastics. Moreover, they may rebuild the empathy bond with the user, breaking the vicious circle of rapid "use-and-throw" process and redefine the acceptability of natural materials including some forms of refuse and overtly maintaining their characteristics. These would include among others non repeatable textures, colors, surface roughness and specific/mixed odors, and of course would offer variable characteristics over time, as typical for really naturally occurring materials. In the long run, this will also include the presence of signs of degradation as a neutral aspect, without any esthetic judgement, in the understanding that this will change our interaction and empathy with the material.

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