Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Annals of Biological Research, 2021, 12 (4):58-61
(http://scholarsresearchlibrary.com/archive.html)

ISSN 0976-1233
CODEN (USA): ABRNBW

Recent Progress of Cell-Plastics as Neo Bioplastics: AMini Review

Akihito Nakanishi[1,2*], Kohei Iritani[3]

[1]Department of Bionics, Tokyo University of Technology, Hachioji, Japan
[2]Department of Bioscience and Biotechnology, Tokyo University of Technology, Hachioji, Japan
[3]Department of Engineering, Tokyo University of Technology, Hachioji, Japan

Corresponding to: Akihito Nakanishi, Department of Bionics, Tokyo University of Technology, Hachioji, Japan, Tel: +81 42-637-2427; E-mail: nakanishiah@stf.teu.ac.jp

ABSTRACT

Plastics are used for various application purposes such as social infrastructures and consumables in recent society so that those are essential materials. Although the researches and developments regarding the carbon cycling via plastics have been vigorously progressed throughout the world so far, only 9% of discarded plastics (6.3 Gt) could be re-used as the recycling resources. Then, the bio plastics deriving from CO2 as a carbon source were researched, resulting in the many productions derived from the metabolites extracted from plants and microorganisms. However, the processes for the fabrications aretime- and money-consuming and complicated. Then, up to now, the concepts of cell plastics havebeen proposed that the unicellular green algal cells could be directly used as carbon recycling sources. The cell plastics were progressed for modifying mechanical characteristic, endowing water-repellency and evaluating biodegradation so on. The researches and developments of the cell plastics aims not to the only replacement of the plastics derived from petroleum soon but to discovering new research seeds of the technologies relating the cell plastics such as efficient preparation of algal cells and environmentalcleanup in 2050. Afterword, the researches and developmentsprogresswith fusions of each relating technologywidelybasedon Life Cycle Assessment (LCA) including theproduction using CO2 asacarbonsource and discarding the cell plastics.

Keywords: Sustainable society; Carbon recycles; Bioplastics; Cell-plastics; Green algae

INTRODUCTION

Sustainable plastics

In recent society, plastic materials are essential in our life because of their utilities in various fields such as social infrastructures, automotive and aviation materials, and medical products as well as consumables. The total production of plastics was reported to be overstepped 8.3 Gt throughout the world in 2015 [1]. Which is equivalent to the production of approximately 1.1 t per person? Currently, 99% of the produced plastics are derived from non-recycling petroleum [2]. So the Researches and Developments (R and D) for escaping the petroleum dependence are strongly required to construct the sustainable society of carbon sources. Although the R and D is aggressively progressing to realize the construction, approximate 6.3 Gt of the discarded plastics were accumulated in filled ground or environment (79%), incineration (12%) and the use as the recycling resources (only 9%) [1]. additionally, the plastics accumulated in natural environment affects adverse effects such as micro plastics in ecosystem like ocean. Then, the R and D of bio plastics derived from CO2 as a carbon source has be progressed to make the plastics recyclable resources without using non-recyclable petroleum resources, and a report expected that 11 Mt of petroleum-based plastics will be replaced by bio-based plastics in near future [3,4]. The bio plastics, however, involves several problems aiming to spread them to society: on aspect of the production, the bio plastics are expensive because of complicated processes of extraction and purification of the resource (e.g., lactic acid polymer, which exists 10.3% in the environment) on the other aspect of the discarding, the several bio plastics such as bio-polyethylene, bio-polypropylene, bio-polyester and bio-polyimide are hardly decomposed in environment even using biochemical [5,6]. Therefore, the R and D has

been strongly required with the unprecedented idea resolving those problems, resulting that the cell plastics, which are composed of unicellular green algae as the ingredients, were proposed.

LITERATURE REVIEW

Ideas of cell plastics

So far, the cell plastics have been fabricated with the cells of green alga Chlamydomonas Reinhardtii as a raw material [7-10]. Unicellular and/or simple microalgae including C. reinhardtii are able to be autotrophically cultured with well biomass production depending on 10-50 times higher CO2 assimilating property than the general terrestrial plants [11]. C. reinhardtii has the rigid cell wall as well as other microalgae and its cell wall is normally broken with beads beating [12]. Additionally, we expected that the cell plastics formed by single-celled C. reinhardtii would be exhibited plasticity because the cells could be placed freely in space unlike multicellular organisms. Based on those reasons, the cells could be effectively supplied as raw materials directly from atmospheric CO2; the cell wall of the supplied cells could endow the mechanical strength; unicellular cells could be used for free plastic fabrication, resulting that the direct use of the cells C. reinhardtii were proposed to fabricate the cell plastics as raw materials of carbon recycling. In the proposal of the cell plastics, simple use of the cells was expected without extraction and purification because of the direct use of cells but not the intracellular contents. However, the cell plastics comprise several subjects as below: adding filler should be required to connect each unicell; endowing water-resistance should be also needed like existing plastics. Additionally, the cell plastics with biodegradable polymers as the filler could be biodegradable in nature since the cells are naturally degraded in the environment.

Multi-layered cell plastics

The first cell plastics were fabricated as multi-layered cell plastics: the cell-layers, composed of C. reinhardtii cells as sheets, were multi-layered to reinforce the cell plastics after coating on them with less than 1% (w/w) of a two-dimensional polymer as an organic thin film [7]. The cell-layers were prepared with fillers of glycerol (cell-layer with glycerol: L-Gly) or a mixture of glycerol and bovine serum albumin (cell-layer with glycerol/BSA: L-Gly/BSA) as biodegradable compounds to

cell. To confirm the fact that the cells were functionally used as components of the cell plastics, the surfaces of the cell plastics were analyzed with a Scanning Electron Microscope (SEM). SEM observations revealed that the surface of cell plastics was consisted of aligned cells, indicating that the unicellular green algal cells could be used as ingredients. In addition, the mechanical properties of the multi-layered cell plastics were evaluated to presume practical use. The tensile strengths of the cell plastics constructed with L-Gly and L-Gly/BSA were 0.29 MPa and 0.32 MPa, respectively. The tensile strengths of the multi-layered cell plastics were lower than the ones of commodity plastics such as Polyethylene (PE), Polypropylene (PP), and Polyethylene Terephthalate (PET) (10-30 MPa, 35.5 MPa and 69 MPa, respectively) disclosing that the multi-layered cell plastics were easily cracked rather than commodity plastics [13]. Additionally, the Young's modules of the multi-layered cell plastics were also lower (PE: 200–1400 MPa; PP: 1380 MPa; PET: 2200 MPa) revealing that the multi-layered cell plastics were soft materials rather than commodity plastics [13]. Those results indicated that the commodity plastics were difficult directly to be replaced with the multi-layered plastics. Additionally, in the producing process, the cell-layers required the long time and efforts to be dried because of containing glycerol and to be multiply covered with the two-dimensional polymer. Therefore, the multi-layered cell-plastics should be improved for the mechanical properties and the processes. As a next step, aiming to overcome those problems, the blended cell plastics were proposed that the cells were simply connected with biodegradable polymers.

Blended cell plastics

Firstly, the blended cell plastics were produced with biodegradable Polybutylene Succinate (PBS) as filler [8]. The film was constructed using a mixture of the cell and a dichloromethane solution of PBS, subsequently dichloromethane was evaporated after the mixture was coated on a glass substrate. The mechanical properties of the blended cell plastics were evaluated in the same way to the multi-layered cell plastics. The experimental results showed that the tensile strengths and Young's modules of the PBS cell plastics attempted to be decreased depending on increasing the cell contents in the cell plastics from 25 MPa of tensile strength and 450 MPa of Young's module of PBS. The tendency could depend on the not-well blending of the cells and PBS, and the cell existence might disturb

the connection of PBS itself. In fact, hydrophobic PBS in dichloromethane was completely separated from cells harvested from the broth. The PBS in the solvent was difficultly blended uniformly even with the dried cells. The use of dichloromethane induced not only the separation of the components but also toxicity to human; therefore, instead of using dichloromethane, the cell blending was supposed with molt PBS by heating. The evaluation of mechanical properties showed that the tensile strength and Young's module of the PBS-cell plastics contained the cells as 50% (w/w) were 8.8 MPa and 240 MPa, improving the mechanical properties of the cell plastics. Regarding the water repellency, although the PBS-cell plastics contained the cells as 91% (w/w) has no the repellency, the ones contained the cells as less than 83% (w/w) showed the property.

Aiming to well-mixing of the cell and filler, other blended cell plastics were produced with hydrophilic Polyvinyl Alcohol (PVA) or starch as filler [9-10]. The processes producing those cell plastics were considerably easier than ones of PBS-cell plastics because the wet cells were simply blended with those fillers due to their hydrophilicity even without drying the cells out. The reason why PVA and starch were used as filler instead of PBS was not only to simplify the producing process but also to increase the mechanical properties. Especially, because a cross-linked structure of PVA is generally formed by glutaraldehyde, the cell plastic using cross-linking PVA (cPVA) was expected to exhibit the better mechanical properties. In fact, the cPVA-cell plastic contained the cells as 50% (w/w) exhibited 15 MPa of tensile strength and 1.2 GPa of Young's module so those properties exceeded ones of the any cell plastics so far. Additionally, the cPVA-cell plastics have a property of stable absorbency after multiple dry-absorption, indicating the possibility of the use as a functional material like water absorption resin. As another blended cell plastics with a hydrophilic filler, the starch-cell plastic contained the cells as 50% (w/w) showed approximate 13 MPa of tensile strength and 330 MPa of Young's modules, also exceeding those properties of PBS-cell plastic contained thecells

as 50% (w/w). Regarding the repellency related to water resistance, initially, the water-droplets on the surfaces of starch-cell plastics were analyzed whether those could be maintained. As the results, although the starch plastic showed no water repellency, the starch-cell plastics exhibited the property. Secondary, the surfaces of the starch-cell plastics were evaluated to realize the reason of water repellency by SEM analyses, revealing the alignment of cells on the surface. Therefore, the starch-cell plastics were possibly endowed the repellency as the lotus effect even though the cells and starch were hydrophilic. Furthermore, the water resistance of the starch-cell plastics was performed with immersing them in water for 24 h. In addition, we investigated biodegradability of the starch cell plastic in the natural environment because the degradation should be an important property as bioplastics. The starch-cell plastics in the environment could be expectedly degraded as biological or physical decomposition. Therefore, in order to evaluate the biodegradability, starch-cell plastics were immersed in water containing α-amylase for 24 h, resulting that the starch-cell plastics could not maintain their shapes and be biodegraded with α-amylase, which is universally present in the environment.

CONCLUSION

As described above, the R and D has been progressed by evaluating cell plastics using CO2 as a carbon source. However, the current R and D on the cell plastics is not just about replacing existing petroleum-derived plastics right now. The R and D is not only fabrication of cell plastics but also discovering new research seeds including the relating technologies such as the novel system to prepare the cells and environmental clean-up. For instance, the research seeds should be like as below: the use of a large numbers of blue-green algae as the environmental pollution for fabricating cell plastics and cleaning up simultaneously; the construction of the cell plastic-producing systems beside the factory evacuating abundant CO2 and so on. In the future, R and D on cell plastics will be widely spread and integrate various peripheral technologies with considering Life Cycle Assessment (LCA) from production to disposal using CO2 as a carbon source.

ACKNOWLEDGEMENT

This work was supported by the Feasibility Study Program of the New Energy and Industrial Technology Development Organization (NEDO) connect each

REFERENCES

[1] Geyer, R., Jambeck, JR., Law, KL., Sci Adv, 2017.3(7):e1700782.

[2] Ciel. Fossils, plastics, petrochemical feedstocks: Fueling Plastics, Center for International Environment Law, (Commercial Press, Washington DC, 2017).

[3] Nakanishi, A., Iritani, K., Sakihama, Y., J Nanotech Nanomaterials, 2020.2(1):72-85.
[4] Brooks, AL., Wang, S., Jambeck, JR., Sci Adv, 2018.4(6):eaat0131.
[5] Bioplastics market data 2018. Europ Bioplastics, Berlin, Germany 2018.
[6] Moroni, M., Lupo, E., Pelle, V., Pomponi, A., Marca, F., Separations, 2018.5(2):26.
[7] Nakanishi, A., Iritani, K., Sakihama, Y., et al., AMB Expr, 2020.10(1):112.
[8] Nakanishi, A., Iritani, K., Sakihama, Y., et al., Int J Microbiol Biotechnol, 2020.5(4):159-164.
[9] Iritani, K., Nakanishi, A., Ota, A.,et al., Global Challenges, 2021.
[10] Nakanishi, A., Iritani, K., Sakihama, Y., et al., Appl Sci, 2021.11(2):847.
[11] Wang, B., Li, Y., Wu, N., et al., Appl Microbiol Biotechnol, 2008.79(5):707-718.
[12] Ho, SH., Nakanishi, A., Ye, X., Biotechnol Biofuels, 2015.8:48.
[13] Brandrup, J., Immergut, EH., Grulke, EA., Polymer handbook, 1999.2(5edn):162-165