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Scale up production of bio-composites using natural fillers from agricultural and industrial crops

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Introduction

A large share of plastic waste is generated (up to 40 %) from single use materials such as packaging. Coated and multi layers packaging are hardly recyclable and when properly collected are generally incinerated or landfilled. A solution to reduce the environmental impact of packaging consists in the replacement of the traditional plastics with biodegradable ones. Polybutylene succinate (PBS) is a promising material, that exhibits good thermal stability, excellent mechanical properties and high biodegradability in industrial compost, that can be enhanced, in particular for disintegration, by addition of natural fibres, allowing valorization of agro-industrial residues.

In the present work, composites based on PBS, enriched with polyphenols extracted from not-compliant coffee green beans (PPh) were developed and characterized for the production of active coffee capsules. Moreover, polyphenols and residues, from the protein extractions carried out on legume chickpeas (LC), were added into a PBS matrix by melt mixing. The new composites were characterized in terms of thermal stability and mechanical performance at lab-scale. The up-scaling of the whole process, leading to the production of cosmetic jars and body coffee capsules as prototypes, was carried out and discussed in terms of feasibility and reproducibility

Experimental

A preliminary lab scale study was conducted by mixing PPh (3 wt%) and/or different amounts of LC residues in the range of 5-30 % (wt/wt, respect to PBS) in Brabender extruder. Mechanical, morphological and thermal properties were tested and the best formulations were scaled up by using a Comac twin-screw extruder.

Results and Discussion

Prototypes based on a PBS blend were produced by mixing PPh in order to obtain an antioxidant packaging, suitable for the realization of coffee capsules (Figure 1, a-b). Moreover, chickpeas solid fibrous residues (LC) after protein extraction were added to a PBS matrix (Figure 1, c). The presence of fibres improved the disintegration and compostability of the items while decreasing the amount of polymer and consequently the cost of the final material. Moreover, to the PBS + LC material, 3% w/w of PPh were added conferring antioxidant functionality to the jar (Figure 1, d). This feature may positively impact the shelf-life of the cosmetic product. The Tensile tests show that the addition of fibres leads to an increase of the elastic modulus from 0.70 GPa to 0.85 GPa together with a reduction of the strength at break from 19.93 MPa to 12.98 MPa. The Charpy impact tests confirm the rigidity of the material from 010 KJ/m^2 to 5.6 KJ/m^2. These results show the limited interfacial interaction and substantially inefficient load transfer between the polymer matrix and the fibres.

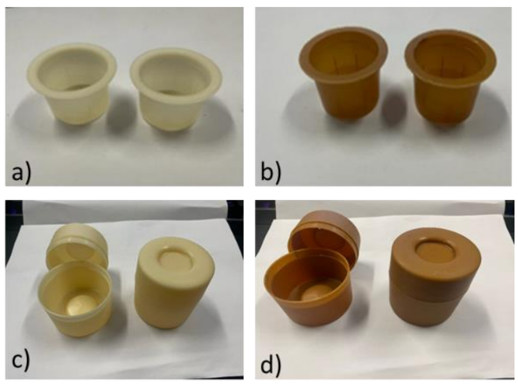

Figure 1. a)-b) body coffee capsules in PBS/PBAT or PHBV without and with polyphenols and c)-d) cosmetic jar prototypes in PBS + residues of chickpeas without and with polyphenols

Conclusions

The development of cosmetic jars resulted thus quite advanced, and scaling up to industrial production may be feasible and the mechanical properties resulted positive. In PROLIFIC it was demonstrated that PBS + 10% chickpea protein (LC) jar, has the potential to be commercially produced to store dry products, such as colour cosmetics, deodorant powders, hard capsules for food supplements, etc. For coffee caps the prototypes developed is just one part of a final coffee caps and further tests would be necessary for matching performance, cost and safety, in particular related to migration. These aspects will be further deepened in the exploitation plan.

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Biography

Norma Mallegni is a senior technician in Industrial Chemistry at University of Pisa. She has been awarded with a Chemical Engineering PhD at Pisa University of Pisa in 2018 with a thesis on the development of biodegradable blends and composites from natural resources. In 2022, she worked as a visiting Scientist at Massachusetts Institute of Technology (MA, USA).

Her research is focused on the biodegradability, processability, mechanical, morphological, and thermal properties of sustainable polymers and bio-composites for structural and packaging applications. She co-authored 25+ scientific articles on national and international journals, 20+ contributions to national/international conferences and workshops, and several book chapter. In parallel to her academic activity, she has been involved in different European projects and collaborations with national and international prestigious companies.