European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

International Conference on Renewable Energies and Power Quality
(ICREPQ'10)
Granada (Spain), 23th to 25th March, 2010

QUALITY OF PELLETS FROM OLIVE GROVE RESIDUAL BIOMASS

A. García-Maraver [a,*], A. F. Ramos-Ridao [a], D.P. Ruiz [b], M. Zamorano [a]
[a] *Department of Civil Engineering, University of Granada, Campus de Fuentenueva s/n. E.T.S Ingenieros de Caminos, Canales y Puertos, 18071 Granada, Spain*
** Telephone number: 034 687679232; e-mail: agmaraver@ugr.es.*
[b] *Department of Applied Physics, University of Granada, Campus de Fuentenueva s/n. Facultad de Ciencias, 18071 Granada, Spain*

Abstract

Two of the main environmental problems that man currently faces are the high rate of waste generation and energy consumption, both bearing directly upon climate change. The situation requires a change in waste management models, with a greater focus on waste reduction, recycling and appraisal, as well as a change in energy models. This signifies the use of renewable energy sources to supply part of the future demands of fossil fuel. Such sources include biomass sources from agricultural waste. Southern Spain has a large supply of biomass of a residual nature from agricultural activities, such as olive pruning. However, the use of pellets made from olive tree leaves or a mixture of different parts of olive trees is not as yet widespread. This research shows that the use of different types of raw materials from olive grove residues results in pellets with different physical and chemical properties, which define their possible application. More research is needed to design the production of pellets, which will have properties suitable for specific applications and which will possess the quality that satisfies accepted standards and norms.

Key words

Olive tree residues, pellets, quality, renewable energy, biomass.

Introduction

Energy demands are growing day by day. As a result of this level of consumption, millions of metric tons of greenhouse-effect gases are released into the atmosphere, 80% of which come from fossil fuels.

In response to the need to fight global warming, a number of measures have been proposed. At the international level, the Kyoto Protocol set the goal to reduce by 5%, by the year 2012, global emissions of six of the gases responsible for global warming [1]. Energy policy and policies for the protection of the European climate have taken shape in three strategic objectives encompassed in the new Plan of Action for Energy Efficiency (2007-2012): a reliable, efficient and environmentally compatible supply [2]. To reach these goals, it is necessary to take action in the prioritary areas of energy generation and use, as well as with regard to emissions.

Biomass resources include various natural and derived materials mainly categorized as agricultural residues, wood and wood wastes, animal dung or municipal solid wastes [3,4]. The use of biomass as an energy resource entails significant socioeconomic and environmental benefits. It is an abundant resource, and its renewable facet is a guarantee of sustainable use. Moreover, its application means a reduction in atmospheric emissions, in which the net cycle of CO_2 does not contribute to the greenhouse effect, and it also plays an important role in national economies, since it avoids the importation of fossil fuels. However, because of its high moisture content, irregular shape and size, and low bulk density, biomass is very difficult to handle, transport, store, and use in its original form. Densification has prompted significant interest in developing countries in recent years as a technique for using residues as an energy source [3,5]. Pelletization technology represents mass and energy densification that provides easier biomass fuel handling and feeding.

Since Spain is one of the countries with the highest dependency on imported energy resources in the European Union [6], the use of biomass resources for power generation offers numerous benefits of interest to political decision-makers. Some of these include fuel security, rural and industrial development, and ecological benefits. The use of residual biomass reduces the amount of residue deposited in landfills, and promotes minimization, reutilization, recycling, and valorization principles.

One of the aims of this study is to improve the quality of pellets from woody agricultural residues and their application in the domestic and industrial sectors, especially one of the most common woody residues in southern Spain (i.e. olive tree residues). Their extended use will permit the energy appraisal of this kind of agricultural waste, one of the strategic objectives of waste management regulations.

1. Materials and methods

A. The manufacturing process

The general manufacturing process of these pellets is summarized in Figure 1. The raw material, which is of different sizes, arrives at a reception area, where it is weighed and its moisture measured. In a first stage, the size of the material is reduced to 20 - 40 mm with a hammer splinterer. Since the raw material has different levels of moisture, it is necessary to dry it until its moisture is lower than 15%. The reduction in moisture content is achieved by a rotary drier. The generation of hot air for the drying process comes from a biomass

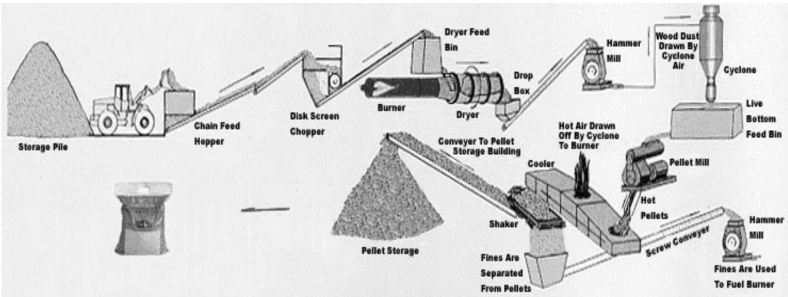

Figure 1. Scheme of pellets manufacturing process.

heating, composed of a burner, a combustion chamber, and a decanter of ashes. Magnets and screens are used to remove undesired particles before the dried material reaches a hammermill. The pellets, 6 or 8 mm in diameter, are produced without any additives.

The pelletising process involves high temperatures, and attention has to be paid to proper cooling and heat removal before pellets leave the production plant, especially with regard to the storage stage.

B. *Raw materials for pellets production*

Olive grove residual biomass (branches of different sizes and leaves) was used to manufacture pellets tested in this research. The raw materials were the result of agricultural activities in Granada. Fresh materials were collected and chipped at the point of origin with specific machinery used for that purpose, and transported in trucks to the pelletizing plant, where the material was processed to obtain pellets. Figure 2 shows both types of pellets tested.

Figure 2. Pellets from olive tree branches and olive tree leaves, respectively.

C. *Technical Specification CEN/TS 14961:2005*

The European Standard Committee CEN/TC 335 is the technical committee that has developed the experimental Technical Specification CENT/TS 14961 regarding solid biofuels, fuel specifications and classes [7]. It describes different forms of solid biofuels, including wood chips, wood pellets and briquettes, logs, sawdust and straw bales. The norm also classifies pellets depending on the origin of the raw materials (wood biomass, herbaceous biomass and biomass from fruit, and a mixture of the previous type of biomass) and recommendations for quality parameters, depending on the use of pellets. Table 1 summarizes guiding values included in this standard, showing how to label solid biofuels depending on the values of certain specific parameters. Table 2 recommends quality guidelines for pellets that are to be used in domestic heating.

Table 1. Classification of parameters included in CEN/TS 14961:2005 published by the European Standard Committee CEN/TC 335 including specifications for solid biofuels and analytical techniques [7].

PARAMETER	CLASSIFICATION
Size (diameter and length) (mm)	D06: D≤ 6±0.5 and L≤ 5D
	D08: D≤ 8±0.5 and L≤ 4D
	D10: D 10±0.5 and L≤ 4D
	D12: D≤ 12±10 and L≤ 4D
	D25: ≤ 25±10 and L≤ 4D
Moisture content (%)	M10: ≤10%
	M15: ≤15%
	M20: ≤20%
Ash content (%)	A0.7:≤0.7%
	A1.5:≤1.5%
	A3.0:≤3%
	A6.0:≤6%
	A6.0+:>6%
N (%)	N0.3: ≤0.3%
	N0.5: ≤0.5%
	N1.0: ≤1%
	N3.0: ≤3%
	N3.0+: >3%
S (%)	N0.05: ≤0.05%
	N0.08: ≤0.08%
	N0.1: ≤0.1%
	N0.2+:>0.2%
Cl (%)	CL0.03: ≤ 0.03
	CL0.07: ≤ 0.07
	CL0.1: ≤ 0.1
	CL0.1+: > 0.1
Durability	DU97.5: ≥97.5
	DU95.0: ≥95
	DU90: ≥90
Fines content (% < 3.15 mm)	F1.0: ≤ 1 %
	F2.0: ≤ 2 %
	F2.0 +: > 2 %
Bulk density (kg/m^3)	Recommended value should be included by manufacturer
Heating value (kcal/kg)	Recommended value should be included by manufacturer
Additives	Binding materials and ash inhibitory should be included in the label

D. Laboratory procedures

An analysis program was established in this research, in terms of certain quality parameters and guiding values included in the literature and Technical Specification CENT/TS 14961.

Laboratory procedures according to Spanish norms are necessary to determine those characteristics that affect pelletization as well as the quality of the final product: for example, humidity, production of ash, composition, etc. This allows for the selection of pelletizable materials from olive trees, and for possible combinations of this material to enhance the quality of the final product.

Table 2. Classification of parameters included in Annex A.2 of CEN/TS 14961:2005 published by the European Standard Committee CEN/TC 335 in relation to guidelines specifications for pellets applied for domestic use [7].

PARAMETER	CLASSIFICATION
Size (diameter and length) (mm)	D06: D≤ 6±0.5 and L≤ 5D
	D08: D≤ 8±0.5 and L≤ 4D
Moisture content (%)	M10: ≤10%
Ash content (%)	A0.7:≤0.7%
N (%)	No guideline is included
S (%)	S0.05: ≤0.05%
Cl (%)	No guideline is included
Durability	DU97.5: ≥97.5
Fines content (% < 3.15 mm)	F1.0: ≤ 1 %
	F2.0: ≤ 2 %
Bulk density (kg/m^3)	No guideline is included
Heating value (kcal/kg)	E4.7: ≥ 4.7 kWh/kg = 4,042 kcal/kg
Additives	< 2 %

1) *Particle density.* The particle density of pellets was determined according to CEN/TS 15150:2005 [8] by measuring dimensions, using a digital vernier caliper CLD-150, and weight of three randomly selected individual pellets per sample. The calculated particle density represents the average value of these measurements.

2) *Bulk density.* The volume and the weight of a pellet sample have to be measured in order to be able to determine the bulk density according to CEN/TS 15103:2005 [9]. Weight measurements were performed with a laboratory balance, the volume of the samples was determined by using a graduated cylinder. The average bulk density was calculated from three measurement series per sample.

3) *Moisture content.* Three samples from raw material were milled to determine moisture content in an oven-dried at 105±2◦C to a constant weight and according to CEN/TS 14774-2:2004 [10].

4) *Crushing resistance or hardness.* Three randomly chosen pellets of each material were chosen for the calculation of the crushing resistance or hardness (compressive resistance), defined as the maximum crushing load a pellet can withstand before cracking or breaking. Compressive resistance and tensile strength of the densified products were determined by diametrical compression test using a KAHL tester working between 0 and 100 kg. It consists of the determination of compressive resistance and tensile strength of the densified products by diametrical compression test. A single pellet was placed between two flat, parallel platens, which had facial areas greater than the projected area of the pellet. An increasing load was applied at a constant rate, until the test specimen failed because of cracking or breaking due to the tensile forces resulting from the applied compressive force or stress. The load at fracture was recorded as compressive strength and reported as force or stress.

5) *Number of particles of pellets.* Three random samples of 100 g of each material were used to determine the number of pieces per 100 g of pellets.

6) *Size.* Forty randomly chosen pellets were used to determine the length and the diameter of the pellets (mm) using a digital vernier caliper CLD-150.

7) *Ash content.* Three samples of pellets were chosen and the ash content was measured by measuring loss of ignition at 550 ºC, according to CEN/TS 14775:2004 [11].

8) *Heating value.* Three samples from raw material were milled to determine the heating value by using a bomb calorimeter IKA C 2000 and according to UNE 164001:2005 EX [12].

2. Results and discussions

The results of the analysis program of densified biomass tested in this research are summarized in Table 3. These results are analyzed and discussed in the following subsections.

1) *Particle density*

The samples of pellets from olive tree branches showed particle density values similar to other wood pellets given in the literature [13,14,15,16]. However the samples of pellets from olive tree leaves showed a lower particle density value. The energy density is of importance because it contributes to more efficient storage, transport and energy production [3,5,17]. Besides, it also influences the combustion behavior. Higher particle density values could have negative effects in the combustion process because dense particles show a longer burnout time [13].

The Technical Specification CENT/TS 14961:2005 does not include a guideline value for this parameter.

Table 3. Physical and chemical parameters of samples of pellets in the study (Average value).

PARAMETER	OLIVE TREE BRANCHES	OLIVE TREE LEAVES
Bulk density (kg/m^3)	582.53	481.56
Density (kg/m^3)	1259.22	1083.47
Moisture (%)	5.37	6.57
Crushing resistance (kg)	22.50	4.00
Compression resistance (kg)	21.33	8.33
Length (mm)	20.36	10.65
Diameter (mm)	5.94	6.04
Ratio L/D	3.43	1.76
Number per100 g	176	322
Particle size distribution (%) > 16/16-10/10-7/7-4/4-2.5/<2.5 mm	0.22/1.81/93.69/3.71/0.04/0.01	0.00/1.76/76.22/13.23/5.39/3.39
C (%)	44.84	42.80
N (%)	0.95	1.09
S (%)	0.00	0.00
H (%)	7.64	7.05
Ash content (%)	4.79	12.34
Heating value (kcal/kg)	4410.67	4437.67

2) *Bulk density*

Pellets made with waste from olive tree branches showed bulk density values similar to the bulk density of pellets from fresh logging residues [3], other wood pellets [15] or pellets from certain herbaceous crops [18]. However samples from leaves of olive trees showed lower values for this parameter. The bulk density is of importance with regard to pellet storage and transport, because the necessary storage and transport capacity decreases with an increasing bulk density [3,5,17]. The Technical Specification CENT/TS14961:2005 does not include a guideline value for this parameter although a recommended value should be included by the manufacturer.

3) *Moisture content*

The water content has an influence on the net calorific value, the combustion efficiency, the temperature of combustion and the equilibrium moisture content with the ambient moisture content, affecting storage conditions [19]. Pellets from olive tree leaves had a higher moisture content than samples from olive tree branches (Table 3). The values obtained were similar to those of other wood pellets given in literature [13] although they were lower than the moisture content of pellets from fresh sawdust, logging, and bark, with values between 7.9 and 21.3% [15].

The Technical Specification CENT/TS 14961:2005 includes guideline values for this parameter (Table 2). It was possible to conclude that values attained the levels established for pellets manufactured for domestic use.

4) *Crushing resistance or hardness*

This parameter is not included in the Technical Specification CENT/TS 14961:2005 (Tables 1 and 2). However some literature includes the compressive resistance test to simulate the compressive stress due to the weight of the top pellets on the lower pellets during storage in bins or silos and the crushing of pellets in a screw conveyor [5,16,17].

Pellets from olive tree leaves showed a significantly lower hardness value than samples from olive tree branches.

The compressive resistance test provides a quick measurement of the quality of pellets as soon as the pellets are produced by the pellet mill, and aids in adjusting the pelleting process to improve pellet quality [14,17].

5) *Number*

This parameter is not included in the Technical Specification CENT/TS 14961:2005 either. However some literature relates it to the resistance test of pellets and particle density [5,15,19].

Samples of pellets from olive tree leaves showed a significantly higher number of pieces in a 100 g sample of pellets (Table 3). These results could be related to the tensile strength of samples. Pellets with lower values of tensile strength could also have a greater number of pieces.

The same conclusion was obtained with the relation of the number or particles and the density. Pellets with lower density value and lower tensile strength were easily broken down during the handling, transportation, and storage. Consequently, the number of particles was higher than in the case of samples of pellets with higher density values [5,15,19].

6) *Size*

The dimensions of the pellets, both diameter and length, are also important factors with respect to fuel feeding properties and to combustion. Thinner pellets allow a more uniform combustion rate than thicker ones; the shorter the pellets, the easier the continuous flow can be arranged [15]. Moreover, the ratio length/diameter has particular relevance if pneumatic feeding systems are used, due to the fact that even a single long pellet is able to block the transport pipe of such systems [13].

Visual observations of the pellets tested showed differences between them (see Figure 2). Most of the pellet samples obtained had a diameter of about 6 mm because all the samples were produced in the same industrial plant and under the same conditions. However, some differences were detected in relation to their length and ratio length/diameter. Pellets from olive tree leaves had a shorter length and ratio values than pellets from olive tree branches.

Some references have related the length of pellets to the density of their particles [15,19]. Pellets that were more densified (olive tree branches) broke less frequently than pellets with lower density particles (olive tree leaves). These results should be considered in relation to pellet storage and transport [19].

The Technical Specification CENT/TS 14961:2005 includes guideline values for this parameter. It was possible to conclude that the values obtained fulfilled limits established for pellets for domestic use.

7) Chemical composition

The Technical Specification CENT/TS 14961:2005 includes different chemical parameters, including the use of additives. The values obtained showed a higher percentage of nitrogen than the limits established (< 0.3%).

Since the manufacturing process of pellets did not use additives, the requirements established in relation to this parameter were fulfilled.

8) Ash content

Pellets from the leaves of olive trees generated a higher percentage of ash content than pellets from olive tree branches. In any case, it was observed that values exceed the usual ash content of wood, whose values are between 0.4 and 0.8 % for softwood and between 1 and 1.3 % for hardwood [13], or values given in the literature on sawdust pellets with values lower that 0.5% [15].

The Technical Specification CENT/TS 14961:2005 includes guideline values for this parameter (Table 2). In order to maintain a high operating comfort for end users in the residential heating sector, high ash content must be avoided. On the one hand, it must be avoided because of the demand of emptying the ash box at periodic intervals, and on the other hand, because of the increasing danger of slag and deposit formation in the furnace as well as because of rising dust emissions [13,20,21].

It was possible to conclude that the values obtained did not fulfill the established limit (≤0.7%) for pellets manufactured for domestic use.

The fact that the ash content of samples was higher than the guiding values in the norms could possibly be related to the contamination of the raw material used, for example, by sand or earth [17].

9) Heating value

The gross calorific values for the different samples of pellets from olive tree branches and leaves were within the typical ranges given in the literature consulted [15,17,18,22] and no differences between them were detected.

The Technical Specification CENT/TS 14961:2005 includes guideline values for this parameter. It was possible to conclude that the values obtained fulfill established limits for pellets for domestic use

3. Conclusions

In this research physical and chemical characteristics of different samples of pellets from olive trees have been analyzed. Results have also been compared to the guidelines established for pellets for domestic use in experimental Technical Specification CENT/TS 14961:2005.

The use of different type of raw materials from olive grove residues results in different physical and chemical properties of pellets, and conditions the application of pellets. The results of our study showed that neither samples from olive tree branches nor samples from olive leaves fulfilled all the parameters considered in the experimental specification for domestic use. However, samples of pellets made only from olive tree leaves showed lower quality, thus affecting the handling, transportation, storage and combustion phases. The higher ash content was highlighted because it could affect the operating comfort for end users in the residential heating sector.

Nevertheless more research is needed regarding the effects of raw material characteristics, seasonal variations, collection and storage of raw material as well as the manufacturing process to facilitate a steering of production in the desired direction to produce pellets that meet the quality standards requirements established by other norms and in consonance with the specific application of pellets.

Acknowledgements

This research has been funded by the Innovation and Science Division of the Andalusian Regional Government (Research Project P08-RNM-03584) and the Spanish Ministry of Science and Innovation (Research Project CTM2009-07199).

References

[1] Kyoto Protocol to the United Nations Framework Convention on Climate Change.United Nations, 1998.

[2] Action Plan for Energy Efficiency: Realising the Potential. Communication from the Commision of the European Communities. Brussels, 19.10.2006 COM(2006).

[3] Vinterbäck J. Pellets 2002: the first world conference on pellets. Biomass and Bioenergy 2004; 27: 513–520.

[4] Rofiqul M, Rabiul M, Rafiqul M. Renewable energy resources and technologies practice in Bangladesh. Renewable and Sustainable Energy Reviews 2008; 12: 299–343.

[5] Kaliyan N, Vance R. Factors affecting strength and durability of densified biomass products. Biomass and Bioenergy 2009; 33: 337-359.
[6] Dinica V. Biomass power: Exploring the diffusion challenges in Spain. Renewable and Sustainable Energy Reviews 2009; 13: 1551–1559.
[7] CEN/TC 335 Published standards. CEN/TS 14961:2005. Solid biofuels. Fuel specification and classes.
[8] CEN/TC 335 Published standards. CEN/TS 15150:2005 Solid biofuels. Methods for the determination of particle density.
[9] CEN/TC 335 Published standards. CEN/TS 15103:2005 Solid biofuels. Methods for the determination of bulk density.
[10] CEN/TC 335 Published standards. CEN/TS 14774-2:2004 Solid biofuels. Methods for the determination of moisture content. Oven dry method. Part 2: Total moisture. Simplified method.
[11] CEN/TC 335 Published standards. CEN/TS 14775:2004 Solid biofuels. Method for the determination of ash content.
[12] Spanish Association for Standardisation and Certification (AENOR) Experimental norm UNE 164001:2005 EX Solid biofuels. Method for the determination of heating value.
[13] Obernberger I, Thek G. Physical characterisation and chemical composition of densified biomass fuels with regard to their combustion behavior. Biomass and Bioenergy 2004; 27: 653–669.
[14] Li Y, Liu H. High-pressure densification of wood residues to form an upgraded fuel. Biomass Bioenergy 2000;19: 177–186.
[15] Lehtikangas P. Quality properties of pelletised sawdust, logging residues and bark. Biomass and Bioenergy 2001; 20: 351–360.
[16] Rhén C, Gref R, Sjöström M, Wästerlund I. Effects of raw material moisture content, densification pressure and temperature on some properties of Norway spruce pellets. Fuel Processing Technology 2005; 87: 11–16.
[17] Gilbert P, Ryu C, Sharifi V, Swithenbank J. Effect of process parameters on pelletisation of herbaceous crops. Fuel 2009; 88: 1491-1497.
[18] Celma AR, Rojas S, López-Rodríguez F. Waste to energy possibilities for industrial olive and grape by-products in Extremadura. Biomass and Bioenergy 2007; 31: 522–534.
[19] Lehtikangas P. Storage effects on pelletised sawdust, logging residues and bark. Biomass and Bioenergy 2000; 19: 287-293.
[20] Ollero P, Serrera A, Arjona R, Alcantarilla S. The CO2 gasification kinetics of olive residue. Biomass and Bioenergy 2003; 24: 151–61.
[21] Öhman M, Boman C, Hedman H, Nordin A, Boström D. Slagging tendencies of wood pellet ash during combustion in residential pellet burners. Biomass and Bioenergy 2004; 27: 585–596.
[22] Öhaman M, Nordin A, Hedmam H, Jirjisc R. Reasons for slagging during stemwood pellet combustion and some measures for prevention. Biomass and Bioenergy 2004; 27: 597–605.