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Thermal Properties of Pomace Olives in a Composite Mixture

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Abstract

The olive oil extraction waste, including pomace and alzibar (liquid waste) can be a source of energy in commercial energy generation and heating. The possibility of using diesel, pomace and alzibar composite fuel in heat installations in the power industry as a composite of alternative fuels is limited by ratios of the component, homogeneity and fuel properties. The properties of the fuels and the effect of some chemical additives are presented including thermal comparative between the composite fuel and pure diesel. The article presents the possibility of using a composite fuel - code B2 (20% alzibar, 40% diesel and 40% Pomace) as an alternative for diesel with a high thermal efficiency. The results showed the effect of the added thermal activators such as ethanol in reducing the amount of the remaining results of fuel combustion process by adding 5% ethanol.

Keywords:
Thermal properties,
Diesel,
Pomace,
Mixture,
Alzibar,
ASAA,
Ethanol.

1. Introduction:

Fossil fuel has been the primary source of fuel ever since it was discovered and comes in the form of coal, petroleum and natural gas. With excessive usage of fossil fuel as source of energy, amount of fossil fuel around the world is declining at a rapid rate. With petroleum being the main source of fuel in automotive industry and power generation, this lead to price hike globally with the fastest depletion rate. Experts forecast that complete depletion of petroleum in the world is expected to happen in between 50 to 80 years depending on the consumption. (Musalam and Qaraman, 2016).

Fossil fuels have limited supply and the increasing cost of these fuels has led to the search of renewable fuels to ensure energy security and environmental protection. With increased interest in emissions and reduction of fossil fuels, considerable attention was focused on the development of supported resources, which decrease the consumption of Fossil fuel (Musalam, 2014). One of these supported resources is a waste of olive oil production, namely olive pomace and AlZibar.

Middle East is the primary diversification center for olive in the Mediterranean basin and Palestine respect as one of the producing countries of olive oil where it is an important base of its agricultural economy.

In Palestine, olives occupies about 45% of agricultural land produce 120,000 tons olive fruitful and about 25,000 tons of olive oil produced per year, which means that about 55,000 tons of pomace olive waste produced per year. Gaza produce about 2.6% of this quantity of olive oil.

This pomace olive can be used as a fuel, which means that, Palestine has an energy resource called olives pomace and this resource can be consumed for power generation (Table 1) (Abu Amro, 2016).

Table 1 *Statistic production of olive oil in Palestine*

Factors	Statistic
Olive fruitful production	120.000 tons
olive oil production	24,758 tons
pomace output	55.000 tons
Alzibar	8×10^5 m^3
Oil losses rate in pomace by dry weight	10.3%
oil losses in pomace	2400 tons
Phenol rate	0.5 -2.4 g / L

Source: (Aladham, 2012; Khatib, 2008).

The olive oil extraction process produces huge amounts of liquid waste called olive mill wastewater which called locally (Alzibar), which are produced within few months (October to December). The annual AlZibar production of the Mediterranean olive growing countries is estimated to amounts ranging from 7 to over 30 million m^3 (Niaounakis & Halvadakis, 2006). Olive mills in the Palestine generate about 800 thousand m^3/year of AlZibar (Aladham, 2012).
Al-Zibar is a mixture of vegetation water and soft tissues of the olive fruit and the added water used in the various stages of the oil extraction process. Typical AlZibar composition by weight is 83-94% water, 4-16% organic compounds and 0.4-2.5% inorganic compounds (mineral salts) (Niaounakis & Halvadakis, 2006).
Recent research revealed that there is a major contamination occurring through the olive oil production process. Olive mills wastewater Al-zibar, was found to be the highest source of environmental pollution in the countries of Mediterranean region (Alfano et al., 2009).
Despite its negative impact, The Al-zibar has large amounts of proteins, polysaccharides, mineral salts, and other useful substances for agriculture, such as humic acids, Al-zibar has a high fertilizing power. Therefore, Al-zibar might be used as natural, low-cost fertilizer available in large amounts. However the pH of this Al-zibar is acidic in nature (pH~ 4).
Wastewater from the different olive-mills located in and around the different villages in Palestine is being disposed of into the wadies. There, it is mixed with the untreated flowing municipal wastewater or with rainwater. The resulting high organic polluted wastewater affects the soil and water receiving bodies (Shaheen & Abdel Karim, 2007).

Another byproduct from olive extraction is pomace which called locally (Jeft) or the solid waste of olive processing, which is one of the solid residues of olive oil industry that consists of four main components: extractives, hemicelluloses, lignin (polyphenols), and mainly carbohydrate (specifically cellulose). This component will be mixed with the Al-Zibar as well as with the white powder from the stone factories to make a suitable mix as a fuel. The heating value of this material was measured as 24.5 MJ/kg which equivalent to 28212 TOE, (Tone Oil Equivalent) (Al-Hamamre, 2011) .
The research demonstrated that the olive pomace could be effectively burnt in fluidized bed with high combustion efficiency and very low emissions of unconverted gaseous and solid pollutants in a temperature range between 800 °C and 850 °C (Brachi, et al., 2015).
A stable and controlled flame is obtained in burning of pulverized olive byproduct mixture particles (Bounaouara et al., 2014), the combustion efficiency were improved as the percentage of pulverized olive byproduct mixture in the diesel fuel increased from 7% up to 20 wt % (Okasha, 1996).
Many countries around the world are using the pulverized olive byproduct mixture as a source of energy. As example, Andalusia, a region on the south of Spain, have promoted and built a plant to produce energy through the combustion of depleted olive pomace Biomass processes, 100.000 tons/year are used to generate 126.144.000 kWh/year (Brščić et al., 2009).

2. Materials and methods:

2.1 Materials:

1. Pomace olives powder (about 75 microns) Contain 46% fixed Carbon.
2. Alzibar water from olives, estimated rate of bio-oxygen ratio (45624.7) mg/L and rate of chemical oxygen (8999.7 mg/L), rate of total nitrogen (527) mg/L, total suspended solids TSS also increases to (16963.7) mg/L, rate of total suspended dissolved solids TSD (35212.7) mg /L (Schoenfeld, 2005).
3. Diesel with heat of combustion 4.01×10^4kJ /kg.
4. ASAA (Amido betaine Surface-Active Agent) are supplied from Merck and used as such.
5. Ethanol 95%.

Table 2 *Physical and chemical*

properties of olives pomace

Analysis size 2-4 mm	Value %
Oxygen	40
Carbon	46
Hydrogen	5
Nitrogen	0.8
Sulfer	0.1
Oil content	%10
volatiles	75
Ash	5-4
moisture	2
Heating value	23 MJ/kg

Source: (Miranda et al., 2008)

2.2 Instrumentation:

The following instruments are used for measuring the thermal properties of the (PFW) mixtures

1. Thermosensors connected with control panel
2. Camera
3. Milivoltameter
4. Muffle furnace
5. Mixer

2.3 Method of experimentation:

Preparation of Pomace-water fuel was completed by mixing different ratios of blended fuel (Table 3). The Pomace-water fuel (PWF) are prepared by dissolving 0.5 % of ASAA (by weight of Pomace olives powder) in alzibar then adding to the diesel- Pomace olives powder mixture.

The mixing is carried out under continuous and vigorous stirring for about 15 min in (8000 rev/min) mixer. Thorough stirring, the suspension was adjusted to a homogeneous mass state.

The thermal behavior of different blended fuel samples was carried out by the thermosensors and after the samples was completely burned the combustion residuals was weighted.

Table 3 *Different ratios of blended fuel*

Blended fuel	Diesel	Alzibar	Pomace olives powder
B1	40%	10%	50%
B2	40%	20%	40%
B3	40%	30%	30%
B4	40%	40%	20%

3. Results and discussion:

Atomization is the breakup of bulk liquid jets into small droplets using an atomizer or spray (Som et al., 2010). Adequate atomization enhances mixing and complete combustion in a direct injection engine and therefore it is an important factor in engine emission and efficiency. This applies to micro thermo-gravimetric turbine (Prussi et al., 2012). Feasibility of PWF as a renewable fossil fuel replacement for power generation, must also consider emissions of pollutants including oxides of nitrogen (NOx), oxides of sulfur (SOx), carbon monoxide (CO), and particulate. This is true for both emergency (backup) power and base load applications. Fuel stability still remains an issue during storage, a hurdle which must be overcome in order to maintain fuel quality. Combustion systems for environmentally preferred alternative fuels like PWF have yet to be fully optimized for emissions. As a result, the feasibility of PWF as a low emission alternative fuel option is still being evaluated (Bolszo & Mcdonell, 2009).

The atomization of fuel is crucial in the combustion and emission on engine but the atomization process in engine and in micro turbine are completely different. Both microturbine and diesel engine have the same fundamentals where both operate through combustion but the principle of the atomization process in the both cases varies because the fuel injector for microturbine and diesel engine are not similar. For microturbine, the combustion is continuous, so the fuel atomization in microturbine is continuous without any cycles or strokes. Atomization plays major role in combustion and emission in microturbine. By modifying the atomization process, the gas turbine can produce lower emission of nitrogen oxide (NOx) and carbon monoxide (CO). Adequate atomization enhances mixing and complete combustion in a direct injection gas turbine and therefore it is an important factor in gas turbine emission and efficiency (Tan et al., 2013).

Otherwise, the properties of a liquid fuel that affect atomization are viscosity, density and surface tension. The use of fuel with higher viscosity delays atomization by suppressing the instabilities required the fuel jet to break up. An increase in fuel density adversely affects atomization whereby higher fuel surface tension opposes the formation of droplets from the liquid fuel and some researchers (Biodiesel for Gas Turbine Application) analysis show that less viscosity of PWF is good to improve fuel atomization. This can be achieved by using an amphoteric surface active agent (ASAA) which effectively lowering the surface tension (Qaraman, 2016) and as a result lowering the viscosity of the blended fuel.

PWF has more massive fragments and less fine droplets than those of diesel fuel due to its high liquid viscosity, resulting in high mean droplet size. Consequently, it can be postulated that the breakup characteristic is strongly dominated by not only the surface tension but also the friction flow inside a droplet (Kim, et al., 2010). To increase the poor atomization of PWF fuel compared to diesel, ethanol as thermal activator can be blended together with PWF. This is because ethanol has lower kinematic viscosity with active interaction with ambient gas. In other words, blending ethanol with PWF will enhance atomization characteristics.

However, following research be conducted to achieve the optimum blend in terms of cost, environmental effect and availability. A brief commentary is provided on the principal influences of fuel properties on atomization quality.

The thermal behavior of different ratios of PWF is followed in thermo-gravimetric station, (Figure 1) under normal atmosphere pressure, to determine the appropriate ratio of a composite fuel.

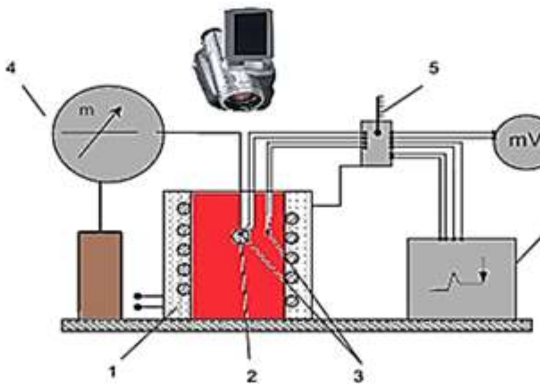
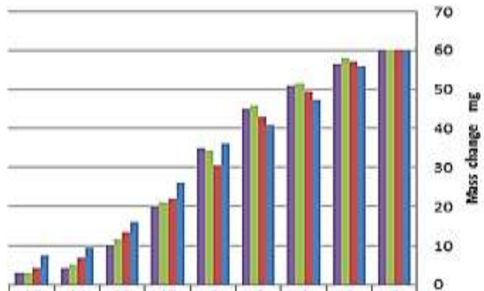


Figure 1 *Station Thermogravimetric*

1- muffle furnace; 2- PW F sample; 3- Thermocouple; 4- Mass Scale; 5- Thermometer; 6- Millivoltmeter; 7- Autographic

The thermal behavior of homogenize composite fuel drops is studied by prepare different ratios of composite fuel and determine the thermal behavior of each of them, The combustion process take place at atmospheric pressure and within 16 seconds, the results shown in (Figure 2).



Time t s	16	14	12	10	8	6	4	2	0
Temperature C	750	700	670	610	530	480	420	350	300
B1	7.6	9.5	16	26	36	41	47.5	56	60
B2	4.3	7	13.5	22	30.5	43	49.5	57	60
B3	3.12	5	11.5	21	34.5	46	51.6	58	60
B4	2.9	4.3	10	20	35	45	51	56.6	60

Figure 2 *Composite mixture mass changed by Temperature*

The results show that combustion residuals increase by increasing the pomace percent in fuel while it decrease by increasing the temperature and the time. The lowest residuals is achieved for B4 where the residuals reached 2.9 mg after 16 seconds at 750 C°. The actual change process of the fuel droplets combustion begin at 300° C.

This research aimed to increase the pomace ratios as much as possible, this because the economic goal of the research is to produce a cheap efficient fuel. The results show that no significant difference in the combustion residues between the B2, B3 and B4 mixtures so we will choice B2 due to its high content of pomace.

Therefore, we will focus to improve the thermal efficiency of B2 composite fuel by adding different additives to improve the thermal efficiency and reduce the residue resulting from the combustion.

Figure 3 illustrate that the combustion of diesel and Pomace oil included three stages (a, b, c) with low to moderate temperatures ranging from 400 to 800 k°. On the other hand, the composite fuel shows two stage only, the combustion temperature of second stage (d) is high and reaches about 1100 k°. According to the results, the composite fuel possess the highest combustion temperature compared with diesel and Pomace oil. The process takes place at a low intensity to achieve a high combustion temperature.

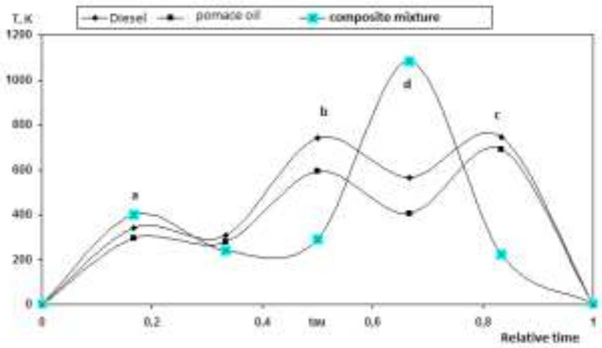


Figure 3 *Thermal comparison between the composite fuel, diesel and pomace*

A comparative thermo gravimetric study of the proposed properties of the composite fuel and diesel in high-temperature environment is taken place. A sample of each was placed into a furnace. The temperature in the furnace was adjusted to 600 K. The boiling point of the composite fuel reached T = 400 K at 16 seconds.

It is clear that there are three phases of combustion of both diesel and pomace. In diesel, the three phases refer to the combustion of the volatile components, light liquid and then the viscous liquid while in the pomace the phases refer due the combustion of the volatile matter, liquid and the solid components.

The composite fuel combustion have two phases only, the first phase refer to the combustion of the volatile components while the second refer to the combustion of the homogeneous liquid consisting of alzibar, diesel and fine pomace powder, this represent at d peak, which has the highest thermal efficiency. The previous results show that the composite fuel has more efficient thermal behavior than diesel alone.

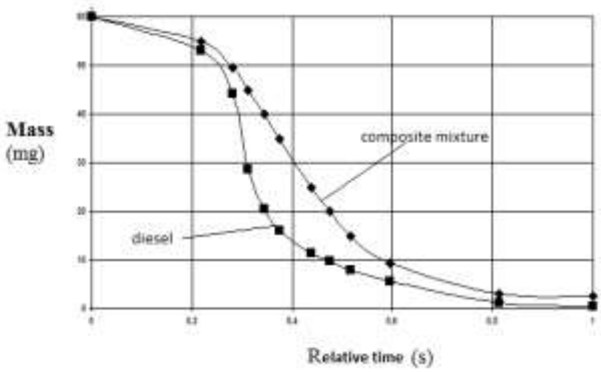


Figure 4 *Thermal change in mass of the composite fuel compared with diesel by time*

Figure 4 shows a thermal change in mass of the composite fuel compared with diesel by time, the main difference between diesel thermal behavior and the behavior of the composite concentrated in the center of thermal curve, in the distance of time of 0.2 to 0.6. In addition, it was found that the residue of the composite fuel combustion equal 2 mg, which it about 3% of initial composite fuel mass. The challenge now is to minimize the combustion residuals of the composite fuel as possible. To achieve this goal, the composite fuel is mixed with 5% ethanol as thermal activator. The new composite mixture thermal behavior is followed-up and compared with diesel.

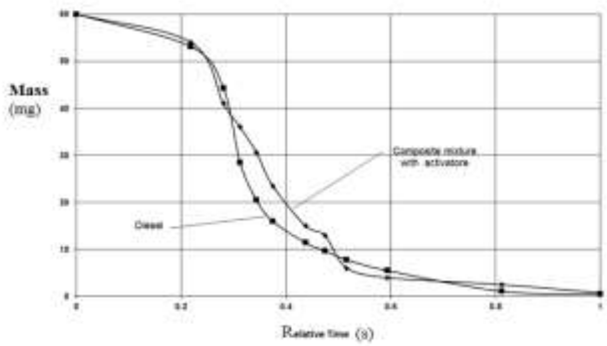


Figure 5 *Thermal change mass composite fuel with Acton compared to diesel by time*

Figure 5 shows the efficiency of adding the ethanol as thermal activator on the rate of combustion. The results improved that adding ethanol as an activator is already succeed to minimize the difference in the thermal behavior between the composite fuel and diesel with focus on the period of 0.2 to 0.6 s. On other hand the activator, minimize the combustion residue to less than one mg.

Conclusions:

From the previous results, it can be concluded:

1. Combustion residuals increase by increasing the pomace percent in fuel while it decrease by increasing the temperature and the time.
2. The composite fuel possess the highest combustion temperature compared with diesel and Pomace oil.
3. Adding the ASAA homogeneous the composite fuel combustion leading to produce two thermal phases only, the first phase refer to the combustion of the volatile components while the second refer to the combustion of the homogeneous liquid consisting of alzibar, diesel and fine pomace powder.
4. The results improved that adding ethanol as an activator is already succeed to minimize the

difference in the thermal behavior between the composite fuel and diesel beside its ability to minimize the combustion residue of the composite fuel to less than one mg.

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الخواص الحرارية لجفت الزيتون ضمن خليط مركب

تهدف هذه الدراسة إلى استغلال مخلفات استخراج زيت الزيتون مثل الجفت و الزيبار كوقود فعال معالج حراريا كمصدر للطاقة و لتدفئة. وذلك ضمن خليط مركب من جفت الزيتون و الزيبار و الديزل وذلك بدأ بإجراءات مقارنات حرارية بين الوقود الديزل و الوقود المركب للوصول الى خليط ممكن ان يكون قريب من الخواص الحرارية لوقود الديزل بحيث يمكن استغلاله في مجالات الحرارية المختلفة. اثبتت التجارب ان الوقود المركب B2 المكون من 20 % ماء الزيبار و 40% ديزل و 40 % جفت ممكن ان يكون بديل عن وقود الديزل النقي. كذلك اوضحت نتائج التجارب العملية وجود تأثير عند اضافة منشطات مثل الايثانول في تخفيض نتاج المتبقي من عملية الاحتراق وذلك بإضافة 5٪ ايثانول الذي يعمل ايضا على تسريع العمليات الحرارية.

كلمات مفتاحية:
العمليات الحرارية ،
ديزل،
جفت زيتون،
مركب،
الزيبار.