Vegetable oil utilization for electricity and heat generation

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Abstract: - The paper focuses upon the possibility of vegetable oils utilization for stationary application as biofuels. That is an opportunity of a new usage in our country of the vegetable oils, for electricity production and heating, instead of the current situation of using it in transportation as biodiesel fuel. The research is concentrated on crude vegetable oils obtained from some indigenous cultures: rape, soy, sun flower, corn and bastard saffron. An analysis of the agricultural potential of oleaginous plants is made, the feedstock and the costs being essential in the choosing of the energy crops sort. The typical properties of some crude vegetable oils are presented and the first experiments on their ignition conditions.

Keywords: crude vegetable oil, energy, ignition, burning, electricity, heating

1 Introduction

The research on the vegetable crude oil utilization for electricity and heat generation aims a new utilization for vegetable oil in our country, for energy purposes, instead of the current situation of using it in transportation as diesel fuel.

The decision to develop the renewable energy sources is a practical response of the European Communities to the problems of the energy supply security, the EU's increasing dependency on oil and gas imports, constantly rising oil and natural gas prices and EU commitments to reduce greenhouse gas emissions. Three sectors are in view: transports, electricity and heating.

There are 3 parallel paths in the biofuels industry development:

- The first path is to use food-type feedstock (wheat, vegetable oils...).
- The second path is to make biofuels out of the residues or waste of current agriculture or forestry and industry. Some problems can occur regarding the concentration of the residues or the amount of food-crop production.
- The third path is to use energy crops, i.e. biomass that is grown on purpose for biofuels applications.

Various legislative actions are in place to help achieve this target, notably:

- Promotion of renewable energy-based electricity generation from 14.0% in 1997 to 21.0% by 2010 (Directive 2001/77/EC).
- Promotion of biofuels for transport applications by replacing diesel and petrol to the level of 5.75% by 2010 (Directive 2003/30 EC) accompanied by detaxation of biofuels (within Directive 2003/96/EC).
- Promotion of cogeneration of heat and electricity (Directive 2004/8/ EC).

To ensure that these medium term objectives are met, at the European Union level a decision was taken to double the contribution of the renewable energy sources to the total consumption of primary resources by the year 2010, so that, gradually, it will reach 12 % as opposed to 6% in 1995. In this context an important action plan was proposed to promote the use of biofuels as a wider application of biomass, a renewable source of energy with a huge potential. This plan will reduce Europe's dependence on imported energy, cut greenhouse gas emissions, protect jobs in rural areas and extend the EU's technological leadership in these sectors. That is why this decision is in the same time a main component of the sustainable development policy.

In our country, the policy decision to promote the electricity and heat generation from renewable energy sources is reflected in some Romanian government decisions: H.G. 443/2003, 1892/2004 and 1892/2005. In accordance to the target assumed by Romania in the EU integration negotiations, the electricity levels produced from renewable sources in the gross internal consumption will be of 2.22% in 2006, 5.26% in 2008 and 8.3% in 2010-2012. The renewable sources taken into consideration are: biomass, solar, wind, low power hydro (under 10 MW), and geo-thermal energy.

2 Experience in energetic utilisation of crude vegetable oils

Research upon the vegetable oil using is focused to two directions: the use of crude vegetable oil and of the esterified vegetable oil, known as bio-diesel. The pure vegetable oil is produced from oil plants through pressing, extraction or comparable procedures, crude or refined but chemically unmodified. In comparison with bio-diesel, the crude vegetable oil gives the advantages of a reduced cost and lower energy consumption for its production. Its use in transportation is still least probable because it evolves the transformation of the existing diesel engines and the creation of a distribution infrastructure; instead it is attractive for use in power producing installations, especially in cogeneration and individual heating.

In Europe, the MAN Brennerbau has produced low thermal power testing boilers, in the 15-60 kW range, using rape seed oil mixed with conventional fuel, the proportion of vegetable being as high as 40%. The burning of rape seed oil mixed with kerosene tests made in the U.K. gave very good results, the Dunphy Burners firm producing special purpose burners for vegetable oil [2]. In Spain, research was made regarding the use of sun flower oil in mixture with diesel fuel in heat generation installations. The use of a 10 to 40 % mixture proved to be possible without major modifications of the burning installation, with a stable operation, with significant CO emission reduction, but with a slight increase in NOx emission with respect to the diesel fuel; a supplementary filtering installation was also necessary. In Italy the Novo Pignione Company has made a series of experiments on a 4.5 MWel gas turbine, using refined rape seed oil comparing it with metil-ester. The tests have indicated a good operation with the same pollutant emissions values, possible problems arising in the long term operation due to the high level metal content in the oil, the source for high temperature corrosion and the deposits on the blades surface, and also due to the carbon deposits in the injection nozzles. The high viscosity of the vegetable oil make necessary the fuel provisions for preheating installations, up to about 70°C and the increase in the injection pressure. In Austria and Germany testing installations were made for the cogeneration of electricity and heat using diesel engines in the 4 to 80 kWel power range, using rape oil. The economic viability of these engines is supported by the reduced cost of the oil.

From the vegetable oil tested so far, chances are for production and energy use for the rape oil in Germany an the U.K., the sun-flower oil in France, Spain and Italy and the soy-oil in the USA.

Throughout the world, the concerns view regarding the use of vegetable oil to burn comprised especially the transportation field. Theoretical and experimental research was done to use the biofuels in diesel engines adequately equipped. Research in this direction tries to increase performance and meeting provisions of the pollution standards.

3 Agricultural potential

For the energetic and transportation fields, the non-siccative or the semi-siccative vegetable oils present an interest. The first investigations and experiments concerning to some indigenous crude vegetable oils properties have demonstrated the possibility of energetically utilisation. From our country's cultures the most significant sources with respect to the agricultural potential are sun-flower, corn germs, rape and soy. In addition bastard saffron oil was been proposed by an agricultural society to be tested.

The feasibility of the energetically vegetable oil utilization must be sustained by the agriculture capacity to cultivate oleaginous plants; the evolution of the cultivate lands in Romania is given in (fig. 1) [6]. The current crops are about (1 ÷ 1.6) t/ha (fig. 2), but the climate of our country and soil quality are favorable to obtain high crops, e.g. for rape of about (2.5 ÷ 3.5) t/ha.

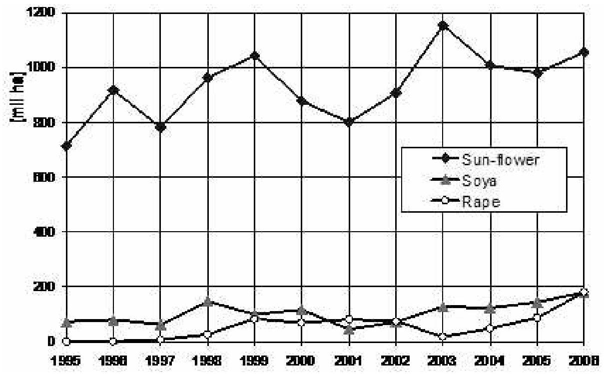

Fig. 1. Culture of the indigenous oil plants

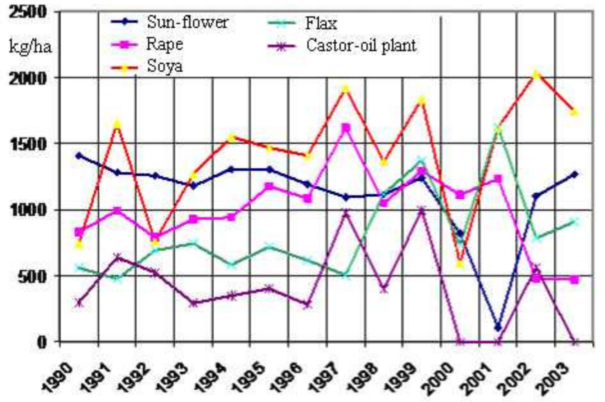

Fig. 2. The oleaginous culture evolution – average crops, kg/ha

A remarkable evolution is expected for rape as energetic culture. In 2004/2005 the cultivated land was of 85.000 ha and for 2010 is expected to be cultivate a surface of about 500.000 ha.

The crude vegetable oils are generally characterized by lower production costs, a better energy balance and a much simpler production technology compared to the corresponding esterified one. All these aspects lead to the consideration that crude vegetable oil can be very attractive for developing electricity and heat energy production at a competitive low costs.

4 Crude vegetable oil characteristics

In comparison with the traditional liquid fuel the vegetable oils are characterized by high viscosity, low thermal stability, high ignition point, very low sulphur content, relatively low cost. These typical properties impose complex research in order to obtain economically-ecologically performance of the future burning technologies, without major modifications of the energy producing installations.

Five types of crude vegetable oils with a possible stationary energetic utilization were tested: rape seed, soy bean, sun flower, corn germs and bastard saffron oils. The characteristics of these five vegetable oils are shown in table 1 in comparison with Diesel fuel and lower fuel oil.

The results show that in comparison with lower fuel oil the kinds of vegetable oil do not differ too much in terms of density, but in comparison with Diesel fuel is about 10% higher. Flash Point is much higher than for Diesel fuel. The high flash point could make more difficult the ignition but it is favorable for transportation and handling that begin much safer.

Calorific value is nearly equal for usually used vegetable oils, excepting soy bean oil, but some percentages less in comparison to Diesel fuel; because of higher density the volumetric content of heat value is about the same and even exceed Diesel fuel.

Table 1 Characteristics of some vegetable oils and fuels usually employed in electricity and heat generation

Fuel Property		Crude vegetable oils					Diesel fuel	Lower fuel oil
		Rape seed	Soy bean	Sun flower	Corn germs	Bastard saffron		
Density at 15 ^{0}C,[Kg/dm^3]		0.918	0.919	0.918	092	0.92	0.84	0.90
Relative viscosity, 50 ^{0}C, [^{0}E]		2.68	2.59	2.81	2.71	2.74	1.2… ..1.7*	1.4*
Low calorific power	MJ/kg	40.24	39.39	39.37	39.22	39.64	42.7	40.6
	MJ/litre	36.96	36.22	36.15	36,08	36.47	35.7	36.5
Ignition point [^{0}C]		267	305.5	313	299.5	285.5	77	50
Sulphur content [% wt]		0.077	0.099	0.088	0.075	0.065	0.29	0.5
Carbon residual [% wt]		0.279	0.353	0.294	0.278	0.278	0.15	1.0

* Relative viscosity, 20 ^{0}C

For most vegetable oils the viscosity is higher than Diesel fuel. In order to have a good pulverization and efficient burning the heating is one of the measures to enable burners to run on vegetable oil.

A remarkable property is the low sulphur content, while normally vegetable oil does not contain sulphur, which reduces drastically the SOx emissions and the necessity of catalyst.

Others properties refer to the content of water, phosphorous and ash, carbon residue, contamination, oxidation. A water-vegetable oil emulsion, despite a difficult stability, can be favorable for burning. A high contamination can block filters and pulverization systems that impose filtering measures.

5 Numerical modeling of oil ignition and burning

For a better understanding of the ignition and burning of crude vegetable oil pulverized jet a numerical model of phenomena has been prepared, using Fluent software. The model has been based on a 2 MWt furnace, in Thermal and nuclear equipment chair laboratory. The ignition has been performed by aid of a natural gas flame.

A reduced flow rate of vegetable oil was utilized in order to evidence the ignition and burning process. Under this condition the volumetric thermal load of the furnace was lower and explains the thermal field and burning rate aspects. The entire quantity of the vegetable oil has burn quickly in the burner proximity. The temperature field is relative lower (1600 ÷ 1700) ^{0}C, as is shown in (fig. 3), and the maximum temperature field (2000 ÷ 2200) ^{0}C, is concentrated in small volume near the oil injection point. The flame was intense radiant and high emissive, as for conventional liquid oil. Naturally, for the rape seed oil the flame volume and the temperature field was higher than for sun flower oil, due to the higher carbon content

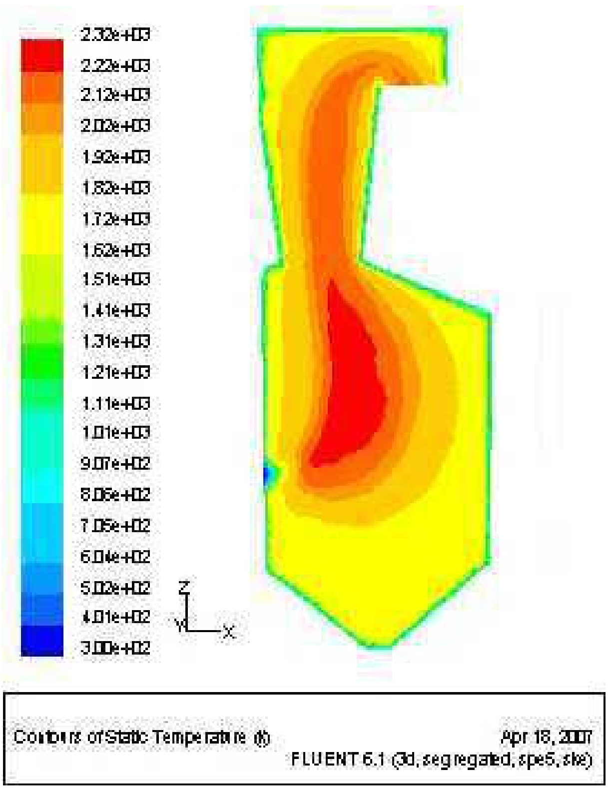

Fig. 3 Temperature field for rape seed oil burning

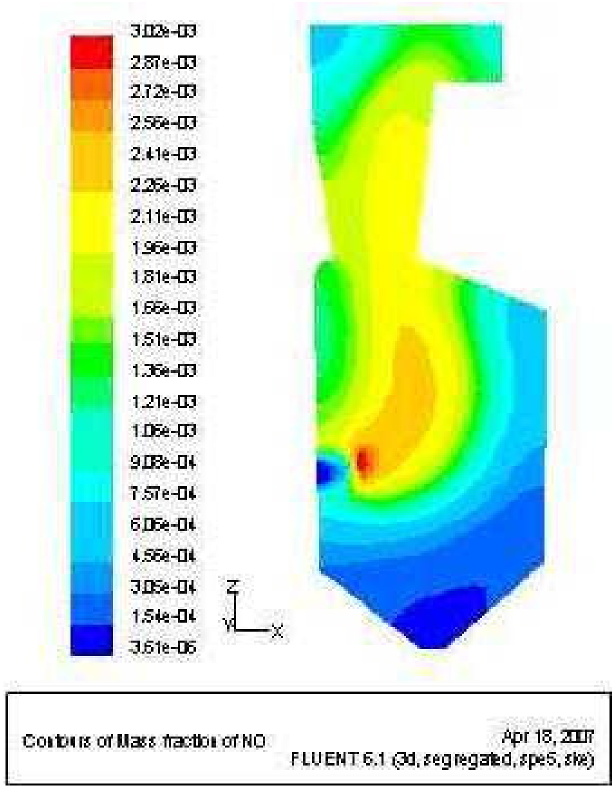

Fig. 4 Mass fraction of NO for rape seed oil burning

The measurements of the pollutant emissions for this particular operation conditions were lower, as is shown in (fig. 4) for NO mass fraction. Relevant results for pollutants will be obtained in the next stage of the experiments, for high thermal load. A direct increasing of the pollutant with temperature is expected.

5 Experimental research

The characteristics of crude vegetable oils that are rather different from traditional fuels impose complex research relative to ignition conditions, flame geometry and stability, deposits and pollutants. The aim of the experiments was to demonstrate that a pulverized jet of oil can be ignited and burned; in addition the ignition conditions can be determined [5].

5.1 Ignition of the vegetable oil droplet

The visualization of the ignition and burning of a single crude oil droplet was the beginning of the experimental research concerning to the ignition capacity of an atomized jet of oil. For that a series of oil droplets were gravitational launched in counter-flow in a natural gas flame, shown in (fig. 5.)

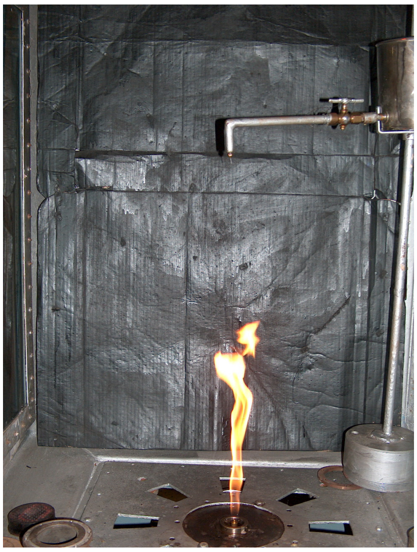

Fig. 5 Stand for ignition and burning of the crude oil droplet in natural gas flame

The droplet ignition point was visualized by a rapid change in flame color, the natural gas flame turning from blue to red-yellow color. In the same time the flame volume have increased. Unfortunately the relative grate droplet diameter and the short residence time in gas flame have made impossible the complete burning of the droplet. A finer droplet generation is necessary to obtain a complete droplet burning.

Despite of the incomplete burning these experiments have demonstrated the ignition capacity of the crude vegetable oil, in presence of an external flame and the possibility to burn vegetable oil in industrial burner.

Fig. 6 Gaseous and liquid fuels furnace view; Thermal and nuclear equipment chair laboratory

5.2 Ignition of a pulverized oil jet

The second experiment was thought in order to demonstrate the ignition property of a pulverised vegetable oil jet from a natural gas flame. The experiments were made on a gaseous and liquid fuels furnace of 1 MW thermal power, shown in figure 6.

The ignition temperature condition was ensured by the natural gas flame. An important condition was to keep the furnace in cold condition, so as the entire ignition tests were made in start up operation time of natural gas flame. In this way the ignition conclusions in cold furnace condition could be applied for a future application on the industrial furnaces.

For this experiment three kinds of crude vegetable oils were used: rape seed, corn germs and bastard saffron. The thermal power of the furnace was 160 kW corresponding to a natural gas rate of flow 15 m^3_N/h. The vegetable oil rate of flow was 15 kg/h that have ensured a thermal power of 550 kW for the burner. Figure 7 shows the flame aspects, for natural gas fuel and for a mixture of vegetable oil and natural gas.

a.

b.

Fig. 7 Flame aspects:
a – natural gas fuel; b – crude vegetable oil and natural gas mixture

The pulverization of vegetable oil was mechanically made, with a similar fineness as those for industrial liquid burners. The pulverization tests have shown a good operation, without problems caused by blockage. The average dimension of the droplets was (65…70)μ, the vegetable oil temperature 35 ^{0}C and viscosity about 3 ^{0}E.

For all three kinds of vegetable oils the test have made in evidence an easy ignition of the pulverised jet, without presence of smoke.

8 Conclusions

The first investigations and experiments concerning to some indigenous crude vegetable oils properties have demonstrated the possibility of energetically utilisation. This new utilization is similar to the conventional fossil fuels but imposes some specific adaptations of the energy conversion technology.

For five types of crude vegetable oils were determinate the main properties, notably: a high calorific value that means a high energy density, a lower content of sulphur that not cause acid rain when used, a high ignition point that increase handling security but cause ignition difficult and a high viscosity that could impose oil preheating and require technology adaptation in fuel injection/atomization.

Crude vegetable oils biofuels, as alternative fuels for stationary energy generation, offer several economic and social benefits: sustainability, reduction of greenhouse gas and other pollutant emissions, regional development, social structure and agriculture, security of supply.

The agriculture potential of oleaginous plants and the cost of feedstock are essential in the choosing of the energy crops sort, which could be utilized for electricity and heat generation. The present crops level, the industrial capacity and experience recommend sun flower and soy, but important recent investments are concentrated on rape plantations.

References:

1. European Renewable Energy Council: “Renewable Energy Target for Europe – 20% by 2020”
2. Chiaramonti, D., Tondi, G. “Stationary application of Liquid Biofuel*s*”, Final Report, Dec. 2003
3. Vaitilingom, G., Perilhon, C., Liennard, A., Gandon, M., “Development of rape seed oil burners for drying and heating” Industrial Crops and Products, Volume 7, Issues 2-3, January 1998, pp 273-279.
4. Thuneke, K., Widmann, B., Schön, H., “Operational Safety of CHP-Units fuelled with Vegetable Oil” Landtechnik 56 (2001), no. 5, pp. 334 – 335.
5. Oprea, I., Prisecaru, T., Mihaescu, L., Pisa, I., “Experimental research upon the ignition of vegetable oil pulverized jet”, National Conference on Classical and Nuclear Thermo-mechanical Equipment, Bucharest, 2007, 5-6 July 2007, pp. 83-87.
6. Romanian annual statistic reports 1990-2005