Grassification

D2.4.1

Production fibre pellets from roadside clippings as half-finished product for biocomposite production

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Document Control Page

Title	D2.4.1 Production fibre pellets from roadside clippings as half-finished product for bio composite production		
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Abstract	PP3, PP6, PP9 (lead), PP10 & PP12 will jointly develop & demonstrate a production method for fibre pellets to be used as half-finished product for bio-composite production. Production, storing & drying of fibre pellets is labour intensive (potential social economy). Reducing size & weight, while increasing storability will result in increased availability & reduced transport cost. Optionally, this can also be tested on the digestated grass from A1.3. Results are bundled in a report.		
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Contents

Executive summary

In D2.4.1 Pro Natura, Hogeschool Gent, Millvision, Delphy and Innec will jointly develop & demonstrate a production method for fibre pellets to be used as half-finished product for bio-composite production. PP9 is leading in this work package. Production, storing & drying of fibre pellets is labour intensive (potential social economy). Reducing size & weight, while increasing storability will result in increased availability & reduced transport cost. Optionally, this can also be tested on the digestated grass from A1.3. Results are bundled in this report.

Fresh, dried and refined roadside grass has been received via Pro Natura / Innec. The received grass contains a lot of sand (+/- 24% of ash) and stones, plastic, metal and other pollutants. After washing the grass, it has been dried until +/- 80% dry matter. The grass is then cut on a hammer mill with a screen size of 2 mm.
It has been decided to make pellets from dried grass at 3 moisture levels: 25%, 30% and 35%, processing the sized grass fibres once through the pelletizer. For the refined grass, process conditions were used as much as the same for the dried grass. Therefore, pellets were made with a dry matter content of 68% and 75%; 65% couldn't be made. Difficulty is reaching the right hardness of the grass pellets able to process in the extruder. The hardness of the pellets is dependent on the moisture content of the grass fibres during production of the pellets in the pelletizer. Furthermore, the times the grass passes the pelletizer plays also an important role. Therefore, it was decided to pass it just once. The hardness of the different pellet samples has been determined with the Kahl pellet tester. Best hardness to directly feed the pellets in the extruder is in the range of 5-9 hardness units.

The best homogeneity of grass fibres in a compound has been obtained when grass pellets with a moisture content of 35% were used. Furthermore, also loose grass fibres and grinded grass pellets were tested in a compound composition. Tensile test bars were made from the compounds via injection moulding. After conditioning of the tensile bars for one week at ambient temperature, they were analysed on mechanical properties.

The mechanical properties of the tested compounds made between the different grass treatments (pellet made, loose fibres added, and grinded pellets) at similar addition level of the grass fibres were not significantly different. Furthermore, use of dried grass or refined grass did not result in a significant difference. Therefore, future production of grass compounds will be made with dried grass material, either as loose fibrous material or as pellets. The latter will be beneficial from transport point of view (less volume). Refined grass may only be an option in case, the business case will justify the refining step making profit on the liquid fraction.

Possible options for producing grass pellets have been explored. The following two options have been found, which needs further to be explored in the next phase of the project:

1) At an industrial producer of straw pellets with an installation with a capacity of 1 ton/h, producing pellets with a diameter of 6mm. There is a possibility to run a test for free – to be confirmed.
2) Buying a second-hand pellet press also with a capacity of 1 ton/h, producing pellets with a diameter of 4-6mm. To be discussed with Pro Natura/Innec.

Introduction

In work package two, PP6 (Hogeschool Gent) – lead partner, PP2 (Provincie West-Vlaanderen), PP3 (Pro Natura), PP9 (Millvision), PP10 (Delphy), PP11 (Stichting Avans) and PP12 (Innec) will jointly develop, test and demonstrate several bio-composite products using fibres from roadside clippings. These products will be tested and demonstrated in lab and real-life demos. In order to improve service life, the use of fibre blends (e.g. addition of raspberry fibre) and/or biobased coatings will be taken into account. Work package 3 will deliver input for legal options and restrictions and will give a first indication regarding business opportunities of use of roadside clippings. Target groups are the fibre processing industry, (local) governments and (nature & recreational) organizations with landscape infrastructure. Product development and dissemination will be done in association with the biobased economy sector in the programme area through their websites, newsletters, a mini symposium with demonstrations and bilateral meetings with stakeholder groups according to the dissemination strategy.

PP3, PP6, PP9, PP10 & PP12 will jointly develop & demonstrate a production method for fibre pellets to be used as half-finished product for bio-composite production. In this work package, PP9 is lead partner. Production, storing & drying of fibre pellets is labour intensive (potential social economy). Reducing size & weight, while increasing storability will result in increased availability & reduced transport cost. Optionally, this can also be tested on the digestated grass from A1.3. Results are bundled in this report.

Experimental

Fresh, dried and refined roadside grass clippings have been received via Pro Natura / Innec in blue tons (see Figure 1). The fresh grass clipping had a moisture content of 55%. The dried grass clippings had a moisture content of 30%, and refined grass clippings had a moisture content of 50%. The received grass samples contained a lot of sand (+/- 24% of ash), stones, plastic, metal and other pollutants. Therefore, it was decided to wash the grass samples first before processing them further. The grass was washed until an ash content of +/-14%, and pollutants were taken out. After washing the grass is dried until +/- 80% dry matter. The grass fibres were too big for grass pellet production, and therefore, the different grass samples were further processed using a hammermill with a sieve of 2 mm.

Figure 1 Dried grass (left) and reduced grass fibres (right)

First initial tests were performed to get if and under which conditions grass pellets could be produced. These tests were done using cleaned sized dried fresh grass clippings. Subsequently, the pellets obtained were processed into a grass compound, to learn which process conditions resulted in a homogenous grass compound.

Grass pellets have been made with moisture content ranging from 15% to 40%. It was learned that with too much moisture very weak pellets were obtained, whereas in case too little moisture was present, grass powder was obtained. Also the times that the grass was processed through the pelletizer had an influence on the structure (at the end resulting into powder). Best pellets were formed at a moisture content between 25% and 35%.

In a next step, pellets were made at three moisture levels, going once through the pelletizer. Cleaned sized dried fresh grass clippings were wetted till 25, 30, and 25% moisture. After wetting the sample, and conditioning them during the night, moisture levels were checked the next day before processing them. Thereafter, the wetted grass samples were processed into pellets (see Figure 2).

These pellets obtained were tested on processability using a double screw extruder. During the compounding step, it was learned that the hardness of the grass pellet has an influence on homogeneity in the polymer matrix. The harder the pellet, the worse the homogeneity of grass fibre distribution in the compound mixture. The hardness of the pellet can be stirred by the moisture content producing the pellet. Best pellets to be processed in the extruder had a moisture content of ca. 35%. However, using these pellets require a drying step, after the pellets were made to prevent the pellets from rotting (mold formation).

Figure 2 Pellets made of dried grass (f.l.t.r. 35%, 30% and 25% moisture)

To dose the grass pellets into the hopper of the extruder, requires a dosing unit with a stirrer. By doing so, the grass pellets are partially broken down during feeding them into the extruder. Best processable pellets were made with a moisture content of 35%, followed by drying them afterwards.

In a comparison, also compounds were made using cleaned sized dried loose fibres (<2mm) and grinded grass pellets (<1mm) using a mill. Dosing these two grass fibre materials learned that loose grass fibres were hard to feed into the hopper due to its low gravity value (voluminous). The grinded grass pellets had a better gravity value and did not give dosing problems during processing.

Furthermore, cleaned sized dried refined grass was processed into grass pellets, using quite the same conditions as with the previous experiments. Pellets were made with a dry matter content of 68% and 75%. Using a moisture content of 65% didn't results in pellets, due to the fact of too little structure left in the grass pellets (easily falling apart). This can be seen in Figure 3.

Figure 3 Pellets made of refined grass (f.l.t.r. 35%, 32% and 25% moisture)

In all cases hardness of the pellets made were determined with a Kahl pellet tester. The results are summarised in Table 1. This Table shows that pellets with a hardness of ca. 5-9 kg pressure are directly processable in an extruder, homogeneously. In case stronger pellets are used, they first need to be grinded resulting in a homogeneous compound. The latter maybe anyhow needed at certain equipment with narrow dosing system.

Table 1 Hardness of pellets

Pellet	**Hardness [kg pressure]**
Referent nature grass pellet	15-19
35% moisture pellet dried grass	5-9
30% moisture pellet dried grass	21-24
25% moisture pellet dried grass	21-25+
25% moisture pellet juiced self-collected 3 times pelletized	10-13
25% moisture pellet received "fresh" grass pelleted 5 times	25+
32% moisture pellet refined grass	5-9
25% moisture pellet refined grass	19-22

Tensile bars were processed using dried grass fibre, grinded dried grass pellets, and dried grass pellets made with 35% moisture compounds using ca. 35-40% grass fibres (see Figure 4). The dried grass pellets were processed into 6 different compounds using recycled HDPE and PLA. Injection moulding of the tensile bars, in case of recycled HDPE went without problems, whereas in case of PLA it went somewhat harder. Processing temperature had to be raised to 185-200°C, and the remaining cooling time had to be increased to 40 seconds. This resulted in somewhat darker tensile bars in case PLA was used. After conditioning, these test bars were analysed on mechanical properties.

Figure 4 Tensile bars with dried grass pellets (f.l.t.r. fibre, grinded pellet, pellet in recycled HDPE and fibre, grinded pellet, pellet in PLA)

In Table 2 the mechanical properties of the different test samples made are summarised.

Table 2 Mechanical properties dried grass compounds

Compound	**E-modulus** [MPa]	**Force max** [MPa]	**Stretch @Fmax** [%]	**Force @break** [MPa]	**Stretch @break** [%]
Recycled HDPE	899±48	20,2±0,6	7,03±0,05	13,0±1,2	7,04±0,05
Recycled HDPE + ± 35% grass fibre grinded <2mm	2290±89	21,7±0,35	2,78±0,07	20,8±0,5	3,36±0,29
Recycled HDPE + 40% grinded grass pellet 35% moisture <1mm	2190±239	19,5±0,11	1,97±0,09	18,8±0,2	2,27±0,16
Recycled HDPE + 40% grass pellet	1990±156	18,2±0,64	1,46±0,09	16,8±0,4	1,60±0,19
PLA + ± 35% grass fibre grinded <2mm	4620±124	43,8±0,68	1,44±0,11	43,7±0,6	1,43±0,11
PLA + 40% grinded grass pellet 35% moisture <1mm	5290±86	40,9±0,23	1,14±0,05	40,9±0,2	1,15±0,06
PLA + 40% grass pellet	5150±99	40,6±0,30	1,08±0,07	40,6±0,3	1,09±0,06

This table clearly shows that in case grass fibres are added, the material will become stiffer, and the maximum strength is increased. Furthermore, the stretch of the fibre compounds is lowered. This behaviour is normally observed.

Furthermore, no hugh difference are observed between the different type of grass materials used within the recycled HDPE and PLA compounds.

For compounding the refined grass, 4 different types of grass pre-treatments were used: 1) grass pellets made at 68% moisture, 2) ground pellets <1mm made at 68% moisture, 3) ground pellets <1mm made at 75% moisture and 4) ground loose grass fibres <1mm. Subsequently, these grass materials (40%) have been processed into compounds using recycled HDPE matrix. As comparison, a blanc recycled HDPE, and a compound with 40% wood fibre have been included. No problems were observed during the extrusion process. The processability of the different grass types went well, resulting in a homogeneous compounds.

Also these compounds were transformed into tensile bars via injection moulding (see Figure 5). The injection moulding went without any problems (No clocking, temperature fluctuations or other problems were observed). After conditioning of the test bars, they were analysed for physical mechanical properties. These results are summarised in Table 3.

Figure 5 Tensile bars with refined grass (f.l.t.r. recycled 100% HDPE, composite with loose fibres, composite with grinded pellets 25% moisture, composite with pellets 32% moisture, composite with grinded pellets 32% moisture, and composite with wood fibres)

Table 3 Summarised the mechanical properties of the refined grass material including the references

Compound	**E-modulus** [MPa]	**Force max** [MPa]	**Stretch @Fmax** [%]	**Force @break** [Mpa]	**Stretch @break** [%]
Recycled HDPE	885±23	18,7±0,16	>7,12±-	17,4±1,46	>7,12±-
Recycled HDPE + 40% loose grass fibres grinded <1mm	2570±32	18,1±0,05	1,50±0,04	17,5±0,29	1,75±0,17
Recycled HDPE+ 40% grinded grass pellets 32% moisture <1mm	2140±47	18,9±0,20	2,41±0,07	17,9±0,45	3,20±0,34
Recycled HDPE+ 40% grinded grass pellets 25% moisture <1mm	2040±25	17,0±0,09	2,26±0,33	16,1±0,18	2,8±0,40
Recycled HDPE+ 40% grass pellets 32% moisture	2340±105	18,7±0,46	1,93±0,06	18,2±0,56	2,21±0,11
HDPE+ 40% wood fibres	2880±67	21,9±0,09	2,40±0,04	19,8±0,51	3,61±0,31

This table clearly shows that when fibres are added to the polymer matrix stiffness (E-modulus) is increased and the stretch is reduced. Regarding the maximum strength, the grass fibres do not give extra strength. In case wood fibres are used a slight increase in strength is observed.

To give clearer overview of all strength (max. Force) and stiffness (E-modulus) results of the fresh cleaned dry grass material compounds and the cleaned dried refined grass material compounds, results have been summarised in graphs (see Figure 6 and Figure 7).

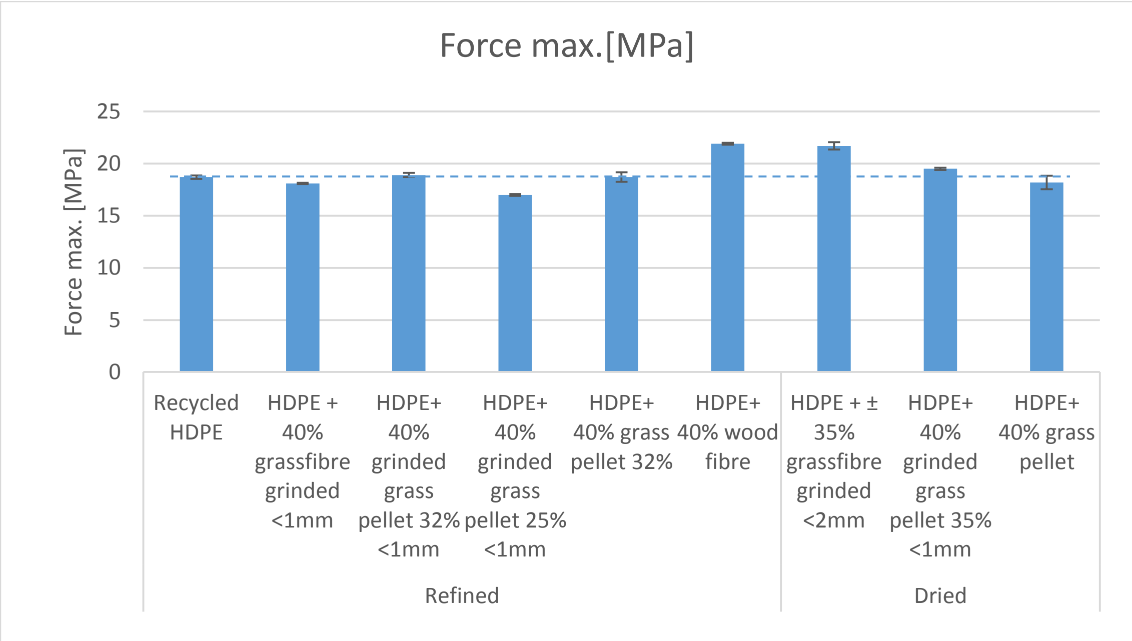

Figure 6 Strength of the grass compounds (max. Force)

Regarding strength properties (max. Force) of the grass compounds, no real difference in strength is observed when cleaned dried fresh grass is compared to cleaned refined dried grass. A decrease in strength is observed in case pellets are made with a lower moisture content. This may be a result of more cutting the fibres due to more dry fibres during the pellet process. In case the grass fibres are longer strength is increased significantly. And furthermore, it is observed that processing wood fibres also results in a better strength.

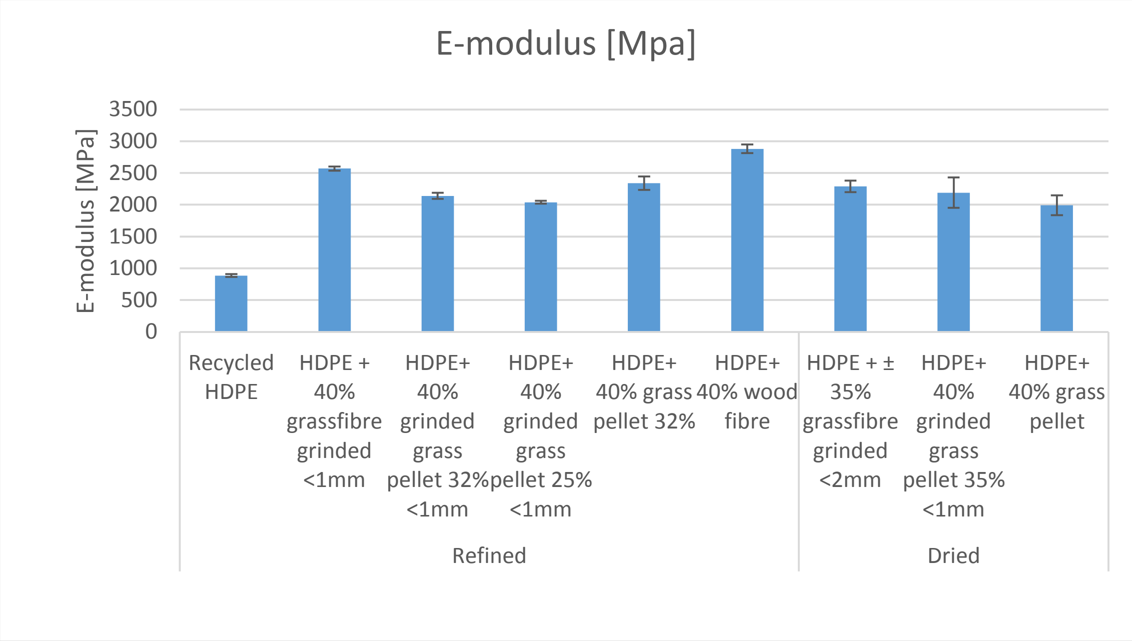

Figure 7 Stiffness of the grass compounds (E-modulus)

Regarding the stiffness (E-modulus) properties of these grass compounds, no hugh difference in stiffness is observed when cleaned dried fresh grass is compared to cleaned refined dried grass. The 100% polymer matrix has a much lower stiffness as expected, whereas the compound with wood fibres gives a better stiffness. The latter is probably due to a better fibre structural properties.

Summarised, it can be concluded that there is no significant difference in mechanical properties of the compound in case the cleaned dried grass is processed into pellets. Furthermore, mechanical improvement has been observed when the cleaned roadside clipped grass is refined. Of course, in case the liquid fraction can be further processed leading to a valuable product, justifying the refining step, refining should be performed. From transport or storage point of view, grass pellets are a better option compared to loose grass fibres. Therefore, in the next step of this project cleaned fresh dried roadside grass will be grinded, and either be processed into pellets or as loose fibres to enter the next stage of developing different compound recipes.

Protocol making grass pellets with the pelletizer of Millvision

- Make sure that the roadside grass clippings are freed of sand, plastic, metal etc.
- The grass should be dried till ca. 70% before the clipped grass can be further grinded.
- Once the grass is dried, it should be grinded till a maximum length of 2mm.
- Moisten the grass until a dry matter content of ca. 35-40% and mix in the water till a homogeneous mixture. Once the mixture is homogeneous, the grass is ready for making the pellets.
- Warm up the pelletizer, using a standard mixture of sand, oil and flour.
- After the pelletizer is warmed up, clean the device. Subsequently, remaining of sand mixture is wash-out using ca. 200 grams of the cleaned grinded wetted grass sample (moisture content 35%).
- Pelletize the grass sample by paying attention to an even dosage of the wetted clean grinded grass material. By doing so, homogeneous structured pellets are obtained.
- After pellet processed is finished, use the standard mixture of sand, oil and flour to clean the pelletizer of remains of the grass material.
- The grass pellets processed are dried in an oven at 105°C.
- Once the dried pellets are obtained (moisture content below 1% moisture), hardness of the pellets is measured with a Kahl pellet tester.

Industrial scale production of grass pellets

So far, Hogeschool Gent has found two possible options for producing roadside grass clipping pellets on industrial scale:

- An industrial producer of straw pellets is willing to set up a test with 50-100 kg (or more, if available) on a 1 ton per hour installation, producing 6 mm pellets. Soonest, these tests can be performed in July-August 2019. The installation allows to add binders and feeds to 5 presses.
  Perhaps the mowing demo in Maldegem can provide us with enough raw material for such a test. Hogeschool Gent will contact this firm for a test in July or August.
- A second-hand pellet press of 30 HP capable of pressing 1000 kg/hr. (4- 6 mm diameter) have been offered as possibility of acquiring which would allow us to do industrial-scale pelletizing tests ourselves. The seller guarantees the equipment has been revised and fully operational. The equipment will cost 2500 euro, and maybe worth taking a risk. Interesting, because also tests could be performed with other types of biomass like i.e. hemp and knotweed. Innec/Pro Natura will be contacted regarding this opportunity.

So, the industrial-scale pellet production is not ready for the report on our side. Hogeschool Gent propose to continue the upscaling in the framework of the value chain development (WP3) and as contribution to a part of D2.4.2 which is due for the end of the year. This can be motivated due to the fact that fibre material of Vanheede (large-scale batch AD) will become available at September 2019.

Supply of roadside grass clippings

The supply of feedstock of the roadside grass fibres and liquids to WP2 partners have been arranged by Pro Natura and Innec via subcontractors. Besides fresh and dried roadside clippings also pre-treated roadside clippings have been arranged by them. The following grass samples have been collected and distributed:

Description of samples of grass from roadside cuttings

Batch 1:
Location: Roadside cuttings from highway of the municipality in Utrecht.
Date: Mowing 8/11/2018
Screw press: 8/11/2018

Machinery used:
Mowing process: Flail mower
Pressing: Screw press ('counter pressure screw press') adapted for biobased resources at RhineTech producing liquid (fraction of 42,8% of original material) and fibres (fraction of 57,4%% of the fresh material.
Freezer: kitchen freezer to freeze the liquid samples, for the ability to store it for a longer time.
Samples provided:
Liquid fraction (fresh samples send to WP 2 partners 8/11/2018; frozen sample brought to WP 2 partners 11/2018)
Fibres fresh (fresh samples send to WP 2 partners 8/11/2018 and week later)

Batch 2:

Location: Roadside cuttings from Hengelo, Gelderland
Date: Mowing: 2018
Screw press: 2018
Ensiled: 2018
Forced Drying: 6/2/2019

Machinery used:
Mowing process: Flail mower
Pressing: Screw press ('counter pressure screw press') adapted for biobased resources at RhineTech producing liquid (fraction of 50% of original material) and fibres (fraction of 50% of the fresh material).
Ensiled in bales and air tied stored.
Forced drying: Dried for 25 hours with heated air (40°C) forced through grass fibres placed in wooden boxes covered with a kind of mosquito netting at the bottom to let the heated air pass through. Installation used at ILVO (seed drying installation), Merelbeke - Belgium.
Samples provided:
Dried fibres to WP 2 partners: 26/2/2019

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