CREATING HIGH-VALUE BIOCOMPOSITES USING PERCEPTION DESIGN

T. Manu[1]*, Ali Reza Nazmi[1], Bahareh Shahri[1], Nick Emerson[1] and Tim Huber[2]

[1] School of Product Design, University of Canterbury, Christchurch, New Zealand,
[2] Department of Materials Research & Technology, Luxembourg Institute of Science and Technology, Luxembourg

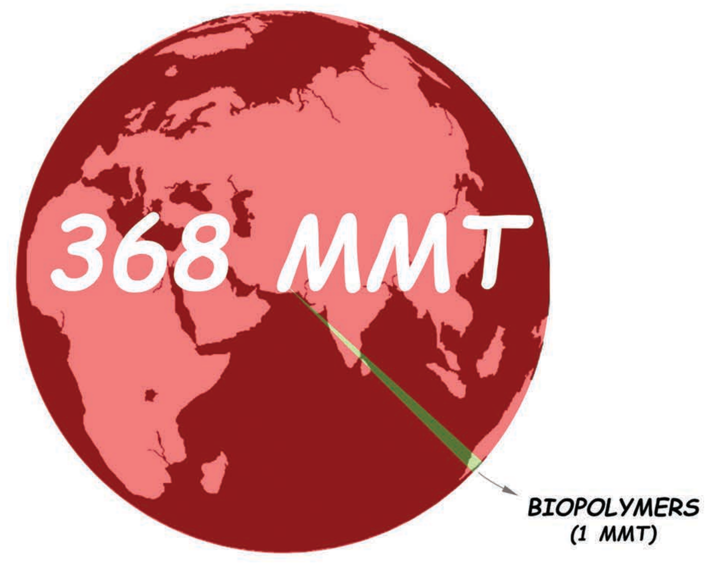
UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY LIST

PLEASE SCAN THIS QR CODE FOR ACCESSING PUBLICATIONS ON THIS TOPIC:

Why don't we see more sustainable materials in products?

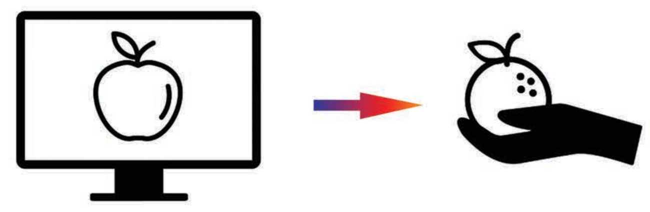
Unsustainable production as well as disposal of fossil-based materials used in mass production is one of the main challenges the world faces today. By 2050, natural oil reserves are estimated to be exhausted at our current consumption rate [1], and this would have a substantial impact on the cost and production of synthetic polymers. This precarious situation of conventional plastics and composites makes a compelling case to develop sustainable material alternatives, and biobased composites are a significant prospect. Biobased composites can be sourced from sustainable, biological resources and many of them also offer biodegradability. While there have been many breakthroughs in material development in this field, the market share of these materials in comparison with conventional materials is very limited. An indication of this is that in 2020, the production share of bioplastics (biobased non-biodegradable and biodegradable combined) was only 0.6% of total global plastic production [2].



This poor performance despite favourable market conditions has been explored in detail [3], where the main handicaps of biocomposites were identified and classified into two broad categories:

(a) **technical handicaps** and
(b) **perceptual handicaps**

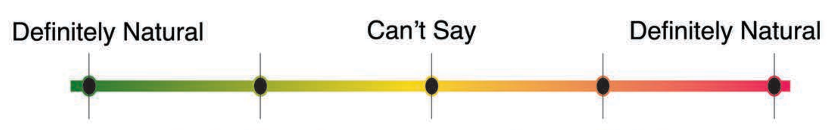
The common research approach to creating new materials has been centred on solving technical handicaps like poor strength, hydrophilicity and processing limitations. We propose a novel approach for the creation of high-value biobased composites, overcoming perceptual handicaps using perception design. The role of perceptual handicaps may be more vital than previously thought as many biocomposites are burdened by poor aesthetics and a lack of distinctive identity [3].



Another critical application of understanding the relationships between senses, material characteristics and material perception is in the field of online marketing and e-commerce. In 2021, the total value of e-commerce sales stood at 4.2 trillion USD and 75% of these consumers solely depend on product photographs for purchase decisions [4], effectively forming their perception based on visual stimuli. Hence, it is necessary to understand the role of senses in forming perception, and if it changes in online mode (visual) versus physical mode (visual-tactile).

Understanding material perception

To examine the relationship between roughness perception and tactility, a perception study was conducted using the Semantic Differential (SD) method. A sample group of eleven material samples with eight biobased composites and three natural materials as references were used in this study. This sample set was presented to two groups of respondents, with the first group (113 participants) only exposed to photographs of the materials and the second group (51 participants) given physical access to the samples.



An example for the Semantic Differential Scale

The participants were then asked to rate the materials on a Likert scale with bipolar adjectives (e.g. *Rough* and *Smooth)* at the extreme ends. These ratings (visual and visual-tactile) were analyzed to identify correlated perceptual attributes. An analysis of the material surfaces for roughness was also conducted to examine the perceptual accuracy of tactility. This helps to benchmark the roughness quantitatively so that the confidence level of human ratings could be correlated with the surface characteristics of biobased composites.

Material samples used in the study

Impact of roughness perception

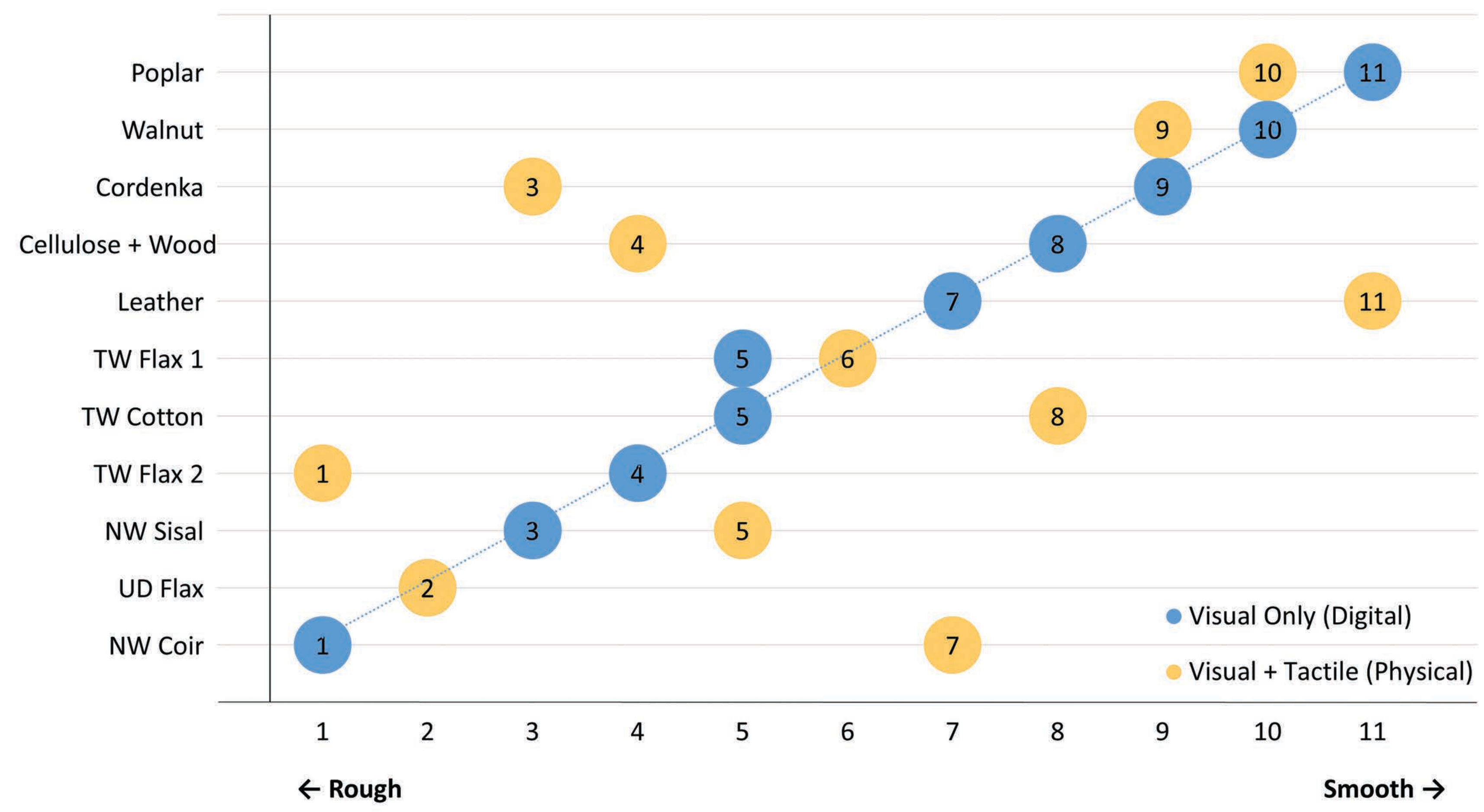


Figure 1: Comparison of Roughness Perception of Various biobased Material Samples in Digital Mode and Physical Mode

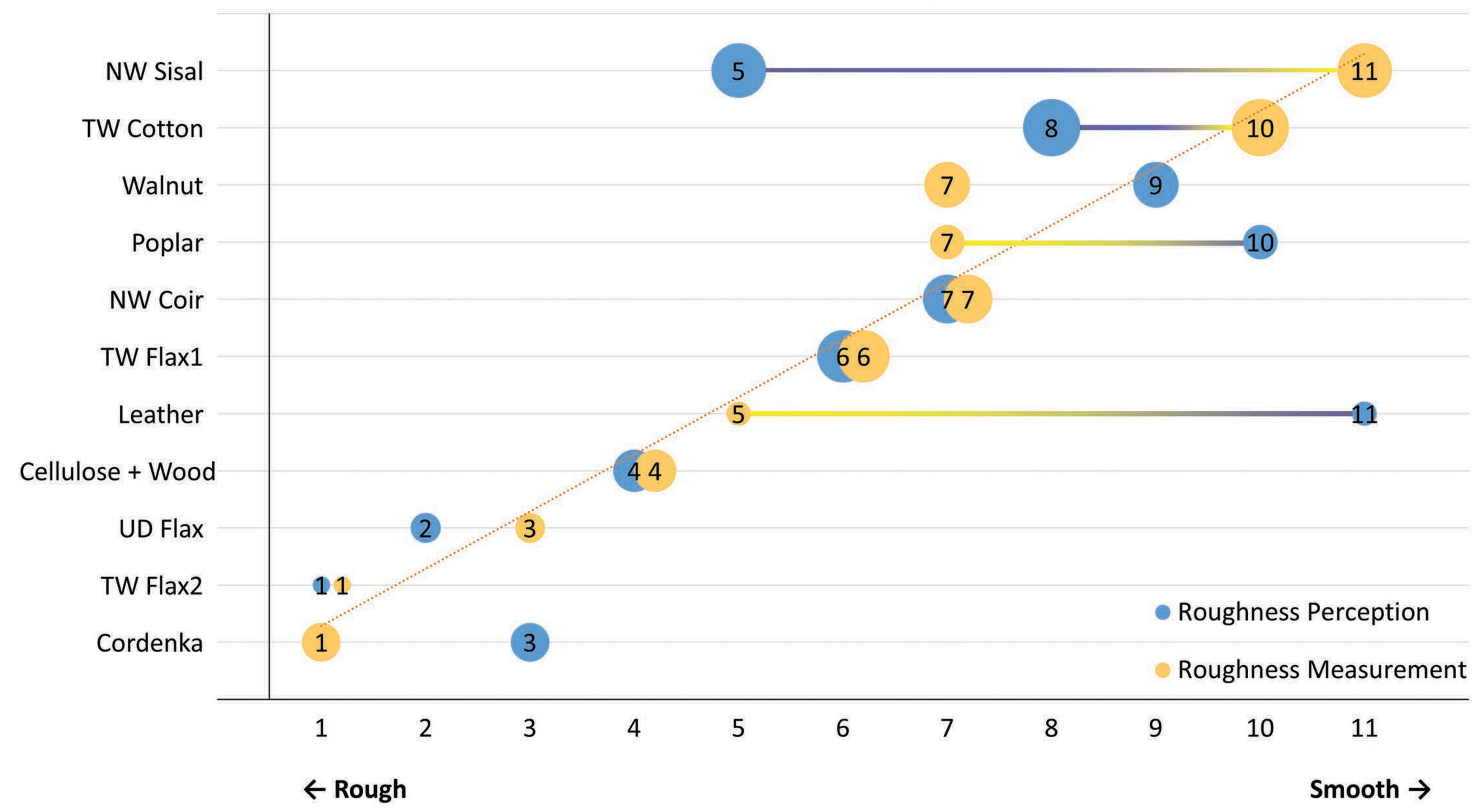


Figure 2: Comparison of Roughness Perception and Measured Roughness; Size of the Bubbles Correspond to their Shore D Hardness

The comparison of perception (visual vs visual-tactile) (Figure 1) shows no correlation between the material rankings, thereby highlighting the perceptual incongruity in these two modes. This is significant in the context of product design, as there is a strong risk of materials being perceived incorrectly while observed through digital interfaces.

The comparison between human perception of roughness and actual roughness of biobased composites in general shows a correlational relationship, with most materials exhibiting similar ranking scores (Figure 2). However, some materials show divergent behaviour, like NW Sisal & TW Cotton evoking a rougher feeling perceptually, while Walnut, Poplar, Leather and Cordenka present a smoother feeling perceptually in comparison with actual surface roughness. This points to the rather complex tactile interactions while assessing any material by touch.

The main element contributing to the disparity in the perceptual assessment of roughness may be sliding friction; the relationship between sliding force and surface roughness varies with material context [5]. Okamoto et al. [6] point to this aspect when they suggest the presence of a 'friction dimension' (moistness/dryness and stickiness/slipperiness) while tactilely perceiving materials. This feeling of friction is also generated along with a cluster of other feelings like texture, shape, force, etc. and the relationships between these variables are not well understood, resulting in no consensus on the definition of roughness [7]-[9].

In the case of smooth materials being perceived as rougher (NW Sisal & TW Cotton), this may be attributed to the micro-roughness of the material leading to larger surface contact and weaker vibrational feedback [10]. Both of these materials were comparatively hard (high Shore D) and had the least surface undulations leading to a 'hard-and-level' quality which created higher friction. This elevated friction may have caused a higher perception of roughness in these materials.

In the case of rough materials being perceived as smooth (Walnut, Poplar, Leather and Cordenka), the reverse may be happening with a 'soft-and-uneven' quality. Walnut and Poplar being wood samples have fine raised fibres on their surface [11], and Cordenka had visible fibres on the surface reducing the contact area with the finger. This leads to less resistance while finger movement, creating a perception of smoothness on uneven surfaces. Beyond friction, the impact of hardness has also been suggested with Hollins et al. [8] proposing a 'springiness' dimension to tactile texture assessment. This may be the cause in the case of leather, with the sample deforming with finger strokes offering less resistance and vibrational cues of roughness.

Analysis of sample ratings using Spearman's rank correlation method revealed a strong positive correlation between perceived roughness with naturality, while roughness negatively impacted key material attributes such as beauty, strength and value (Figure 3).

The focus of this research on perception design has been on expressing material perception through attribute ratings and understanding the relationships among the attributes. It has been observed that visual perception of roughness cannot be considered a good representation of actual material roughness. While there is a broad congruence between the physical perception of roughness and actual roughness, sliding friction in materials could significantly influence those assessments. The results of these explorations when compared with the sensory characteristics of the biobased composites are expected to uncover the underlying relationships that link the physical characteristics of the material and its perceived character.

This perception-based design approach could be used to control material characteristics and thereby evoke desired material perception, which is critical in the case of consumer products.

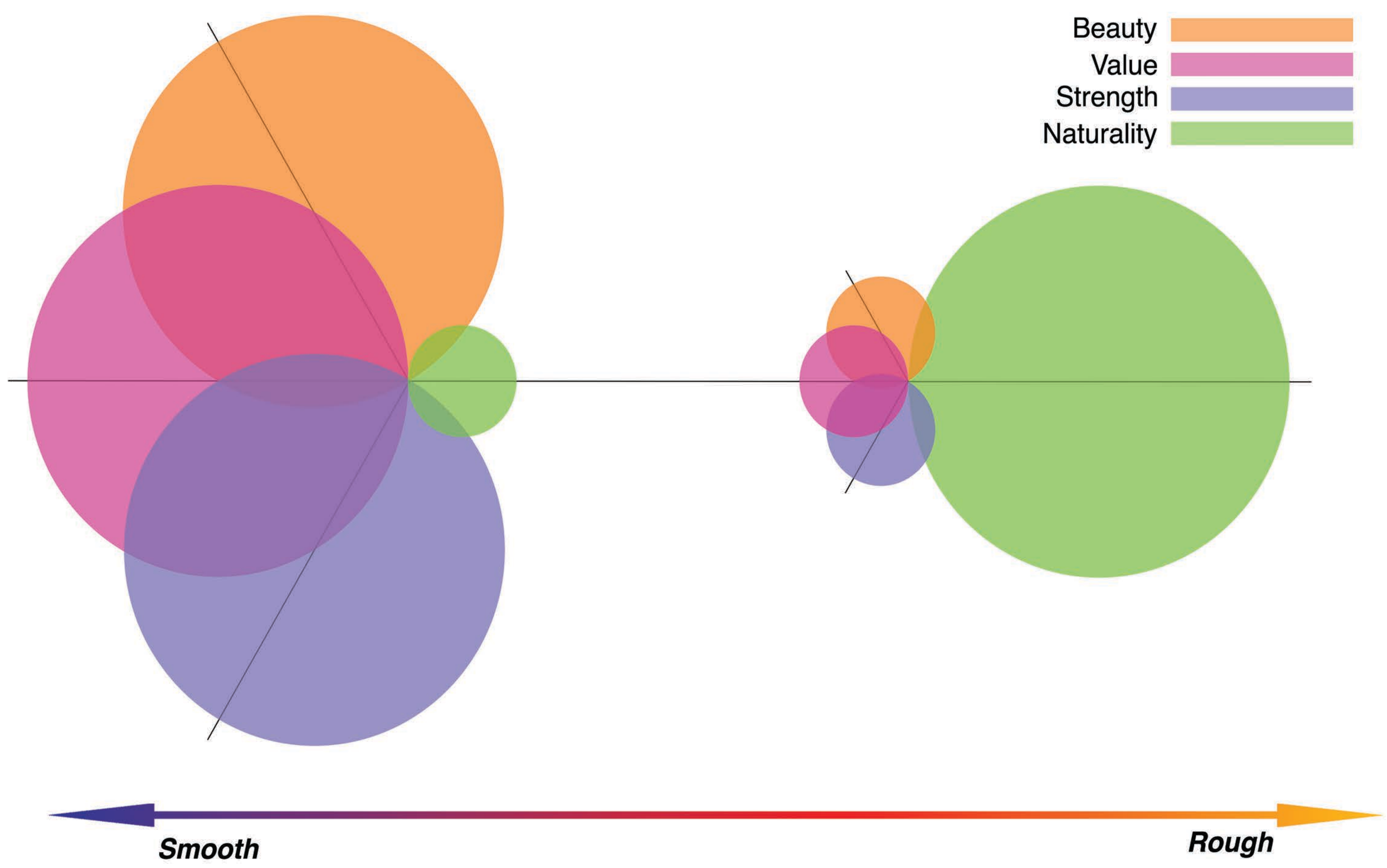


Figure 3: Effect of Surface Roughness on Perception of Beauty, Value, Strength & Naturality

References

[1] N. A. Owen, O. R. Inderwildi, and D. A. King, "The status of conventional world oil reserves-Hype or cause for concern?," Energy Policy, vol. 38, no. 8, pp. 4743–4749, Aug. 2010, doi: 10.1016/J.ENPOL.2010.02.026.

[2] "BIOPLASTICS: Facts and Figures," 2021. Accessed: Oct. 13, 2022. [Online]. Available: https://docs.european-bioplastics.org/ publications/EUBP_Facts_and_figures.pdf.

[3] T. Manu, A. R. Nazmi, B. Shahri, N. Emerson, and T. Huber, "Biocomposites: A Review of Materials and Perception," Mater. Today Commun., p. 103308, 2022, doi: 10.1016/j.mtcomm.2022. 103308.

[4] S. Ariella, "20+ Fascinating Online Shopping Statistics [2022]," www.zippia.com, Jul. 04, 2022. https://www.zippia.com /advice/online-shopping-statistics/ (accessed Oct. 10, 2022).

[5] D. K. Cohen, "If you need less sliding friction, should you make the surface rougher or smoother? ," Quality Magazine, Jan. 03, 2017. https://www.qualitymag.com/articles/ 93749-if-you-need-less-sliding-friction-should-you-make-the- surface-rougher-or-smoother (accessed Apr. 12, 2023).

[6] S. Okamoto, H. Nagano, and Y. Yamada, "Psychophysical dimensions of tactile perception of textures," IEEE Trans. Haptics, vol. 6, no. 1, pp. 81–93, 2013, doi: 10.1109/ TOH.2012.32.

[7] B. Khojasteh, M. Janko, and Y. Visell, "Complexity, rate, and scale in sliding friction dynamics between a finger and textured surface," Sci. Rep., vol. 8, no. 1, Dec. 2018, doi: 10.1038/s41598-018-31818-3.

[8] M. Hollins, R. Faldowski, S. Rao, and F. Young, "Perceptual dimensions of tactile surface texture: A multidimensional scaling analysis," Percept. Psychophys., vol. 54, no. 6, pp. 697–705, Nov. 1993, doi: 10.3758/BF03211795/METRICS.

[9] J. Dargahi and S. Najarian, "Human tactile perception as a standard for artificial tactile sensing - a review," Int. J. Med. Robot. Comput. Assist. Surg., vol. 01, no. 01, p. 23, 2004, doi: 10.1581/mrcas.2004.010109.

[10] R. Sahli et al., "Tactile perception of randomly rough surfaces," Sci. Rep., vol. 10, no. 1, pp. 1–12, 2020, doi: 10.1038/ s41598-020-72890-y.

[11] P. D. Evans et al., "Microstructure and Mechanism of Grain Raising in Wood," Coatings, vol. 7, no. 135, 2017, doi: 10.3390/ coatings7090135.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION