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Nature-Inspired Circular-Economy Recycling for Proteins: Proof of Concept

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The billion tons of synthetic-polymer-based materials (i.e. plastics) produced yearly are a great challenge for humanity. Nature produces even more natural polymers, yet they are sustainable. Proteins are sequence-defined natural polymers that are constantly recycled when living systems feed. Digestion is the protein depolymerization into amino acids (the monomers) followed by their re-assembly into new proteins of arbitrarily different sequence and function. This breaks a common recycling paradigm where a material is recycled into itself. Organisms feed off of random protein mixtures that are "recycled" into new proteins whose identity depends on the cell's specific needs. In this study, mixtures of several peptides and/or proteins are depolymerized into their amino acid constituents, and these amino acids are used to synthesize new fluorescent, and bioactive proteins extracellularly by using an amino-acid-free, cell-free transcription–translation (TX–TL) system. Specifically, three peptides (magainin II, glucagon, and somatostatin 28) are digested using thermolysin first and then using leucine aminopeptidase. The amino acids so produced are added to a commercial TX–TL system to produce fluorescent proteins. Furthermore, proteins with high relevance in materials engineering (β-lactoglobulin films, used for water

1. Introduction

The world's projected population will be 10 billion by 2050.[1] One of the most daunting sustainability challenges linked to such a large population size will be the handling of all plastic products,[2] that is, the production and recycling of polymers.[3] Not surprisingly, there are large world-wide efforts in research for polymer recycling. Mechanical recycling tends to lead to the original material but with lower quality.[4] A better possibility is chemical recycling,[5,6] that is, thermally,[7] chemically,[7] or biologically[8] catalyzed depolymerization of a polymer into its constituent monomers in order to re-polymerize them into either the same virgin quality material, or a new (co)polymer.[9,10] Another approach is repurposing of a polymer