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Technical and technological solution for vegetal bio-stimulants obtaining

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Abstract. The paper presents a modern technology for bio fertilizers resulted from waste plant mass after harvesting crops Experimental products were obtained rich in nutrients, but unstable in terms of existing microorganisms. Therefore, they conducted further studies to obtaining bio fungicide herb, so in all investigations undertaken so far in the laboratory, were able to conclude that the introduction of medicinal plant extracts with fungicidal effect into the bio fertilizers obtained by degradation of plant material post-harvest can get various bio-stimulants with nourishing effect upon the plants. Following this technology the paper's objective is to identify a flux scheme for experimental equipment which can produce as final outcome this type of bio-stimulant. Also, in this work, this equipment will be chosen and will be designed following and obeying to the request of every step of the above technology.

1. Introduction

The designed biodegradation platform is intended to produce vegetal bio-stimulants starting from organic waste, resulted after harvesting the agricultural and horticultural crops, mixed with bio-fungicides, as medicinal herbs extract, mixtures that provide the mineral elements and increase the disease resistance for various crops.

The technological process to produce bio-stimulants is sequenced as follows:

- Landfill supply with organic waste (bio-mass), mainly as straw and leaves;
- Chopping of organic waste to suitable dimensions;
- Compost (chopping) conveyance into a mixing basin;
- Mixing the chopping with hot water and air, thus resulting a compost with high humidity;
- Making even and biodegradation of humidified compost by stirring for one week;
- Filling the basin with water, the result being the final compost, that is periodically stirred for homogenization and biodegradation purpose, for one more week;
- Compost outlet and its pressing;
- Separation by pressing of the liquid part (bio-fertilizer) from solid part;
- The bio-fertilizer is collected in an outlet basin where it is mixed up with medicinal herbs extract this way resulting the vegetal bio-stimulant;
- The vegetal bio-stimulant is pumped to a bottling station in plastic recipients;

- The solid part of the compost is out flown on a conveyor belt, being used as solid substrate for vegetation boxes and aqua-ponic crops or it is bagged and delivered to greenhouses as solid organic substrate.

2. Flow diagram of pilot station

Based on the process stages presented within previous section results the flow diagram [7] of the pilot station shown in figure 1. The pilot station will be located in an industrial hall and will have a landfill attached for raw material (bio-mass). The landfill is supplied by road vehicles, and the mix of biodegradable waste is unloaded by tilting inside the landfill. The landfill is crossed [3] by a conveyor belt (1), electrically driven and provided with a feed at the end where the vegetal waste chopper (2) is located.

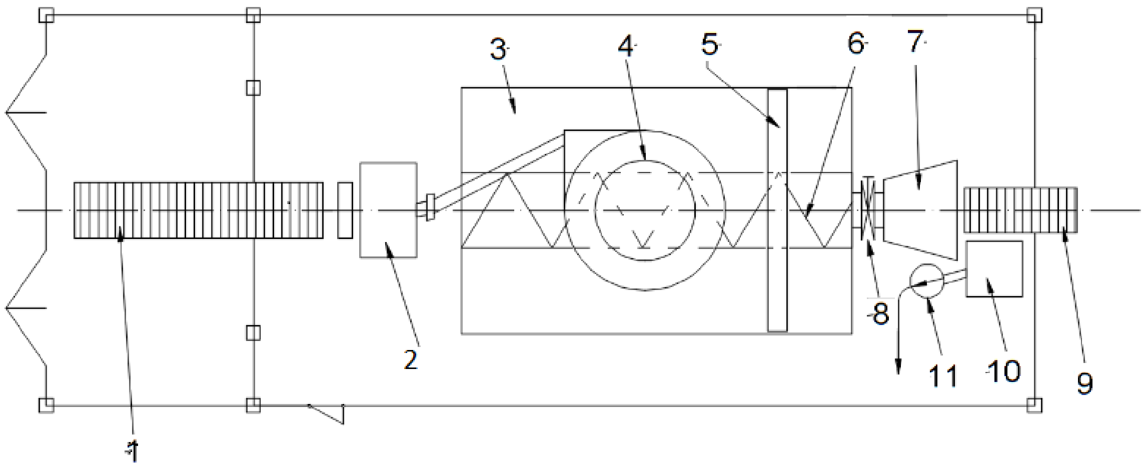

Figure 1. Flow diagram of the pilot station.
1 - bio-mass conveyor belt, 2 - drum type straw chopper, 3 - mix basin, 4 – de-dusting cyclone, 5 - stirrer, 6 – worm conveyor, 7 - dewatering press, 8 – valve, 9 – conveyor belt for solid compost from press, 10 – final product tank, 11 – pump

The chopper is of rotating drum type with six knives on generating line and one counter-knife fixed on the housing. The chopped matter will be out flown by the chopper into the de-dusting cyclone (4) its air vent passing through the hall ceiling to the outside to remove the dust resulted from chopping process.The cyclone is centrally located above the mix basin (3), and the compost will fall down, through the lower outlet connection of the cyclone, into the mixing tank.In the basin, the compost will be mixed with hot water, respectively cold water in the two distinct stages of the process. During the two stages, the compost will be periodically stirred by the vertical/horizontal stirrer (5), for homogenization and biodegradation purpose.

After the two stages biodegradation process is finished, the compost will be directed to a dewatering screw press (7) and taken out by an open type worm conveyor (6). The dewatering press separates the liquid part from solid part. The liquid part resulted after pressing is a bio-fertilizing substance and is collected in a final product tank (10) where it is mixed with medicinal herbs extract. After mixing, the result is the final product, meaning the liquid bio-fertilizer that is conveyed by pumping (11) to the station for bottling into plastic recipients.Resulted recipients are labelled and sent for sale.

The solid part will have a maximum final humidity of 20% and be removed through a conveyor belt (9) to a concrete platform [4] located in front of the basin, following to be delivered as solid substrate for vegetation boxes and aqua-ponic crops or be bagged and sold as solid organic substrate.

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3. Dimensioning calculation for industrial micro-pilot station equipment

The calculation refers to determination of production capacity, main geometrical dimensions and the power needed for driving, of the component equipment of the process line highlighted in the flow diagram.

Dimensioning is based on the quantity of yearly plants chopping (straw + leaves) produced for one charge needed to fill the tank having $15m^3$ volume.Specific weight of the straw + leaves chopping is variable among $10\text{-}20kg/m^3$[6]. Within dimensioning calculation the specific weight (density) of $10kg/m^3$ will be used.In this case, the mass quantity of chopping prepared will be $15m^3 \cdot 10kg/m^3 = 150kg$. It is set that the mass flow of chopping (bio-mass) suitable for requirements of the bio-stimulant production process will be Q=150kg/h, so the volume flow of the chopping installation will be $V=15m^3/h$.

3.1 Bio-mass belt conveyor

In case of bulk materials conveyor (straw + leaves mixture) the productivity of belt conveyor is calculated by using the relation [1].[2]:

$$Q=3.6\cdot F\cdot\gamma\cdot v[kg/h] \tag{1}$$

where:

F – cross section of the material to be conveyed on the belt; $[m^2]$

γ - specific weight of conveyed material; $[kg/m^3]$

in our case $\gamma = 10\ kg/m^3$

v – conveyor speed; [m/s]

It was set that the efficiency (capacity) of the belt conveyor to be Q=150kg/h.

Under these circumstances, the belt speed will be calculated with the relation:

$$v = \frac{Q}{3.6\cdot F\cdot\gamma}[m/s] \tag{2}$$

Section of material layer in case of flat belt the installation is equipped with will be calculated with the relation [1],[2]:

$$F=\frac{B^2}{4}tg\rho[m^2] \tag{3}$$

where:

B – belt width; [m]

ρ - the angle of straw and leaves mixture loaded on the belt;

$\rho\cong75^0$

A rubber belt having the width B=1m, with five textile inserts is chosen.

$$F=\frac{B^2}{4}\cdot3.8\cong1m^2$$

So

$$v=\frac{150}{3.6\cdot1\cdot10}\cong4\ \ m/s$$

So, the belt conveyor will have the productivity Q =15 m^3/h chopping, be equipped with flat belt with width B =1m, made of rubber, with five insert layers, having the speed v = 4m/s.

The drive power of conveyor will be given by the relation [1]:

$$N_{inst}=\frac{K\cdot N_0}{\eta} \tag{4}$$

where:

K= 1.4–overstress coefficient

$$N_0=(N_1+N_2+N_3)\cdot K_3+N_4[kW]$$

$N_1=K_1\cdot L\cdot v\ [kW]$ - idle power needed to resist inertia moment

$K_1=0.24$ – damping coefficient selected based on belt width

$L=4m$ - length of conveyor belt

$v=4m/s$ – belt peripheral speed

$$N_1=3.84\cong 4\ [kW]$$

$N_2=K_2\cdot Q\cdot L$ [kW]–load running power, useful for material handling

$K_2=0.00015$

$Q=0.150t/h$ - hourly weight flow

$L=4m$ – conveyor belt length

$$N_2\cong 0.00009\ [kW]$$

$$N_3=\frac{Q\cdot H}{3.6\cdot 102}\text{–motor power for material conveyance on sloped plane [9]}$$

$H=0$–elevation

$N_3=0$ kW

Because lifting height is H=0, results that $N_3=0$ kW

N_4 is the power needed for car travel on belt. For a belt without car $N_4=0$ [kW]. From above relations, results that:

$N_0=(4+0{,}00009+0)\cdot K_3$

where:

$K_3=1.2$ is a coefficient for power supplementing in case of short belts (L< 15m).

$N_0=4.8\cong 5$ [kW]

Installed power of the drive motor will be [1], [9]:

$$N_{inst}=\frac{K\cdot N_0}{\eta} \quad (5)$$

where:

$K=1{,}1$

$\eta=0.9$ - transmission efficiency

$N_{inst}=5.86\ kW\cong 6\ kW$

Based on above calculation, a three-phased drive motor is chosen N= 6kW and speed n_1 = 750 rot/min. To adapt the motor operation to the drive speed of conveyor belt drum, a gearbox will be connected to the motor shaft ensuring the operation speed of conveyor belt, as follows:

$$n=\frac{60\cdot v}{\pi\cdot d}\ [rot/min] \quad (6)$$

$v=4m/s$

$d=0.3$ m -diameter of conveyor belt driving drum

$n=254.77\cong 255$ [rot/min]

Gearbox ratio:

$$i=\frac{n_1}{n}=\frac{750}{255}\cong 3$$

3.2 Straw and leaves chopper

The chopper is equipped with a feeding box located at lower part of the conveyor driving drum, in vertical plane that pass through the drum axis [6].

The top part of the box will exceed the active part of conveyor belt by 600mm.

The vegetal waste (straw + leaves) chopper will be of drum type with six rotating knives located on the drum with a slope of 15^0so that cutting of vegetal mix to be progressively done not by one direct hit (by impact) [5].

The chopper drum will have the diameter D=500mm, equipped with six sloped knives and one horizontal counter-knife. The drum will be driven by an AC motor supplied with 380 V voltage, with power 7.5 kW and speed 750 rot/min. Motor power was chosen by using an industrial reference model with capacity of 3000 kg/h chopped straw [2].

At 750 rot/min the chopper will do 6 cuts/rotation, so:

$$T=750\cdot 6=4500\frac{cuts}{minute}\ \text{or}\ \frac{4500}{60}=75\,cuts/s \quad (7)$$

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The chopped material resulted, in case we take into calculation the feed in horizontal position of the mix will be:

$$L=\frac{v}{T}=\frac{2000\text{m/s}}{75\text{ cuts/s}}=28\text{mm} \quad (8)$$

3.3 Pneumatic conveyance installation for chopped material

As it is very difficult to quantify the ventilation effect produced by rotating drum with knives of the chopper, a blower will be used for chopped material conveyance from the chopper to the de-dusting cyclone, the air used for chopped material conveyance will be out-flown into the duct for chopped material through a funnel located at lower part of the chopper. At the final point (de-dusting cyclone) the material is separated from air and together with the dust are directly out-flown to the atmosphere or through a dust filter, if the location require limits as to micro-particles disposal in atmosphere.

The air speed will be v_{air}=20 m/s and the quantity of needed air for pneumatic convey is set by the relations [1], [2]:

$$\mu=\frac{Q_S}{L_A}\text{–weight batching} \quad (9)$$

Q_S [Kg/h] – hourly material quantity to be conveyed

L_A [Kg/h] - hourly air quantity needed for convey

$\mu=0.3\div0.5$ – weight batching for fibber type chopped material

I have chosen $\mu=0,3$

$$L_A=\frac{Q_S}{\mu}=\frac{150}{0.3}=500\text{ Kg/h}$$

Air mass flow, needed for convey, will be:

$$L_{AV}=\frac{L_A}{\gamma_a}=\frac{500}{1.2}=420\text{ m}^3\text{/h}$$

$\gamma_a=1.2$ [Kg/m^3] - specific weight of the air at 15^{0}C and atmosphere pressure

So, the air volumetric flow rate will be:

$L_{AV}=420\text{m}^3/\text{h}\cong0.12\text{m}^3/\text{s}$

Convey duct will have the diameter[1]:

$$d_{cond}=\sqrt{\frac{4\cdot L_{AV}}{\pi\cdot v_{air}}} \quad (10)$$

$$d_{cond}\cong0.15\text{m}$$

Duct diameter is chosen as being:

$$d_{cond}=0.25\text{m}=250\text{mm}$$

Total pressure drop to be overcome by the fan for chopped material convey will be equal to [1]:

$$H_T=H_D+H_S[\text{Pa}] \quad (11)$$

Where [4]:

$$H_D=\frac{\gamma_a\cdot v_{air}}{2g}(1+0.7\cdot\mu)\ [\text{Pa}] \quad (12)$$

Dynamic load needed to overcome the inertia of conveyed (chopped) material and the mix it is conveyed with:

$$H_S=H_{rid}+H_{frec}+H_{cot}+H_{sep}[\text{Pa}] \quad (13)$$

where:

$H_{rid}=\mu\cdot\gamma_a\cdot h$ [Pa]- needed load to lift the chopped material to the height of $h\cong7$m.

$$H_{rid}=0.3\cdot1.2\cdot7\cong2.5\ [\text{Pa}]$$

$$H_{frec}=f_0\cdot\frac{1}{d}\cdot\frac{\gamma_a\cdot v_{air}^2}{2\cdot g}(1+k\mu)\ [\text{Pa}]$$

where:

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$f_0=0.0125+\frac{0.001\cdot l}{d}$ – horizontal pressure loss coefficient

$f_0=0.016$

$H_{frec}=19.79\cong 20Pa$

$H_{cot}=\sum C_i\cdot\frac{\gamma_a\cdot v_{air}^2}{2\cdot g}$ [Pa] are the pressure loss due to direction changes in the route of the convey duct.

The duct has three bends at abt. $120^0$for which C_i =0.7 (coefficient for local loss pressure).

So

$H_{cot}=54.138$ [Pa]

H_{sep}[Pa] - separator pressure loss which has the value experimentally determined $H_{sep}=10^3\div 6\cdot 10^3$ [Pa]

For calculation, the following value is taken:

$H_{sep}=3\cdot 10^3$ [Pa]

By summing-up we find the value of total pressure drop:

$H_{tot}=3.08\cdot 10^3$ [Pa]

Under these circumstances, the total power of the blower will be[1]:

$$N=K\cdot\frac{H_T\cdot L_{av}}{1000\cdot\eta} \qquad (14)$$

where:

K=1.2 – overpressure coefficient

$\eta=0.5$– equipment efficiency

$N=2.22$ kW$\cong$ 2.5 kW

A standard type blower will be chosen, having features closer to the values:

Air flow: $L_V=0.3$ [m^3/s], Outlet pressure: $H_T=3.08\cdot 10^3$ [Pa], Drive motor power: $N=2.5$ [kW]

3.4 De-dusting cyclone

This will be of centrifugal type and located above the wetting basin. The air duct of the cyclone will pass through the hall roof wherein the basin is, to evacuate to the atmosphere the air and dust mix resulted from centrifugal action on the chopped material pneumatically conveyed in the cyclone.

The connection duct from collector room of the chopper to the cyclone will have the diameter Φ=250mm and out-flows into the cyclone having a much more section area than the duct, increasing a lot the mix speed and implicitly the centrifugal force projecting the chopped material onto the cyclone walls, realizing a strong de-dusting effect [9].

The de-dusted chopped material will fall down through the outlet connection of the cyclone, on a sloped plane for spreading into soaking basin. Periodically, the chopped material will be equalized by its spreading into the basin by means of a worm stirrer.

3.5 Soaking basin

The basin will have the capacity of 15m^3 (5x3x1)and store the straw and leaves chops, periodically wet and mixed with hot water.

The basin will be of steel construction design with side walls, front walls and bottom made of stainless steel plate thick 3mm[9].The walls will be ribbed with rolled profiles protected by corrosion protective paint.The basin will be located on a metallic structure at 0,6m height, above ground, having a visiting platform of 0.8m width protected with a metallic rail, on the side walls.

On the front wall, opposite to the store, the basin will have an outlet connection of 0.5m diameter with valve for emptying the mix from the basin into a dewatering press.

Due to high consistency of the compost, the basin cannot be gravitationally emptied [9]. By this reason, for emptying, a semi-open helical conveyer will be located on the basin bottom.

The open type helical conveyer will be located into the chute formed on the mix basin bottom. An open type helical conveyer having diameter D=0,4m, step S=0,7 m and speed n = 40 rot/min will be chosen.This will have the convey capacity:

$$Q = 60 \cdot \frac{\pi \cdot D^2}{4} \cdot S \cdot \Psi \cdot n \cdot \gamma \cdot c \;\; [t/h] \tag{15}$$

where:
$D = 0.4\,m$; $\Psi=0.12$ - filling coefficient; $S=0.7$ m;$n=40\frac{rot}{min}$;$\gamma=0.8$ t/m^3 - compost density (wet chopped material);$c=1$- sloping coefficient (on horizontal c=1).

$$Q = 60 \cdot \frac{\pi \cdot 0.4^2}{4} \cdot 0.7 \cdot 0.12 \cdot 40 \cdot 0.8 \cdot 1 = 20.25 \;\; [t/h]$$

Helical conveyer drive motor power will be [1], [2]:

$$N=\frac{Q}{367\cdot\eta}\cdot(L\cdot\omega\pm H)\ [kW] \tag{16}$$

where:
$L=5m$- conveyer length; $\omega = 2.5$- friction coefficient; $H=0$- for horizontal convey; $\eta=0.7$ - transmission efficiency.

$$N = 0.985\ [kW]$$

A motor of N = 2 kW is chosen, with a greater power needed to overcome friction and outlet of the compost into press [8].

3.6 Dewatering screw press

The dewatering press will separate the solid part from the liquid part of the compost, which is the final product of this process.
The press which is used for dewatering the mixture from the soaking basin is a screw press, conical, horizontal made of following subassemblies: metallic case within which will be installed a cylindrical screen and a screw which has a circular motion, with speed n = (20-30) rot/min.
The mixture with consistency (7-12) % is taken by the screw, dehydrated during the space between the screw and the screen and send to opposite end of the press. The dilution water drains through the screen holes and is collected into a collector tank.
The solid part will and be removed through a conveyor belt (9) to a concrete platform located in front of the basin, following to be delivered as solid substrate for vegetation boxes and aqua-ponic crops or be bagged and sold as solid organic substrate.
The screw press capacity will be calculated using the equation:

$$Q=60\cdot\frac{\pi\cdot D^2}{4}\cdot S\cdot\Psi\cdot n\cdot\gamma\cdot c \tag{17}$$

where:
$D=0.5m$ - the highest press diameter ; $S=0.3m$ - screw pitch; $\Psi=0.2$ - filling coefficient;
$n=25$ rot/min – screw rotation speed; $\gamma=0.8\,t/m^3$ - mixture density; $c=1$ - for horizontal press
The press will has the length of 1.5m, the highest diameter $D_1=0.5m$and the smallest diameter$D_2=0.15m$.
So: Q = 17.66 t/h
In these conditions the basin will be drained in round one hour. The motor power is calculated using the equation:

$$N=N_T+N_P\ [kW] \tag{18}$$

Where: $N_T=\frac{Q}{367\cdot\eta}(L\cdot\omega\pm H)$ and $\eta=0.7$ - transmission efficiency; $L=1.5m$ - the press length;
$\omega=2.5$- constant of material; $H=0$- for horizontal press; $N_T=0.45$[kW];
$N_P=\frac{p\cdot V}{10^3}$ [kW] and $p=1.5\cdot10^5$ $[\frac{N}{m^2}]$; $V=30\,m^3/h = \frac{30}{3600}\,m^3/s$; $N_P=\frac{1.5\cdot10^5\cdot\frac{30}{3600}}{10^3}=1.25$[kW]

$$N=0.45+1.25=1.65\cong 2kW$$

It is necessary to choose an AC three-phase motor, with nominal power N = 2 Kw and speed n_1 = 750 rot/min.

The motor will drive the screw press through a gearbox having the gear ratio: $i=\frac{n_1}{n}=\frac{750}{25}$ (n_1=750rot/min, n=25rot/min).

3.7 Belt conveyor for solid compost from press
This type of belt conveyor is the same with the bio-mass belt conveyor, so that the calculation is the same. So: belt length L = 2 m, belt width B = 0.5 m, belt speed v = 3 m/s, driving motor power N = 3 kW, driving motor speed n = 750 rot/min, i = 2.7.

4. Conclusions

This research is part of a project which aims to develop new plants bio-stimulants from organic wastes after harvesting crops, to re-join thus the natural cycle of mineral elements through assimilation by plants, giving both resistance to attack by pests and diseases due active principles derived from medicinal plants.

The objective of this project is to design and build a bio-degradation platform for a technology to obtain specific recipes of plants bio-stimulants from post-harvest agricultural waste and medicinal plants extracts, followed by testing and obtaining a certification of technology and bio-stimulants produced.

This paper proposes a solution for the bio-degradation platform design in three distinctive steps. First of all, the research identifies the stages of the technological process to produce bio-stimulants. Then, for the each stage (stages) was found the proper equipment linked into adequate technological flow and resulting a pilot station concept. In the last step (but not the least) chosen equipment were calculated and dimensioned for nominal work conditions [7].

5. Acknowledgments

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