

Determination of Flue Gas Emission Values of Cotton and Sesame Stalk Briquettes

Sefai BİLGİN

Bartın University, Vocational School of Bartın
sefaibilgin@bartin.edu.tr

Received (Geliş Tarihi): 19.07.2010

Accepted (Kabul Tarihi): 17.08.2010

Abstract: In this study, flue gas emission values of cotton and sesame stalk briquettes which were produced in a conical type briquetting machine were aimed to determine. In order to determine flue gas emission values, the briquettes were burned in a traditional bucket type stove used for household heating. In the study, flue gas emissions such as CO, CO₂, SO₂, NO_x, H₂S and O₂, flue gas temperature and combustion efficiency were measured by means of flue gas analyzer. At the end of this study, when the combustion process had a steady-state condition, the flue gas emission values measured during burning of the briquettes were found to be very low. When the combustion process had a steady-state condition, the lowest CO emissions were 57 ppm and 160 ppm, average NO_x emissions were 196 ppm and 146 ppm, H₂S emissions were 37 ppm and 27 ppm, CO₂ emissions were 7.92% and 7.41% and O₂ emissions were 12.81% and 13.33% for cotton and sesame stalk briquettes, respectively. During the combustion process, cotton and sesame stalk briquettes had no SO₂ emission. During the steady-state condition, the average flue gas temperature and combustion efficiency for cotton and sesame stalk briquettes were 400 °C and 403 °C, 70% and 69%, respectively.

Key words: Biomass, briquette, flue gas emission

INTRODUCTION

Biomass energy accounts for about 14% of the world's primary energy consumption and about 30% of the primary energy consumption in the developing countries (IEA, 2003; IEA, 2003c). Furthermore, biomass often provides more than 90% of the total rural energy demand in the developing countries (Bhattacharya and Salam, 2002). In Turkey, the share of biomass energy in total energy production was 19.32% in 2006, its share in total energy consumption was 5.27%.

Biomass combustion provides basic energy requirements for cooking and heating rural households and for process heat in variety industries in the developing countries. However, biomass energy will play an important role in energy production to obtain electricity or heating in the future.

Energy accounts for about 65% of the world's greenhouse gas emissions. Depending on population growth and energy requirements, the amount of CO₂ emission released into the atmosphere as a result of using fossil energy sources has risen rapidly, and for millions of years, CO₂-equivalent changing between 180-280 ppm reached 450 ppm level in the last half

century. According to the scenario described, this level of concentration is expected to give rise to a global temperature increase of 2 °C (IEA, 2009).

In general, biomass fuels have lower nitrogen and sulphur content than fossil fuels, and do not produce any CO₂ that contributes to the greenhouse effect. Furthermore, NO_x emissions are lower than fossil fuels because of the lower combustion temperature, and the ash content is also lower.

Although the carbon from biomass is mostly released into the atmosphere as CO₂ during combustion, the CO₂ gas is taken up during plant growth by the process of photosynthesis, and consequently, does not contribute to increase the greenhouse effect (Smith et al., 2000; Bhattacharya and Salam, 2002; Gonzalez et al., 2004).

When combustion of biomass fuels is complete, products of combustion is only CO₂, H₂O and ash. But, incomplete and inefficient combustion releases health-damaging pollutants and greenhouse gases such as CO, N₂O, CH₄, polycyclic aromatic hydrocarbons, etc (Bhattacharya and Salam, 2002; Ndiema et al., 1998).

Emission of pollutants varies depending on the quantities of the biomass fuels consumed. Also, cookstoves of small, simple and locally made devices cause higher pollution per kg of biomass fuel used compared to other biomass combustion systems.

As a result, domestic cooking and heating are the major source of emissions from biomass energy use in the developing countries. Therefore, a significant reduction in emissions from cooking and heating is expected to cause significant reduction in total emission from biomass energy use.

An increase in biomass use efficiency will reduce emission from biomass combustion. Also the energy provided by biomass could be potentially provided by lesser amount of biomass used currently (Bhattacharya and Salam, 2002).

The construction of the traditional stoves leads to combustion processes inside stoves to be non-ideal, thus favoring incomplete combustion (Miah et al., 2009). Traditional biomass stoves have less thermal efficiency and high flue gas emissions than improved biomass stoves. However, biomass stoves generally release high flue gas emissions due to formation and properties of biomass fuels. Therefore, these flue gases cause serious health problems and environmental air pollution (Bhattacharya et al., 2002a). In recent years, negative health effects of particles from biomass combustion in household stoves have been observed (Lighty et al., 2000). Particles generated from small-scale combustion consist of fly ash and soot and its particle size ranges from 0.1 to 0.3 μm (Johansson, 2002).

Various studies on biomass burning in different combustion systems and flue gas emissions were conducted and their results were explained.

The concentrations of pollutant emissions released into the atmosphere by biomass combustion have been investigated by Ndiema et al. (1998). The results of the study showed that biomass stoves should be used where there is adequate ventilation because of the high emission of carbon monoxide.

Dare et al. (2001) evaluated the combustion performance of two samples of biomass fuel in a small scale 50 kW laboratory scale stoker type combustor. The results of this study have shown that the emissions of CO and CH₄ have increased due to higher moisture content of biomass fuels.

The effects of different parameters such as moisture content of fuel, size of fuel and method of ignition on performance and emissions of three biomass fired stoves have been investigated (Bhattacharya et al. (2002b)). At the end of the study, it was found that increase in fuel moisture content resulted in decrease in stove efficiency, increase in the emission of CO and decrease in the emission of NO_x; a slight decrease in CO₂ emission was also observed, while emission of CH₄ was not significantly effected. The fuel size did not show any significant influence on the efficiency of the stove, however, at lower fuel size, the emission of CO was found to decrease slightly, while that of NO_x increased slightly. In general, emission of CO and NO_x was significantly less in case of top ignition in comparison with conventional bottom ignition.

Bhattacharya and Salam (2002) present an analysis of a number of selected options to reduce total greenhouse gas emission. The results of the study show that greenhouse gas emission in terms of CO₂-equivalent for cooking is the lowest in case of producer gas and biogas fired stoves and kerosene fired stoves generate the highest emission of CO₂ equivalent. As a result, this study shows that modern biomass based cooking options such as improved biomass, biogas and producer gas fired stoves can potentially play an important role in mitigating greenhouse gas emission.

Flue gas emission values of sunflower stalks in two different forms were measured three types of grates and under three different burning conditions by Ünal and Alibaş (2002). At the end of the study, the lowest CO values belonging to the first form of sunflower stalk were realised in the bottom natural draft burning condition of mixed hole grate and oblong hole grate with 2834.8 and 2953.9 mg/Nm³, respectively. In the experiments with the second form, the lowest CO quantity was obtained in the bottom force draft and bottom natural draft burning conditions of oblong hole grate with 1626.3 and 1765.5 mg/Nm³, respectively.

Koyuncu and Pinar (2007) burned various biomass fuels in the improved biomass stoves and have investigated the flue gas emissions. The results of this study show that the flue gas emissions have different values depending on the characteristics of biomass fuels and charcoal is the most suitable biomass fuel for biomass stove.

The aim of study

Every year, huge amount of agricultural biomass residue are produced from agricultural fields in Turkey, but majority of agricultural residues are either burnt or dumped out around the agricultural fields. These agricultural residues can be used as solid bio-fuel. The amounts of biomass residue for cotton and sesame crops are given in Table 1.

Table 1. Biomass residue of cotton and sesame crops

Crops	Residues	Production field (ha)*	Residues in dry basis (t/ha)	Total residues (t/year)
Cotton	Stalks	495000	4.10**	2029500
Sesame	Stalks	29224	7.42***	216842

* TÜİK, 2008, ** Kürklü and Bilgin, 2007, *** Sarkar and Pal, 2005

In Turkey, the coal is generally used for household heating in traditional stoves or in centers of combustion systems (boilers). Hence, air and environmental pollution threat on human health occurs during the winter, especially. In order to prevent pollution of air and environment and live a more healthy life, biomass fuels which are renewable and clean energy sources should be burned in this type of combustion system.

In this study, flue gas emission values released into the atmosphere during the burning of cotton and sesame stalk briquettes, which were produced in a conical type briquetting machine, in a traditional bucket type stove were aimed to determine.

MATERIAL and METHOD

Material

The experiments were conducted at the Department of Agricultural Machinery of Agricultural Faculty of Akdeniz University.

In the experiments, 57 mm diameter and 75 mm length cylindrical briquettes with a central hole of 25 mm and outer surface partially carbonized due to heating system produced from cotton and sesame stalks were used as a fuel (Figure 1). The briquettes were produced in a conical type briquetting machine and the properties of briquettes are given in Table 2. Any binder material was not used during the briquetting process.

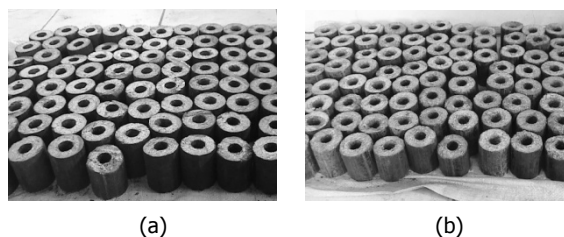


Figure 1. Cotton (a) and sesame (b) stalk briquettes

Table 2. Properties of briquettes

Briquettes	Moisture Content (%)	Ash Content (%)	Density (kg/m ³)
Cotton stalk briquette	6.80	5.35	1157
Sesame stalk briquette	6.56	5.21	1153

A flue gas analyzer (TESTO 350 M/XL-454) was used for measurement of flue gas emission. Flue gas analyzer consists of unit of flue gas analyzer, hand control unit and gas probe (Figure 2). Technical data of flue gas analyzer are given in Table 3.



Figure 2. Flue gas analyzer

Table 3. Technical data of flue gas analyzer

Parameter	Measurement Range
O ₂	%0...%25
CO	0...+10000 ppm
CO ₂	0...CO ₂ max.
NO	0...+3000 ppm
NO ₂	0...+500 ppm
SO ₂	0...+5000 ppm
H ₂ S	0...+300 ppm
Flue gas temperature	-40 °C...+1200 °C

A traditional bucket type stove with primary (bottom) and secondary (top) air inlet channels was used (Figure 3).



Figure 3. Traditional bucket type stove

Method

The briquettes were burned in a traditional type stove used for household heating in order to determine the emission values of flue gas. The emission values and temperature of the flue gas and combustion efficiency were measured using a measuring device and transferred into computer online. Emission measurements were carried out in accordance with the reference values 13% O₂ (percentage of the amount of standard oxygen) and 20.3% CO_{2max} (the percentage of maximum carbon dioxide in flue gas for each fuel) given in The Regulation of Control of Air Pollution Resulting from Warming concerned with solid fuel combustion systems and burning of wood and vegetable waste and the values were entered and defined in the measurement device before the test. The gas probe was placed into the gas sampling point opened slightly above the midpoint of the vertical stove pipe in such a way that it is in the centre of the section of the stove pipe (Figure 3) and measurements were carried out at one point during the experiments. Pieces of wood were burned in the stove so as to ignite the briquettes and when the pieces of wood turned into ember, three briquettes (approximately 580 g) for each experiment were placed into the combustion chamber vertically. Then, flue gas analyzer was launched online on the computer and gas sample was allowed to pass through the electrochemical cells in the analyzer and the measured values were transferred into computer online. The measurements went on from the beginning of the combustion to the end and the same operations were repeated for each experiment. During

the experiment, primary and secondary air inlet channels were kept open 100 percent.

The average combustion efficiency and flue gas temperature values were calculated by taking the average of values measured during the steady state condition.

RESULTS and DISCUSSION

Variation of flue gas emissions released into the atmosphere during burning of cotton and sesame stalk briquettes in a bucket type stove widely used for household heating are given in Fig. 4 and 5.

When the changes in the values of flue gas emissions in Fig. 4 and 5 were examined, it was observed that carbon monoxide (CO) and carbon dioxide (CO₂) emissions increased rapidly as a result of decrease in oxygen (O₂) content in the combustion chamber at the very beginning of the combustion with the ignition of briquettes and the increase in sesame stalk briquettes was much more. For cotton and sesame stalk briquettes, the increase of CO emission was up to 1286 ppm and 5234 ppm and the increase of CO₂ emission was up to 11.03% and 13.86%, respectively. Meanwhile, O₂ content for cotton and sesame stalk briquettes in the combustion chamber dropped by 9.32% and 6.66%, respectively. When the combustion process was at the beginning of steady-state condition, CO and CO₂ emissions started to drop rapidly with increase of O₂ content in the combustion chamber. When the combustion process had a steady-state condition, CO emission followed a horizontal line till the end of the steady condition and the lowest CO emissions were 57 ppm and 160 ppm and average CO emissions were 218 ppm and 195 ppm for cotton and sesame stalk briquettes, respectively.

The results obtained in the experiments were similar to those obtained by Bhattacharya et al. (2002), El Saeidy (2004) and Koyuncu and Pinar (2007). At the same time, average CO₂ emissions for cotton and sesame stalk briquettes were 7.92% and 7.41%, respectively.

At the end of steady-state condition, CO emission increased rapidly with increase in O₂ content in the combustion chamber whereas CO₂ emission decreased rapidly.

As a result, inadequate O₂ content in the combustion chamber caused by uncontrolled burning in traditional

stoves and insufficient flue draft led to extensive fume and high CO emissions at the beginning of combustion.

Likewise, towards the end of the combustion process, CO emissions increased rapidly due to the fact that excess air in the combustion chamber broke the balance of combustion.

NO_x emissions for cotton and sesame stalk briquettes from the beginning to the end of the combustion were very low levels. These results were similar to those obtained by El Saeidy (2004) and Koyuncu and Pinar (2007). During the steady-state condition, NO_x emissions didn't change much and it ranged from 175 to 234 ppm and 88 to 66 ppm and average NO_x emissions were 196 ppm and 146 ppm for cotton and sesame stalk briquettes, respectively. These values were below those determined for olive cake fuel (Al-widyan et al., 2006).

While cotton and sesame stalk briquettes had no SO₂ emissions during the combustion process, H₂S emission for all briquettes was very low (37 ppm for cotton stalk briquette, 27 ppm for sesame stalk briquette).

Using of these types of fuels in combustion systems will reduce especially the formation and effects of acid rains caused by SO₂ and NO_x emissions. Moreover, the harmful effects of NO_x emissions, which are important factors in the formation of photochemical smog and which have the same effect as poison on human health and flora, will be reduced.

In conclusion, cotton and sesame stalk briquettes are in a good position with respect to flue gas

emission values released into the atmosphere during burning in a traditional bucket type stove used for household heating. A center hole in the briquette helped in combustion because of sufficient circulation of air, therefore flue gas emissions were reduced during the steady-state condition. The outer surface of the briquettes is partially carbonized facilitating easy ignition and combustion, and briquettes burned without being broken into pieces until the end of the combustion process.

Fig. 6 and 7 shows the variation of flue gas temperature and combustion efficiency values measured during burning of cotton and sesame stalk briquettes. With the ignition of briquettes, flue gas temperature increased rapidly and it was 414 °C at the highest for cotton stalk briquette and 441 °C for sesame stalk briquette. Flue gas temperatures almost followed a horizontal line from the beginning to the end of the steady-state condition for all briquettes, but it is very clear for cotton stalk briquette. During the steady-state condition, average flue gas temperature was 400 °C and 403 °C for cotton and sesame stalk briquettes, respectively. The fact that flue gas temperature for all the briquettes was fairly high showed that most of the energy obtained from the burning of briquettes was released into the atmosphere through the flue. This case is one of the negative properties of using traditional stoves for household heating. The decrease in flue gas temperature at the end of the steady-state condition showed that combustion process was about to finish.

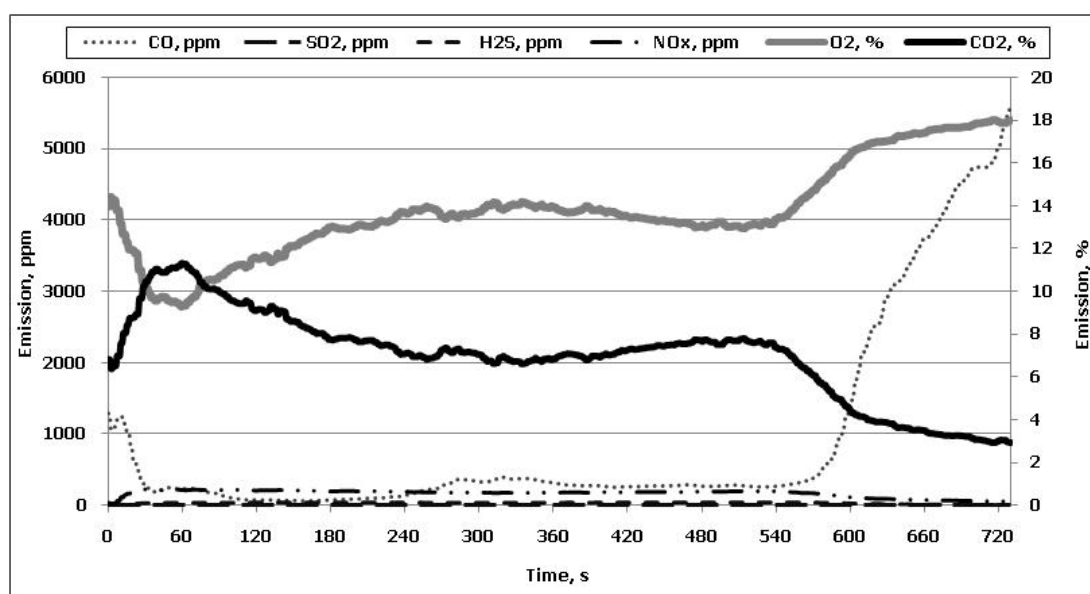


Figure 4. Variation of flue gas emission values of cotton stalk briquettes

When the combustion efficiency of the briquettes was examined, the combustion efficiency for cotton stalk briquette exhibited a relatively balanced dispersion during the steady-state condition. Average combustion efficiency for cotton and sesame stalk briquettes was determined as 70% and 69% during the steady-state condition. Combustion efficiency values were quite below the values obtained by burning various biomass materials in fluidized bed combustion systems (Topal et al., 2002; Al-Widyan, 2006). This case resulted

from failing to control combustion process and air-fuel ratio in this type stove.

When the results are examined as a whole, it is possible to burn of solid biofuels produced by briquetting of agricultural residues in traditional stoves used for household and greenhouse heating. Thus, it will be possible to prevent air pollution caused by burning coal in especially such type of stoves. Nevertheless, traditional stoves should be developed in order to obtain lower flue gas emissions, higher combustion efficiency and lower flue gas temperatures.

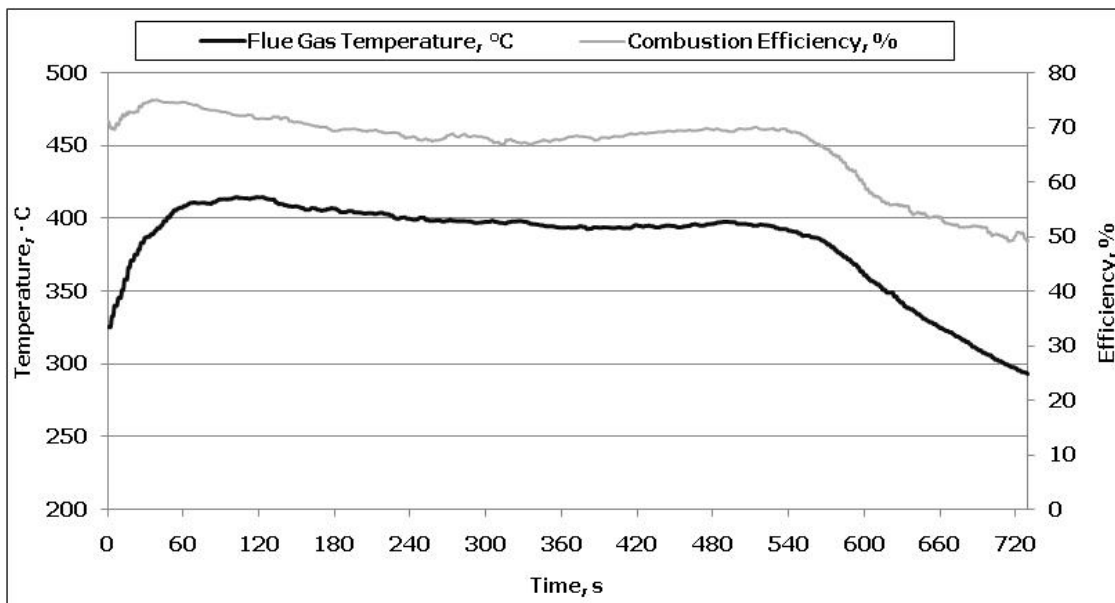


Figure 6. Variation of flue gas temperature and combustion efficiency values of cotton stalk briquettes

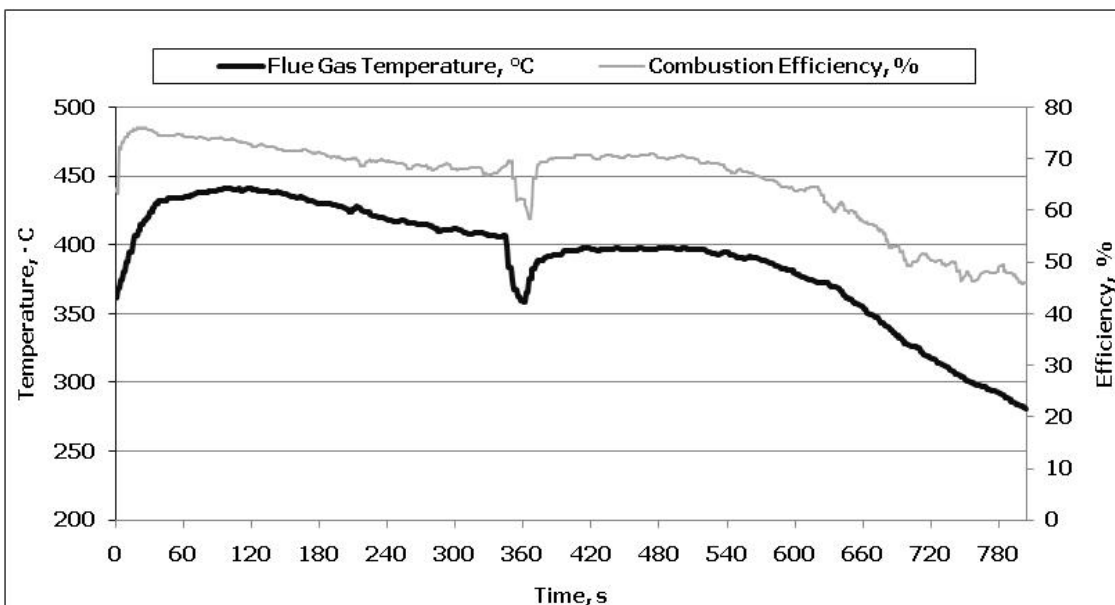


Figure 7. Variation of flue gas temperature and combustion efficiency values of sesame stalk briquettes

CONCLUSIONS

The conclusions that can be drawn from this study are as follows:

- It is possible to burn briquettes in stoves for household and greenhouse heating.
- When the combustion process had a steady-state condition, the flue gas emissions released into the atmosphere were found to be very low.
- During the combustion process, SO₂ emission for briquettes was null.
- The outer surface of the briquettes is partially carbonized facilitating easy ignition and combustion.

REFERENCES

- Al-Widyan, M.I., G. Tashtoush, A. M. Hamasha, 2006. Combustion and Emissions of Pulverized Olive Cake in Tube Furnace. *Energy Conversion and Management* 47: 1588–1596.
- Bhattacharya, S.C., P.A. Salam, 2002. Low Greenhouse Gas Biomass Options for Cooking in the Developing Countries. *Biomass and Bioenergy* 22: 305-317.
- Bhattacharya, S.C., D.O. Albina, P.A. Salam, 2002a. Emission Factors of Wood and Charcoal-Fired Cookstoves. *Biomass and Bioenergy* 23:453-469.
- Bhattacharya, S.C., D.O. Albina, A.M. Khaing, 2002b. Effects of Selected Parameters on Performance and Emission of Biomass-Fired Cookstoves. *Biomass and Bioenergy* 23:387-395.
- Dare, P., J. Gifford, R.J. Hooper, A.H. Clemens, L.F. Daminao, D. Gong, T.W. Matheson, 2001. Combustion Performance of Biomass Residue and Purpose Grown Species. *Biomass and Bioenergy*, 21:277-287.
- El Saeidy, von M.Sc.E., 2004. Technological Fundamentals of Briquetting Cotton Stalks as a Biofuel. Ph.D. Thesis (unpublished), Humboldt-University of Berlin.
- Gonzalez, J.F., C.M. Gonzalez-Garcia, A. Ramiro, J. Gonzalez, E. Sabio, J. Ganán, M.A. Rodriguez, 2004. Combustion Optimisation of Biomass Residue Pellets for Domestic Heating with a Mural Boiler. *Biomass and Bioenergy* 27:145-154.
- IEA, 2003. Energy Balances of non-OECD and OECD Countries, 2000-2001. International Energy Agency, Paris.
- IEA, 2003c. Statistics, Renewable information. International Energy Agency.
- IEA, 2009. How the Energy Sector can Deliver on a Climate Agreement in Copenhagen. Special Early Excerpt of the World Energy Outlook 2009 for the Bangkok UNFCCC Meeting.
- Johansson, L.S., 2002. Characterisation of Particle Emissions from Small-Scale Biomass Combustion. Thesis for the Degree of Licentiate of Engineering, Chalmers University of Technology, Göteborg.
- Koyuncu, T., Y. Pınar, 2007. The Emission from a Space-Heating Biomass Stove. *Biomass and Bioenergy* 31(1):73-79.
- Kürklü, A., S. Bilgin, 2007. A Study on Briquetting of Cotton and Sesame Stalks (In Turkish). *Journal of Agricultural Machinery Science* 3(3):151-159.
- Lighty, S.L., J.M. Veranth, A.F. Sarofim, 2000. Combustion Aerosols: Factors Governing Their Size and Composition and Implication to Human Health. *Journal of the Air and Waste Management Association* 50:1565-1618.
- Miah, Md. D., H. Al Rashid., M.Y. Shin, 2009. Wood Fuel Use in the Traditional Cooking Stoves in the Rural Floodplain Areas of Bangladesh: A Socio-Environmental Perspective. *Biomass and Bioenergy* 33:70-78.
- Ndiema, C.K.W., F.M. Mpendazoe, A. Williams, 1998. Emission of Pollutants from a Biomass Stove. *Energy Conversion and Management* 39(13):1357-1367.
- Sarkar, R., P.K. Pal, 2005. Effect of Crop Geometry, Fertility Level and Nipping on Physiological Parameters in Relation to Productivity of Sesame (*Sesamum Indicum*). *Indian Journal of Agricultural Science* 75(3):143-146.
- Smith, K.R., R. Uma, V.V.N. Kishore, J. Zhang, V. Joshi, M.A.K. Khalil, 2000. Greenhouse Implications of Household Stoves: an Analysis for India. *Annual Review of Energy and the Environment* 25:741-763.
- Topal, H., A. Atımyay, A. Durmaz, 2002. Combustion of Olive Cake in A Circulating Fluidized Bed for Clean Energy and the Investigation of Emission Characteristics (In Turkish). IV. National Clean Energy Symposium, s. 833-840, 16-18 October, İstanbul.
- TÜİK, 2008. Cereals and Other Vegetable Products. Turkey Statisticak Institue. http://www.tuik.gov.tr/VeriBilgi.do?tb_id=45&ust_id=13 Access: May 2010.
- Ünal, H., K. Alibaş, 2002. Burning of Sunflower Stalk as a Biomass Energy Source and Determination of Chimney Gas Emission Values (In Turkish). *Journal of Agricultural Faculty of Uludağ University* 16 (2): 113-128.