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A Different Empathy Towards the Use of DIY Biocomposites in Design

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Abstract. The interaction of oil-based plastics with the user is limited to the sight and possibly touch, being in any case predictable and not very satisfying. Since bioplastics have been prevalently designed to fit the needs for plastic substitution, the natural elements present in it have intentionally been concealed, so that it is difficult for the user to recover the sense of what using a natural material is like, even worst of what is dealing with an upcycled waste in a material fit-for-use in design and not intended for single use. In this work, the preparation of DIY materials including different kinds of food or non-food waste according to a self-developed and tailored recipe may constitute a possibility. The surface aspect and the expressive properties of a set of twelve selected DIY materials developed in Università di Camerino according to an opposite characteristics map are reported, to serve as reflection of their likely empathy content and on building a richer and more reputable interaction with materials including waste, in view of an effective upcycling process.

Introduction

We may prove feelings towards objects and materials that constitute them: this in what makes a product or any artifact emotionally durable [1]. These sensations are constituted by a complex 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 [2]. 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 [3]. A "five senses" interaction with some materials and objects is possible, even if not always desired: some examples are even curious e.g., the possibility to improve the self-diet by obtaining selenium by licking stones, which is one of the paradigmatical category of materials traditionally used in history [4].

This interaction is complex and sometimes very difficult to be elicited and brought to the surface in rational terms, hence, to be quantified. However, the success of recent communication is due to an effective interaction design, starting e.g., with touch screen design, which is ultimately the result of a well-tailored, though sometimes disrupted e.g., by the presence of contaminants, tactile relation the users have with a conductive film in indium tin oxide (ITO) [5]. In this case, and with other objects of common use, empathy, if ever it exists, is difficult to be described, the significance of ITO in a touch screen is strictly confined to its (mostly) satisfactory interaction with the user. However, also in this field, the possibility to have a variable stiffness device leads to haptic design, where physical sensations are really felt through vibrations or touch [6]. Still, it is probably inappropriate to talk about real empathy for haptic interaction, especially as regards the effect of it.

In the case an empathy is really existing between the user and the material, however, an effective interaction does represent the reason why we like/dislike some object, and decide to buy/keep/repair it, or ultimately to preserve it, even if damaged or no longer functioning, or to dispose of it [7]. In other words, there is a kind of convergence between our personal feelings and what we think of the object, in a sense on how it matches our sensations, even coinciding with them. If there is empathy, the effect of materiality, including all aspects of our interaction with the artefacts, can create a sense of well-being, and it is suggested that empathy towards materials, and their combinations, might contribute to sustainability [8].

Post-plastics interaction with materials and objects

Having said that, from 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 includes also 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 [9].

There are also further nuances to this concept of “technocentric city”, which is no longer widely accepted. For instance, it has been reported that, as regards single use plastic packaging (“plastic bags”), a sense of guilt might be even experienced if they are not correctly disposed of, while in reality reducing the carbon footprint of plastics goes often well beyond what the common citizen can do (though it is of paramount importance that he/she abides to the disposal regulations) [10].

Clearly the situation has not always be like the above described: at the early times of oil-based plastics there was 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). This lightness and also the odorless characteristics of plastics was also coupled with hygiene and safety, since it was connected with the limited, if any, contamination of plastics by bacteria and other polluting agents [11]. 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. In contrast, the sensation that plastic objects could offer bright colors, offered by the mass-coloration process with dye substances introduced directly in the masterbatch, remained overtime, but of course allowed a kind of empathic behavior of the material just as far as the sense of sight is concerned [12].

In contrast, the touch sensation of plastics was a quite repetitive and uniform smoothness, to the point that 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 offering no nuances to the touch [13].

Proto-plastics as precursors of biocomposites

The above characteristics of oil-based plastics in terms of poor interaction with the user and limited to touch and sight are not able to be referred back to the previous generations of proto-plastics, which were developed during the XIX century, initially thermosetting, looking for developing some thermoplastics to ease molding [14]. A pivotal example, in terms of its distance from contemporary plastics, was bois durci, a mixture of sawdust and bovine blood, most clearly two sources of waste from different sectors [15]. Another material obtained from refuse, more specifically 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 changes in temperature due to day-night cycles, and the structural limitations represent still a problem in a possible up-to-date reprise of it [16]. Also, galalith was able to absorb and retain also environmental odors, in particular some specific scent from their production matter, such as it is the case for milk whey in galalith [17]. Galalith can be also interpreted as the substitute for the use of natural protein structures, such as tortoise shells and bovine horns, in a plasticized form, which was equally diffused at the time [18].

Another protoplastic, yet based on sugar derivatives (polysaccharides), and inherently moldable, and whose history was even more successful than it is the case for galalith, was cellulose acetate, which was able to resist the historical passage to oil-based plastics, being marketed down to these days, though in slightly modified form. Once again, cellulose acetate can be thought of as originated from some kind of waste: cellulose derives from paper production and acetic acid is a by-product from wine and spirits production. Though apparently neutralized by thorough washing until neural pH is reached, it is well known that cellulose acetate showed over time a typical polysaccharidic scent, especially when produced at higher thicknesses than the typical film one, hence over than 500 microns [19].

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, considering the existing connection with the durability and 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 [20] and concrete/constructions [21].

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, to escape from the narrow mindedness of single use, which has significant environmental impact in a throwaway society, especially in that it does not reduce the amount of materials produced and consumed [22]: a possible approach is convert end-of-use plastics into value-added materials [23].

In itself, the application profile of single-use plastics (SUP), which have been increasingly challenged until a process to put them off-market has effectively started e.g., by 2019/904 European Commission directive, excludes to even thinking 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 [24].

It can be easily suggested that we feel no empathy towards consumables, especially because empathy would imply that we would like to prolong the life of the object: instead, consumables are there to be worn out and disposed of in the prescribed time. This is because, as above clarified in the case of plastics, single-use consumables are designed as such first of all for hygienic purposes: for instance, it would appear senseless and dangerous to re-use non washable diapers. While their environmental impact is well known and widely investigated, these consumables would 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 [25]. The question stays open so far since technical issues in producing compostable and hygienic consumables are still unresolved. However, also possibly to mitigate the aforementioned sense of guilt generated by "black bag" disposal of these consumables, it can be noticed that packaging for discarded diapers is made also in color with some potential for possible empathy so to make it easier and more likeable the process to include the used diaper and therefore correctly dispose of it [26].

Their single-use nature has also 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 [27]. 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 [28]. 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 [29].

However, the absence of empathy has been extended over time to those items that are not designed for single use, such as garments in a "fast fashion" philosophy. This concerns the material used, which is prevalently polyester, hence poly(ethyleneterephtalate) (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 [30].

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 to produce some empathy with the user [31]. These objects will be therefore going beyond their pure functionality, in a way to be discarded only when it is irreparably damaged and even its repair might come back into the picture, which is seldom the case with plastic objects. This might ultimately break the link between product innovation and absence of empathy [32].

A good occasion has been the recent replacement of conventional oil-based plastics (described sometimes as "petroplastics") with biodegradable ones, which in most cases are also 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 degradability, 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" [33]. Unlike marble, eternal but not moldable, and concrete, which was deemed eternal until its proneness to environmental degradation was discovered, the inalterability yet absence of empathy of plastic stands still as a proof of very long life [34]. Unfortunately, and possibly with only economical but not common sense, after the 70s, single use plastic objects literally flooded the market.

A shift towards longer use bioplastics

However, the association of biodegradable materials with single use has been fading away with time, by the production also of durable, then intrinsically empathic objects, using the so-called "bio-plastics". This can go, and has gone indeed, to exceedingly long distances, such as in the production of a "biodegradable chair" [35]. For example, a chair or more generally a seat is an iconic object, which needs to be empathic to us, since we have a direct interaction and cannot easily avoid touching it, when we suppose it is e.g., dirty, or somehow contaminated. It is also one of the objects in which defining factors leading to users' satisfaction is more complex, leading to specific studies to assess it [36].

Over time, plastics also entered the field of chair production, for specific reasons, which include lightness, hence ability to be displaced when needed, resistance to environmental agents, and easy packing or stacking ability. Yet, making it in biodegradable materials obviously accelerates ageing of the seat and may lead to premature failure, although it might be claimed that using bioplastics in durable products would reduce food waste sent to incineration and worst landfilling [37]. Yet, there is nothing special about empathy when using bioplastic in this specific way, as it looks and feels the same that conventional plastics, being treated to be processed with the same methods: it is only less durable. Also, an excessively fast biodegradability, as it occurs for compostable materials, would possibly oppose to a long duration of an object, while the sudden failure of such an empathic object, such as chairs, would be likely to create frustration if not refuse in the user.

To summarize, biodegradability does possibly improve end-of-life of materials and objects, whenever compostability conditions are met, but in another sense, if this is done, it deeply modifies our empathic relation with the obtained object. This occurs, in particular, whenever its aspect is modified over time and use: the effect of interaction with environment is virtually nullified in the case of conventional plastics, while for biodegradable plastics carries together some phenomena, such as color change, presence and gradual release of odors, surface modification, roughening/smoothing/levelling of the texture/aspect. In a word: ageing. Conventional undamaged plastics, as in Faust's myth, does not show any particular sign with time passing by. More dramatically, plastic has been defined as "simultaneously eternal and eminently disposable, perfect yet utter rubbish" [38]. At a certain moment, it may simply fail, but this occurs only in case of under-dimensioning.

In practice, concentrating on claims on waste reduction, bioplastics have been presented in a way to offer the same characteristics of traditional plastics (including a very reduced empathy with the user), in addition being biodegradable to the point of being compostable, which again is debatable. In other words, they have been designed as being aimed at single-use even when they are not. The consequence of this is that the introduction of bioplastics led to an increase of waste, hence to a more reduced empathic acceptance from the user (it is sufficient to think of the difficulty to reuse bioplastic bags, too brittle and gradually degrading for the purpose). 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.

To obtain a different empathic process using biocomposites, and also to reconstruct the link between the users and natural materials, which leads to its acceptance, a self-production process is proposed, to obtain objects from materials that can be defined as DIY materials: in that way, the empathic map can be really different from the very poor interaction experiences with oil-based plastics.

DIY materials (biocomposites) 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. Bio-based material in composites might be in the form of a resin, or in the form of a filler, which can take different geometries, from very elongated to quasi-spherical. The name of "biocomposite" is in effect attributed to a material in which any of these components is bio-based, which means originating from nature, although the same term bio-based does refer also to polymer resins, in which only the raw material is bio-based, yet the obtained material is not biodegradable.

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) [39] or more definitely polysaccharidic, such as it is the case with algae or mucilage [40], but also with crustaceans' shells [41]; proteinic, such as it is the case with animal fibers, such as silk, wool, feathers, horns, etc., or mineral, such as it is the case with calcium carbonate structures obtained from shells, or calcium phosphate structures, obtained from fish bones [42], etc.

As far as empathy is concerned, this general classification of biocomposites may be only partially helpful for a number of reasons. In particular, the bio-fraction in the material can be too limited, which, apart from raising doubts about the possible "green-washing" philosophy followed in that specific case, 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 much 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 [43], 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 be not uniformly white nonetheless, so that 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 lost as an effect of 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 [44].

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 enable detaching 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 [45]. It is from the esthetical characteristics of all these materials that a possible empathic interaction is generated. 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 (limited) 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 by exploring and taking knowledge from cooking uses and 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 1, 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).

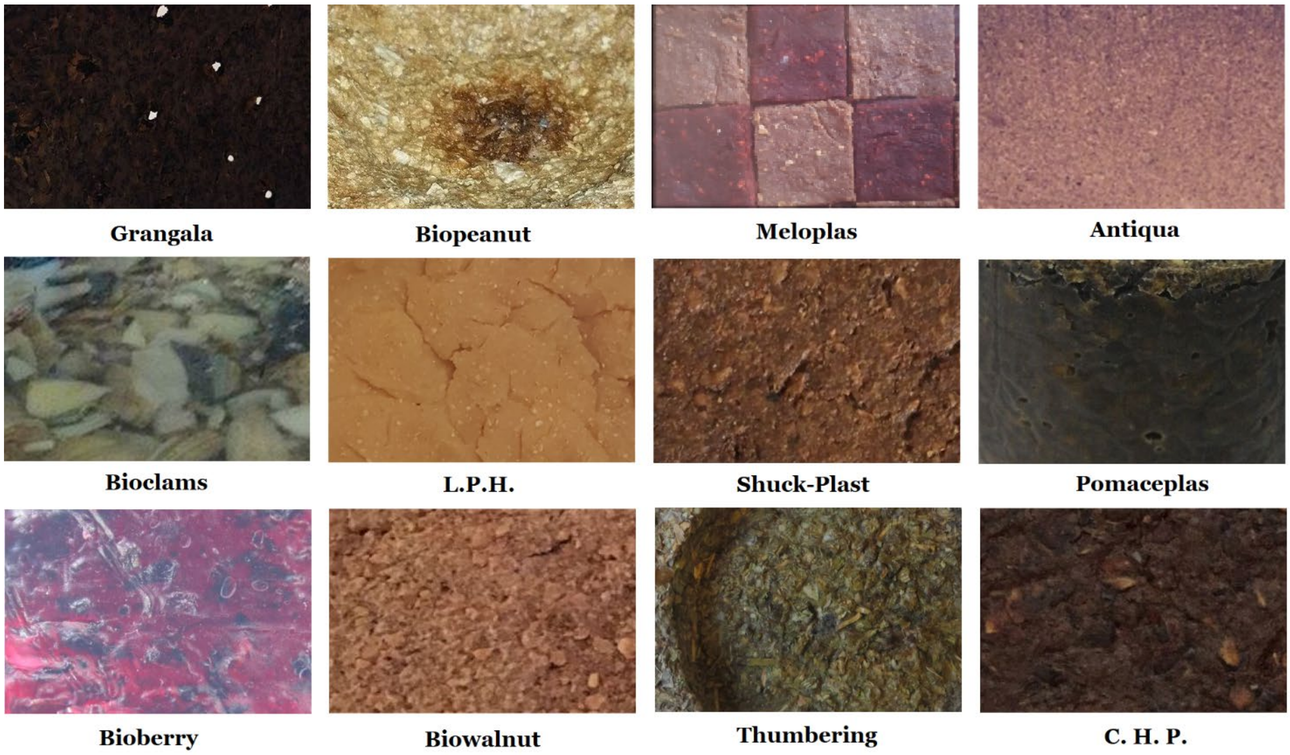

Fig. 1. Surface samples of twelve DIY materials

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

Table 1. Main waste components characterizing each DIY material

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

Suggestions for empathy to be developed are offered in the map reported in Figure 2. 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.

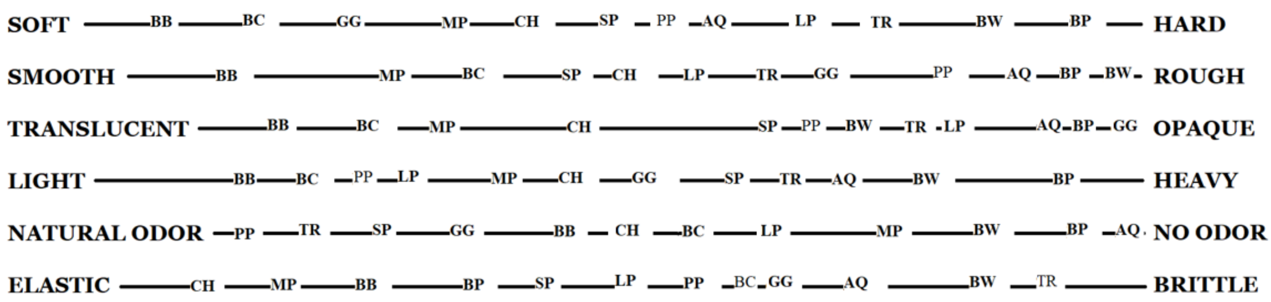

Fig. 2. Characteristics of DIY materials reported on an opposite scale

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 real plastic behavior does seldom occur in reality.

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, which is schematically reported in Figure 2, 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.

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.

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