Development of new PLA-based biodegradable compounds for micro-irrigation applications

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Abstract. New biodegradable compounds having high renewable resources starting materials content were developed and formulated at Lab, pilot and industrial level. Pipes were prepared using the here developed compounds, and perfectly mimic the mechanical behavior as well as the chemical resistance of the currently used polyethylene based materials. This work is currently developed within the EC founded HYDRUS project.

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INTRODUCTION

Micro-irrigation, also known as drip irrigation or trickle irrigation, is an irrigation method that applies water slowly to the roots of plants, by depositing the water either on the soil surface or directly to the root zone, through a network of valves, pipes, tubing, drippers and emitters. Of the various forms of micro-irrigation, drip irrigation is the one most widely used because it can save water, reduces the use of horticultural chemicals, it is relatively insensitive to environmental effects, and increases the rate of plant growth.

FIGURE 1. Example of drip irrigation

Drip irrigation is an effective irrigation system in terms of water conservation. The use of micro-irrigation is rapidly increasing around the world, and it is expected to continue to be a viable irigation method for agricultural production. According to the Food ad Agriculture Organization of the United Nations, FAO, only the 11% of the total world land area can be farmed without being irrigated, drained or otherwise improved. [1] Micro-irrigation can be used on most agricultural crops, although it is currently most often used for high value culture such as vegetables, ornamentals, vines, olives, fruit crops and greenhouse plants. In Europe, the percentage of irrigated crop area over the cropland is 7.9%.[2] This percentage means that in Europe there are more than 24 millions of hectares irrigated with different methods. From this, the 2.25% of total irrigated crop area (540,000 ha) is irrigated using a micro-irrigation system.[2] In other words, around 11,000 millions of meters of polyethylene micro-irrigated pipes (20,000 m/ha) are currently needed in Europe, thus representing a very big market for pipe manufacturers.

Moreover, the use of micro irrigation systems is expected to reduce the water consumption around 60%, i.e. 70,000 millions m^3/year.

STRATEGY

In this framework, a consortium of four RTD performers and six SMEs was constituted and involved in development of the three years FP7 Project *"Development of crosslinked flexible bio-based and biodegradable pipe and drippers for micro-irrigation applications"* (HYDRUS, Figure 2) with the aim to be able to confront a technical challenge: the development of a new biodegradable/bio-based irrigation pipe, eventually cheaper than the ones currently on the market, which will provide them a competitive position in the current agricultural market. The main objective of the HYDRUS project[3] is the development of pipes and drips for micro-irrigation, produced starting from bio-based and biodegradable polymer materials. The pipe and drips will maintain the functional properties during lifespan but will biodegrade after use. Therefore, remove and disposal after use will be no more required, as currently is, thus solving the most important problem related to the use of micro-irrigation pipes: their removal and disposal at the end of their useful life.

However, the biodegradable materials currently available on the market can not fulfill all the requirements for this application in what regards mostly to thermal and chemical resistance. To overcome these limitations, we here propose a similar approach than used currently for commodity plastics, i.e. to increase the thermal and chemical resistance by a cross-linking reactive process.

FIGURE 2. Logos of the Hydrus Project

In particular, the main innovations claimed in HYDRUS are:

1) The use of bio-based materials.
2) Biodegradability in soil.
3) Development of a micro-irrigation pipes and a drips.
4) Development of controlled reactive extrusion for biopolymers at pilot plant and industrial level.
5) Improvement of the thermal and chemical resistance of biodegradable materials.
6) Fine tuning of mechanical properties.

RESULTS

Poly(lactic acid), PLA was chosen as the base biodegradable polyester, because its low cost, market availability and homogeneity, are key requirements for good cross-linking control. Besides, to improve the flexibility that the cross-linkable polymer will lose when the cross-linking process is carried out, it will be blended with a low flexural modulus biopolymer or plasticizer by reactive extrusion. The process essentially forms chemical bonds between the polymer chains resulting in a dense network of very high molecular weight. This polymer becomes less mobile when subjected to heat or mechanical loads, and with this, properties such as heat distortion, creep and abrasion resistance are enhanced. However, regardless of the cross-linking method employed, the final products have very similar stable, irreversible structures and increase its fragility. This method has been practiced extensively by the wire and cable industry for many years. It requires special compounds containing an initiator, usually organic peroxide in its original unprocessed chemical structure, and special downstream cross-linking equipment. The compound must be prepared and extruded at low temperatures, below the peroxide's decomposition temperature, then cross-linked in the downstream equipment at significantly higher temperatures and pressures to complete the process. However, care must be taken not to exceed the desired level, since loss of some properties can occur with too high level of cross-linking percentages.

The pipes obtained with the new biodegradable materials showed good processability in a conventional pipe extrusion line, good mechanical properties, which mimic the trend of the currently used polyethylene based materials (see figure 3). Moreover, the here developed biodegradable compounds showed very good elastic recovery, and, in addition, they withstand the chemical resistance trials.

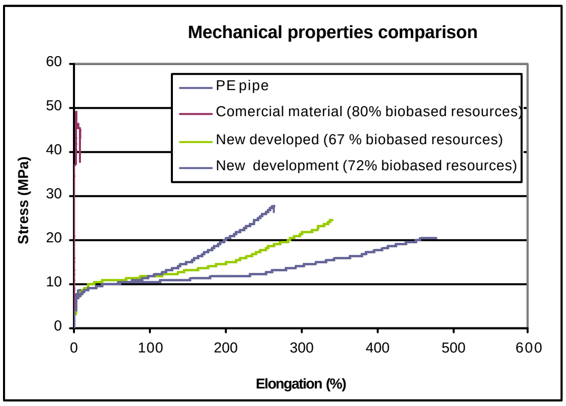

FIGURE 3. Mechanical properties of different pipes obtained at pilot plant level.

Noteworthy, the pipes produced using the new biodegradable compound developed within the HYDRUS project showed:

1) Good processability in a conventional pipe extrusion line.
2) Good mechanical properties and elastic recovery.
3) Good chemical resistance.

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Please note that due to the ongoing character of the project, and the potentially patentability of the project results at this stage, no significant technical data came be here given and discussed. Anyway, all the scientific results will be given during the presentation.

REFERENCES

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