

Experimental Tests of Ventilation on Biomasses to be used for Energy Purpose

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Abstract

Original Research Article

The penetration of biomass into the energy market depends on precise territorial planning and the geological and soil and climatic characteristics of the area considered, potential resources, economic costs of crops and their economic and environmental benefits. In this article, tests were carried out on a plot divided into 28 rows with 251 olive trees of the CORATINA and OGLIAROLA species, using the Quickpower machine, a new-concept round baler for pruning and pruning, extremely versatile and technologically advanced. With this biomass research work, which was followed by field tests and laboratory tests lasting about 6 months, we highlighted the importance of using biomass, which represent an alternative source as they are renewable compared to to gas and oil, and they pollute less.

Keywords: biomass, soil, CORATINA, OGLIAROLA.

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INTRODUCTION

The penetration of biomass into the energy market depends not only on an adequate enhancement of the energy component of agricultural products and by-products, but also on a punctual territorial planning that takes into account factors, such as the geological and pedoclimatic characteristics of the area considered, potential resources, the economic costs of crops and their economic and environmental benefits, the market for alternative fuels to biomass for energy use, local energy needs. Concluding, among renewable energy sources, biomass plays an exclusive role, because it represents a form of accumulation of solar energy widely distributed on Earth, which can be used, directly or through transformation processes, as biofuel for the production of thermal energy or electricity. The amount of carbon dioxide released into the atmosphere during biomass combustion is considered equivalent to that absorbed by biomass during their growth with a zero greenhouse gas emissions balance. Energy recovery, in the form of electricity, fuel or heat, can take place through various technological methods and with different plant and production scales according to the type of biomass available. The commitment in this direction cannot however be attributable only to central governments, but must be able to involve local authorities, social categories and the whole population. Furthermore, a change of course in the energy sector cannot be separated from an overall reduction in

demand, since renewable energy sources do not appear to date to be able to completely replace energy demand from fossil sources.

Therefore, an overall cultural change must inevitably take place, aimed at supporting the energy efficiency of each sector (residential, industrial, agricultural, transport, etc.). By promoting technological innovations capable of eliminating waste and enhancing local resources, this will lead to a reduction in energy demand, which does not limit social needs and expectations, but rather "free" resources that can be invested in other sectors sustainable development[1].

In recent years, biomass from agricultural waste has become increasingly interested in the possibilities of energy use that they can offer. The main problems related to this type of use are generally attributable to the dispersion and territorial variability of biomass sources, the quantities available, the seasonality of the crops, the qualitative variability, economic convenience and logistical-environmental aspects. Among the numerous sources of biomass of agricultural waste available, pruning residues represent

¹Bellomo F., D'Antonio P., Come meccanizzare l'oliveto per avere più reddito; L'informatore agrario 2008.

a particular type that has not been exploited so far under the point of view of energy use. In fact, the management of tree crop residues has always responded to two main needs: \rightarrow free the intra-row spaces from decomposable organic residues by cutting and shredding the shredded product on site; \rightarrow fight (optional or compulsory) against phytopathologies by collecting and burning residues. In both cases, however, there is a net loss of the thermal energy contained in the residues themselves.

Recently, due to climate change and the structural growth of the costs of petroleum products, the need has arisen to enhance the residues of tree crops pruning, for energy purposes. This aspect assumes decisive importance for our country, given the strong wine, fruit and olive growing vocation, with a predominantly hilly territory and an energy dependence on non-renewable sources of almost 90%, of which a good 84.5% of foreign import. Considering an annual production of residues and pruning branches varying from 0.8 to 2.4 t / ha for the vineyard and up to 6.2 t / ha for the orchard - albeit with a wide dispersion due to the varieties and the type of pruning (breeding or production) and considering that the areas invested in specialized tree crops in Italy alone can be estimated in almost 500,000 ha of specialized vineyards, 550,000 ha of orchard and citrus grove and almost 1,000,000 ha of olive groves, you can understand the large space still little used by specialized mechanical construction sites for the recovery of pruning residues for energy purposes and, in particular, their enormous contribution to the production of pellets for energy use, if the latter method will establish itself as the source of energy solid of the future, as many indicators seem to suggest[2].

MATERIAL AND METHODS

Operations for collection and storage. The recovery of energy from agricultural by-products generated by the cultivation of tree crops, such as pruning and / or pruning residues, must always interface with the logistical and shipbuilding aspects related to their collection, transport and storage. These operations can also significantly affect the productivity of the technologies adopted and, therefore, the possible economic convenience of the entire supply chain. The first aspect to be addressed, in this regard, concerns the reduction of the apparent volume of pruning residues and their removal from the rows which, with current technologies, can be obtained essentially in two ways:

1) by packing the residues as they are (tq) so as to form prismatic and / or cylindrical bales that double the density of the biomass tq and subsequent collection of the packs;

²F. Bellomo, P. D'Antonio, Using a grape harvester in super-intensive olive cultivation, *Journal of Agricultural engineering* 39 (1), 2008, pp.33-39.

2) by defibrating (shredding / chipping) the prunings, obtaining density values similar to those of the previous technique, but with a productivity of 2-2.3 times higher, achieved, however, with power demands of 2 to 4 times greater[3].

Innovations

The developed project intends to significantly improve the performance of the technology based on the packaging of the prunings, in order to exploit their advantages (low power demands, compact and in-line collection sites, facilitated management of the storage of wet residues, ease of carrying out temporary storage) filling what until now constituted an operating limit of this technique with respect to shredding and, that is, the low productivity expressed in t / h of biomass extracted from the rows. This limitation is constituted, with the current packaging technique, by the fact that the machines unload the bales, interspersing them along the rows and generating the need for a subsequent collection intervention. Operating within tree crops, this subsequent harvesting operation is hampered by the presence of the rows, which constitute a vertical physical obstacle capable of limiting the speed of extraction of the bales, which are spaced every 20-30 m along the path of the 'packing. Furthermore, operating with cylindrical bales in a hilly environment, there is the need to unload the packs only on flat ground or to stabilize them to avoid rolling downstream, further slowing down the operating times. The developed accumulator allows you to stack up to 7 round bales, bringing the overall autonomy of the construction site to 8 round bales, if you consider that contained in the compression chamber of the packer[4].

Considering that each round bale contains the residues collected on 20-30 linear meters of inter-row, the site allows collection autonomy of 160-240 m before requesting the unloading with a significant increase in hourly productivity, if we take into account the quantity of biomass extracted from cultivation and stored in the header. It should be noted that, at present, there is no similar machine on the market capable of performing the same storage operation and doing it without compromising mobility within the rows[5].

³Cantisani G., Biomasse come fonte di energia rinnovabile, Relazione presentata all'Università degli studi di Basilicata, Facoltà di Ingegneria, anno accademico 2007/2008.

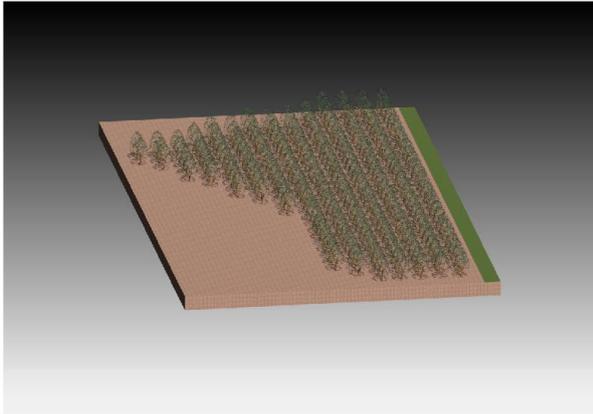
⁴Cardinale D., D'Antonio P., Moretti N., Scalcione V. N. Risk perception in forest utilizations: experimental analysis in the Basilicata forest sites, *Journal of Forestry, wild life and Environment*, Vol. 1, Issue 1. 2020.

⁵Cavalaglio G., Cotana S., Barbanera M., Giraldi D., Valorizzazione energetica degli scarti di potatura dei vigneti, 7° Congresso Nazionale CIRIAF, 2000.

RESULT

During the month of May, in the Vulture area, from the inhabited center, to carry out samples on a plot of olive land of about 1259.155m².

This plot, with a 5x5 m planting layout, is divided into 28 rows with 251 olive trees of the CORATINA and OGLIAROLA species.



Plant of the olive plot

Field operations

Field operations involved:

- The measurement of swaths in length and width, i.e. The residues of prunings coming from pruning and collected at the center of the row, to facilitate the interception of this material by the machine;
- the packaging of the prunings, with the measurement of the machine's working times;
- The weight of a meter meter of prunings, with the taking of 50 samples measuring the length, the average, maximum and minimum diameter.

The machine used

The machine used is Quickpower, a new concept, extremely versatile and technologically advanced round baler for pruning and pruning, as it is equipped with a bale accumulator to increase productivity and reduce processing times; it is also equipped with a rotation inverter, which allows you to unlock it in the event of flooding due to the insertion of unsuitable materials in the pressing chamber.

This machine has become very important for the research and development of biomass, in fact, every year, the pruning of the main tree crops in Italy (vines, olive trees, orchards) produces a variable quantity of residues (branches, prunings, etc.) from 1 to 3 t / ha depending on the conditions.

Transport and storage. After the operations in the olive grove, the bales were transported on a truck and stored at the Laboratory of physical-mechanical properties of the food of the UNIVERSITY OF THE STUDIES OF BASILICATA, where some bales were

subjected to natural ventilation, i.e. the product left at ambient temperature, and other bales subjected to forced ventilation, by means of the experimental system developed at the Laboratory.

The bales were picked up, transported and stored at the Food and Physical-Mechanical Properties Laboratory of the Economic and Technical Department for Agricultural and Forestry Territory Management (DITEC) based in the University of Basilicata in Potenza.

The research activity, carried out at the Laboratory, involved the development of a prototype of a biomass ventilation system and related forced ventilation tests, to evaluate the weight loss of each individual bale obtained compared to normal natural drying[6].

This paragraph presents the equipment and methods developed for conducting the experimental activity.

The bales were weighed and two experimental theses were compared, described below:

Thesis T (Witness): Sample left in a condition of natural ventilation;

Thesis A: Sample subjected to forced ventilation for 8 hours a day for 4 days, by fan, using the inverter with a frequency equal to 20 Herz.

For thesis T, or for the Witness, the bales were left at room temperature to check the natural weight drop at room temperature values of around 17 ° C and a humidity of 81%; the bales were weighed weekly for about three months to check for weight loss.

As for thesis A, relating to forced ventilation, the bales were weighed and inserted inside the ventilation system developed in our laboratory and weighed at the end of ventilation.

DISCUSSION

As regards the measurement of swath samples, we have found that the heights vary from a min. of 0.30 m to a max. of 0.70 m, the width varies from a min. of 0.70 m to a max. of 1.20 m.

⁶ F. Bellomo, P. D'Antonio, Come meccanizzare l'oliveto per avere più reddito; L'informatore agrario 2008, pp. 36-44.

Table-1: Swath size

Swaths	WIDTH	HEIGHT
1	1,45	0,55
2	1	0,7
3	1,1	0,6
4	1,13	0,4
5	1,38	0,49
6	0,88	0,3
7	0,93	0,4
8	1,1	0,58
9	0,85	0,63
10	1,15	0,59
11	1,25	0,55
12	1,09	0,39
13	0,65	0,45
14	0,99	0,43
15	1,05	0,55
16	1,2	0,49
17	1,1	0,45
18	1	0,29
19	1,2	0,47
20	0,85	0,41
21	0,94	0,45
22	0,95	0,6
23	1,02	0,41
24	0,9	0,6
25	0,8	0,42
26	0,8	0,44
27	0,7	0,4
28	0,77	0,42
29	1,1	0,55
30	1,15	0,75

The processing times of the machine for the formation of bales and the plants used for the formation of the plant material are shown on the following tables:

Table-2: Processing times of the Quickpower round baler

bale.	N ° plants / bale	t bale (s).	Length (cm)	Diameter (cm).	Bale weight (Kg) 19/5/19	Bale weight (Kg) 23/5/19	Bale weight (Kg) 26/5/19	Bale weight (Kg) 5/31/19
1	4	36	63	43	33,8	32,5	31,8	31
2	4	49	65	42	33,7	32,9	32,6	32
3	4	28	62	42	32,1	31,1	30,6	29,8
4	4	27	64	41	27,3	26,6	26,2	25,7
5	3	39.08	64	38	31	30	29,5	28,8
6	6	28.06						
6	3	12	62	43	32,7	30,8	29,4	27,4
7	3	27.15	63	42	33,2	31,9	31,1	29,7
8	5	33.67	63	42	28,3	27,7	27,4	27
9	4	41.71						
10	4	20.86						
11	2	31						

12	4	18.30						
13	2	24.60						
14	2	10						
14	2	19.50						
15	4	23.81						
16	4	38.13						
17	4	34.78						

The weight of one meter of pruning residues taken is 29.1 kg.

Table-3: Size of samples taken

N ° samples.	Total length (cm).	Minimum diameter (cm).	Average diameter (cm).	Maximum diameter (cm).
1	85	0,10	0,50	0,70
2	75	0,10	0,40	0,80
3	71	0,10	0,40	0,60
4	61	0,10	0,50	0,60
5	81	0,10	0,40	0,80
6	92	0,40	0,60	0,80
7	116	0,10	0,80	1,11
8	8	0,10	0,70	1,11
9	75	0,10	0,30	0,40
10	84	0,10	0,30	0,60
11	9	0,10	0,40	0,60
12	93	0,10	0,40	0,80
13	106	0,20	0,90	1,30
14	83	0,10	0,60	0,90
15	8	0,20	0,60	0,80
16	96	0,20	0,50	0,70
17	37	0,10	0,30	0,50
18	75	0,10	0,60	0,90
19	109	0,10	0,70	0,90
20	83	0,30	0,40	0,90
21	85	0,10	0,70	1,00
22	63	0,10	0,40	0,60
23	73	0,10	0,60	0,90
24	73	0,10	0,50	0,60
25	60	0,10	0,40	0,70
26	76	0,10	0,40	0,60
27	90	0,10	0,50	0,80
28	40	0,10	0,30	0,40
29	74	0,20	0,40	0,50
30	113	0,20	0,40	0,90
31	75	0,10	0,30	0,50
32	63	0,10	0,30	0,50
33	93	0,10	0,40	0,70
34	67	0,10	0,30	0,40
35	86	0,10	0,60	1,00
36	88	0,10	0,60	1,10
37	88	0,30	0,70	1,30
38	100	0,20	0,60	1,30
39	83	0,30	0,90	1,30
40	73	0,10	0,30	0,50
41	72	0,10	0,30	0,50
42	75	0,10	0,40	0,70
43	90	0,20	0,30	0,70
44	60	0,10	0,30	0,60
45	88	0,20	0,70	1,10
46	105	0,10	0,60	0,90
47	92	0,10	0,50	0,70
48	86	0,10	0,50	0,90
49	86	0,10	0,60	1,20
50	87	0,30	0,70	0,90

50 samples were taken and the minimum, maximum and average diameter measured.

As regards the power demand, absorption peaks of around 7.0 kW attributable to the round baler alone were recorded, while the additional power requests due to the accumulator were borne solely by the hydraulic circuit of the tractor to operate independently, the side rake brushes (only if and when it is necessary), the elevator and the unloading hatch, the unloading pallet with chain and sprockets. The choice of the low-power tractor, the execution of the tests at a power take-off speed between 350 and 380 rpm and the operation of the accumulator never simultaneous with the operation of the round baler, support these conclusions.

The operator has shown that she can operate in line, with autonomy of collection of 8 round bales or up to 210-240 m of inter-row freed before having to unload the accumulator.

This result was achieved thanks to the arrangement of the associated operators and their sequence operation. Packaging and accumulation of the round bales take place in relatively rapid sequences; in particular, the accumulation of each bale takes place during the unloading of the preceding bale and, therefore, does not affect the packing capacity of the packer. Furthermore, the presence of swath brushes allows you to operate even with the product not assembled in the swath.

The size of the construction site is partly determined by the type of tractor used; the associated operator alone was 2450 mm long, however a 500-510 mm accumulator section overlaps the length of the tractor, resulting in an increase in the maximum longitudinal dimensions of the tractor-operator complex of 1950-2030mm depending on the type mounted lift; in addition, in tight maneuvers the operator can be raised allowing sufficient maneuverability of the site.

No problems were found regarding the height, since it was found to vary from 1680 mm frontally to 1760 mm rearward; if we consider that the height of the tractor to the protective frame was 2080 mm it can be concluded that the dimensions in height do not exceed the normal specialized tractors with raised arch; however, even if the protective arch is lowered with the tractor with a maximum height of 1230 mm at the wheel, it must be considered that pergola training systems rarely have fixed structures less than 1800 mm high.

The problem relating to the masses is linked both to the type of tractor used and to the mass transfer during transport and to the type of product. The choice of the type of tractor (standard or isodiametric) can influence the ballast request of the same or the distribution of the maximum approved loads.

The weighings made on the bale samples left at room temperature reported the following values:

Table-4: natural weight loss values

n.° B	19/5/19	26/5/19	3/6/19	9/6/19	17/6/19	24/6/19	1/7/19	04/7/19	11/7/19	15/7/19	18/7/19
1	36,5	34,2	32,7	31,6	30,1	28,9	27,9	27,6	26,9	26,6	26,2
2	37,7	35,4	33,7	32,6	30,7	29,3	28,2	27,6	26,7	26,2	25,8
3	16,3	15,5	14,7	14,4	13,9	13,3	12,7	12,6	12,3	12,2	11,9
4	34,5	32,6	32	31,8	31,1	30,6	30	29,9	29,5	29,3	28,9
5	30,4	28,3	27,6	27,4	26,9	26,4	25,9	25,8	25,5	25,3	25,1
6	33,8	31,8	30,5	29,8	29,2	28,1	27,3	26,9	26,2	25,9	25,6
7	33,7	32,6	31,7	31,1	30,6	29,6	28,8	28,4	27,8	27,5	27,1
8	32,1	30,6	29,5	28,8	28,4	27,4	26,7	26,4	25,8	25,5	25,1
9	27,3	26,2	25,3	24,9	24,4	23,6	23	22,8	22,4	22,1	21,8
10	31	29,5	28,4	27,8	27,3	26,3	25,7	25,4	24,9	24,5	24,2
11	32,7	29,4	26,5	25	24,1	22,5	21,7	21,3	20,7	20,4	20,1
12	33,2	31,1	28,8	27,4	26,6	25,2	24,5	24,3	23,7	23,4	23,1
13	28,3	27,4	26,7	26,4	26	25,4	24,8	24,7	24,4	24,2	24

As we can see from table 13, the bales left at room temperature with humidity equal to 88% for about two months showed an average weight variation equal to 7.6 kg.

As regards the tests conducted using the fan, developed in the laboratory, the bales subjected to forced ventilation (for eight hours for four days) showed a weight loss of 3.3 kg, with a weight loss percentage of 9.7%.

CONCLUSION

With a view to increasing the energetic use of pruning residues and considering the increasingly concrete prospects of an affirmation of pellets as a form of end use, the mechanization of the collection of this by-product will allow overcoming the first bottleneck of the entire chain Logistics. The reduction of the density of the residues and their stacking outside the spatial limitations imposed by row crops are the key elements to be solved. The option offered by the packaging of residues is consolidated and equipped with numerous machines on the market capable of performing it,

however, to date, the logistical burden due to the need to extract the unloaded bales within the production units must be considered in order to concentrate them in the storage areas.

The development of an accumulator operating in line is a decisive innovation in the solution of this problem which, even if it can be improved in the future, already today proves to be able to increase the work capacity of the construction site, with the same operating conditions, by about 40% compared to the solution based on packaging only and subsequent stacking with a trailer.

With this biomass research work, which was followed by field tests and laboratory tests lasting about 6 months, we highlighted the importance of using biomass, which represent an alternative source as they are renewable compared to gas and oil, and they pollute less.

Drawing energy from biomass allows you to eliminate waste produced by human activities, produce electricity and reduce dependence on fossil fuels. It is a source of clean energy on which the EU has decided to invest in the same way as wind and constitutes an additional economic and social advantage, as the sector reuses and disposes of waste in an ecological way. If in the past the prunings were considered a problem for the olive grower, who to get rid of them, resorted to on-site burning or burying, contributing, in the first case, to the increase of atmospheric pollution, in the second case to the spread of any inoculi present in the wood, today a correct management of the prunings, which foresees their recovery, could constitute a source of income if the agricultural entrepreneur started to consider them as biomass usable for energy purposes. However, attention should be paid to the concept of biomass, so as not to confuse it with that of waste thermal destruction. Biomasses are exclusively plant-based waste and should not be confused with waste from human activities. Biomass will play an increasingly central role in achieving the European 2020 targets.

Everyone will have to work hard to realize the growth objectives that exist and that must be achieved, but to do this, a series of provisions must be put in place which clarify and encourage their development. It is necessary to increase the efficiency of production processes, also making the most of marginal land, promoting the balance between food and non-food production. It will be necessary to define the support mechanisms for energy production as soon as possible and at the same time to resolve the regulatory gaps concerning the classification and use of agricultural and agro-industrial by-products, whose role is crucial, but which risks being limited by interpretations. Restrictive regulations.

REFERENCE

1. Bellomo F, D'Antonio P, Come meccanizzare l'oliveto per avere più reddito; L'informatore agrario; 2008.
2. Bellomo F, D'Antonio P., Using a grape harvester in super-intensive olive cultivation, Journal of Agricultural engineering. 2008; 3 (1).
3. Cantisani G. *Biomasse come fonte di energia rinnovabile*, Relazione presentata all'Università degli studi di Basilicata, Facoltà di Ingegneria, anno accademico; 2007/2008.
4. Cardinale D, D'Antonio P and Moretti N, Scalcione VN. *Risk perception in forest utilizations: experimental analysis in the Basilicata forest sites*, Journal of Forestry, wild life and Environment; 2020; 1(1). 2020.
5. Cavalaglio G, Cotana S, Barbanera M, Giraldi D. *Valorizzazione energetica degli scarti di potatura dei vigneti*, 7° Congresso Nazionale CIRIAF; 2000.
6. Cotana F, Costarelli I. *Impianti Sperimentali per il Recupero Energetico da Potature di Vite, Olivo e Frutteti, Recupero Energetico*, Perugia; 2005.
7. D'Antonio P, Romano FV, Scalcione VN, D'Antonio C. Technologies and sustainable development: the case studies of cultural landscapes in the Mediterranean area IJRDO - Journal of Agriculture and Research.
8. D'Antonio P, Romano FV, Scalcione VN. Technologies and sustainable development: the cultural landscapes of the Mediterranean. Journal of Advance Research in Food, Agriculture and Environmental Science Marzo; 2020.
9. Scalcione VN. Digital Humanities: ICT for a Teaching of Inclusion. Agricultural Research & Technology: Open Access Journal. 2020;23(5):58-9.
10. D'Antonio P, Scalcione VN. *The teaching of technologies for monitoring the anthropic landscape through the development of the Internet of Things*, Journal of Bioinnovation, nov. 2020; 9(3): 261-263.
11. D'Antonio P, Scalcione VN, D'Antonio C. Innovative systems in the production and organization of forest biomass and urban green areas, IJRDO - Journal of Agriculture and Research; 2020.
12. D'Antonio P, Scalcione VN, D'Antonio C. *Sustainable urban green management systems: battery powered machines and equipment*. International Journal for Research in Agricultural and Food Science. 2020; 6(3).
13. D'Antonio P, Scalcione VN. Software and satellite technologies for precision agriculture: the potential with the 5 g network. EPH-International Journal of Agriculture and Environmental Research (ISSN: 2208-2158). 2020 Apr 4;6(3):01-6.
14. D'Antonio P, Scalcione VN, Romano F. The use of satellite technology for digital citizenship: experimental tests and investigation methods.

- International Journal of Food Science and Agriculture. 2020;4(1).
15. ENAMA, *IV Programma di sperimentazione di macchine agricole innovative*, Dicembre; 2010.
 16. Energicamente, *Energie da Biomasse, Utilizzo delle biomassa .agro-forestali a fini energetici, Regione Marche*, Assessorato all'Ambiente – Servizi Ambiente e Paesaggio, aprile; 2007.
 17. P.O.R. Sardegna 2000-2006, *Ricerca e sviluppo tecnologico nelle imprese e nel territorio, Rapporto sulle migliori tecnologie disponibili per la produzione di energie da biomasse*, luglio; 2008.
 18. Porceddu PR, *Percorsi di riqualificazione per addetti del comparto della meccanizzazione agricola, Meccanizzazione per le filiere bioenergetiche. Tecnologie esistenti e sviluppo di innovazioni tecnologiche e tipologiche*, Perugia; 2006.
 19. ProBio Centro di Eccellenza per le bioenergie, Regione Basilicata; 2006.
 20. QuicPower, *Accumulatore di balle*, Segnalazione Eima, 2008, Caeb International.
 21. Troina E. *Energie pulite il punto, in Scuola e Ambiente*, Agosto; 2002.
 22. Valentini E. *Vantaggi e Criticità delle biomasse*, *Ecoscienza* n° 2, anno 2011.
 23. www.greenstyle.it/rinnovabili-in-arrivo-i-finanziamenti-per-le-biomasse; 2011.