Technical report prepared in December 2019

Deliverable A1.D2

Protocols for collection and sorting of hop waste defined

Deliverable prepared by **Slovenian Institute of Hop Research and Brewing (IHPS)** in collaboration with **Zelfo Technology**

Abstract

After harvest of hops beside the hop cones, we get also a huge amount of biomass that is left behind (leaves and stems). The process of harvesting the hops involves removing the entire hop plants from the fields. This post-harvest hop biomass provides a valuable source of organic mass and nutrients. The LIFE project BioTHOP is aiming to replace polypropylene twine, that is used for guiding of hop plants and was so far the cause of inappropriate biomass disposal, with compostable poly-lactic acid (PLA) twine. So far, the ideal way of treating the hop biomass after harvest was composting with addition of sieving at the end to eliminate polypropylene twine. Using BioTHOP PLA twine will enable complete composting of hop biomass after harvest to produce rich organic fertilizer. Besides that, the biomass can be used as source of fiber for to create new products.

In Slovenia, there were about 23,762 tons of hop biomass after harvest produced in 2019 (calculated from average hop biomass after harvest got after harvest, which is 15.7 t/ha). Even small hop producers, that grow hops on less than 5 ha, produce enough biomass for one compost pile (about 39 tons). In our investigation, the hop biomass after harvest had C : N ratio of 13 : 1. When composting the whole hop biomass (stems and leaves), the addition of substrates with high carbon content might be needed. Composting only stems with C : N = 23 :1 ratio would be better, regarding the nutrient availability.

Most of horticulture waste has a considerable amount of cellulose, which can be extracted as a form of fibers. Hop belongs to the same family as hemp (*Cannabaceae*) so it offers similar use. High fiber content gives an opportunity to use those in other sectors like paper production, textile industry and industry of bioplastics.

There are several ways of collection of hop waste with the purpose of fibre extraction. There are two major options of collecting hop biomass after harvest regarding the picking machine: the stems and twine on one heap and leaves on other or stems and leaves mixed in one mixed heap and shredded in smaller fragments.

Following deliverable elucidates current circumstances in hop growing sector and it's possibilities for collection of hop waste. The fact is that the whole biomass appears in one month, from approximately mid-August to mid-September and we have to use it as a row material for composting or prepare it for other planned use right away, because this is fresh plant material.

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1. Introduction

The earliest forms of what modern people might call beer contained no hops. However, for approximately 1,000 years of which we are aware hops have been used as one of the primary ingredients. Hops were listed in the German Purity Law of 1516 (Reinheitsgebot), as one of 3 ingredients allowed for use in the production of beer (water, malt, hops). Brewers use hops for the aromatic flavors they impart, for their bitterness, and for their preservative qualities.

While hops would grow almost anywhere, in the 20th and 21st centuries they are produced in commercial quantities and prices in approximately 20 countries to supply the world's brewers. The world hop acreage in 2019 equals to 61,500 ha – where two countries dominate the world's production of hops, The United States and Germany.

Slovenia is one of the leading hop producers worldwide, exporting between 95% and 99% of its hop production. Slovenia is the sixth biggest hop producer in the world, after the US, Germany, China, Czech Republic and Poland, representing 3% of global hop production (IHGC, 2019). Hop production is one of the most important agribusiness sectors in the Lower Savinja valley.

After hop harvest, beside the hop cones we get also a huge amount of biomass that is left behind (leaves and stems). In the process of hop harvest, the whole hop plants are taken from the field. Hop biomass after harvest presents a valuable source of organic mass and nutrients. In Slovenia, there were about 23,762 tons of hop biomass after harvest produced in 2019, calculated from the data of average production 15.7 t/ha. Even small hop producers, that grow hops on less than 5 ha, produce enough of it for one compost pile (about 39 tons). In our investigation, the hop biomass after harvest had C : N ratio of 13 : 1. That is why we predict that when composting the whole hop biomass after harvest (stems and leaves), the addition of substrates with high carbon content might be needed. Composting only stems with C : N = 23 : 1 would be better, but they should be cut on smaller, 1 cm pieces and properly humid.

Until now, composting of hop biomass after harvest was the only reasonable solution, and there were big problems because of the polypropylene twine intertwined in the biomass as well. With the start of the project LIFE BioTHOP, we have obliged to transform hop biomass after harvest into new - bioplastic materials too and write technological guidelines for proper composting to turn it into fine good quality compost.

a) Hop plant

The hop plants (*Humulus lupulus* L.) are grown exclusively for the brewing industry where resins and essential oils form female cones are used for aroma (Almaguer et al., 2014). Optimal growth conditions rely upon the length of the daylight, summer temperature, annual rainfall and soil fertility (Verzele and Keukeleire, 2013). Hop plant is a dioecious, perennial, climbing plant with growing season (in the Northern Hemisphere) from April until September. In one season, it can grow up to 7 m high (Majer et al., 2002). The cones present only 1/3 of the plant biomass therefore the 2/3 (leaves and stems) of the biomass is mostly treated as a waste (IHPS data).

***Figure 1**: Hop plants on the field in the beginning of growth season.*

b) Production of hops in 2019

In the year 2019, the hop production acreage in the world was around 61,500 ha. The two countries that dominate the world's production of hops are The United States and Germany. Slovenia follows with hop acreage on the 6th place and produces 2–3% of all hops at global level (IHGC, 2019). In 2019, 124 hop growers in Slovenia grew hops on 1,595 ha (Livk, 2019).

c) Production per hop grower

In Slovenia, there were 124 active hop growers in year 2019. The most hop growers grew hop on less than 5 ha (45), followed by farmers that grew hop on 5–10 (26) ha and 10–15 ha (22).

There are 15.7 tons of biomass left behind after harvest from the hectare of hop field (Čeh et al., 2019a). A farmer that grows hop on 12 ha has to deal with 188 tons of hop biomass after harvest. Taking into account all hop production areas in Slovenia, there is more than 23 thousand tonnes of hop biomass at the end of the season.

***Table 1**: Mass of hop biomass after harvest in Slovenia in 2019*

Acreage (ha)	Nr. of hop growers	Hop biomass after harvest* (t)
140–145	2	2,198–2,277 (2,237)
35–50	3	549.5–785 (589)
30–35	4	471–550 (510)
25–30	4	393–471 (432)
20–25	11	314–393 (353)
15–20	7	236–314 (275)
10–15	22	157–236 (196)
5–10	26	79–157 (118)
0–5	45	0.05–79 (39)
Total	**124**	**23,762**

*range and average

2. Hop harvest

Hop harvest season varies upon the variety and consequently maturity of the cones. When cones reach technological maturity, hop harvest season begins (Majer et al., 2002). **In normal year, the hop harvest season lasts from mid-August (around 15th) until around 20th of September. All biomass arise in that period of 1 month.** An average farmer can harvest around 0.5 ha, whereas the upper capacity for harvesting is about 1 ha per day when continuously working the whole day.

The hop harvest can be divided into three different processes:

- Cutting, pulling and loading plants on trailers.
- Transport to picking machines.
- Separating cones, leaves and stems on picking machines.

Field cutting and pulling is usually done by tractor and a harvest equipment. The plants are cut at the bottom and the stem goes to the chain system for plant pulling. The plants are being loaded on the trailer. The tractor is driving in the line and when the trailer is full it goes to the picking machine. The picking machine is usually placed in a separate building, together with the drying kiln. The plants are being loaded into machine manually, plant by plant. The machine separates cones with leaves from the stem and afterwards cones from the leaves. Cones are being transported into the drying kiln whereas stems are being cut into smaller residues. The residues are being discarded on a concrete floor behind the building in a shape of a heap. When the heap becomes too high, it is being pushed on a side until the end of a harvest season (Majer et al., 2002).

3. Collection of hop waste

Hop growers have different picking machines and, consequently, different particle sizes of hop biomass after harvest.

1) First option is that hop biomass after harvest is separated into leaves and 15 cm long cut stems in the harvest machine itself,
2) second is that the leaves and stems are shredded into 3 cm fragments and collected together,
3) third and not very common option is collection of separated leaves and uncut stems. The complete removal of leaves is not possible.

Leaves present easily degradable organic matter and are usually returned to the field. Stems are put on a pile where long composting process occur and after about 2 years, the farmer would rent a machine for separating humus from plastic twine nowadays.

***Figure 2**: Hop biomass can be collected in two separate heaps – leaves (left) and stems with twine (right) right from the harvest machine.*

***Figure 3:** Stems with BioTHOP PLA twine. Complete removal of leaves is impossible.*

***Figure 4**: Mixed heap with leaves, stems and twine.*

a) Composting

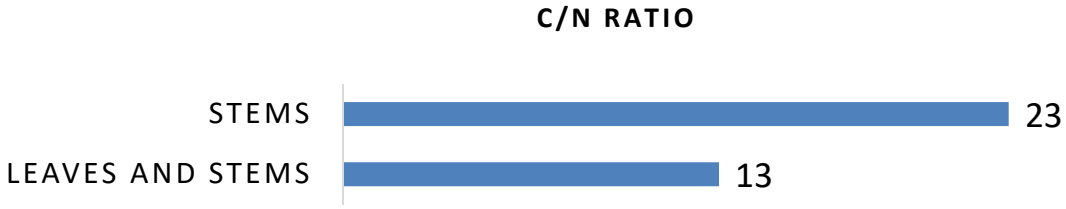
There are several ways of composting that have already been described in **deliverable A1.D1 Requirements and limitations over the current PLA twine for hop growing sector**. We must take into account that right now farmers do not possess any specific composting equipment such as compost aerators, mixers nor infrastructure like closed halls or constructed floor.

The most common way of composting is collecting the hop biomass after harvest and forming a pile, for example on a side of a field. The most suitable way of preparing compost pile is in 2 m high trapezoidal shape. After some time, the pile is covered with black foil and left until the spring. Afterwards it is uncovered, mixed and left until utilization.

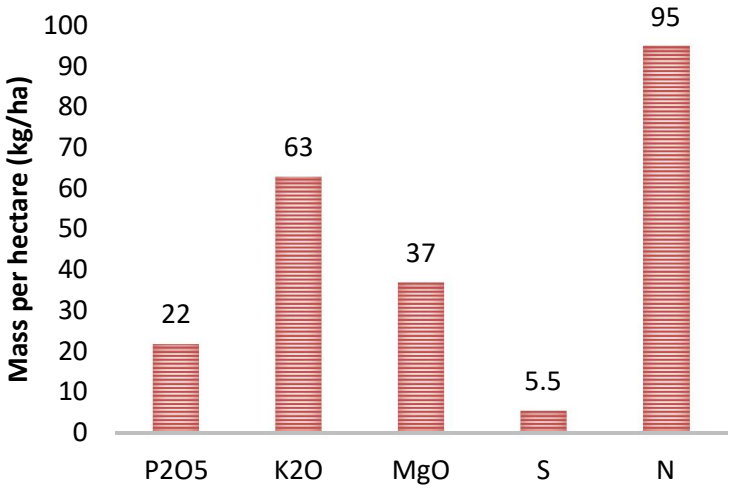
The major problem of composting hop biomass after harvest is polypropylene twine that is intertwined with the stems. Composting this mixed materials is possible, but utilization of humus is possible only if mixture is sieved and the plastic is disposed, what is a hard and costly work.

Figure 5: *Compost pile intertwined with polypropylene twine.*

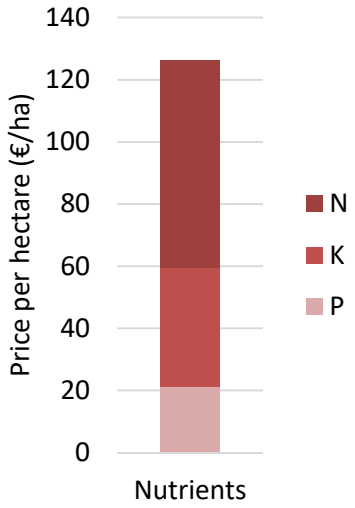
Different compost substrates can be more or less susceptible to degradation. When analysing hop biomass after harvest, we have discovered that the C : N ratio is quite low 13 (Graph 1) (Čeh et al., 2019b), compared to what is referred in the literature. Low C : N ratio can cause leaking of ammonium from the pile. Hop biomass after harvest is reach in nutrients (Graph 2) therefore; it should not be treated as a waste. Hop biomass after harvest produced on 1 ha in our investigation contained 21–22 kg P_2O_5, 50–71 kg K_2O, 32–41 kg MgO, 5.5 kg S and 88–99 kg N. The nutrients have high economic value and by returning the nutrients to the soil by compost, we can reduce the money spent on mineral fertilizers. In terms of economy, 1 ha of hop biomass after harvest has a value around 120 € (Graph 3) when summing the value of main nutrients (phosphorus (P), potassium (K) and nitrogen (N)) (Čeh et al., 2019c).



***Graph 1**: C : N ration of hop stems and hop stems and leaves combined.*



***Graph 2**: Nutrients per of hop biomass per hectare.*



***Graph 3**: Value of nutrients.*

b) Hop biomass after harvest as source of fibers

Many agricultural by-products are being produced after harvest and most of them are composed of considerable amount of cellulose, which can be extracted as a form of fibers. Since hop belongs to the same family as hemp (*Cannabaceae*) it offers similar use. Hemp fibers are used to produce fibers for textile industry. The compositions of the fibers depend on many parameters, such as variety, maturity or extraction conditions. Hop stems contain 10.5 to 19.5% of lignin (Frangež, 2016). Reddy and Yang (2009) report similar content of cellulose in hop fibers and cotton. The content of cellulose is higher in hop fibers extracted from hop stems than the content in hemp fibers. High fiber content gives an opportunity to use those in other sectors like paper production, textile industry and industry of bioplastics (Yang et al., 2014; Reddy and Yang, 2009).

Hop biomass after harvest is full of nutrients and the processes of biodegradation start almost right after the harvest. The temperature in the heap can reach up to 68˚ C in 4 days (IHPS trial 2019). When the heap is made of sole stems, the temperature rise slowly, still the degradation can start. Considering these facts, the transport to site of fiber extrusion should be fast to prevent degradation.

4. Collection protocol for other purposes than on site composting

There are two major options of collecting hop biomass after harvest regarding the harvest machine:

a) stems intertwined with twine on one heap and leaves on other or
b) stems and leaves in one mixed heap (smaller fragments).

When the harvest machine separates stems and leaves, stems are usually cut into 15 cm fragments, in this case the heap of 15 cm stems can be redirected directly on transport vehicle. In one day it is expected to load (0.5 ha * 15.7 t * 0.5 (ratio of stems)) about 4 tons. In other case, when the hop grower collects mixed biomass in smaller fragments, the technical modifications of harvest machine should be made to redirect leaves before going into knife to get sole shredded stems with twine.

Due to fast degradation potential, the most suitable solution might be on site transformation of biomass into fibers.

Drying of stems before transport was also considered in the study, however its costs are predicted at this moment to be economically unjustified. In the time of hop harvest, the drying machines are fully loaded by hop cones that have to be dried before packing namely. Option would be drying on the ground for smaller quantities. This issue will be taken firther into account in the continuation of the project.

Figure 6: *Loading the hop biomass after harvest for transport.*

Guidelines for collection hop stems for fiber extrusion:

- Extrusion of fibers form plant material is delicate. To prevent damages of the machines, the biomass **should not include any metals, stones, dirt or other objects**. Regarding this criteria, the most suitable is collection of biomass directly in the shipping container.
- Fiber extrusion is more efficient when stem fragments are smaller, therefore the **reduction in size of particles** must be considered.
- If there are options for **drying** hop biomass after harvest, the step of drying is advisable, but because at this time it seems as not suitable - at the time that biomass after harvest should be dried the drying machines are fully occupied with hop cones drying this issue will be worked on in the continuation of the project.
- When shipping fresh material, **shipping has to be as fast** as possible, due to potential of fast degradation of biomass.
- If the extrusion facility cannot process the capacities of delivered amount of biomass, shipping in time intervals is an option.
- In case of **on-site extrusion,** the degradation issue and shipping costs are avoided.
- The twine might cause problems with the extrusion therefore, it is advisable to remove the twine when possible.

5. References

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