THERMAL CHARACTERIZATION OF JATROPHA BASED BIODIESEL BLEND WITH FOSSIL DIESEL USING TGA

by

MOHD NAJIB SA'AT
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FINAL PROJECT REPORT

Submitted to the Department of Mechanical Engineering
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for the Degree
Bachelor of Engineering (Hons)
(Mechanical Engineering)

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Department of Mechanical Engineering
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In partial fulfillment of the requirement for the
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Approved:

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Ir. Kamarudin Shehabuddeen
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

MAY 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Mohd Najib Sa'at

ACKNOWLEDGEMENTS

First and foremost, I would like to express my utmost gratitude towards Allah S.W.T. It is due to His will that I have been able to conduct this project and successfully finish it within the given time. My sincere appreciation goes to my supervisor, Ir. Kamarudin Shehabuddeen for his endless support and guidance throughout the whole process of this project from beginning till the end. His valuable advice, support and encouragement have helped me a lot during these two semesters.

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ABSTRACT

Application of Thermogravimetric analysis (TGA) to the renewable energy sources has becoming popular in recent year. TGA is commonly used to determine selected characteristics of material that exhibit either mass loss or gain due to oxidation or decomposition. Investigations on alternative fuels are conducted due to several reasons such as environmental pollution and global warming, increasing cost and the predicted reduction on conventional petroleum-derived fuel. *Jatropha curcas* is a nut belonging to the *Euphorbiaceae* family. It is cultivated in central and south America, South East Asia, India and Africa. In Malaysia, Wild *Jatropha curcas* tree is also known as *jarak pagar* particularly in Peninsular Malaysia area. *Jatropha curcas* tree which can easily be propagated by cutting is widely planted as a hedge to protect the field's erosion, as it is not browsed by cattle. In this project purpose is to study thermal characterization of *Jatropha* based biodiesel blend with fossil diesel by using TGA. Therefore, *Jatropha Curcas* biodiesel blends with Fossil Diesel at different percentages are exposed to isothermal heating under Nitrogen Gaseous with 20ml/min flow rate. The experiment used TGA with constant heating rate of 10°C/min from ambient temperature until 800 °C. However, the result stated that the mixed biodiesel had two stages decomposition, first decomposition is a diesel and second decomposition is *Jatropha Curcas* Biodiesel. The percentage rates of the biodiesel influence the second stage of the decomposition.

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NORMENCLATURES

TGA: Thermagravimetric Analysis

DSC: Differential scanning calorimetry

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND STUDY

Application of thermogravimetric analysis (TGA) to the renewable energy sources has becoming popular in recent year. According to Wikipedia TGA is a method of thermal analysis in which change in physical and chemical properties of materials are measured as a function of increasing temperature (with constant heating rate), or as function of time (with constant temperature or loss constant mass loss. TGA is commonly used to determine selected characteristics of material that exhibit either mass loss or gain due to oxidation or decomposition. In this project purpose is to study thermal characterization of *Jatropha* based biodiesel blend with fossil diesel by using TGA.

Biodiesel is an alternative fuel made from renewable biological sources such as vegetable oils both (edible and non-edible oil) and animal fats. Vegetables oils are usually ester of glycol with different chain length and degree of saturation. It may be seen that vegetable contains a substantial amount of oxygen in their molecules.

All countries are at present heavily dependent on fossil fuel for transportation and agricultural machinery. The fact that a few nations together produce the bulk of petroleum has led to high price fluctuation and uncertainties in supply for the consuming nation. The alternatives fuels being considered are methanol, ethanol, biogas and vegetable oils [2]. This project will focus on *Jatropha* based Biodiesel.

Jatropha, previously a neglected oilseed crop, has become the latest rage among global alternative energy corporations, given its tremendous potential as a viable and “cheapest” feedstock for biodiesel production. Interestingly, since the *Jatropha* fruit is non-edible, using it to produce biodiesel would not affect or be affected by demand for food, a major problem that is constantly faced by the palm oil-based biodiesel and corn “ethanol” industries.

1.2 PROBLEM STATEMENT

Investigations on alternative fuels are conducted due to several reasons such as environmental pollution and global warming, increasing cost and the predicted reduction on conventional petroleum-derived fuel etc. Biodiesel as a new energy source has drawn attention of many researchers. This study has been conducted in order to investigate the effect of biodiesel blending on combustion at different percentages of diesel. Therefore, Fossil Diesel and blend of biodiesel with fossil diesel at different percentages are exposed to isothermal heating with heating rate of 10°C/min using thermogravimetric analyser (TGA).

1.3 OBJECTIVES

The main aim of the study is to observe the combustion behavior of Jatropha based biodiesel and fossil diesel blends at different blending rates using TGA.

1.4 LIMITATION AND SCOPE OF STUDY

The input of this study will be focused more on thermal characterization of *Jatropha curcas* Biodiesel blend with Fossil Diesel using TGA.

CHAPTER 2: LITERATURE REVIEW

The world is moving towards an energy crisis because of the depleting reserve fossil fuels. In addition, the rapid rise in the use of fossil fuel is favoring this depleting. Besides, increasing fossil fuel price, emission of greenhouse gases and the security and diversity of energy are tending the scientist to turn their attention to find out alternatives sources of fuel. Biodiesel is one of the best sources of alternative fuel [3]. It is renewable and clean fuel for diesel engines. It is also called environment friendly as it nontoxic, biodegradable, safer to breathe and emits less greenhouse gases [4].

Jatropha curcas is a nut belonging to the *Euphorbiaceae* family. It is cultivated in central and south America, South East Asia, India and Africa. In Malaysia, Wild *Jatropha curcas* tree is also known as *jarak pagar* particularly in Peninsular Malaysia area. *Jatropha curcas* tree which can easily be propagated by cutting is widely planted as a hedge to protect the field's erosion, as it is not browsed by cattle. *Jatropha curcas* can grow well under such adverse climatic because of its low moisture demands, fertility requirement and tolerance to high temperatures [5].

Figure 2.1: *Jatropha* seed.

The plant that is generally cultivated for the purpose of extracting *Jatropha oil is Jatropha curcas.* The seed are primary source from which the oil is extracted. Owing to the toxicity of *Jatropha* seeds, they are not used by humans. The major goal of *Jatropha* cultivation is performed of extracting *Jatropha* oil. Analysis of *Jatropha* curcas seed shows the following chemical compositions:

- Moisture: 6.20%
- Protein: 18.00%
- Fat: 38.00%
- Carbohydrates: 17.00%
- Fiber: 15.50%
- Ash: 5.30%
- The oil content is 25 -30% in the seed. The oil contains 21% saturated fatty acids and 79% unsaturated fatty acids. These are some of the chemical elements in the seed [6]

Density, viscosity, heating value, flash point, acid value, pour point, cetane number, etc. are considered as the most important properties of a fuel for its application in engine. These properties indicate the quality of the fuel. Engine performance and emission are also directly related to these. There are different types of standard like ASTM, EN, ISO, etc. to define the limit of each of the fuel properties. Among them ASTM is the most widely followed standard. To meet the standard engine performance and emission, the value of the fuel properties must be in the range. In this regard study of fuel properties are the most important part to use any liquid as fuel. Now-a-days, blending is widely being used to improve biodiesel fuel properties. Sometimes biodiesel from two or more feedstock are blended to improve the properties. Use of more feedstock can easily improve fuel properties rather than two because most of the important fuel properties like density, kinematic viscosity, oxidation stability, flash point, calorific value and cetane number vary linearly in case of multiple fuel blends [11–14]. The most widely used vegetable based biodiesel fuel properties are discussed. Table 1 contains fuel properties of seven discussed vegetable based biodiesels.

Table 2.1: Fuel properties of ordinary diesel and common vegetable based biodiesel.

Properties	Kinetic viscosity 40 °C (cSt)	Density (kg/m^3)	Cetane number	Calorific value (MJ/kg)	Flash point (°C)
ASTM limit	1.9–6	-	47 minimum	-	130 °C minimum
Diesel	2.5–5.7	816–840	45–55	42–45.9	50–98
Jatropha	3.7–5.8	864–880	46–55	38.5–42	163–238
Palm	2.95–4.92	843–890	49–65	38.73–40.39	135–259
Coconut	2.61–4.1	844–930	51–60	35–38.1	112–241.5
Cottonseed	4–4.9	874–885	51.2–55	40.32–42.73	70–110
Sunflower	4.5–5.9	877–882	49–52	39.7–40.56	85–178
Soybean	4.08–4.97	884–896	40–53	38.31–39.76	69–144
Canola or rapeseed	4.2–4.5	837–886	49–52.9	36.55–40.5	94–183

Kinetic Viscosity of the biofuel as define fuel flow sprays and atomization characteristics are directly governed by the kinetic viscosity of the fuel. Higher viscosity increases fuel pump power consumption and causes poor spray and atomization and also increases fuel consumption. In these respects, lower viscosity is desired. Density and viscosity are directly proportional to each other. Higher density increases energy concentration of fuel and minimizes fuel leakage. It also influences the fuel atomization efficiency.

This oil can be easily processed into fuel that can replace or mixed with petroleum based diesel. This will relate to savings on imported petroleum oil. As potential source for biodiesel, the *Jatropha* plant can produce an oil content of 30-58%, depending on the quality of the soil where it is planted. Its seeds yield an annual equivalent of 0.75 to 2 tons of biodiesel per hectare.

The benefits of *Jatropha* as biodiesel include the reduction of greenhouse gas emissions, as well as the country's oil imports. Local production of *Jatropha* is also practical because as a non-food crop, it will not compete with food supply demands. It can also grow on marginal degraded land, leaving prime agricultural lots for food crops while at the same time restoring the marginal and degraded land's fertility. All of these benefits can possibly be achieved by the presence of this locally fabricated high efficiency *Jatropha* oil extractor equipment.

The reason why *Jatropha* was chosen as the fuel-source crop over other plants is because of its several advantages:

- It can thrive under adverse conditions;
- It is not eaten by animals;
- It is a vigorous, drought and pest resistant plant and when planted as a fence repels rodents and has phytoprotective action against pests and pathogens and thus provides additional protection to intercropped plants.

The first consideration is its economic aspect. If the crude oil is not widely available, it cannot be used as engine fuel. Engine performance is the next parameter which indicates whether a fuel is economical or not. Brake power, brake specific fuel consumption (BSFC) and brake thermal efficiency are the performance indicators for engines. Not only fuel properties but also fuel injection pressure and timing, air-fuel mixture, amount of injected fuel, fuel spray pattern etc. affect engine performances. Usually engine brake power, brake torque and BSFC are tested against load or speed. Engine performance parameters for different biodiesel and their blends are discussed here:

I. *Jatropha* Biodiesel

Most of the experimental results have shown that *Jatropha* biodiesel and its blends yield higher thermal efficiency at higher fuel consumption. Its blends often produce more brake power than petroleum diesel. However, in some cases, lower efficiency was also found.

II. Palm oil Biodiesel

Palm biodiesel usually gives lower power, torque and thermal efficiency at higher fuel consumption. But in some cases, it gave higher thermal efficiency and lower fuel consumption than petroleum diesel [4]

2.1 Thermal Gravimetric Analysis

Thermal gravimetric analysis (TGA) uses a highly sensitive balance to monitor the weight loss of a sample vs time, temperature, and gas environment. This project is using TGA in order to measure the mass loss of the fuel and fuels behavior. The other ways to study thermal characterization is by using DSC. The both application are useful for the study of thermal degradation [1].

Figure 2.2: The example of thermal gravimetric analyzer. Source from http://www.materials.co.uk

Thermogravimetric techniques have a very wide field of application. The technique can be used in the examination of absorptive surfaces, together with the nature and processes involved in thermal decomposition and oxidation processes. TGA are used in order to examination of water of crystallization and in forensic work involving the identification and comparison of varnished and other surface coating. TGA also can be used for determining the age of art treasures, particularly paintings and in determining the stability of explosive.

2.1.1 The Working Principle of TGA

TGA instrument can be divided into two general types which is vertical and horizontal balance. Vertical balance instrument have a specimen pan hanging from the balance or located above the balance on a sample stem. Besides that, the horizontal balance instruments normally have two pans (sample and reference) and can perform DSC measurement. The measurement is normally carried out in air or in an inert gas atmosphere such as Helium or Argon, and the weight is recorded as a function of increasing temperature. In order to slow down the oxidation the measurement is performed in a lean oxygen atmosphere (1 to 5 % O_2, in N_2 or He). In addition to weight changes, some instrument also record the temperature difference between the specimen and one more reference pans (differential thermal analysis) or the heat flow into the specimen pan compared to that of reference pan. The latter can be used to monitor the energy released or absorbed via chemical reactions during the heating loss process.

CHAPTER 3: METHODOLOGY

3.1 Research Methodology

In this phase, it is divided into five different stages. The project begins with some preliminary research work. The process continues with the critical review based on the identified literature objectives and followed by testing and evaluating the work. Next is the stage where result analysis and discussion being done with some space for improvement if necessary. The final stage will be the final documentation pile up everything from beginning until the last stage together with the outcomes of the project.

3.1.1 Preliminary Research Work

This stage focusing more on data collection related to the project. It involves compilation of information gained from various journals, books and technical paper associated with the topics. Great understanding particularly in thermal characterization of *Jatropha* oil blend with fossil diesel using TGA are obtained from a thorough research pertained to that project. This information will be used in conducting literature review and further stage of the project.

3.1.2 Critical Review Work

Based on the information earned form the research, critical review of the information gathered will be done in order to summarize and evaluates all the important. This process is crucial as it will give the author the necessary input about the project and sufficient scope of research in order to continue the work in later stages.

3.1.3 Experiment Sample of Biofuel

After completing all previous stages of work, the samples determined are 10% and 20% of *Jatropha* Curcas Biodiesel. The sample preparation is the 10ml of volume has been set, the 10% of *Jatropha* curcas biodiesel is a 1ml of *Jatropha* curcas biodiesel and 9ml of fossil diesel. The sample tested using Pyris 1 TGA machine exposed isothermal heating rate 10°C/min with Nitrogen gas from ambient temperature to 800 °C.

3.1.4 Result Analysis and Discussion

During this phase, the data will be analyzed and evaluated by supervisor and experts. The result provided should meet and satisfy all the requirements of the project. Some modification for improvement could be made if necessary before entering the final stage. This analysis will use Pyris 1 TGA model that can define weight and time or weight and temperature. The study of thermal characterization of *Jatropha* biodiesel blends with fossil diesel, the weight of the specimen which is the different ratio of weight as define independent variable. The getting result will show the flash point of the substances. The chemical reaction made to define the atomic mass of the *Jatropha* biodiesel and fossil diesel. The sample will analyze with heating rates 10°C/min. The sample will give to the lab technologist for analyze using TGA monthly for two sample due to the TGA machine are not suitable for fluid sample.

3.1.5 Final Documentation

All the works related to this project will be documented in a proper manner for future use. In order to keep the individual responsible for the project on track and ensure the project to meet the necessary requirements, the documentation process will be done continuously. The flow chart of the research methodology is shown at the next page.

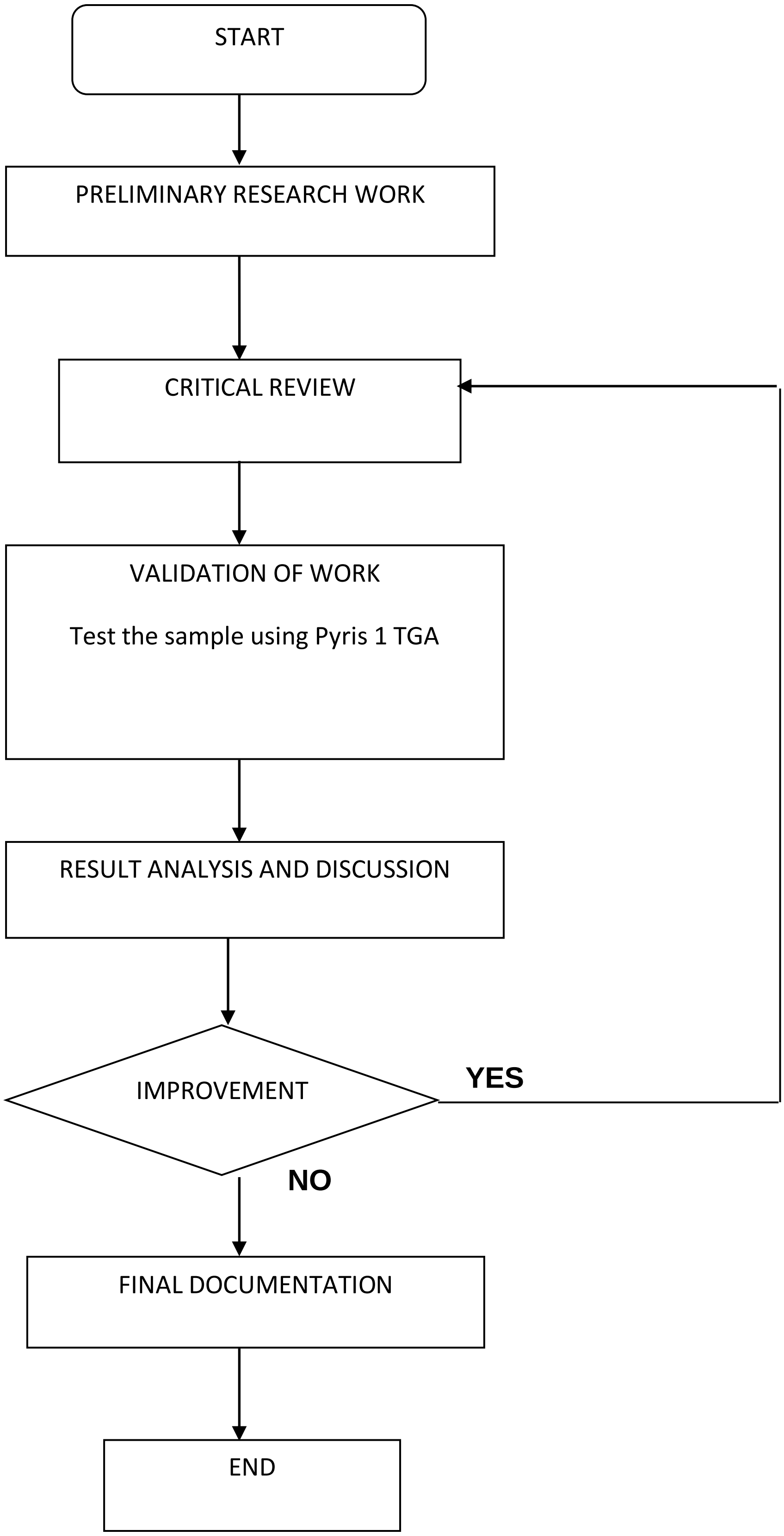

Figure 3.1: Project Flow Chart

Semester May 2013

No	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Preliminary Research Work	■	■													
2	Lab Arrangement			■	■	■	■	■								
3	Preparation of Samples					■	■									
4	Submission of Samples						■									
5	Data Collection									■						
6	Analysis & Discussion of result										■	■	■			
7	Final Report Writing													■	■	■

Figure 3.2: Gantt chart

Project Milestones

		FYP 1					FYP 2				REMARKS
		J	F	M	A	M	J	J	A	S	
1	FYP Title Selection	◆									Completion of Title selection
2	Submission of FYP Title Proposal		◆								Completion FYP title proposal
3	Submission of Extended Proposal			◆							Completion extended proposal
4	Proposal Defend				◆						Completion proposal defend
5	Submission of Draft Report				◆	◆					Completion draft report
6	Submission of Interim Report					◆					Completion interim report
7	Lab Arrangement						◆				Completion lab arrangement
8	Preparation of Samples						◆				Completion preparation of samples
9	Submission of Progress Report						◆				Completion progress report
10	Submission of Samples							◆			Completion submitted samples
11	Data Collection							◆			Completion data collection
12	Analysis & Discussion of Result							◆			Completion Analysis & discussion of result
13	Pre-SEDEX Presentation								◆		Completion of Pre-SEDEX
14	Submission of Technical Paper									◆	Completion technical report
15	Submission of Final Report									◆	Completion final report

3.2 Validity & Suitability of Data

This project is using TGA machine model Pyris 1, in order to complete the testing of *Jatropha* curcas biodiesel blend with fossil diesel, the sample of the mixed biodiesel was conducted, the apparatus used are syringe 3 ml and 5 ml and the specimen container. The mix of the fossil diesel and biodiesel is defined by volume percentage of the oil. The 10 % of *Jatropha* curcas biodiesel means in the specimen container, the 1ml of *Jatropha* curcas biodiesel and 9 ml of fossil diesel. The *Jatropha* curcas biodiesel in this project provided by supervisor meanwhile, fossil diesel find from petrol station.

Figure 3.3: Specimen container used for store the mixed biodiesel.

Figure 3.4: Syringe used to measure the volume of oil to be mix.

The mixed of the *Jatropha* curcas biodiesel and fossil diesel are prepared for 10%, 20%, 30% and 40% of *Jatropha* curcas biodiesel. The sample is ready to be test with TGA and DSC machine, the sample is keep with room temperature and avoid from vaporize.

Figure 3.5: Sample prepared and keep in room temperature.

The Pyris 1 machine has been set with flow rate of Nitrogen gas is 20 ml/min. The sample of the mixed *Jatropha* curcas and fossil diesel was in the range of ≈ 5 mg weight. Samples were heated between ambient temperatures to 800 °C with preset heating rate 10 °C/min. The isothermal heating conducted at 20ml/min flow rate of Nitrogen gas. Weight loss versus temperature data were continuously collected by Pyris 1 TGA machine data analysis system.

CHAPTER 4: RESULT & DISCUSSIONS

4.1: 10 % of mixed Biodiesel result (Data on Appendix)

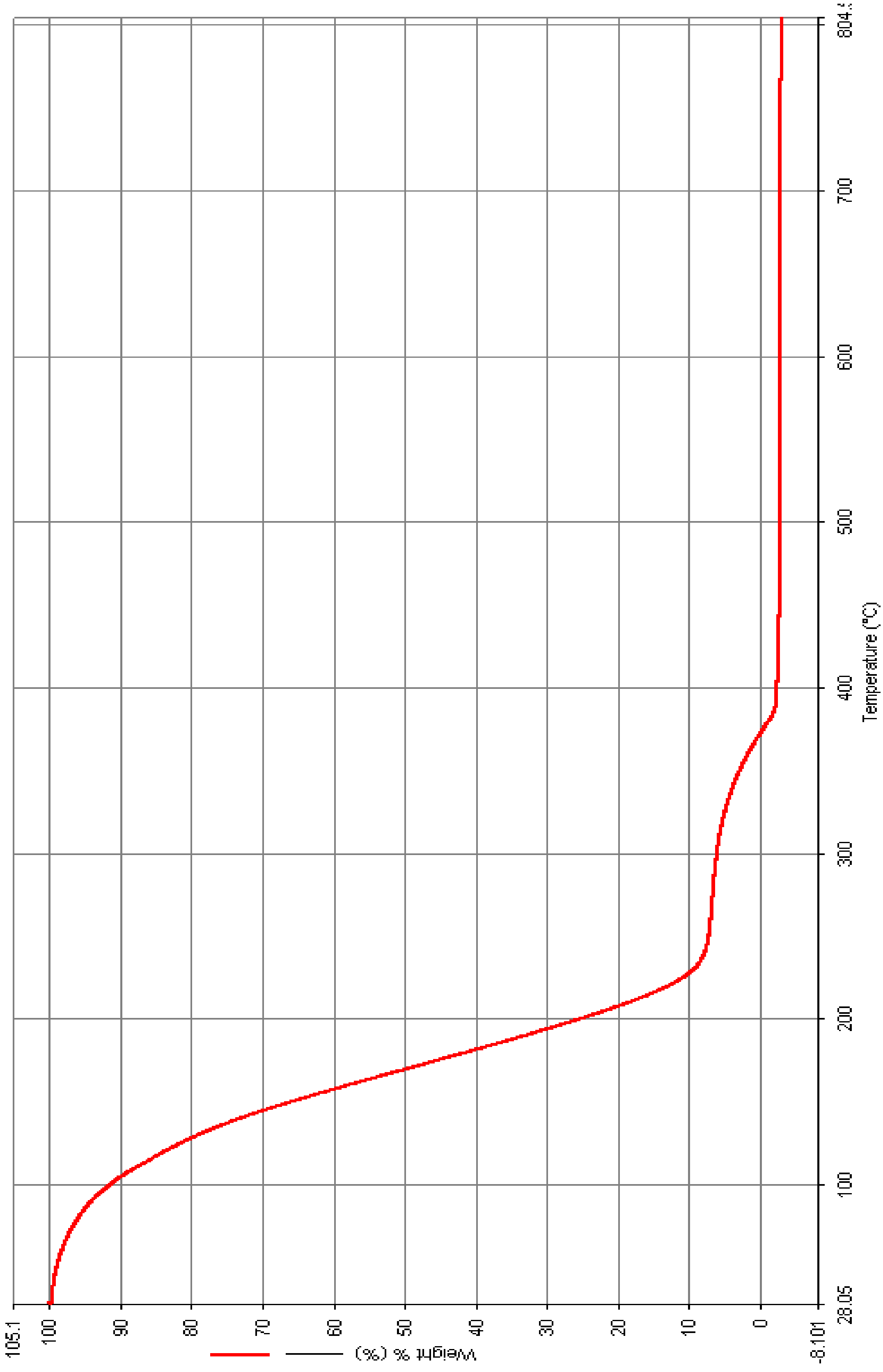

Figure 4.1: Weight vs Temperature of 10% mixed biodiesel

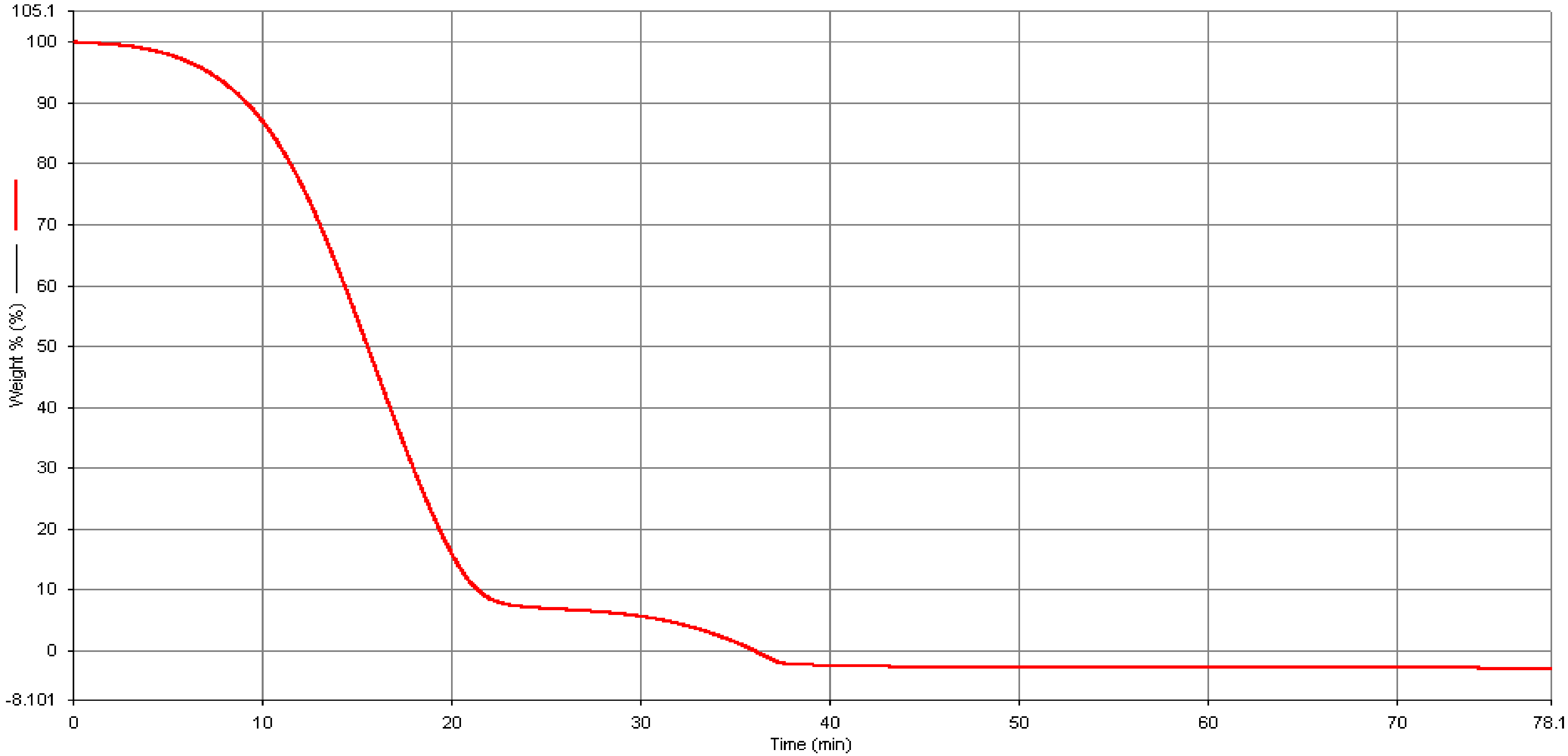

Figure 4.2: Weight vs Time(min) of 10% mixed Biodiesel

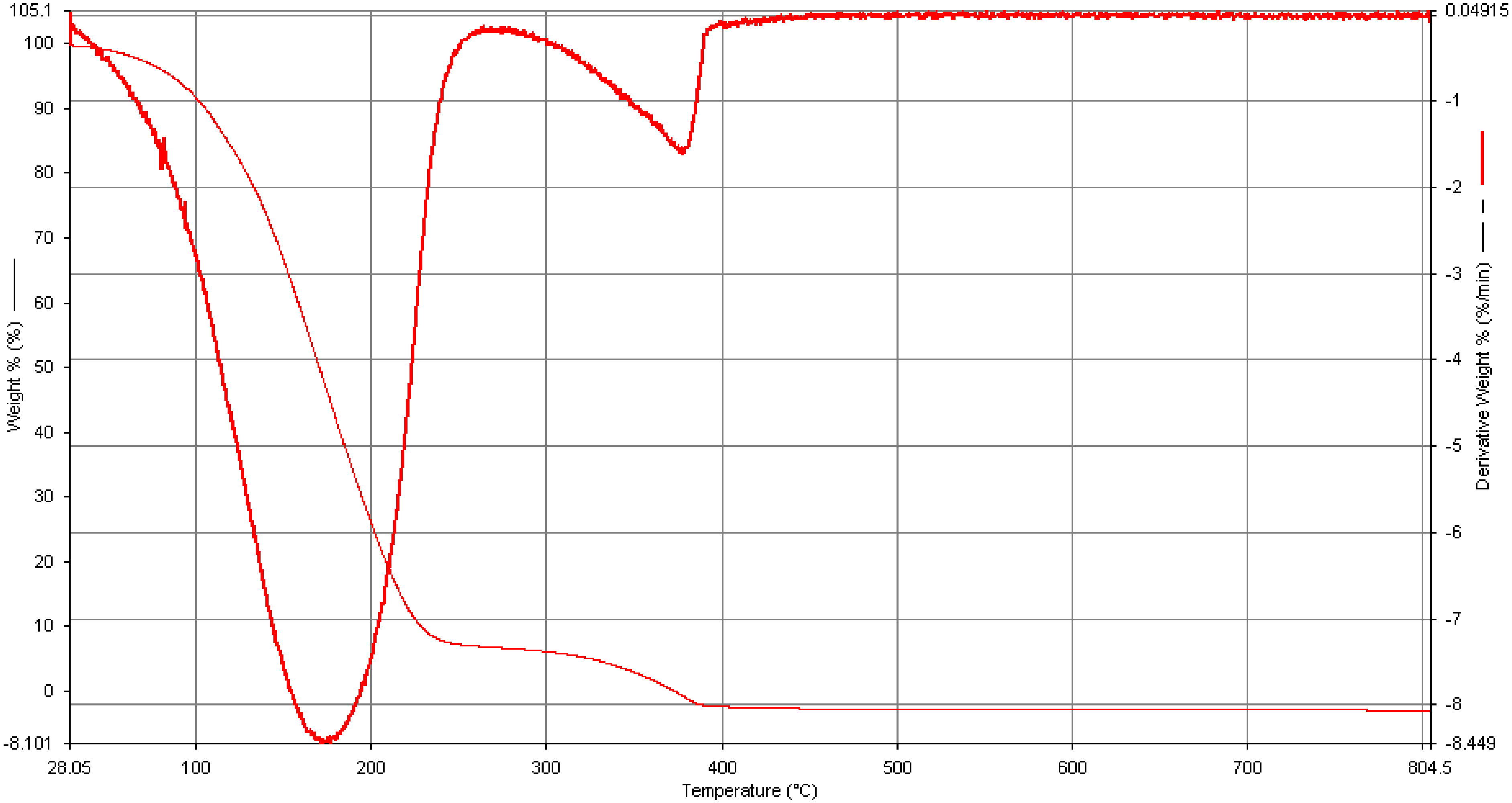

Figure 4.3: Derivatives weight of 10 % mixed Biodiesel

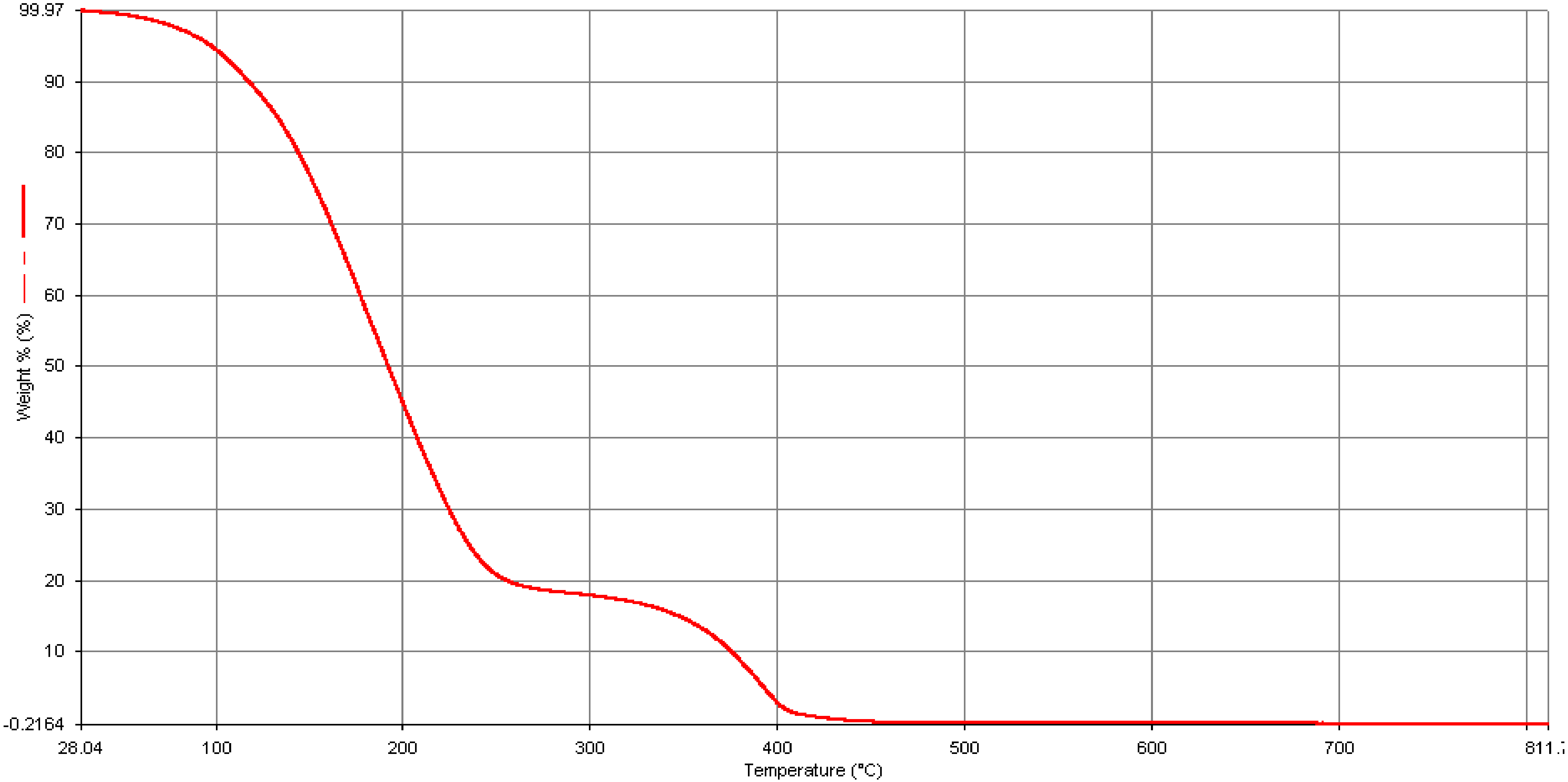

Figure 4.4: Weight vs Temperature of 20% mixed biodiesel

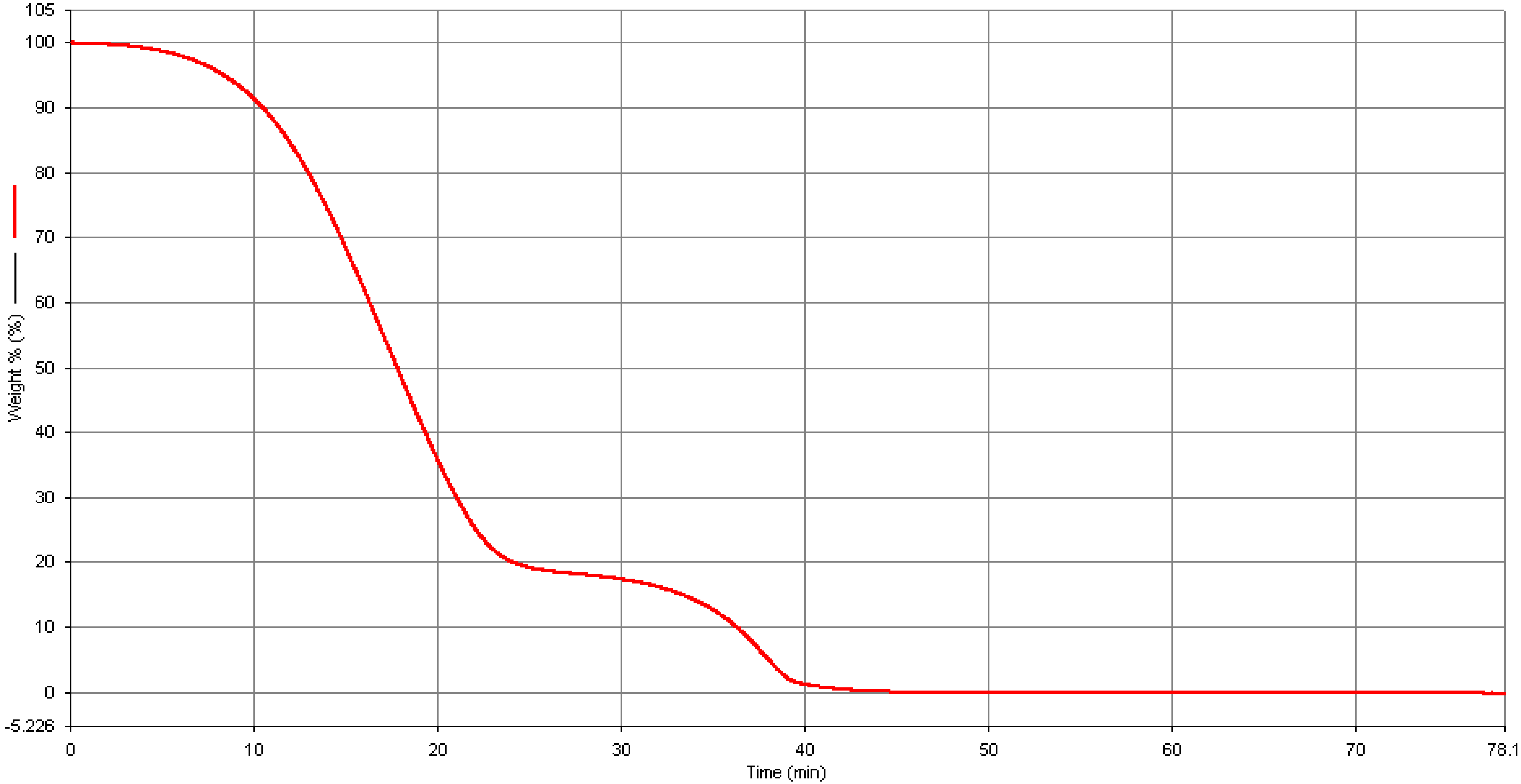

Figure 4.5: Weight vs Time(min) of 20% mixed Biodiesel

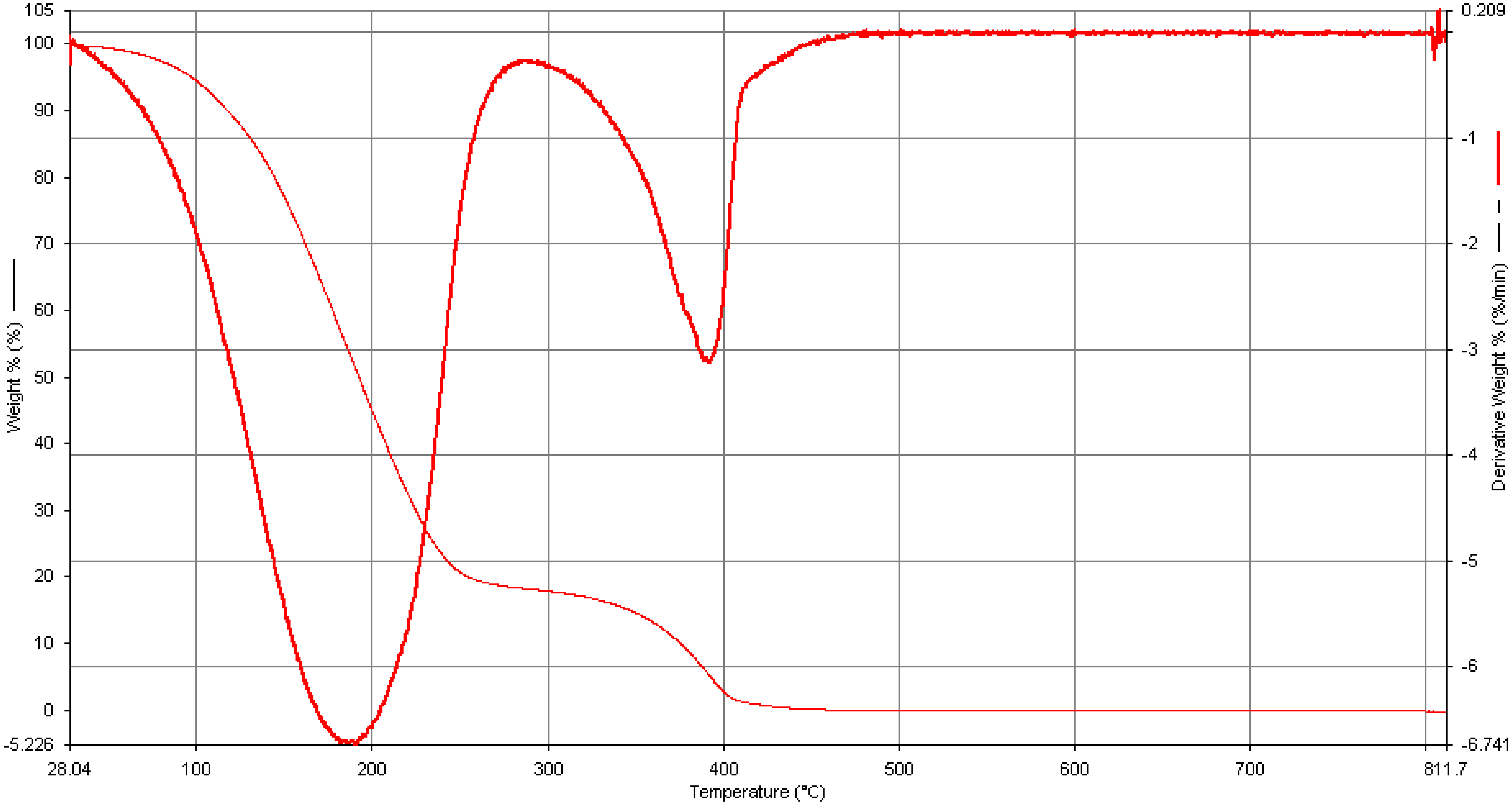

Figure 4.6: Derivatives weight of 20 % mixed Biodiesel

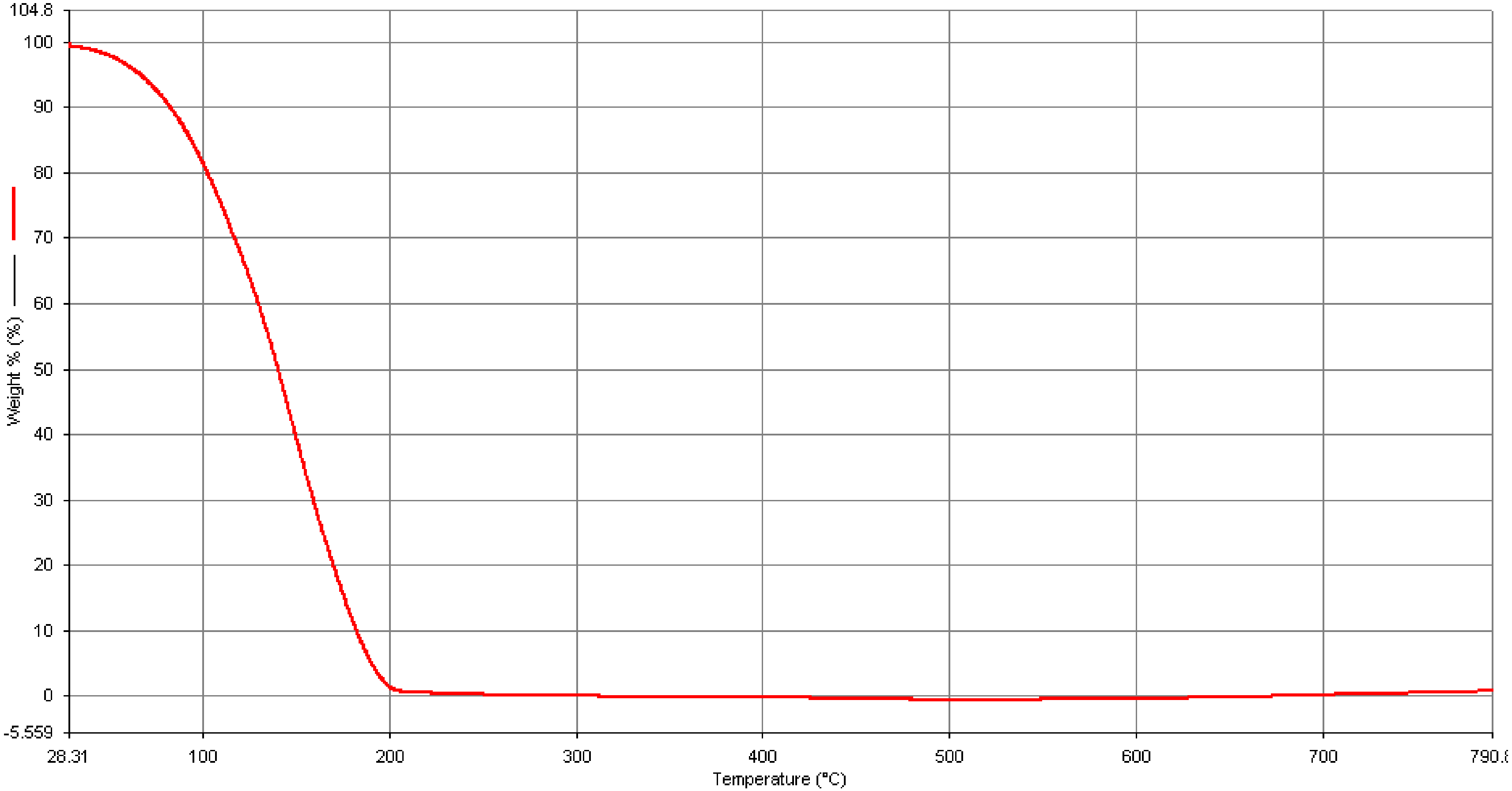

Figure 4.7: Weight vs Temperature of Pure Diesel

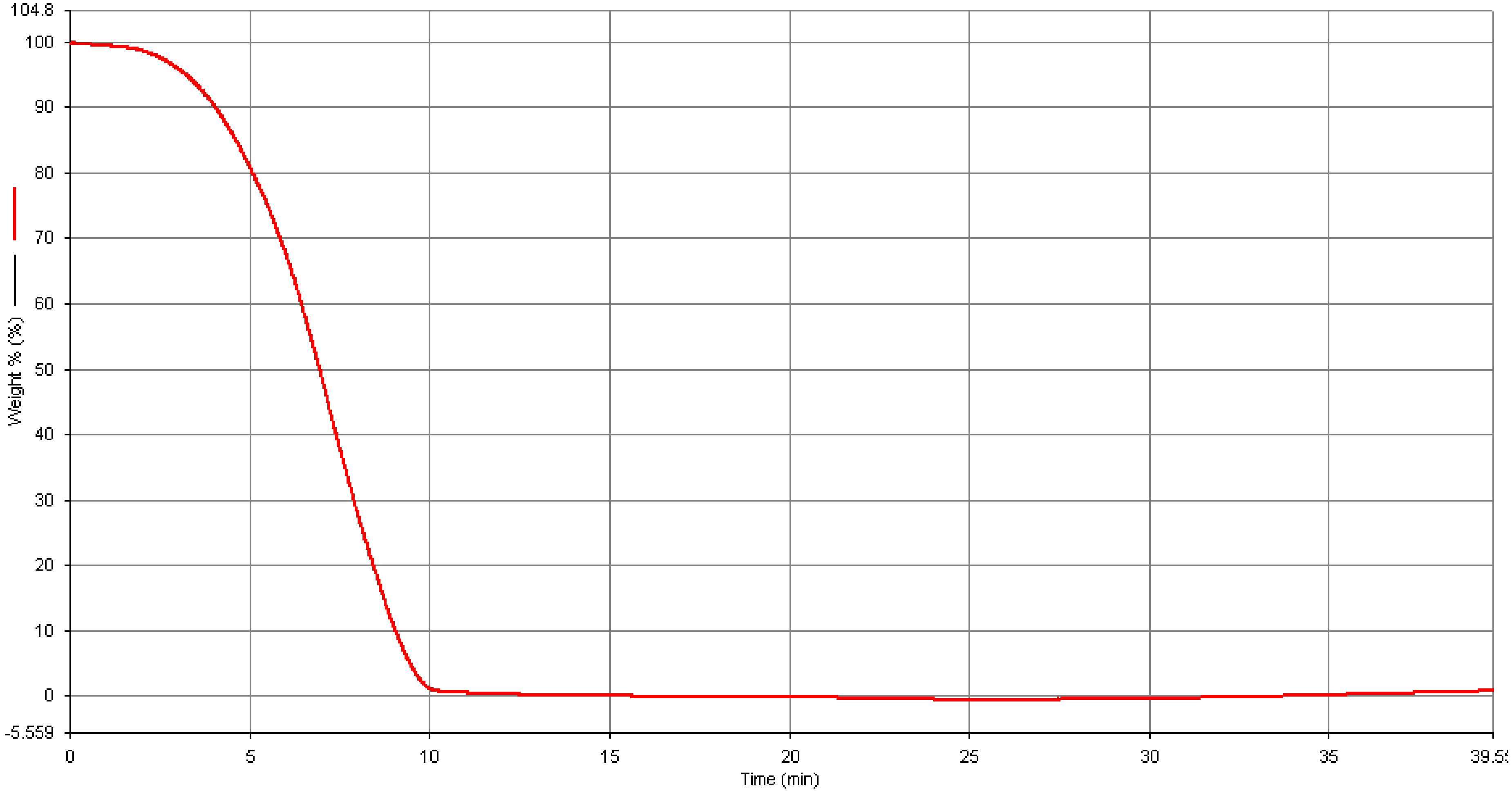

Figure 4.8: Weight vs Time(min) of Pure Diesel

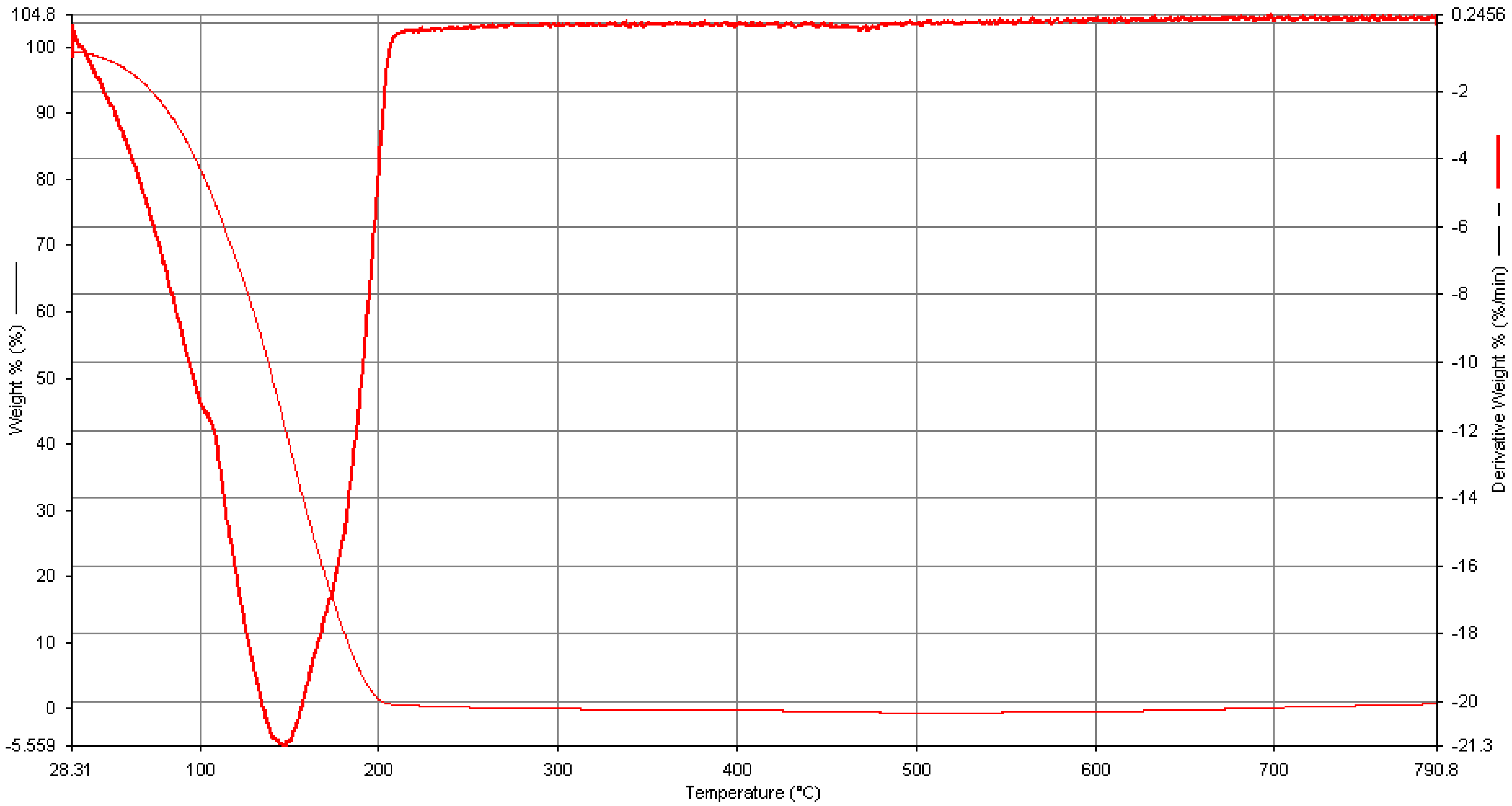

Figure 4.9: Derivatives weight of Pure Diesel

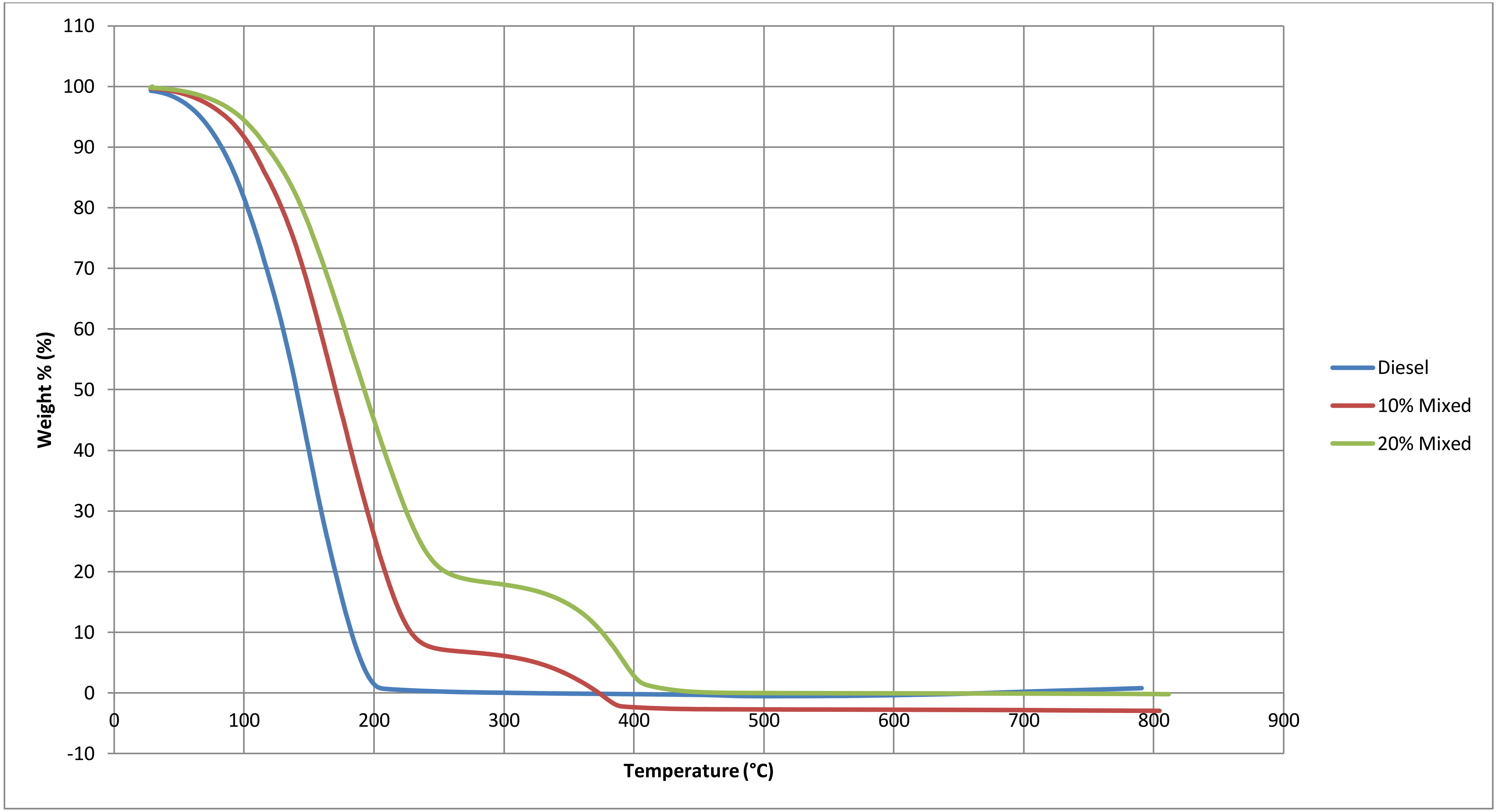

Figure 4.10: Weight vs Temperature (Diesel, 10% & 20 % Mixed Biodiesel)

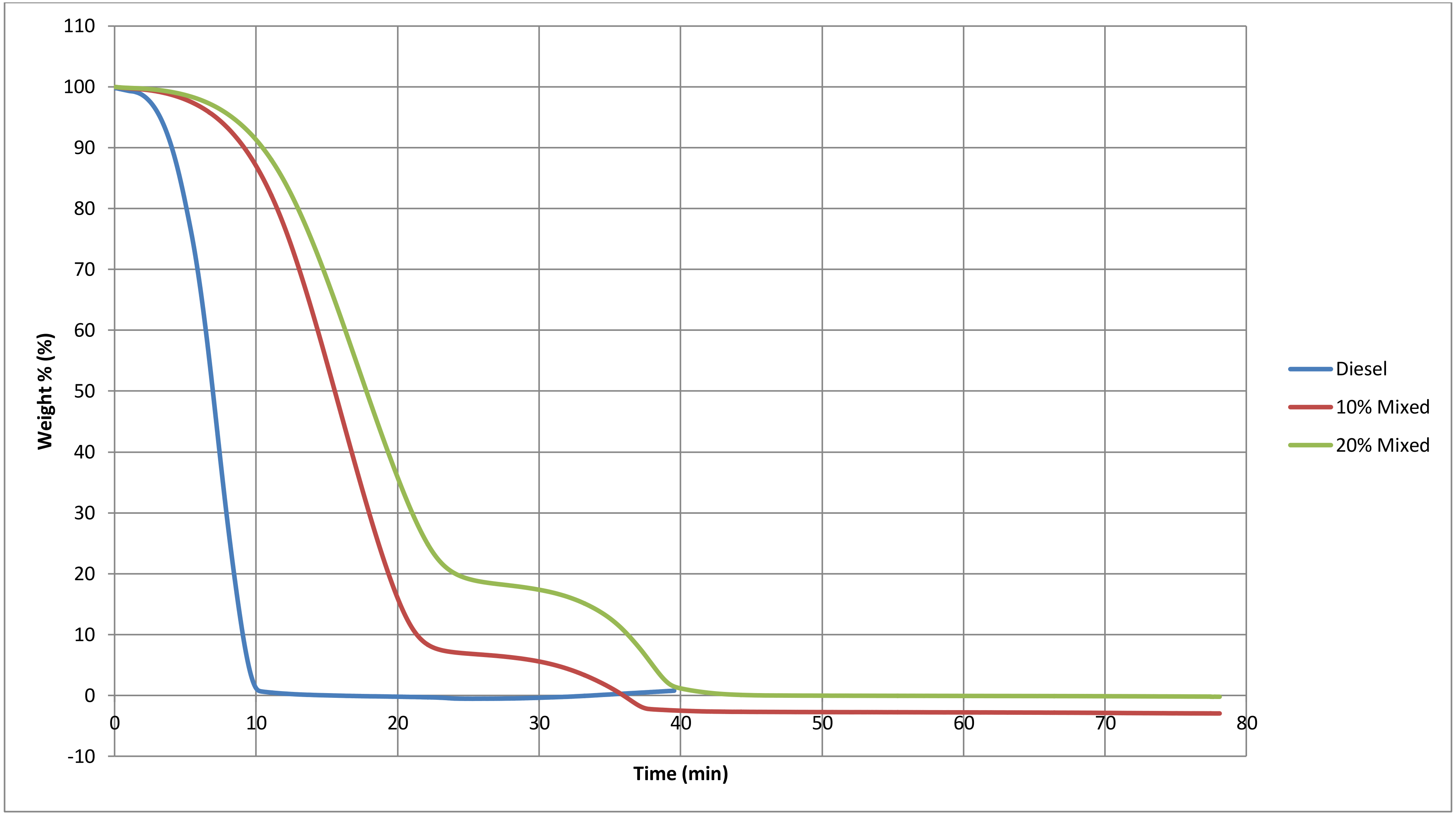

Figure 4.11: Weight vs Time (Diesel, 10% & 20 % Mixed Biodiesel)

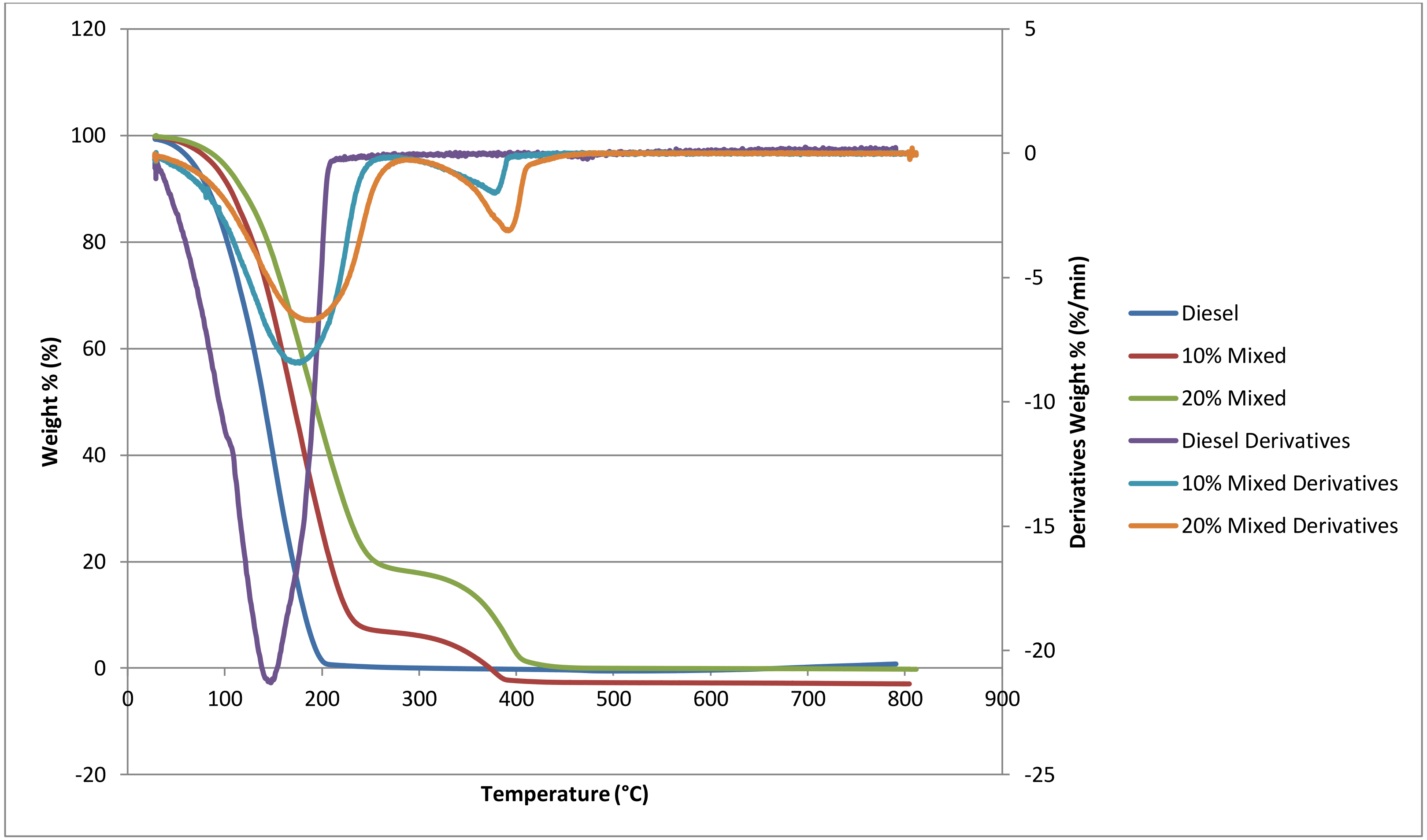

Figure 4.12: Derivatives Weight (Diesel, 10% & 20 % Mixed Biodiesel)

DISCUSSIONS

The weight losses for the 10% mixed biodiesel are shown in Figure 4.1. These shown the first decomposition of the biodiesel at 97 °C this same change trend continue until the second decomposition at the range 90–230 °C. The second decomposition occurred at the range 230-380 °C. These curves exhibit the trend firstly slowness, intermediately rapidness, slowness, intermediate rapidness and at the last slowness. This experiment temperature range is from ambient temperature until 800 °C. The measurement of the first decomposition is 92% of weight and second derivatives is 8%.

The second data from figure 4.4, 4.5 and 4.6 is the 20% mixed biodiesel. The first decomposition is almost the same of the 10% mixed biodiesel. The parallel of the substance is to start to combust at 95 °C and range of the first derivatives is 90°C until 250 °C. However, the second decomposition temperature is 250 °C until 400°C the major contrast of the 20% mixed biodiesel is the weight of the substance start to combust is 20% of the total weight mixed 20% Biodiesel, is shown that the second derivatives is a *Jatropha* based biodiesel.

Hence, the pure diesel data is used to compare the mixed *Jatropha* and the pure diesel. The pure diesel data is on figure 4.7, 4.8 and 4.9. In fact the data shown that the pure diesel is single decomposition and start to combust at 96 °C until fully combusted at 210 °C.

Table 4.1: Substances temperature start to combust

Substances	First Decomposition		Second Decomposition	
	Temperature	% of Weight	Temperature	% of Weight
10 % Mixed Biodiesel	97 °C	92%	230 °C	8%
20 % Mixed Biodiesel	95 °C	80%	250 °C	20%
Pure Diesel	96 °C	100%	N/A	N/A

Table 4.1 shows that the range of the diesel start to combust is 96 °C, this is a first decomposition of the substance and the second decomposition show that only mixed biodiesel have it. This result proves that the second decomposition is a *Jatropha* biodiesel start to combust at 240 °C. The two different substances with different flash point, density and viscosity shows in the TGA result, the substances combust separately with two different temperatures.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

The objective of this project to observe the combustion behavior of *Jatropha Curcas* Biodiesel and Fossil Diesel at different blending rates using TGA is achieved. The mixed *Jatropha* biodiesel and fossil had two stage of the decomposition and is proved that the first decomposition is a substance of diesel and the second decomposition is a *Jatropha* Biodiesel this correlative data is from the combustion behavior of the pure diesel. The two substances had a two different temperature start to combust due to different flash point, density and viscosity substances. The percentage of the mixed biodiesel influences the percent of the substances for the second stage of decomposition. The temperature range of the Diesel start to combust is 90 °C ~ 100°C and the temperature range of the *Jatropha Curcas* Biodiesel start to combust is 220 °C ~ 270 °C.

The recommendation of this project finding that the equipment of the other experiment such as Bomb Calorimetric Analysis, Density Test, Deferential scanning calorimetric (DSC) and other is not work properly and is restrict for any fluid especially the substance is oil type. The institution of studies must provide all the equipment for undergraduate studies and special machine that can use for type of oil substances.

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APPENDIX