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USE OF FRYING OIL BIODIESEL IN BRAZIL - FINDING OF B5 TESTS ON A CAPTIVE LORRY FLEET

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Resumo
This paper demonstrates the production and distribution system of biodiesel made from left-over frying oil in Brazil, as well as the behaviour of this fuel in the cargo shipment system, based on the tests conducted through two hospital garbage collection vehicles in the City of Rio de Janeiro. These vehicles were monitored on a daily basis, one of them fuelled by a blend of frying oil biodiesel at 5% and the other with 100% mineral diesel, as a benchmark. Through this monitoring campaign, information was collected on consumption, performance and drivability, as well as mechanical anomalies and wear and tear. The fuel injection systems were tested and sealed by their manufacturer, Bosch, before the tests began and were then returned for analysis and final testing. A similar procedure took place at the Technology Research Institute (IPT) with the motor of the vehicle using the B5 mixture.
Key-words: Logistic; Sustainability.

1. INTRODUCTION

Brazil offers a high potential for producing biofuel, including biodiesel, which is an alternative to mineral diesel (petrodiesel). It is produced through the transesterification of oils or fats, originating in untreated plant oils such as castorbeans, peanuts, soybeans and several other regional crops that can be grown in Brazil, in addition to the spent frying oil covered by this study. This biofuel may be used by decentralised power generation units, production and farm equipment, civil construction machines and vehicles used to ship cargoes and transport passengers.

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It is noted that the latter account for some 82.1% of the energy end-consumption of petrodiesel, which is the main oil product imported by Brazil. Of this percentage, almost 97% is absorbed exclusively by road shipments of cargoes and passenger transport (MME, 2005), which is the main factor in Brazil's transport matrix, accounting for more than 60% of all cargoes shipped in Brazil (ANTT, 2006). The following pie-chart demonstrates the composition of Brazil's transport matrix (figure 1) and the consumption of petrodiesel by its transport system (figure 2).

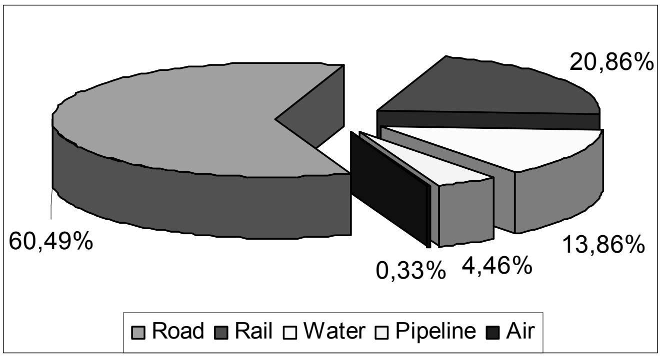

Figure 1: Brazil's Transport Matrix

Source: National Land Transport Regulator (ANTT), 2006

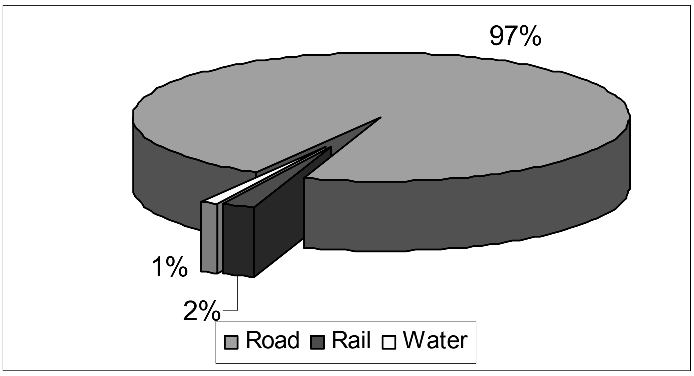

Figure 2: Petrodiesel Consumption by Transport System

Source: Ministry of Mines and Energy (MME), 2005

This alternative may result in a reduction in greenhouse gases emissions (GGE) and atmospheric pollution related to the production and use of petrodiesel. As an example, Germany currently runs a fleet of vehicles on biodiesel produced from rapeseed and methanol (methyl route). Additionally, major urban hubs such as Paris are already testing a 10% (B10) blend.

In environmental terms, biodiesel helps reduce pollution at the local level (particulate matter and aromatics), as well as at the regional (SO_x) and global (GGE) levels. However, tests have shown that NO_x emissions are higher than for petrodiesel, although the quantification of these emissions is still in the research stage. In economic terms, this fosters the generation of jobs and income in urban and rural areas while reversing capital flows through lessening imports of oil and oil products, in parallel to possible exports of fuel and sale of avoided GGE certificates, based on feedstock produced in Brazil.

In major urban hubs, huge amounts of spent frying oils and oils from other sources that would otherwise be discarded can be used as feedstock for making biodiesel, easing the impacts caused by improper dumping.

From the economic standpoint, biodiesel made from spent oils tends to be cheaper, as this consists of waste inputs with low added value that can also generate income when a reverse logistics network is set up to collect this oil.

The main purpose of this study is to demonstrate the technical feasibility of using biodiesel with 5% (B5) frying oil in a captive fleet of cargo shipment vehicles, as will be shown below in the test findings. As a secondary objective, the Brazilian frying oil biodiesel production and distribution chain will be demonstrated, as suggested by this study.

2 PRODUCTION AND DISTRIBUTION OF FRYING OIL BIODIESEL IN BRAZIL

2.1. Frying Oil Biodiesel Production and Distribution Chain

The frying biodiesel production and distribution chain in Brazil consists of the following stages: waste oil collection, biodiesel production, fuel distributors and sales to consumers, as presented in Figure 3.

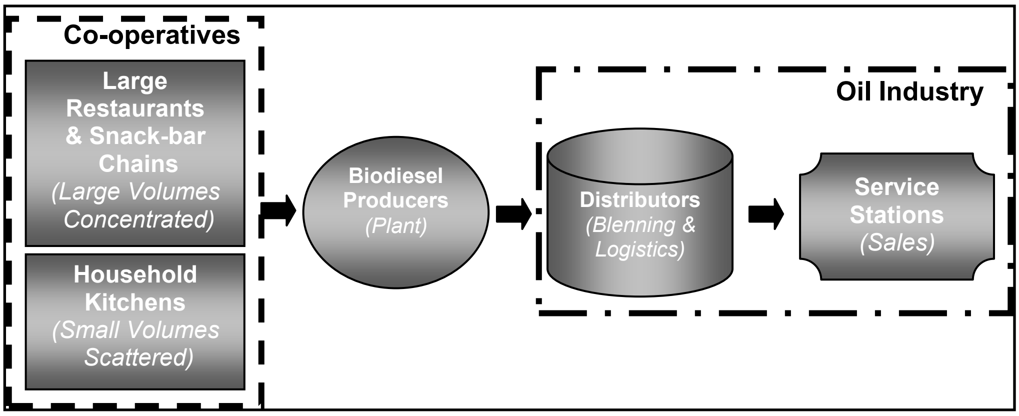

Figure 3: Biodiesel Production and Distribution Chain in Brazil

2.1.1. Waste Oil Collection

Waste oil consists of: spent oils, fatty acids resulting from refining plant oils, animal fats obtained from slaughter-houses (beef, pork and chicken fat, as well as fish oils) and sewerage oils, which together account for 1.5 billion litres a year (OLIVEIRA, 2006).

However, it is stressed that this paper covers only spent oils resulting from frying foods. Deep-frying is a process that uses plant fats or oils as a means of transferring heat, whose importance is undeniable for the production of foods served in snack-bars, fast-food outlets and commercial or industrial restaurants all over the world. The length of time that the oil is used varies from one establishment to another due mainly to a lack of legislation stipulating the replacement of spent oils. With the vast variety of establishments using these oils, this is why it is hard to conduct an accurate survey of the availability of this type of solid waste in major urban hubs. However, the Environmental Health Centre under the Curitiba Mayor's Office (2005) estimates that around a hundred tons of frying oil are generated each month in the industrial restaurants of this City and the Metropolitan Region, some of which is used to produce soaps, glazing putty and animal fodder, with the remainder discharged directly into household sewerage network.

This initial stage requires the development of a reverse logistics network that can ensure a steady flow of oil channelled to the biodiesel production plants. It seems likely that actions designed to enhance the value of discarded oil would allow oil collection cooperatives to be set up, similar to the systems currently working with cans, cardboard and scrap metals. Thus, the cooperative members would initially collect the oils from places with large spent volumes, such as restaurants, industrial kitchens, fast food chains and others, taking these wastes to the headquarters of the cooperative (centralising unit) and used subsequently to make biodiesel. At the moment, part of this discarded oil already has a market value for companies that hydrogenate oils to make soaps and detergents used for industrial and household cleaning purposes. The hydrogenation companies collect the spent oils and in exchange provide cleaning products derived from these oils to snack-bar and restaurant chains. However, it is estimated that oil supplies are higher than the demands of these companies, resulting in large amounts of raw materials being left over.

Over the long term, consideration may be given to collecting oil used in large residential buildings through selective collection, which is already well known (although not widely encouraged), where appropriate recipients are set aside to hold oil used to fry food, and then collected by the members of the cooperatives. It is important to stress that actions such as this are effective only when backed by incentives and awareness-heightening campaigns run by the Government and related entities.

At this stage, the amount of oil collected is directly linked to the quality of the fuel and the percentage conversion of the oil into biodiesel, meaning the higher the number of times the oil has been re-used, the lower its yield in biodiesel. Thus, it is important to ensure the correct use of frying oils, avoiding over-use which can result in health problems while lowering its quality as a raw material for biodiesel production. In large industrial kitchens, a qualified nutritionist is always in attendance, ensuring the correct use of oil and thus guaranteeing the quality of the feedstock.

From the environmental standpoint, this new use for waste oils would significantly reduce the problems related to the improper disposal of frying oils in municipal sewerage networks, in addition to making fuel from a product that would otherwise be dumped as garbage.

Another important question arising from biodiesel production and use is related to the average price of petrodiesel and the oil used as an input for the biofuel, as the end-price of biodiesel at the commercial level must be compatible with that of petrodiesel. As this is a raw material that is available immediately (with no need for growth lead-times), and is available at competitive prices (as it would otherwise be dumped as garbage, with disposal fees sometimes even resulting in negative costs), it is believed that biodiesel made from frying oil would be available at fairly competitive levels.

2.1.2. Biodiesel Production

This phase consists of the effective industrial production of the ester that will subsequently be classified in compliance with the directives issued by the Brazilian Oil, Gas and Biofuels Industry Regulator (ANP) and only then will it be possible to place it on the market. During this phase, technological development is required that can ensure better production quality, taking into consideration the many different sources of the raw materials used to produce frying oils in Brazil.

Biofuels are currently being tested in several parts of the world. Countries such as Argentina, the USA, Malaysia, Germany, France and Italy are already producing biodiesel commercially, encouraging its development at industrial scales. During the early 1990s, the biodiesel industrialisation process began in Europe. At the moment, the European Union produces more than 1.35 million tons of biodiesel a year at some forty production plants. This accounts for 90% of global biodiesel production (BiodieselBr, 2006). The Government offers tax incentives to producers, in addition to promulgating specific laws covering their products, in order to upgrade environmental conditions through the use of cleaner energy sources. Taxes are extremely high on petroleum-based fuels in Europe, including petrodiesel, endowing biodiesel with a keen competitive edge on the market.

According to the American Biofuels Association (2005), biodiesel sales could well top 760 million litres a year if spurred by Government incentives comparable to those given to ethanol, replacing 8% of petrodiesel consumption on US highways.

At this market penetration level, biodiesel could probably be used by bus and heavy truck fleets (mainly through a 20% blend with fossil diesel) as well as ships, agricultural and construction machinery, in addition to home heating and power generation purposes.

According to the ANP (2006) Brazil's authorised biodiesel plant production capacity hovers around 85.3 million litres a year. This current production level is a major challenge for meeting the target stipulated through the National Biodiesel Production and Use Programme, which will require some 800 million litres (2% of the forty billion litres of petrodiesel consumed in 2005) at its initial phase. This means that the current production capacity meets only 11% of the demand, based on the B2 blend. It is also stressed that the required capacity will have to triple by 2013, with the new directive that adds 5% biodiesel to petrodiesel.

A wide variety of oilseeds is currently available in Brazil from which large amounts of oil can be extracted, constituting the main raw material of biodiesel. With favourable climate conditions and good soils, Brazil has ample plant oil sources available nationwide.

It is important to recall that each part of Brazil specialises in the production of a group of oilseeds, resulting in a segmentation of the sources of feedstock to produce this fuel. To some extent, this is positive, as there is no need to introduce crops in regions that might prove unsuitable, requiring massive research efforts in order to adapt these plants to other climates and soils in regions where they have never grown. If each region specialises in its own traditional crops, research efforts can be channelled towards boosting production capacities and increasing harvests. The Figure 4 offers an overview of the variety of oilseeds available in Brazil, by region:

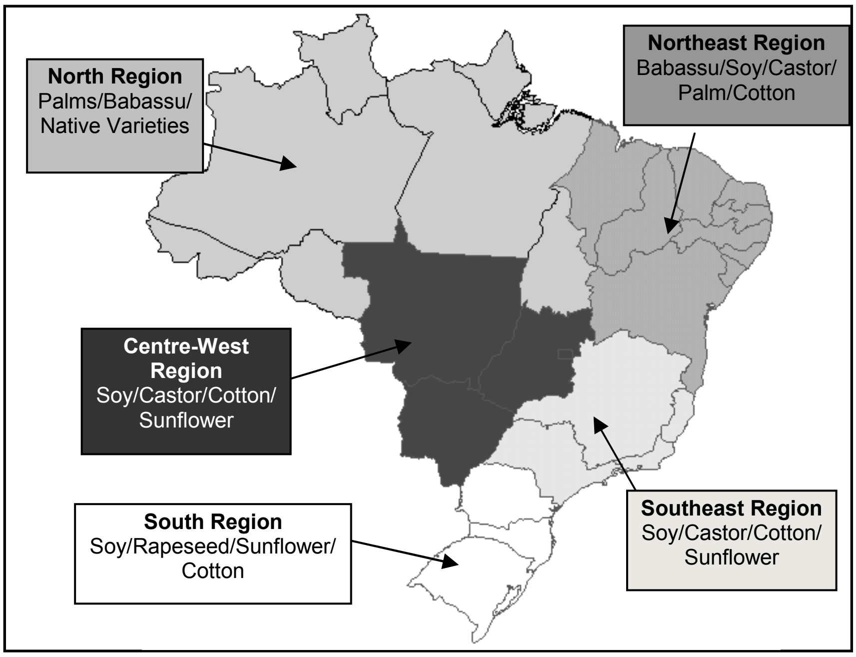

Figure 4: Oilseeds typical of each Region of Brazil

Source: Brazilian Agricultural Research Enterprise (EMBRAPA), 2005

Outstanding among the feedstock currently used to produce biodiesel is methanol (methyl alcohol), when biodiesel is produced by the methyl route, and ethanol (ethyl alcohol) when it is produced through the ethyl route.

Due to the wider availability of ethyl alcohol in Brazil, it is intended to produce biodiesel on a large scale through this route, as it available nationwide, in addition to being a feedstock that is safer to work with for the plant operators.

However, analysing the situation in the City of Rio de Janeiro, the methyl route transesterification process is strongly indicated, as one Brazil's leading methanol producers is located in this City, resulting in ample availability of this feedstock. Additionally, the use of feedstock based on wastes is recommended, as neither the City or State of Rio de Janeiro is well-suited for growing oilseeds, in parallel to the ample availability of waste oils from many different sources in the Rio de Janeiro Metropolitan Complex. It is also important to stress that the process of producing biodiesel from waste oils is fairly similar to the virgin oil process, requiring only a pre-filter stage in order to eliminate impurities resulting from its earlier uses.

2.1.3. Fuel Distributors and Consumer Sales (Service Stations)

The fuel distributors will blend petrodiesel and biodiesel in compliance with the specifications issued by the Brazilian Oil, Gas and Biofuels Industry Regulator (ANP). These distribution units become important, as the accuracy of the blend percentages will be controlled completely at this stage in the chain. During this phase, it is vital to fine-tune the logistics chain in order to ensure that the product retains its initial quality standards, maintaining its price and with guaranteed continuity of supply.

In a continent-sized country like Brazil, where the physical distribution of products is rather complex due to the large number of service stations to be supplied, in addition to the widespread use of the highway network to ship cargoes over roads offering critical operating and safety conditions, all these aspects contribute to Brazil's widespread and costly distribution system. Thus, the same problems encountered by petrodiesel distribution that arise from these complex logistics in Brazil would also apply to biodiesel and its feedstocks.

For biodiesel distribution, an infrastructure should be set up for this purpose, included within the existing infrastructure that services other fuels. Thus, modifications will be required to terminals and refineries, as well as transport vehicles, in order to ensure efficient supplies of this product.

Notable among these difficulties is the question of where the biodiesel / petrodiesel blending will take place, as this can be conducted at bases (fuel terminals) or at refineries. It is known that the Brazilian Government intends to supply biodiesel already added to petrodiesel, initially at 2% biodiesel blended with 98% petrodiesel.

However, the blending sites must be selected carefully in order to ensure product quality (accurate quantities), with these facilities being strategically located in order to obtain the best logistical advantages.

At the moment, Brazil is endowed with the following fuel production and distribution infrastructure: thirteen refineries, three petrochemical complexes, 63 primary bases, 56 secondary bases and 22,000 service stations. The following data portray its consumption: three million vehicles, forty billion litres (petrodiesel); 27 States and five regions. The Figure 5 demonstrates the complexity of the Brazilian fuels market:

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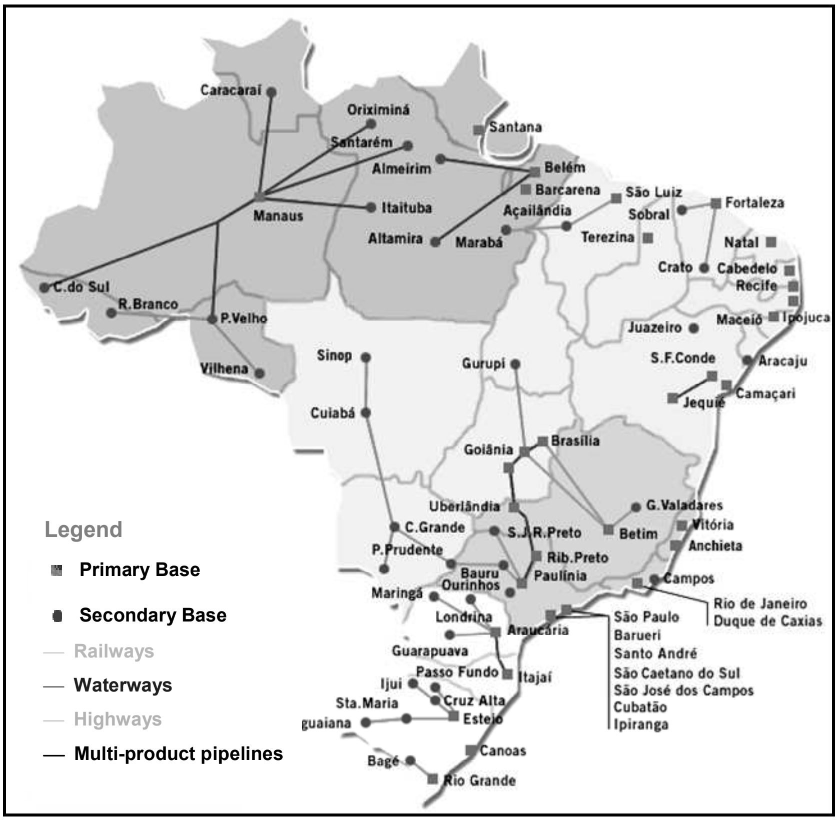

Figure 5: Fuel Distribution Network in Brazil

Source: National Fuels and Lubricants Distribution Company Association (SINDICOM), 2005.

Another issue related to distribution is biodiesel storage, which is sometimes subject to oxidation and flowpoint problems that may adversely affect its physical and chemical characteristics, downgrading product quality. Thus, the storage sites and tank farms must be appropriate for this purpose, complying with the specific characteristics needed for biodiesel made from many different sources.

For consumer sales, petrodiesel/biodiesel blends must be received in conditions appropriate for use, including certification, so that it can be sold to the consumer public. It is important to stress that in some countries, in addition to biodiesel already pre-blended by the distributor / refinery, service stations also offer 100% pure biodiesel, so that consumers can blend the fuels in their vehicle tanks in the desired proportions, as happens in Brazil with bi-fuel vehicles (gasoline with alcohol). However, the Brazilian Government currently intends to distribute and sell only the pre-blended product, as described above.

3 FRYING OIL BIODIESEL TESTES IN COLLECTION VEHICLES

3.1. Description of Tests and Preparation of Vehicles

The main purpose of the tests carried out was to collect information about the consumption, performance, drivability, wear and tear and mechanical anomalies in the vehicles tested for subsequent comparisons and conclusions. To do so, five new vehicles (zero kilometres) were used in the project, designed for collecting hospital wastes in the Rio de Janeiro Municipality, in compliance with the mechanical descriptions presented in Table 1 for all the vehicles. However, this paper presents the tests carried out on only two of these vehicles (Collection Vehicle A and Collection Vehicle B). The former runs on a blend of 5% frying oil biodiesel added to 95% petrodiesel; the second vehicle runs on petrodiesel and serves as a benchmark for the tests conducted with the first vehicle. All biodiesel used in the tests was produced at the Experimental Biodiesel Plant and analysed at the Chemical Analyses Laboratory, both linked to COPPE/UFRJ.

Table 01: Technical Data - Collection Vehicle A

Brand/Model	**Ford/FC 1617**
Tare Weight	16,000 T
Wheelbase	4,800 T
Chassis	A 81 (05/01)
Motor B 5.9	Cummins
Engine Revs	800 - 3070 rpm

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For Collection Vehicle A, it was decided to send the injection system to the manufacturer, Bosch and forward its engine to the Technology Research Institute (IPT) for these components to be analysed, tested and recorded by these organisations. At the end of the test, the two components returned to these entities in order to identify any possible anomalies or alterations arising from the use of the biodiesel / petrodiesel blend.

Only the injection system of Collection Vehicle B was forwarded to Bosch for analysis, trials and registration, repeated at the end of the tests.

3.2. Monitoring the Field Tests

These monitoring activities were carried out on a daily basis during the twelve months of testing for all the vehicles, including those described in this paper, analysing: amounts of fuel, odometer readings when filling up, distances covered, average consumption and occasional observations on the function of the vehicle or any anomalies noted. The Figure 6 shows the Test Vehicles fuelling process.

Figure 6: Fuelling the Test Vehicles

Collecting these data allowed a detailed daily monitoring spreadsheet to be drawn up, containing the calculations and other important notes on the tests. The tests carried out on these two vehicles are described separately below, together with their consumption graphs and other remarks.

3.3. Preparation and Findings of the Tests on Collection Vehicle A

3.3.1. Vehicle Preparation

As mentioned, the motor was removed from this vehicle and forwarded to the IPT for dynamometric bench tests. In parallel, the injection system (injection pump and injector nozzles) was forwarded to Bosch for testing and registration.

The purpose of the dynamometric bench tests conducted at the IPT was to test the motor performance (capacity, torque and specific consumption at full load) in addition to measuring the emissions through a thirteen point trial with the engine running on the reference diesel oil (diesel oil standardised in compliance with the Government Directive), base diesel oil (metropolitan diesel oil sold in Brazil) and B5 blends of petrodiesel+biodiesel oil with frying oil (waste oil).

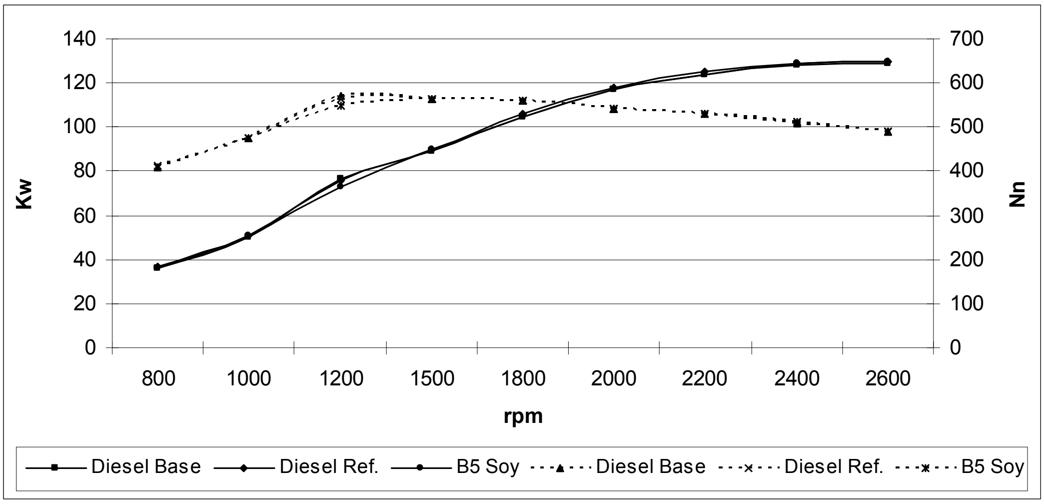

Figure 7: Capacity and Torque Curves

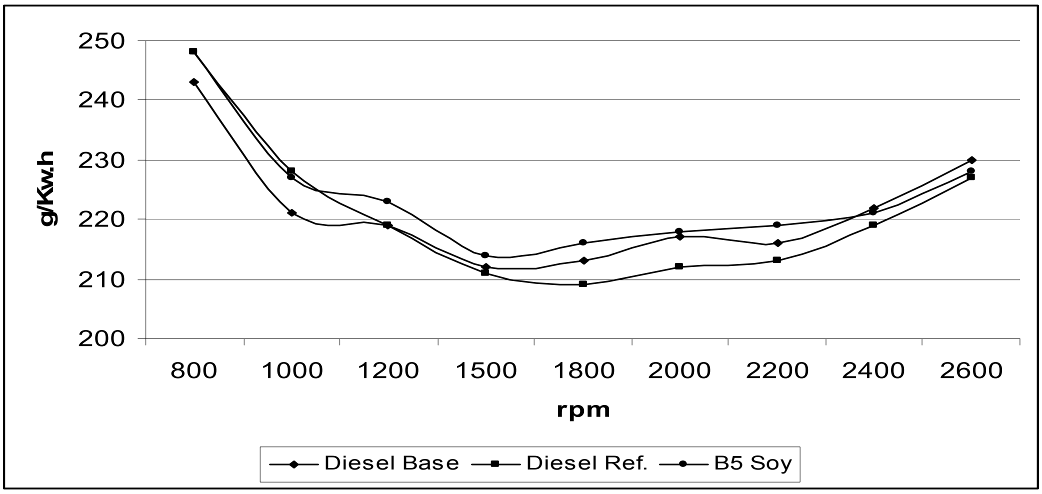

Figure 8: Special Consumption Curve

Figures 7 and 8 present the findings of the thirteen point trial.

Table 2 summarises the findings. The negative figures indicate the reductions and the positive figures indicate increases. The absolute values were obtained through the average of at least five observations with a maximum error of 5%.

Table 02: Summary of the Bench Test Findings

Measured Parameter	Absolute Values		
	Base Diesel	***B5 Frying Oil***	***Variation***
Effective Capacity [kW]	50.8	50.9	0.2%
Specific Consumption [g/kW. h]	189.8	191.0	0.7%
CO [g/kW. h]	0.93	0.92	-1.6%
NO_x [g/kW.h]	6.66	6.71	0.8%
THC [g/kW. h]	0.426	0.424	-0.6%
Soot [g/kW. h]	0.041	0.033	-19.9%
Measured PM [g/kW. h]	0.169	0.163	-3.5%

A minor increase in the corrected capacity may be noted for the B5 frying oil blend, in addition to slightly higher specific consumption, although remaining below 1%.

Lower emissions were noted for substances other than NO_x, particularly a reduction in soot emissions. The increase in the NO_x emissions was less than 1%.

3.3.2. Field Test Findings

In June 2003, Collection Vehicle A began to run on a B5 blend of frying waste oil, with consumption being monitored over the month. To do so, it was necessary to obtain data on fuelling, odometer readings, distances covered, specific consumption, routes and possible observations on the mechanical behaviour of the vehicle. With this information to hand, it was possible to construct the graphs presented below.

The analysis of the consumption based on the loading is presented in Figure 9, which analyses this average ratio during the months of the test.

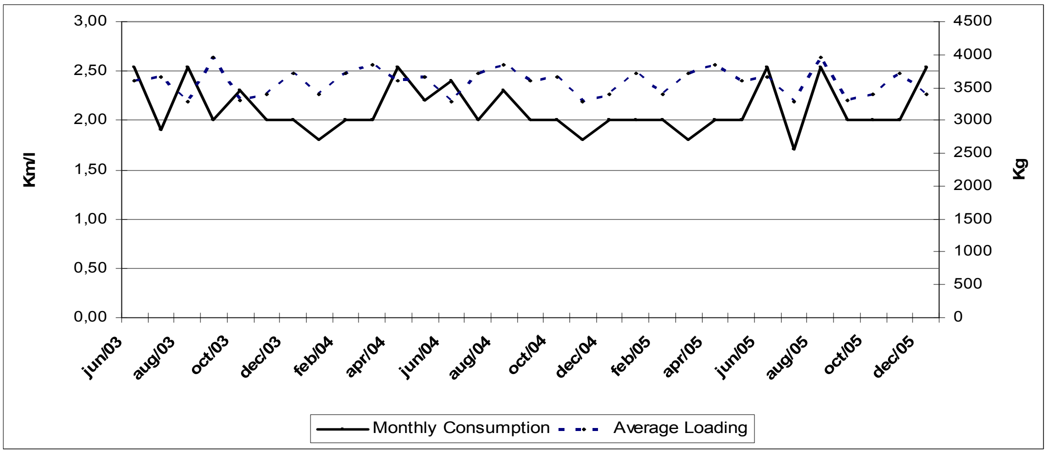

Figure 9: Monthly Consumption x Average Loading

The results presented are similar to those of most cargo vehicles on urban roads, with no significant alterations.

Although the initial test proposal stated that the vehicles would be tested for only twelve months, this vehicle was tested for thirty months, ending in December 2005 when its injection system and motor were removed and forwarded to Bosch and the Technology Research Institute (IPT) for the final tests, as shown below.

After completing the daily monitoring spreadsheet, it was noted that there were no significant alterations in fuel consumption by this vehicle. The variations presented in the graph are due to constant changes of drivers and some alterations to the operating routes. On average, the consumption of Collection Vehicle A throughout the tests horizon was 1.96 Km/l, with a standard deviation of 0.28 Km/l. This is very similar to the consumption recorded for Collection Vehicle B, used as a benchmark and presented below.

3.3.3. Conclusive Technical Reports

After Collection Vehicle A completed its field tests in December 2005, its injection system and motor were removed for conclusive tests and assessments, as described below:

- Fuel Injection System

This system was removed without breaching the seal applied prior to the start-up of the tests, forwarding it to Bosch for the appropriate tests, analyses, component assessments and photographic documentation of these items.

The assessment criteria used by Bosch encompass “functions” and “visual examinations”.

According to BOSCH (2006), the injection pump is in good working order in terms of its functions, as well as wear and tear. The wear and tear noted on the front piston housing may be related to particles (sand) seeping through the filter, and is not necessarily associated with the use of biodiesel.

There was no mechanical or hydraulic influence of this B5 biodiesel blend on the injection system. The crusting noted on the pump had built up as it was driven, with no influence on the functioning of the injection system.

Figure 10 presents two components of the injection system, which was dismantled at the end of the test, showing that there was no alteration or wear and tear to this set of equipment, being in perfect operating conditions.

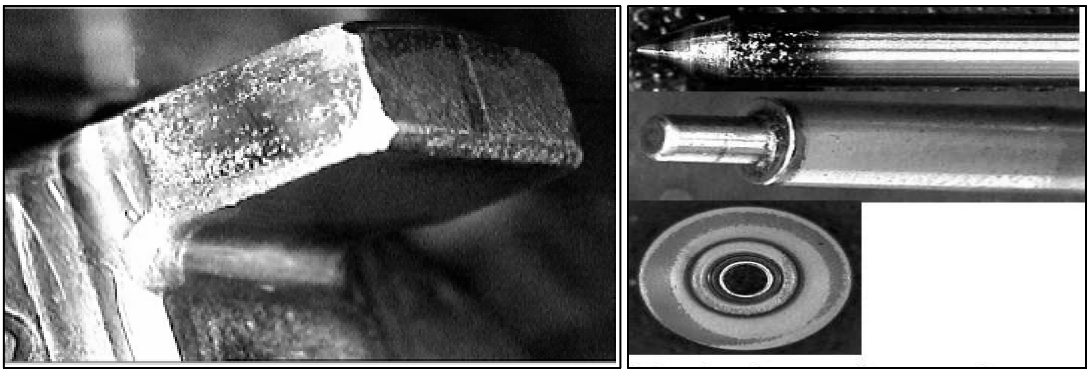

Figure 10: Injection System Components – Collection Vehicle A

- Motor

After opening the motor for visual examination, the following were noted: no crusting, excessive wear and tear, oxidation of components or any anomalies resulting from the use of the B5 blend, that might adversely affect the normal functioning of the engine. Moreover, there were no physical or mechanical alterations to parts coming into direct contact with the blend.

The soot crusted on the piston head and valves was rated as normal for a diesel motor, with no adverse effects on its functioning. There were no indications of oxidation of parts or excessive wear and tear of components coming into contact with the blend. The infrared analyses carried out on the lube-oil shows that it was not contaminated by biodiesel, indicating that the biodiesel was burned completely in the combustion chamber.

3.3.4. Conclusion

After analyses of all the components involved in the tests, conducted by professional staff and qualified entities, the following conclusions were reached: according to the company owning the vehicle, its average consumption is quite normal, as this is a cargo vehicle working under severe traffic and loading conditions, with specific operating requirements. It also concluded that the parts coming into direct contact with the biodiesel+petrodiesel blend were not subject to any alterations and were in perfect operating conditions, meaning that the vehicle is consequently qualified to continue with its collection work.

Thus, the purposes of the project analysing the feasibility of the use of biodiesel were attained satisfactorily, as all the stages of the tests were overseen and monitored. At the end of this process, it was possible to reach a conclusion based on the observations and data collected throughout the entire progress of the project.

3.4. Preparation and Findings of the Tests on Collection Vehicle B

3.4.1. Vehicle Preparation

As this vehicle runs on pure petrodiesel (100% petrodiesel) it was decided to forward only the injection system to Bosch for sealing, with no need for dynamometric bench tests of its motor, as the effects of diesel oil on motors are already known. The motor of this vehicle was new (zero kilometres), and was completely checked and tuned in order to endow the tests with highest possible levels of reliability.

3.4.2. Field Test Findings

Collection Vehicle B ran through the same field tests and had the same questions analysed, thus allowing the following graphs to be constructed.

The analysis of the consumption as a function of the loading is presented in Figure 11, which covers this average ratio throughout the months during which Collection Vehicle B was tested.

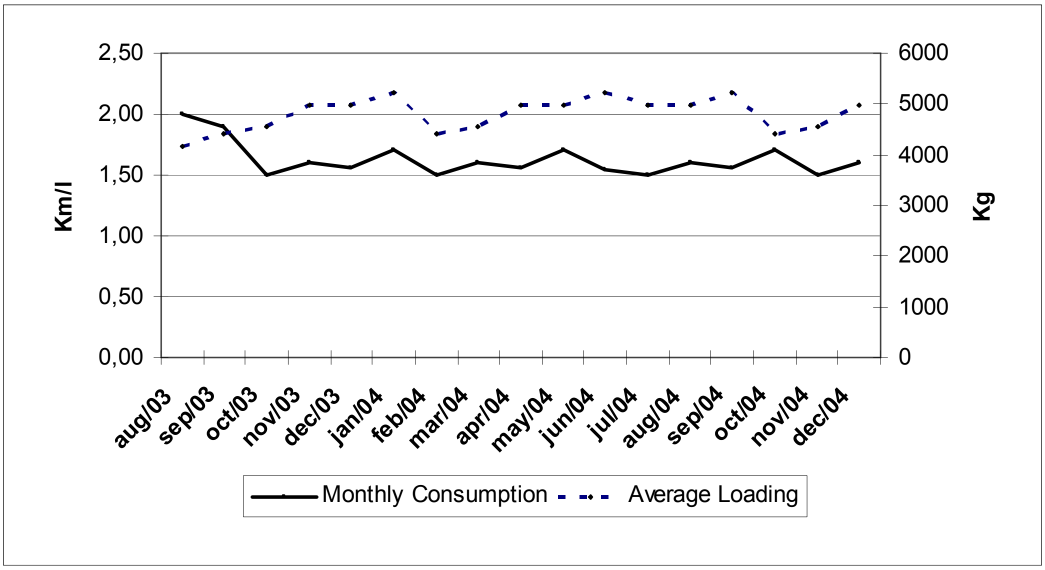

Figure 11: Consumption x Average Loading

As noted previously for Collection Vehicle A, Figure 11 shows that the behaviour of Collection Vehicle B complied with that expected of most cargo vehicles driving in urban road conditions.

In brief, the historic consumption curve of Collection Vehicle B is fully compliant with the expected performance of a cargo vehicle driving on urban roads, with no significant alteration in its consumption, that remained at a historic consumption average of 2.01 km/l with a standard deviation of 0.29 km/l. This is very similar to the consumption of Collection Vehicle A, presented above.

3.4.3. Conclusive Technical Reports

Thus, after completion of the field tests for Collection Vehicle B in December 2005, its injection system and motor were removed for assessments and conclusive testing, as described below:

- Fuel Injection System

This system was removed without breaching the seal applied prior to the start-up of the trials, and was forwarded to Bosch for the necessary tests, analysis and assessments of the components and their photographic documentation.

The assessment criteria used by Bosch encompass “functions” and “visual examinations”.

According to Bosch (2006), the fuel injection system is in good working order in terms of functioning and wear and tear. There were no mechanical or hydraulic effects on the injection system, resulting from the use of petrodiesel. The crusting noted in the pump that built up while driving the vehicle had no influence on the functioning of the injection system.

- Motor

As the motor of Collection Vehicle B did not run through initial dynamometric bench tests, there was no need to repeat this process at the end of its tests. It was also considered that the effects of diesel oil on diesel cycle motors are already widely known in scientific circles and consequently this bench test would not be necessary.

However, the motor of this vehicle was monitored during its tests cycle in terms of anomalies in its functioning and wear and tear on components such as oil filters, hydraulic hoses and lube-oil analyses.

3.4.4. Conclusion

As shown, at the end of its tests in December 2004, Collection Vehicle B was in perfect operating conditions with no mechanical anomalies, which allowed the calibration of the vehicle to be certified for subsequent comparison with Collection Vehicle A. In August 2004, this vehicle completed one year of field tests, but remained in operation through to December 2004.

After analysing its fuel injection system, no physical or mechanical alterations were noted that might indicate that the tests were not reliable.

4 COMPARATIVE ANALYSIS

As presented above, it is noted that the vehicle tested with the petrodiesel+biodiesel blend (Collection Vehicle A) did not present any alteration in the functioning or marked wear and tear on the mechanical components, compared to the vehicle used as a benchmark (Collection Vehicle B). Although its test mileage (measured in kilometres) was significantly higher than that of the benchmark vehicle, the vehicle driving on B5 biodiesel was able to continue its daily collection activities with no need for mechanical corrections. Table 3 presents a summary of the vehicle tests.

Table 3: Summary of tests on the two vehicles

Vehicles	Fuel.	Injection Systems	Motor	Start	Finish	km tested	Current Status
C 03	*B5 Frying Oil*	*Tested and Sealed/ Bosch*	*Tested/IPT*	*June 2003*	*Dec 2005*	*60,000*	*OK*
C 06	*Pure Diesel*	*Tested and Sealed/Bosch*	*Not tested/IPT*	*Aug 2003*	*Dec 2004*	*39,237*	*OK*

It is stressed that minor differences in consumption between these two vehicles are due mainly to constantly changing drivers and eventual alterations in their working routes, characterised as perfectly normal by the company owning the two vehicles being tested.

Thus, it is noted that the purpose of the study was attained, as the vehicles were tested under normal operating conditions, making the study quite realistic.

An analysis of the data thus leads to the conclusion that the B5 blend did not cause any significant alterations in the diesel-powered vehicles for the following aspects: performance, drivability and emissions, and did not cause mechanical anomalies or wear and tear on the components involved directly with the blend.

Regarding frying oil biodiesel in Brazil, it is noted that its price should be relatively lower than biodiesel produced by family farms (virgin oil) and is also available in major urban hubs.

At the moment, the price of regular petrodiesel in the City of Rio de Janeiro, Brazil hovers around an average of US$ 0.79 (US Dollar commercial exchange rate: R$ 2.28). This price is rated as high, as it is the main input for Brazil's cargo shipment and passenger transport system.

This being the case, it is believed that the use of a low-cost input will help cut the end-price of waste oil frying oil biodiesel down to approximately 20% to 30% below that of conventional petrodiesel, as shown in the table 4.

Table 04: Production and Sales Costs

Composition per Litre	***Petrodiesel***	***Biodiesel***
Distribution and Resale	$0.06	$0.01
Taxes	$0.10	$0.06
Fabrication	$0.19	$0.19
Pump Price	$0.79	$0.61

It is stressed that these biodiesel production costs were calculated on the basis of the average prices charged for input materials on the Brazilian market for a biodiesel production plant with an annual capacity of 1,500 m^3/year, in addition to all taxes charged on conventional petrodiesel.

Therefore the use of frying oil to produce biodiesel in Brasil is good opportunity in therms of alternative fuel to substitute mineral diesel, especially in large urban areas, when the availability of frying oil with low cost is huge.

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