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Analysis of the visual language of design of sustainable packaging manufactured from biomaterials

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Abstract

In the context of the environmental problems caused by product packaging, sustainability is becoming one of the main goals of designers. Designers are no longer content to highlight the environmental friendliness of packaging through 'green symbols', 'recycled symbols' or 'renewable symbols'. Instead, designers have opted for bio-materials such as plant fibers, waste from other materials and mycelium to form the bulk of the eco-packaging. The materials themselves are used to create a new design language, which directly reflects the eco-friendly features of the packaging. This paper analyses existing examples of sustainable packaging design and explores the new visual language of sustainable packaging design, mainly by means of literature and questionnaire research.

Keywords: eco-friendly packaging, biomaterials, sustainable design, packaging applications, circular packaging

1. Introduction and background

The evidence is now overwhelming that the depletion of the Earth's finite natural resources is attributable to human behavior (Krausmann, et al., 2009). From the perspective of product packaging, the problem of wasted resources and pollution caused by packaging is the background basis for the research in this article. In the latest packaging bill, until 2030, packaging produced in the EU, should be fully recyclable or reusable and disposable plastic products such as cutlery, straws and beverage containers should be phased out (Matthews, Moran and Jaiswal, 2021). This article will focus on the current state of packaging pollution and new packaging designs in response to sustainable design.

1.1 The environmental problems associated with product packaging recycling

The environmental problems associated with the difficulty of recycling and the low recycling rate of packaging waste are clearly known, and Rokka and Uusitalo (2008) argue that the increase in packaging waste brought about by the food retail industry has led to the greatest environmental problems in the global consumer sector. The packaging waste discussed in this paper is mainly paper, cardboard, wood, plastic, glass and metal. In France, for example, the Statista Research

Department (2022) estimates that the amount of packaging waste in France in 2020 was below 12.7 million tonnes. In a survey of recycling rates for packaging waste, there are significant differences in recycling rates across Europe (Tallentire and Steubing, 2020). In 2019, the packaging recycling rate for paper and board packaging is the highest in the European Union (EU-27) at 82 %. Plastic packaging has the lowest average recycling rate at 40.6 %, but recycling rates vary greatly from country to country (Statista Research Department, 2022). The same is true in the UK, where recycling of packaging waste still fails to reach more than half of the recycling rate. According to UK statistics on waste (2022), the two main materials least recycled of all packaging waste between 2019 and 2021 are plastic and wood, both with recycling rates of 42 % to 47 %. However, when viewed globally, the waste and pollution problems associated with plastic packaging are even more significant, with the UN environment programme (2022) showing that of the 7 billion tonnes of plastic waste produced globally, 36 % is contained in packaging uses and less than 10 % is recycled.

1.2 The environmental problems associated with product packaging production

In addition to the packaging waste pollution mentioned above, which is difficult to recycle, the process of making packaging is also one of the main causes of packaging

pollution. Given the current environmental situation, in addition to the known polluting nature of the production process of packaging made from petroleum-based materials, packaging made from paper and board is not entirely environmentally friendly. Some theories that paper comes from wood, and that the pollution caused by deforestation, the transport of wood, the pulp bleaching process and the packaging printing of paper boxes should all be taken into account as to whether it is environmentally friendly. Due to the non-waterproof and fickle nature of paper, laminating and varnishing are important aspects of paper-based packaging, and Wang, Hou and Lin (2013) found that laminating and varnishing added 239 kg of greenhouse gas emissions to the production of 20 000 color-box packages printed using the lithographic offset printing process.

It follows that, from an environmental point of view, the use of large amounts of non-renewable resources in packaging design and the large carbon emissions generated by the manufacturing process and the low recycling rate of packaging waste do pose a significant threat to the existing environment-in terms of wasted resources, greenhouse gases and environmental pollution.

1.3 Sustainable packaging design and two eco-friendly visual languages

Against the backdrop of global climate issues caused by human behavior, it is easy to see that designers have long turned to designing for the environment with the 3Rs of green design, sustainable design concepts and low carbon design concepts that have been developing since the 20th century. In many regions, attempts have been made to change eco-consumption behavior by raising social and individual awareness and highlighting the benefits that come from choosing eco-friendly products. Since the 1980s, many companies have done this by developing 'greener' formulations of their products, i.e. by developing packaging that is less harmful to the environment than traditional petroleum-based packaging materials, particularly plastics (Bech-Larsen, 1996).

Benson (2007) suggests that to achieve sustainable design, designers should reduce carbon emissions at source by selecting materials that are local or can be manufactured locally to reduce carbon emissions in transit. As the concept of sustainable design evolves, Sustainable Packaging Coalition (2011) put forward some rules on sustainable packaging. Sustainable packaging is purchased in a responsible way, is effective and safe in the whole life cycle, conforms to the performance and cost standards of the market, is manufactured entirely using renewable energy, and once used, it can be effectively recycled.

In the actual use and sale of environmentally friendly packaging materials, there are two main types of design available to show the environmental friendliness of the packaging itself; one is to post a 'green symbol' and the other is to use the characteristics of the packaging material as a visual symbol. The most common approach is for designers to respond to green packaging requirements by posting 'green symbols', 'recycled symbols' or 'renewable symbols' (Figure 1) on the packaging, and there is no denying what Koenig-Lewis, et al. (2014) argue that emotions are an important driver of eco-friendly purchasing decisions, with consumers creating or reinforcing a 'greener self-identity' through product choice. Duckworth, et al. (2022) confirm that consumers are heavily influenced in their consumption choices by 'green-labelled' packaging, particularly in favor of 'sustainable' and 'local materials', and are willing to pay a 'premium' for their products. And without the 'green label', it is difficult for consumers to associate their purchasing decisions with their environmental impact (Rokka and Uusitalo, 2008).



Figure 1: Moebius Loop-sign of recycling material content

However, the use of simple 'green symbols' does not satisfy consumers' understanding of the need to update environmentally friendly materials. Nguyen, et al. (2020) believe that consumers are still unaware of eco-friendly packaging in emerging markets. Consumer anxiety about new technologies for eco-friendly packaging, such as packaging made from organic or edible materials and plastic bottles containing chemicals such as bisphenol A, can lead to a direct reduction in consumer desire to buy (Grunert, 2002). The most salient aspect of eco-friendly packaging as perceived by consumers relates to the packaging material, and the most effective way for them to judge whether packaging is eco-friendly is 'what they see is what they get' (Nguyen, et al., 2020).

2. Method and results

In practice, designers and brands are already applying the 'what you see is what you get' theory, using local biomaterials as the main material for packaging and visually retaining the original material texture. In existing research, the main non-petroleum-based packaging materials used for sustainable design are beeswaxes,

pineapple leaves, mycelium, seaweeds, cocoa beans, starch, rice husks, coconut husks, wheats, sawdusts, seeds and bamboos. There are two main ways of making packaging from biological materials. One is the direct use of a single material for turning or pressing, such as the use of beeswax for honey jars, which does not require the mixing of other materials, and can be completed with beeswax alone. The other is to mix two or more biological materials in order to increase the resilience, compensate for the lack of a single material or to plant it after use, for example by mixing pineapple leaves with seeds, which act as a biodegradable material and provide nutrients for the seeds after use, thus completing the planting.

After the packaging has completed its mission, there are two main types of end-of-life disposal – recycling and composting. In order to discuss the use of sustainable materials in packaging design from different dimensions, five different types of eco-friendly packaging designs are examined in this paper. Case 1, a honey jar using a single material – beeswax (recyclable). Case 2, a plantable snack packaging design that mixes seeds with pineapple leaves (compostable planting). Case 3, compostable mycelium and hull mix – fragile packaging design (compostable) Case 4, an alternative to cardboard packaging design – seaweed paper (compostable). Case 5, a durable take-away box based on discarded cocoa beans (recyclable). The following are specific interpretations and visual characterisations.

2.1 Visual characterization of sustainable packaging based on biomaterials

Case 1: Bee Loop (Figure 2), a Lithuanian honey brand, uses beeswax, a waste product from local honey production, as a raw material for its packaging, thus reducing the use of environmentally unfriendly plastic bottles, glass bottles and plastic stickers. ‘When honey is harvested from the honeycomb and made ready for consumption, we put the honey back where it belongs – into the beeswax. Alternatively, beeswax honey pots can be returned to us or your local beekeeper. When the beekeeper returns beeswax to the hive the circle of honey-making continues’ (Bee Loop, 2022). From the visual point of view, the color of the jars is not bleached, printed or colored, but rather the color of the honeycomb itself. These three types of honey pot are made from their own honeycomb beeswax: with the *Linden Honey Pot* appearing light yellow, the *Buckwheat Honey Pot* amber and the *Forest Honey Pot* brown due to the difference in color of the honey. The honey pots have a rough, unpolished, frosted surface and are wrapped in unbleached wood sourced twine and corrugated paper, revealing the yellow beeswax bottle through its own holes, visually creating a rough dotted symbol.



Figure 2: Bee Loop (2022) honey pot made of beeswax in a box made from corrugated cardboard

Case 2: In the Philippines, one of the world’s largest producers of pineapples, Pat Mangulabnan has made pineapple leaves and seeds into ‘Pinyapel Paper’ (Figure 3) for food packaging, which is printed using organic soy inks (Nagal, 2021). The packaging reuses pure, natural pineapple leaves, which are buried in the soil after use and act as a natural composting material to help the seeds germinate. Visually, the unbleached and uncolored coarse fiber paper has a low-saturation yellow-grey and grey-green color, with a rough and grainy surface due to the lack of further processing of the plant fibers and the addition of plant seeds as a mixture.



Figure 3: A snack packaging box made of ‘pinyapel paper’ printed using natural soy ink (Nagal, 2021)

Case 3: The London-based packaging design company Magical Mushroom (n.d.) has worked with a number of UK beauty, fragrance and skincare brands using the new biomaterial mushroom mycelium to create packaging that naturally degrades in around 45 days (Figure 4). Magical Mushroom claims the mycelium has the unique quality to produce a hard-wearing, cost-effective and fully sustainable alternative to polystyrene packaging. Mushroom packaging is a mixture of mushroom mycelium and various local agricultural waste products – wheat and sawdust, etc. The 3D printed packaging takes just seven days to complete, so visu-

ally, the fibrous properties of mushroom mycelium and other agricultural by-products are retained, with a creamy, rough, grainy surface.



Figure 4: Mushroom mycelium based packaging for Evolve, British skincare brand (Magical Mushroom n.d.)

Case 4: To prevent deforestation, reduce the pressure on forests and the environmental impact of the paper industry, minimize the use of virgin wood and use no synthetic additives, Notpla has partnered with Canopy to launch *Notpla Paper* (Figure 5), an eponymous product made from seaweed and wood pulp for packaging, labels and envelopes (Englefield, 2022). Notpla Paper is based on fibers and biomass left over from the company's extraction of seaweed gum for other products, in order to achieve a new way of recycling whole seaweed. Thanks to the mix of wood pulp and seaweed fibers, Notpla Paper has a smooth surface to the touch but visually has spots and particles of broken seaweed fibers, with the color varying according to the algae species, e.g. brown algae appearing reddish-brown and green algae dark blue-green.



Figure 5: Wrap packaging made of seaweed and wood pulp based Notpla Paper (Englefield, 2022)

Case 5: The *Zero Takeaway Packaging COCOA* (Figure 6), made from cocoa, is an experiment in circular economy principles by PriestmanGoode (2023). *Zero Takeaway Packaging* uses natural materials wherever possible. In addition to the local industrial chocolate production leftovers used in the main body, mycelium is used for insulation, natural rubber is used for the handle section, the outer bag is made from biodegradable and renew-

able materials, the lid section is made from pineapple leaf fibers and algae extract is used as an alternative to cling film. The takeaway box follows the original dark brown color of the cocoa beans and is not finely polished, retaining the uneven dotted texture caused by the difference in color of the granular material itself. Paula Nerlich, the designer of *COCOA*, said in an interview (Savaton, 2022) that the aesthetic impetus for the work was her passion for the texture and color of the material.



Figure 6: Food-safe takeaway boxes made of cocoa and other sustainable material (PriestmanGoode, 2023)

Through the analysis of the production process and visual characteristics of the above sustainably designed packaging, it is easy to see that the designers retain the plant fibers of the material and reduce the bleaching, coloring, fine grinding and highly purified aspects of the production process, reducing time costs, labor costs and the carbon emissions generated during the production process. The original color and rough graininess of the material is a relatively unified choice by the designers, as seen in the designers' and brands' statements, and it can be assumed that the texture of this renewable raw material or biomaterial itself has become a visual design language. It is worth discussing that Nguyen, et al. (2020) point out the importance of the aesthetics of packaging in actual sales, and that designers should balance the aesthetics of packaging design and brand design while being environmentally friendly when dealing with consumers. In a traditional study of packaging design and consumer psychology, Silayoi and Speece (2004) found that the main factors influencing consumers' purchasing decisions were packaging color and graphics. In terms of visual appeal, Magnier and Crié (2015) found that this type of less colorful and simple eco-friendly packaging was not advantageous for consumers. However, designers have not abandoned the practice of retaining plant fibers and original colors, and from a more recent study, Magnier and Schoormans (2017) conclude experimentally that white packaging has a greater environmental bias compared to red packaging in the proposition of eco-

friendly packaging, while fiber-based packaging materials trigger higher product environmental friendliness ratings than plastic packaging materials. Therefore, reducing the inks in the production and manufacturing process of eco-friendly packaging and retaining the original fibers and colors will not only not reduce the visual appeal, but will instead highlight its own environmental value through this simple and effective method.

2.2 Audience perception of environmentally friendly visual symbols for sustainable packaging

In order to further explore the perspectives from which audiences get their eco-feelings from eco-packaging, a simple web-based questionnaire was conducted on the above examples of eco-design from the last two years. The questionnaire explores two aspects: on the one hand, which visual features consumers perceive as environmentally friendly in packaging, and on the other hand, whether consumers can rely on visual judgement alone to dispose of waste packaging. This is a general study of the visual perspective that consumers have on eco-friendly packaging, and the questionnaire was not strictly limited to the audience, ensuring that the product was placed in front of them in a random way. Of the 524 questionnaires returned, 49.4 % were female, 26.3 % were male and 24.2 % were transgender (Table 1). In terms of the age of the respondents (Table 2), 25–30 years old was the largest group, with 27.1 %. This was followed by 18–24 and 31–35 years old. The remaining age groups all accounted for around 10 %. Regarding the educational level of the respondents (Table 3), more than half of them had a bachelor’s degree.

Table 1: Gender of respondent

Gender	Number	Proportion
Male	138	26.3 %
Female	259	49.4 %
Transgender	127	24.2 %
Intersex	0	0.0 %
Undetermined	0	0.0 %
Prefer not to say	0	0.0 %

Table 2: Age of respondent

Age	Number	Proportion
Under 18	53	10.1 %
18–24	97	18.5 %
25–30	142	27.1 %
31–35	92	17.6 %
36–40	45	8.6 %
45–50	45	8.6 %
Over 50	50	9.5 %

Table 3: Education level of respondent

Level	Number	Proportion
Below high school	102	19.5 %
High school	88	16.8 %
Undergraduate	277	52.9 %
Master	55	10.5 %
PhD	2	0.4 %

To ensure that the audience could think about the packaging in a multi-dimensional way, five multiple choice questions were created on the materials and characteristics of the packaging, including:

- Its color makes me feel environmentally friendly,
- Its shape makes me feel environmentally friendly,
- Its roughness makes me feel environmentally friendly,
- Its graininess makes me feel environmentally friendly, and
- I can’t visually perceive its environmental friendliness.

There were also 4–5 options for how the packaging can be disposed of: ‘landfill for composting or planting’, ‘incinerate’, ‘put it in the recyclable bin’, ‘clean it and reuse it’, and Bee Loop (2022) offering a ‘send it back to the manufacturer’ service. The questionnaire received 789 views and the data return reached 524; a return rate of 66.4 % can prove that the results can be used as a reference for this study. In the overall analysis of the data, for each of the five eco-packages, less than 1.0 % of the audience could not intuitively perceive the eco-friendliness of the packaging. Under the assumption that environmentally friendly packaging is used, only 3.1 % to 5.7 % of respondents chose to use the non-environmentally friendly disposal method – incineration.

From the Bee Loop survey, it is evident that the different visual elements provide similar environmental perceptions (Table 4), with 47.3 % to 60.5 % of respondents being able to perceive the eco-friendliness of the Bee Loop product in its unpolished yellow bottle and unbleached corrugated packaging. The most notable of these was the ‘graininess’. In the survey on the ‘disposal method’ of Bee Loop (Table 5), a majority of respondents (42.7 %) said that ‘throwing it in the recyclable bin’ was the most appropriate way to dispose of it, based on visual judgement alone. However, only 11.8 % of respondents opted for the brand’s call to ‘send it back to the manufacturer’.

In the Pinyapel Paper survey, the most evocative of respondents’ environmental feelings was the roughness caused by the fibers of the pineapple leaves and

Table 4: What are the visual aspects of this five packages that consumers can perceive as environmentally friendly (multiple choice questions; N for number, and P for proportion)

Options	Bee Loop		Pinyapel Paper		Magical Mushroom		Notpla Paper		COCOA	
	N	P	N	P	N	P	N	P	N	P
Color	248	47.3 %	284	54.2 %	198	37.8 %	240	45.8 %	291	55.5 %
Shape	276	52.7 %	259	49.4 %	303	57.8 %	275	52.5 %	235	44.8 %
Roughness	237	45.2 %	297	56.7 %	236	45.0 %	214	40.8 %	300	57.3 %
Graininess	317	60.5 %	215	41.0 %	283	54.0 %	308	58.8 %	231	44.1 %
Can not	4	0.8 %	3	0.6 %	2	0.4 %	3	0.6 %	4	0.8 %

Table 5: Consumers judge the treatment of these five packages only from a visual point of view (single choice questions; N for number, and P for proportion)

Options	Bee Loop		Pinyapel Paper		Magical Mushroom		Notpla Paper		COCOA	
	N	P	N	P	N	P	N	P	N	P
Landfill for composting or planting	139	26.5 %	118	22.5 %	179	34.2 %	56	10.7 %	127	24.2 %
Incinerate	16	3.1 %	17	3.2 %	23	4.4 %	25	4.8 %	30	5.7 %
Put it in the recyclable bin	224	42.7 %	203	38.7 %	170	32.4 %	216	41.2 %	198	37.8 %
Clean it and reuse it	83	15.8 %	186	35.5 %	152	29.0 %	227	43.3 %	169	32.3 %
Send it back to the manufacturer	62	11.8 %								

the mix of plant seeds, with a percentage of 56.7 %. It was followed by its yellow-grey and grey-green color, which differed from the highest percentage by only 2.5 %. The remaining two areas were below 50.0 % (Table 4). In terms of recycling (Table 5), apart from the non-environmentally friendly method of incineration, 'landfill for composting or planting', which is the most responsive to the design of the packaging, is the lowest of all the recycling options, with only 22.5 %. The proportion of respondents who chose to put it in the recyclable bin or reuse it was above 35.0 %.

In Magical Mushroom's eco-friendly packaging design, the granular surface and soft shape of the packaging, made up of mushroom mycelium and by-product waste, gave more than half of the respondents a sense of eco-friendliness (Table 4), while the seemingly bleached or colored cream color was less eco-competitive than the other aspects, with only 37.8 % of respondents considering its cream color to be eco-friendly. In the end-of-life survey (Table 5), the visual sense of mycelium was more likely to suggest 'landfill for composting/growing' to consumers, followed by disposal in a convenient way – in the recyclable bin.

In the question on the source of environmental feelings about Notpla Paper (Table 4), the graininess due to the mixture of seaweed and pulp took the top spot, with more than three hundred people having environmen-

tal feelings about it, followed by the simplicity of the shape giving 52.5 % of the audience an environmental feeling. The other two options – color and roughness – were chosen by more than 40.0 % of the audience. In terms of subsequent disposal (Table 5), using visual judgement alone, the highest number of people felt that it could be cleaned and reused, 1.1 % more than 'put it in the recyclable bin'.

In the questionnaire on COCOA packaging design (Table 4), retaining the original color of the cocoa was as environmentally attractive to respondents as retaining the coarseness of the cocoa beans' impurities, with over 55.0 % of the audience choosing both aspects. Both shape and graininess were chosen by around 44.0 % of respondents, a difference of over 11.0 % compared to the first two. In terms of end-of-life options (Table 5), disposal in the recyclable bin and reuse after cleaning were the majority of choices.

The above tables show that the roughness of the material due to fiber residue or the reduction in detail and the color of the material itself, left unbleached or recolored, can evoke a feeling of environmental protection to varying degrees. However, when it comes to the disposal of waste based on visual judgement alone, the easiest option of 'throwing it in the recyclable bin' still dominates, being the first choice three times out of five and the second choice twice.

3. Conclusion

Due to the climate problems caused by pollution in the production of packaging and the low recycling rate of packaging waste, and in response to some policy or action designers are increasingly turning to the use of biomaterials such as plant fibers, waste from other materials and mycelium to produce environmentally friendly packaging in the interests of sustainability. This approach is certainly effective, as designers and producers start by choosing the materials for the packaging, selecting locally produced raw materials to reduce unnecessary carbon emissions due to transportation and other issues, and reducing bleaching, coloring, fine grinding and high purification during the production process to reduce production pollution and labor costs in many ways. The resulting packaging visually retains the original color of the material and the roughness of the fibers, creating a unique design language and visual symbol for environmentally friendly packaging.

The audience is equally satisfied with the product packaging and can feel the environmental friendliness of the packaging through the special colors and textures of the visual symbols. However, in subsequent end-of-life disposal, relying solely on visual judgement, the above visual symbols can only serve the purpose of suggesting to the consumer that the waste should be disposed of in the recyclable bin or cleaned and reused. The choice of composting the waste or sending it back to the producer in response to the call of the design concept is hardly reinforced by visual cues. In all cases, it is easy to see that the more plant fibers are retained in the eco-friendly packaging, the easier it is to direct the consumer towards landfill composting or planting behavior when the waste is subsequently disposed of. In conclusion, existing eco-friendly packaging designs have developed a unique visual language for environmental protection, and the use of plant fiber in subsequent design development can further enhance consumer response to the design concept.

Authors statement

The author reports there are no competing interests to declare.

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