Plant for the Production of Chips and Pellet: Technical and Economic Aspects of an Case Study in the Central Italy

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Abstract. This work is the result of a technical and economic analysis about the process of transformation of forest wood in biofuels, pellets and wood chips. The experimental pilot plant is managed by a forest consortium located in the province of Terni, Umbria Region (central Italy), near the Mountain Community "Valle del Nera" and Mountain San Pancrazio. The structure and all the machinery of the consortium have been realized utilizing government incentives and involving public and private subjects that operate in the district. The production process of woodpellet is more articulated: it is necessary to refine the mixture a bit more, creating a wood dust which is immediately compressed to form the classical cylindrical pellet's shape and to provide a uniform dough-like mass. The study of the productivity of machinery employed in the transformation of the wood material was made analyzing the cards compiled daily from the technicians of the consortium. The economic evaluation has been completed following an analytical procedure considering the hourly manpower cost and the single machines utilized in all the process phases.

Keywords: chips and pellet, biomass, costs, wood materials.

1 Introduction

The consortium examined is located near the village of Arrone, in Terni administrative department: it is a favorable position for harvesting and transforming vegetable biomass, due to the presence of forests, pine groves, coppice stands, olives.

Characterized as strategic point in order to pull down the handling costs for the material, the consortium is situated not far from the places of withdrawal of forest biomass and near one of the most important traffic routes of the territory. It was promoted from the Mountain Community "Valle del Nera and S. Pancrazio Mount" and is constituted by the same agency with the active participation of the Municipalities of Montefranco, Arrone, Polino, Stroncone, Ferentillo, and of the agricultural and forest enterprises that operate in the area. It pursues the following objectives:

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- management of the forest properties conferred from the associates;
- management of the wood - energy row, regarding supplying of the material in entrance, its transformation in biofuel and its commercialization;
- advisings about the administrative management of the properties conferred from the associates;
- advisings for associates and enterprises interested to join to the project.

The consortium was constituted in order to value and to manage the agro-forest resources through the transformation of the same ones in biofuels, standardized chips and pellet, with the dimension and the calorific value for domestic and industrial heating. It is important to know the processes through which the crude biomass is converted in better usable and commercializable products in order to improve qualitative and quantitative level of production. In fact the employment of the renewable sources only turns out sustainable and convenient when the costs supported for supplying and transformation turn out inferior to the revenues obtained from their sale. It is therefore of fundamental importance to understand and to analyze the transformation process, with the aim to find and to propose valid solutions in order to take advantage of renewable energy from biomasses, with the maximum yield.

2 Material and Methods

2.1 Description of Process

Supplying: Thanks to the management of supplying of the raw materials and to contracts stipulated with the associated suppliers of lumber, the consortium guarantees, during the year, a constant contribution of vegetable biomass which is composed mainly from the following species: Pinus halepensis, Pinus pinea, Populus nigra, Fagus sylvatica, Quercus ilex, Quercus pubescens and many pruning residuals of Olea europea and street trees.

The suppliers directly unload the lumber in the great large storage square (ca. 1 ha) near the transformation shed. The material is stacked using a hydraulic loader (model Dalla Bona AS 410) set in action from a tractor Mc Cormik C85 MAX. Dimensions of stacks are15 x 2,5 x 3 meters. These measures are nearly a forced choice, because all the suppliers of the consortium work this type of lumber cutting and logging it at a length of 1 m. As soon as completed, these stacks are quickly covered with burlaps preventing in this way the rain water bathing the wood. All the material is held in stack for approximately three months with the aim of a humidity reduction.

Production of chips: The working process begins transferring the wooden material from the large square to the transformation shed. This phase is carried out loading a towing (with hydraulic loader AS 410) which comes immediately transported and unloaded, thanks to an old tractor Carraro 48,4, in the appropriate space for the feeding of the chipper. The chipper is a Pezzolato model PTH 700/660. The feeding system of the machine is constituted of a small hydraulic loader (model Dalla Bona AS 31) which is set in action from an electrical engine of 4 kW. This element is fixed to earth in a precise point, in lateral position regarding the feeding system of the machine so that the operator has a lateral vision of the process and can take part timely in order to carry out eventual manual regulations.

Chips are pushed from a screw towards the back fan and expelled through the 360° adjustable drainage conveyor. The next machine along the chipping line is the grinding machine MAC 1300. Such machine has a loading hopper in the upper side, where the material expelled from the chipper is directly introduced (thanks to a hydraulic jack) and is crushed against a trituration organ made by a tooth cylinder (that works at a low speed) which grinds the inserted product. In the lower part of the cylinder there is a pierced sheet grill which has the scope to make homogenous the size of the product.

The material exits from the holes of the sheet and falls directly in a hopper that bring it into a screw which transfer the chips to the winnowing silos. This is a great container, equipped to its inside of a three plans vibrating sieve, that realizes product sorting in function of the product destination. In fact the rougher part of chipped material and powder, that constitute the working refuse, are aspired and sent into a container.

The container is transferred afterwards through an elevator OM model XD 25 and it is emptied in a covered greenhouse, used for the storage of the material for the production of the pellet. The scales of intermediate dimensions fall, thanks to gravity, on the bottom of the silos where a mechanical agitator is installed and allows the screws to fish all the material in order to subdivide it in chips to assign to the wrapping in big-bag, in single bags and loose. This last one, like the working refuse, is transported with the elevator in the greenhouse for storage and successively introduced in the pellet line.

The bags of chips are wrapped using a composed machine from a first hopper that is filled up from the material unloaded directly from the screw of silos; a vibrating slab has the task to fill up a second hopper which is connected to an electric balance. The machine creates equal doses based on the inserted parameter. In order to finish such operation, the full bag is closed in the upper extremity through a thermical welding machine, which is situated beside the drainage hopper. Than the bag is put on a pallet. The final product is wrapped with an extensible film and at last fixed with strip, to assure stability during the transport. Using the elevator, the confections in bag or in big-bag are stored in a warehouse, ready for the sale.

Pellet production: The phase of pelletizing is a directly connected process to that one of the chipping, in fact the pellet is the product obtained from an ulterior working of the chips. The material is kept from the greenhouse and unloaded by means of bobcat model 242 B in silos nr. 1, equipped of an inferior mixer that allows to the screw to transfer the material in the continuous dryer, located inside the shed.

The production of pellet is facilitated if the product has a humidity in the dry state comprised in range 12-13% [1] [2]. It is necessary therefore to subject the product to a process of artificial drying that in this system is carried out in the continuous towel, constituted by a great rotary cylinder (handmade prototype), inside of which there are some shovels that stir the cips continuously. The cylinder rotates horizontally with an axis not aligned, since this position determines the advance of the product taking advantage of a game of levels. All the process happens in an atmosphere heated by electric resistances sited longitudinally to the structure. The watery vapor that manifest as a result of the loss of humidity is aspired and transferred in the culvert of drainage from a cyclone with forced air.

The material, after the process, is transported by means of a system of screws to silos nr 2 that is found in the upside part of the hammerings refiner. In fact, when the phase of drying is finished, the material needs an ulterior preparation before being definitively transformed. Through a hammerings mill the dimensions of chips are reduced to obtain a final size of 3 - 5 millimeter This machine is composed from a cut organ that turns at high speed inside of a circular structure composed by a pierced sheet. This operating phase happens under the action of a forced air cyclone, which has the task to unload the refined material.

Now the product is ready for being transformed definitively in pellet through a specific machine (General Dies), which has the ability to transform the material from the form disintegrated to the compact form. The loading of such machine happens through a complex (feeder + air conditioner + forced feeding) located in the upper part of the same one.

The material comes down directly from the silos to the screw feeder, with a modular spin, which allows to vary the material amount that is wanted to be transformed. From the feeder the product comes down in the air conditioner, in which the modification of the humidity of the material can happen through a tap for the water. This passage is carried out above all when the product to press turns out much dry, episode never happened during the period of observation.

The last stage of the phase of loading happens through the forced feeding, that is an impeller that push violently the material inside the draw-plate, where happens the real phase of pressing. The draw-plate is a circular steel element with holes of 6 millimeter disposed in the center, inside of which are some tooth rollers.

The rollers remain fixed and the draw-plate rotates thanks to the action of a powerful electrical propeller with a maximum power of 110 kW. The rollers are lubricated through a specific pump. Moreover is present a pump and a closed circuit for oil necessary for the lubrication of the bearings of the main axis of machine. A radiator cooled from an impeller lowers the temperature of the oil.

The rollers are located in contact with the draw-plate, so the material that interposes between they is pressed. This continuous action of these elements generates also the successive expulsion of the little cylinders of pellet from the opposite part of the draw-plate, where there are some adjustable knives that cut the product in standard dimensions [3]. Such process provokes an excessive increase of temperature in relation to the great pressure that is developed; consequently the product turns out warm excessive for being able to be sacked. The problem is resolved for means of a cooling machine disposed after the press. The finished product comes in a hopper and is carried, through a screw, in a cups elevator; it transfers than it vertically introducing it in it the cooler, that it is a container subordinate to aspiration, for means of a cyclone to forced air. Inside of the cooler the material temperature comes down fastly and once caught up an established level comes unloaded thanks to a moving grid leaves that it to fall directly on a vibrating sieve. This sieve is used to clean up the pellet from the little bits of powder that still remain. After this activity the material is transported again vertically in the last silos of collection, which is set over to sacking unit. The sacking unit is semi-automatic, so the presence of an operator is necessary. Each bag is situated over a balance, and is filled up from a flow of materials till the attainment of fixed weight. The bags, once filled up, are closed trough a thermichal welding machine, which is located beside the balance; then the bags are disposed over a pallet. When the decided weight is achieved, the pallet is wrapped by an extensible film fixed by strips. Now the product is definitively ended, and ready for being stored in warehouse before the commercialization.

2.2 Methods of Analysis

In the examined system the estimation of the medium productivity of machines was made during the year 2007, on the base of the analysis of the daily production cards that are filled in by the person in charge in the yard at the end of every working turn. In these documents, the quantitative of real production and the effective working hours for every production line are reported.

They also reports the loading of the crude material stored in the large square, the storing of the finished product in warehouse, including pauses, time and motivation. The same analysis of the production sheets has concurred to the quantitative definition of the material worked in the unit time along the two lines of transformation (table 1) and the determination of the annual use that is a fundamental parameter to the aims of the calculation of the operating costs. In this way it has been able to state that the system annually works 45.000 tons of raw materials, which are transformed in three main products in order to answer to the various requirements of the customers (table 2).

Table 1. Medium productivity of chips and pellet lines

Line	Average-production (t/h)
Chips line (loose or in big-bag)	3,55
Chips line (single bag)	3,10
Pellet line (single bag)	2,20

Table 2. Tons of raw materials worked annually and division in assortments

Raw Materials		45.000 (t/year)
Obtained assortment	Chips in big-bag	300 (t/ year)
	Chips in bag	700 (t/ year)
	Pellet in bag	3.500 (t/ year)

The system operating costs have been calculated for every machine, following the several productive passages in every single machinery. Without an official protocol, the cost analysis was done considering the main methods proposals in bibliography from several authors [4] [5], bringing opportune subjective modifications to parameters and coefficients. Moreover the parameters of residual value, economic duration and coefficients of repair and maintenance inherent machines used for chips production and pressing, has been obtained through the direct and professional experience of the suppliers. The lubricating and fuel burnup of machines used for the transport of lumber has been found directly during the refueling operations. The administrative office of the consortium has given us the costs of purchase of the machines, thus like the price corresponded to the associates for supplying of raw materials (50 €/t) and the cost for workers (12,5 €/h). Considering that along the two lines electric power supply is widely used, for the hour cost analysis of each machine it has been of fundamental importance to know the maximum power of motors of the single machinery that composes the plant. The first transformation line needs of electricity from the loading of the lumber in the chipper till the packaging of the material. Machines used in this operation demand the power showed in table 3.

Table 3. tons of raw materials worked annually and division in assortments

Chips line	**Max. power (kWe)**
Oil pump and hydraulic arm	4
Chipper	90
Ginding machine	55
Oil system of grinding machine	4
Silos screw feeder	1,5
Vibrating sieve	0,4
Silos mixer	1,5
1st screw	1,5
2nd screw	1,5
3rd screw	1,5
Total	**156,9**

Regarding the transformation of the pellet, it begins with the external loading of the disintegrated wood and finishes with the packing of the product (table 4).

For the operation of the plant, the compressed air and aspiration systems are also set in action electrically (table 5).

Tables 3-4-5 show the value of the maximum power demanded from the electric motors in every transformation line. In order to estimate the percentage of use of the maximal electrical power of motors, an amperometric probe has been used. To know the data of amperometric absorption of every motor, allows to know the electrical power really used by them. As an example, for the motor of the press it has been found that in conditions of maximum production it absorbs approximately 195 A. As the three-phase tension is 380 V the real electrical power absorption is 74,1 kW. As the maximum power of this motor is 110 kW, we can say that the motor itself absorbe approximately 2/3 of the maximum power in working conditions. This procedure is repeated for all the members of the production lines, having stated that for all the users were worth the aforesaid relation. To be more certain and to have further confirmation of such correspondence another test has been done: knowing the total maximum power of the full line, and using the amperometric probe for measuring the current absorption of the full line. The result is that the power absorption of the full line is equal to the 2/3 of the total maximum power. The chips line uses approximately 105 kW, while the pellet line demands approximately 152 kW.

Table 4. Electrical power required (pellet line)

Pellet line	Max. power (kWe)
Ext. Silos mixer	1
Ext.-Int. Screw	1,5
Feeding silos mixer	0,75
Star valve	1,5
Hammerings refiner	75
Air forced cyclone	5,5
Radial valve (under cyclone)	5
Silos screw feeder	1,5
Silos mixer	2,2
Screw feeder	2,2
Air conditioner	5,5
Forced feeding	0,75
Press	110
Screw for elevator	1,5
Elevator I	1,5
Screw for cooler	1,1
Air forced cyclone (cooler)	7,5
Radial valve (cyclone)	1,1
1^{st} sieve motor	0,2
2^{nd} sieve motor	0,2
Elevator II	1,5
Oil lubrication group	0,25
Grease lubrication group	0,18
Total	**227,43**

Table 5. Electrical power required (pellet line)

System of aspiration and compressed air	Max. power (kWe)
Main aspiration	18,5
Screw feeder	1,5
Outlet radial valve	1,5
Compressor equipment	11
Total	**32,5**

3 Results

Table 6 shows the synthesis of operating costs of every single working phase turning out from the technical-economic analysis of the machine's parameters.

Adding the costs of the working phases of each production line, the total hour costs for every manufactured product are obtained (table 7).

To determine the real production cost of a ton of material, taking into account the specific productivity that characterizes every working line, the unit costs in weight have been also defined (table 7).

Table 6. Hour cost of the single phases (comprehensive of 10 workers) (net of Vat)

Nr	Element	Hourly cost [€/h]
1	Stacking and loading of the trailer with hydraulic arm and tractor Mc Cormik	27,04
2	Transport of the wood from the large storage square to the shed with tractor Carraro	28,62
3	Physical transformation of the material by means of trituration line (chipper, crushing, silos-sieve, 1 round screw + 2 flat)	49,05
4	Packing of the crushed material	13,71
5	Transport of the chips in bags to the warehouse with undercarriage elevator	20,37
6	Transport of the chips loose in greenhouse with BOBCAT	20,37

Table 6. (*continued*)

7	Transport of the chips from the greenhouse to the external silos with BOBCAT	16,66
8	Transformation process by means of the refining line (external silos, hammerings mill + 5 round screws) + drying	17,80
9	Pressing and cooling of the material	27,57
10	Packing of the finished product (pellet)	12,78
11	Transport of the packed pellet to the warehouse with BOBCAT	20,37
12	Cost of the aspiration system and compressed air module	2,63

Table 7. total hour cost and unitary cost in weight for each working line

Working costs (total)	Hourly cost [€/h]	Unit costs in mass[1] [€/t]
Chips in big-bag [Elements 1-2-3-5-12]	127,71	35,97
Chips in bag [Elements 1-2-3-4-5-12]	141,42	45,62
Pellet in bag [Elements 1-2-3-6-7-8-9-10-11-12]	222,89	101,31

Costs for the packing materials are shown in the following prospect (table 8). Considering all the showed voices, the production value of every type of assortment realized in the consortium can be calculated. It takes in consideration the costs supported for the production of every ton, comprehensive of expenses for the raw materials, the labor and the materials for the wrapping and the packing, according to the effective potentialities of the system in the considered period of analysis (table 9).

[1] Determined according to the productivity showed in table 1.

Table 8. Cost of the materials for wrapping and packing (net of Vat)

	Pallet (100 x 120 cm)	**Bags with logo for pellet and chips**	**Big-bag (90 x 90 x 120 cm)**	**Strip + Extensible film in polyethylene**
Nr of pieces	4.500	289.000	300	4.200
Unit costs (€)	3,5	0,12	4	0,60

Table 9. Total cost of the assortments (net of Vat)

	Working costs (€/t)	**Pallet (€/t)**	**Bags (€/t)**	**Strip + film (€/t)**	**Raw materials (€/t)**	**Total (€/t)**
Chips in big-bag	35,97	3,5	(2)	-	50	89,47
Chips in bags	45,62	7 (3)	9,6	0,60	50	112,8
Pellet in bags	101,31	3,5	8	0,60	50	163,4

4 Conclusions

To introduce on the market an economic, therefore competitive, product is the objective of every company. All this is possible examineing with attention the technical data regarding times and production costs of the product. Such aspects necessarily go to affect on the decisions and the organizational choices that a company must take. Placing the attention on the final result, therefore on the real production costs of the products, it is thought, according to the analysis realized, that they could be mainly contained. This supposition derives from the ascertainment of the inadequacy of some members of the plant, which are characterized from operating costs extremely elevated that contribute, consequently, to an increase of production costs. As a result of this study we can formulate some proposals for the reduction of the production costs of biofuels. It is possible to carry out improvements regarding the production of the pellet, eliminating some working phases that are extremely useless and uneconomical. It is emphasized the uselessness of the transport of loose chips and of the refuse of winnowing in the greenhouse through the elevator undercarriage and the successive transport of the same ones, by means of the bob-cat, from the greenhouse to the external silos.

Such phases would not have absolutely to be present in a well conceived system, because every single shift of the material involves remarkable energetic cost, above all if machines not conceived in order to carry out such kind of operations are used. These processes could be replaced from specific equipments for the transfer of the disintegrated material, like pneumatic conveyors or simple screws that would increase the speed and the continuity of operation of the transformation line, inducing an increase of the system efficiency.

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[2] Loan of big-bags for use.

[3] For a ton two pallets are necessary.

The new systems of transfer could moreover be employed also in order to avoid that along the production line of the pellet are used chips journeyed in the crushing machine and the sieve, operations that remarkably affect the final production cost of the pellet. In fact, the grinding can happen also only in the hammerings mill, that has the ability to work without problems much crude scales.

In order to achieve this objective a silos for chips could be installed with a system of drainage with stellar valve, connected to the chipper and that it would feed the chips line or the pellet line. Such silos must have adapted dimensions, so as to guarantee, to every working turnover, the amount of necessary raw materials. Bringing such modifications, the greenhouse could be used, due to its vicinity to the packing area, as warehouse for pallets of finished product; infact today the product is stored in atmospheres not completely sluices and therefore not suitable to the conservation of a material extremely sensitive to the atmospheric humidity. Other fundamental parameter to which it must paied attention is the continuous search of the maximization of the hour productivity of machines.

Taking in consideration the carried out analysis, it can be asserted that the biomasses can play an important role in the "energetic competition", but such objective can be hit only perfecting and optimizing the performances of the technologies and the processes of transformation of the raw materials, reducing the production costs and obtaining therefore biofuels that can be commercialized at a competitive price.

The authors contribution in this paper can be considered equal.

References

1. Hellrigl, B.: Il pellet: notizie e informazioni sulla produzione e l'impiego. Aula magna N.3 (2003)
2. http://www.generaldies.com
3. CTI SC09, R03/01 Raccomandazione del Comitato Termotecnico Italiano sui biocombustibili solidi: specifiche e raccomandazioni, Milano, p. 54 (2003)
4. Franco, S., Monarca, D.: La valutazione preventiva dei costi di riparazione e manutenzione delle trattrici. Rivista di Ingegneria Agraria, March 1998 pp.138-147 (1998)
5. Miyata, E.S.: Determining fixed and operating costs of logging equipment. North Central Forest Experiment Station, Forest Service, 14 p. USDA. St.Paul (1980)
6. Biondi, P.: Meccanica agraria. Le macchine agricole. UTET, Torino (1999)