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ECONOMIC FEASIBILITY OF CATALYTIC CRACKING OF POLYMER WASTE FOR FUEL PRODUCTION

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ABSTRACT

Plastic waste represents a major environmental concern, as it does not degrade in the environment and is constantly discarded. The types of polymers most used in the world are polyethylene and polypropylene, mainly for the production of packaging and, therefore, are the most discarded plastic waste in the environment. Some efforts are being applied to mitigate this situation, such as mechanical recycling, which transforms plastic waste into other products. But polymer cracking processes are promising alternatives, converting waste into lightweight materials that can be turned into commercial fuels. However, to be viable, these processes must consume as little resources as possible and, for this, feasibility experiments must be carried out to prove their application on a large scale and in small transformation units. This work presents a methodology for assembling a low-cost pyrolysis reactor to carry out the cracking of polymeric residues, and experiments were carried out with it, whose results showed the technical and economic viability of the described process, obtaining a rate of conversion of plastic into fuels of up to 96%, so it can be widely applied to reduce impacts caused by plastic disposal.

Keywords: Pyrolysis; Polymers; Fuel; Environment; Renewable Energy.

VIABILIDADE ECONÔMICA DO CRAQUEAMENTO CATALÍTICO DE RESÍDUOS DE POLÍMEROS PARA PRODUÇÃO DE COMBUSTÍVEL

RESUMO

Os resíduos plásticos representam uma grande preocupação ambiental, pois não se degradam no meio ambiente e são constantemente descartados. Os tipos de polímeros mais utilizados no mundo são o polietileno e o polipropileno, principalmente para a produção de embalagens e, por isso, são os resíduos plásticos mais descartados no meio ambiente. Alguns esforços estão sendo aplicados para mitigar essa situação, como a reciclagem mecânica, que transforma resíduos plásticos em outros produtos. Mas os processos de craqueamento de polímeros são alternativas promissoras, convertendo resíduos em materiais leves que podem ser transformados em combustíveis comerciais. Porém, para serem viáveis, esses processos devem consumir

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o mínimo de recursos possível e, para isso, devem ser realizados experimentos de viabilidade que comprovem sua aplicação em larga escala e em pequenas unidades de transformação. Este trabalho apresenta uma metodologia para montagem de um reator de pirólise de baixo custo para realizar o craqueamento de resíduos poliméricos, e nele foram realizados experimentos, cujos resultados mostraram a viabilidade técnica e econômica do processo descrito, obtendo taxa de conversão de plástico em combustíveis de até 96%, podendo assim ser amplamente aplicado para reduzir os impactos causados pelo descarte de plástico.

Palavras-chave: Pirólise; Polímeros; Combustível; Meio Ambiente; Energia Renovável.

VIABILIDAD ECONÓMICA DEL CRAQUEO CATALÍTICO DE RESIDUOS DE POLÍMEROS PARA LA PRODUCCIÓN DE COMBUSTIBLE

RESUMEN

Los desechos plásticos representan una preocupación ambiental importante, ya que no se degradan en el medio ambiente y son desechados constantemente. Los tipos de polímeros más utilizados en el mundo son el polietileno y el polipropileno, principalmente para la producción de envases y, por tanto, son los residuos plásticos más desechados en el medio ambiente. Se están aplicando algunos esfuerzos para mitigar esta situación, como el reciclaje mecánico, que transforma los residuos plásticos en otros productos. Pero los procesos de craqueo de polímeros son alternativas prometedoras, ya que convierten los desechos en materiales livianos que pueden convertirse en combustibles comerciales. Sin embargo, para ser viables, estos procesos deben consumir la menor cantidad de recursos posible y, para ello, se deben realizar experimentos de factibilidad para probar su aplicación a gran escala y en pequeñas unidades de transformación. Este trabajo presenta una metodología para el montaje de un reactor de pirólisis de bajo costo para realizar el craqueo de residuos poliméricos, y en él se realizaron experimentos, cuyos resultados demostraron la viabilidad técnica y económica del proceso descrito, obteniendo una tasa de conversión de plástico en combustibles hasta un 96%, por lo que puede aplicarse ampliamente para reducir los impactos causados por la eliminación de plásticos.

Palabras clave: Pirólisis; Polímeros; Combustible; Medio Ambiente; Energía Renovable.

INTRODUCTION

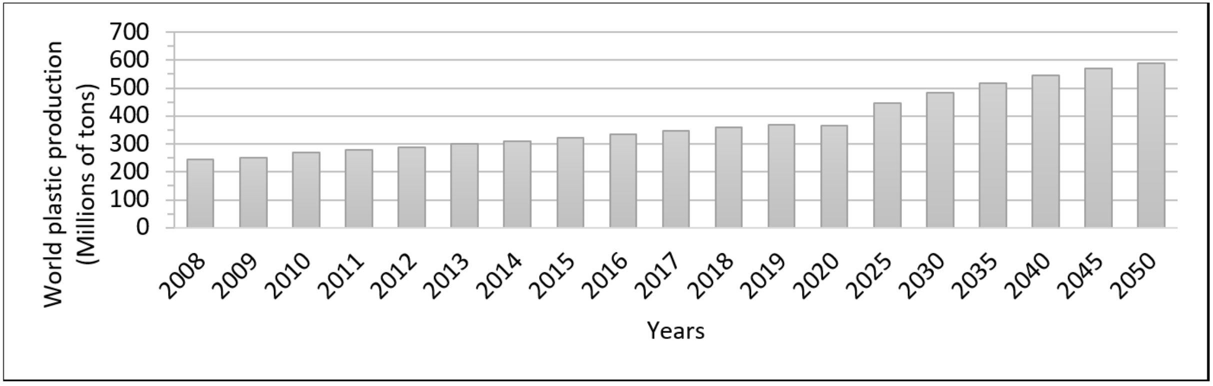
Plastic is increasingly present in homes and in the world economy, facilitating people's daily lives in various aspects, such as transporting groceries, storing food or manufacturing the most diverse products, such as bags, cups or straws. These polymeric wastes represent serious environmental problems, as about 79% of plastic waste accumulates in dumps, landfills, rivers and seas, causing various environmental, economic and social damages over time (GEYER, 2020; KAWAI; TASAKI, 2015).

In addition, polymers represent serious problems for marine fauna through microplastics, which originate from the slow decomposition of plastic waste. These materials are consumed by these animals precisely because they do not distinguish them from their natural foods, usually phytoplankton and zooplankton, also affecting humans (LESLIE *et al*., 2022; SARKER, 2011;

SRININGSIH *et al*., 2015). However, microplastics also affect the terrestrial environment, as they are used by industry for the production of cosmetics, paints, detergents, tires, etc. As a result, they affect the soil, water and atmosphere, while contaminating the food and feed production chain (ALEXY *et al*., 2020; TOUSSAINT *et al*., 2019; ROY *et al*., 2022; WATT *et al*., 2021).

The annual production of synthetic polymers has been increasing, with indications of almost doubling in just over 30 years (Fig. 1). As a result, the environmental problems caused by them will intensify more and more, reflecting the inappropriate disposal of plastic waste, the increase in the world population and, consequently, the growing demand for plastic packaging.

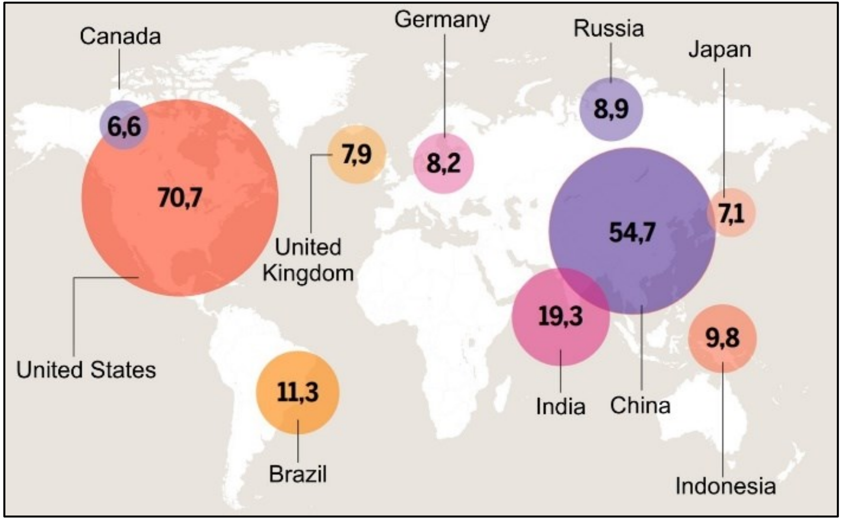
Fig. 1: Evolution in world plastic production (2008-2050).



Source: adapted from Leski and Berkowicz-Płatek, 2021 and Pal *et al*., 2022.

These problems, caused by the inadequate disposal of plastic waste, mainly in countries that adopt consumerist practices, such as the United States and China (Fig. 2), lead to an increase in the need to promote recycling as an important practice inserted in the production chain of this material (LESKI; BERKOWICZ-PŁATEK, 2021).

Fig. 2: Average annual production of plastics between 1950 and 2017 by countries.



Source: Atlas do plástico (2020), p. 16.

In this context, some actions are planned and executed to try to mitigate the problem of pollution caused by plastic waste, such as energy recovery, but it is very polluting, because during burning, many greenhouse gases are emitted into the atmosphere. Alternatively, there is mechanical recycling, which reuses thermoplastics to produce new products, however, the plastic loses strength due to the constant repetition of the process, in addition, the types of polymers must be separated, increasing costs (EZE *et al*., 2021).

With the emerging need for the development of alternative energy resources, pyrolysis or thermal cracking of polymers is being widely studied as a viable solution to reduce or minimize the environmental problems caused by the disposal of plastics (BAJUS; HÁJEKOVÁ, 2010; JIA, 2021). This technique can be defined as a process that, through heating and in the absence or scarcity of oxygen, leads to the decomposition of chemical products, whether natural or organic (NOFENDRI, 2021). Thus, Sharuddin *et al*. (2016), explain this method as “the process of thermal degradation of long-chain polymer molecules into smaller and less complex molecules through heat and pressure”, whereas Qureshi *et al.* (2020) state that “pyrolysis is the thermal decomposition or catalytic process of a material in an oxygen-free or oxygen-limited environment”, and describe the process as follows: “Polymer feedstock is introduced into a reactor at 450 – 600°C to produce a steam. Vapors consist of condensable (liquid and wax) and non-condensable (gas) fractions”.

For Barbarias (2019) and Bezerra (2016) cracking has received a lot of attention and is an excellent alternative to reuse discarded plastic waste. In this process, polymeric waste is converted into fuels or lighter chemicals that can be used as raw materials for the chemical and petrochemical industries (ZHOU *et al*., 2021). In addition to generating products with greater added value, cracking has the advantage of being able to be carried out by mixing different types of plastics (SUNDARRAJ; MEIKANDAN, 2021).

The polymeric cracking process can be carried out in two ways, thermal cracking, with high temperatures, and thermal catalysis cracking, with the aid of catalyst materials to accelerate and improve the process and, therefore, improve the yield of the products obtained (VARGAS *et al*., 2021). Usually, catalyst materials are solid substances with acidic properties, such as zeolites, which when dehydrated, develop a mesoporous structure with ion exchange capacity (VARGAS *et al*., 2021; HERNÁNDEZ *et al*., 2005). However, other materials can be used, such as sodium carbonate, clays and silica, low-cost substances that can reduce the costs of the procedure (BEZERRA *et al*., 2016; LESKI; BERKOWICZ-PŁATEK, 2021). As a result, plastic waste is basically converted into solid, liquid and gaseous fuels, thus obtaining products such as coal or coke, gases (mainly CO, CO_2, CH_4 and H_2) of high calorific value (between 15 and 30 MJ/m^3) and oils that can be separated by other processes, such as distillation, in order to obtain diesel, gasoline or other types of residual oils (RAJCA *et al*., 2020; THI *et al*., 2021; ZAJEMSKA *et al*., 2022).

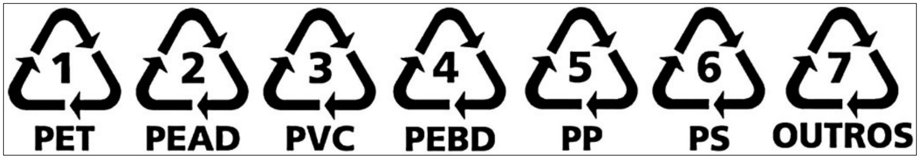
However, feasibility studies are needed that can develop methodologies and techniques for carrying out polymeric cracking at viable costs, whether for small or large transformation plants, since large industrial pyrolysis reactors have a very high cost, around 300 to 500 thousand dollars per unit (ROGERS; BRAMMER, 2012; WOOLF *et al*., 2017). Therefore, this work aims to assemble a low-cost pyrolysis reactor for cracking mixed polyethylene and polypropylene polymers and, thus, evaluate the economic viability of producing fuels compatible with gasoline from this waste conversion system.

With the use of low-cost materials, such as a pressure cooker, camping stove and other improvised materials, the pyrolysis reactor was assembled and tests were carried out in it that proved the effectiveness of the polymer catalytic pyrolysis procedure, when converting waste into fuel, with a rate of up to 96%, and a favorable energy expenditure ratio of 2.46:1.

MATERIAL AND METHODS

The selection of the necessary plastic waste of polyethylene (PE) and polypropylene (PP) was carried out with the accumulation of materials that would be discarded. To identify the types of polymers collected, the indicative symbols were used, printed on the plastic materials, according to the standardization of recyclable polymers of ABNT NBR 13230 (Fig. 3). Thus, materials that presented the corresponding symbols with numbers 2, 4 and 5 were collected.

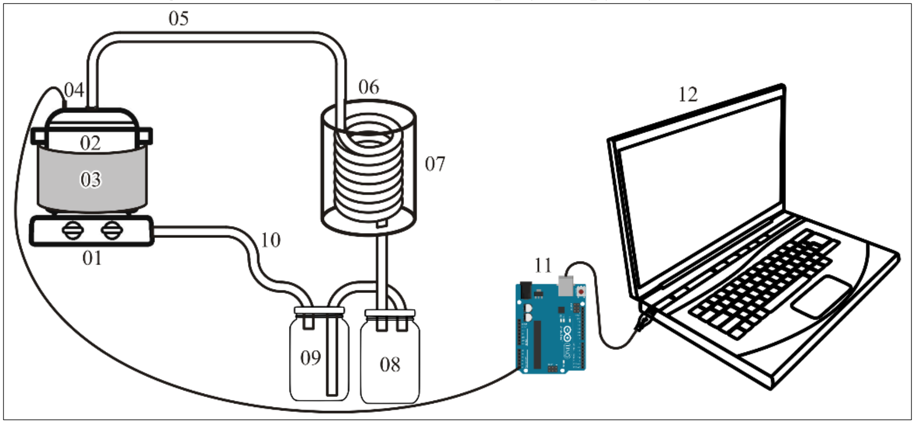
Fig. 3: Symbols of the main recyclable polymers.



Source: Associação Brasileira de Norma Técnicas, 2008.

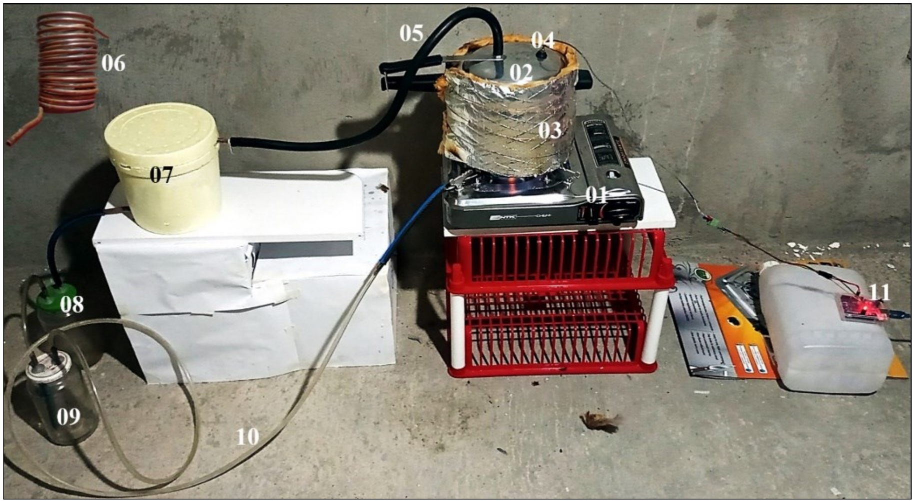
The polymeric cracking tests were performed in a pyrolysis reactor, defined by Ali *et al.* (2022), as “a sealed chamber where a chemical reaction takes place [...] in which plastic waste is burned in the absence of oxygen”. The reactor was assembled following the model shown in Fig. 4a, with low-cost materials, acquired with the author's own resources, in order to prioritize economic viability. The assembled equipment is shown in Fig. 4b.

Fig. 4a: Model of the assembled polymer pyrolysis reactor.



Source: by authors (2022).

Fig. 4b: Pyrolysis reactor assembled.



01 - Stove; 02 - Cracking unit; 03 - Thermal insulation; 04 - Thermocouple sensor; 05 - Piping; 06 - Coil (inside the condenser); 07 - Condenser; 08 - Glass pot A; 09 - Glass pot B; 10 - Hose for energy reintegration; 11 - Arduino Uno board.
Source: by authors (2022).

The experiments were carried out with 200 g of mixed polymers, consisting of PE and PP, due to the volumetric capacity of the cracking unit, and the stove was lit for 45 minutes, adjusted to the intermediate position of the flame to avoid excessive energy consumption and to reach the highest temperature possible under these conditions. Thus, a test was carried out without a catalyst, while the pyrolysis tests by thermal catalysis were carried out with the addition of black clay powder, a type that is richer in aluminosilicates (LESKI; BERKOWICZ-PŁATEK, 2021), in the proportions of 5, 10, 15 and 20% in relation to the mass of the raw material used. The best condition observed with the tests was repeated, but with manual control of the flame to stabilize the temperature around 250-260 °C (Table 1), the temperature at which the beginning of the reactions in the cracking unit was observed in all the tests performed.

Table 1: Experiments carried out with pyrolysis of polymers.

Pyrolysis Type	Polymer mass	Catalyst mass	Condition
Thermal	200 g	-	Stove with intermediate flame.
Thermo-catalytic	200 g	10 g	Stove with intermediate flame.
Thermo-catalytic	200 g	20 g	Stove with intermediate flame.
Thermo-catalytic	200 g	30 g	Stove with intermediate flame.
Thermo-catalytic	200 g	40 g	Stove with intermediate flame.
Thermo-catalytic	200 g	20 g	Stove with controlled flame around 250 - 260 °C.

Source: by authors (2022).

After each procedure performed, the resulting masses of liquid and solid compounds were measured on a precision scale of 1 g (Fig. 10), and the mass of gases was estimated, subtracting the liquid and solid masses from the total mass of polymers used, according to the formula:

$$mG = mP - (mL + mR)$$

Where,

mP = mass of polymers (raw material)
mL = mass of liquid obtained
mG = mass of gases obtained
mR = mass of solid waste

The compounds obtained from liquid fuel were properly transferred to suitable flasks, with this, the tabulated data were analyzed to verify the best condition in which the cracking of the polymers occurred. This analysis was performed observing and evaluating the following criteria:

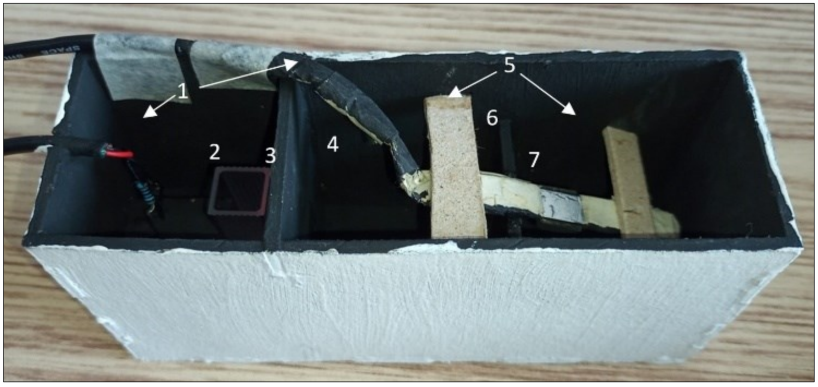
01. Greater amount of liquid fuel collected;
02. Lower energy expenditure, measured by comparing the mass of the LPG (liquefied petroleum gas) gas refill before and after the conclusion of each experiment;
03. Greater amount of fuel, liquid and gas, generated;
04. Greater relationship between fuels produced and energy expenditure with LPG gas.

A sample of the liquid compound obtained in the 3rd experiment, with the best results, was washed with distilled water to remove impurities and then passed through a simple distillation process to separate water residues and, mainly, other residual impurities.

After completing the purification procedures, a sample of the compound was submitted to absorption spectrophotometry analysis, using the WUV-M51 Web Labor spectrophotometer, also performed on a commercial sample of pure common gasoline, obtained by adding and mixing 200 ml of distilled water in 600 ml of regular gasoline, with subsequent decanting and draining of the aqueous/ethanol mixture, as according to Brazilian legislation, regular gasoline must contain up to 27.5% of anhydrous ethanol (BRASIL, 2014), thus obtaining 435 ml of pure gasoline.

To certify the results obtained by the analysis by spectrophotometry, a visible light spectrometer was built (Fig. 5), by which it generates curves of the continuous spectrum of the fluid under analysis. Through it, it was possible to obtain the visible irradiation spectra of both commercial gasoline and pyrolysis oil and, thus, make a comparison between the two results, verifying similarities or discrepancies. For the construction of this equipment, the works of Feng *et al*. (2021) and Silva *et* *al*. (2021) were used as a basis, which prove the effectiveness and precision of their respective projects comparing their results with those of commercial spectrometers. The optimization of the constructed device was carried out by calibrating the position and distance of the camera in relation to the spectrum generated by the diffraction grating, as well as adjusting the spectral curve in the Theremino Spectrometer version 3.1 software. These procedures were performed according to the notes of Gatkine *et al*. (2018), using green (532 nm) and red (645 nm) lasers.

Fig. 5: Built-in visible light spectrometer.



1 – USB cables, connected to the PC/notebook; 2 – Light source compartment (high brightness LED); 3 – Cuvette for spectroscopy; 4 – Light outlet hole; 5 – Fixing supports for camera; 6 – Diffraction grating; 7 – Laptop camera.
Source: by authors (2022).

RESULTS AND DISCUSSION

The results obtained through the first five polymer cracking experiments carried out were tabulated and, with this, it was possible to analyze and verify the most favorable conditions for carrying out polymeric pyrolysis under the conditions described in this research. After identifying the best scenario among the pyrolysis experiments carried out, the conditions in which it occurred were repeated in the sixth test, with flame control to maintain temperatures around 250 °C, reaffirming the best results obtained in the third procedure (Table 2). However, to confirm the best scenario, six tests were carried out with different polymeric raw materials, which obtained different proportions of fuel and waste.

Table 2: Final synthesis of the six cracking experiments of mixed PP and PE polymers.

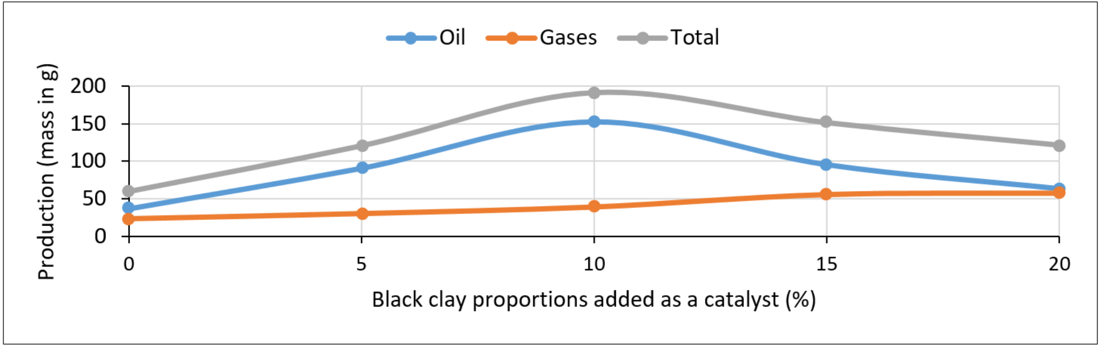
Tests	Maximum temp. (°C)	Catalyst (g)	Byproduct (g)			Residue (g)	LPG consumption (g)	Conversion rate	Energy ratio
			Oils	Gases	Total				
1.º	318,5	0	37	23	60	140	72	30,0%	0,83:1
2.º	331,8	10	91	30	121	79	79	60,5%	1,53:1
3.º	293,3	20	153	39	192	8	78	96,0%	2,46:1
4.º	321,6	30	96	56	152	48	76	76,0%	2,00:1
5.º	310,0	40	64	58	122	78	74	61,0%	1,64:1
6.º	254,0	20	70	37	107	93	65	53,5%	1,64:1

Source: by authors (2022).

The analysis of the results allowed us to point out the third test, which received black clay as a catalyst at a rate of 10%, as the one that presented the best fuel production and high polymer conversion rate, 96% of the polymeric mass, with the lowest relative energy expenditure, exceeding two parts of fuel obtained for each part of fuel consumed, thus presenting a ratio of 2.46:1 (byproduct: consumption).

Using the data in this table, it was possible to build a comparative graph (Fig. 6), relating the production of fuel oil and gases, and the total amount of fuel produced in each of the experiments carried out, according to the percentage of catalyst added. However, the sixth experiment was not included, as it took place in different temperature conditions than the others.

Fig. 6: Comparison in the production of fuels between the experiments carried out.

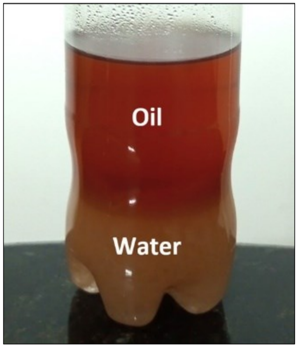


Source: by authors (2022).

From the graph it is possible to notice the increase in the production of liquid and gaseous fuels, as the catalyst material is added in up to 10% of the polymeric mass, at which time there is a reduction in the production of oils, in case of an increase in this percentage, however, gas production does not decrease. It is also verified that the gaseous production becomes more intense to the detriment of the oil production, as the amount of the catalyst is increased.

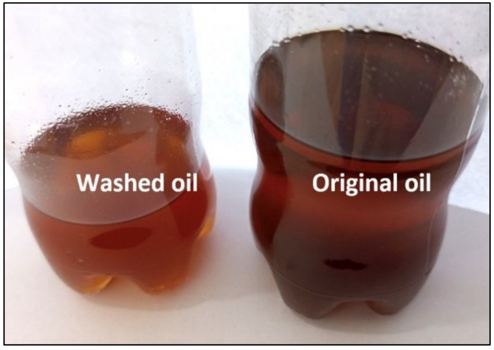
To analyze the pyrolysis oil obtained in the third experiment, a 50 g sample of it was subjected to two purification procedures, washing and distillation. The first procedure, washing, was carried out with distilled water to avoid unwanted reactions between the fuel and the salts present in drinking and tap water. The process was repeated three times in the same sample, aiming at more efficiency. The water, with absorbed impurities, was separated from the oil by decanting (Fig. 7a), thus obtaining a lighter fuel than the original oil (Fig. 7b).

Fig. 7a: Washing the pyrolysis oil.



Source: by authors (2022).

Fig. 7b: Difference between washed oil and original oil.



Source: by authors (2022).

The distillation procedure was carried out by simple distillation, using the infrastructure of the pyrolysis reactor assembled, at temperatures below 100 °C, to separate the lighter compounds from the pyrolysis oil, in the gasoline condensation range. In this way, the washed oil was accommodated in a glass container (distillation flask) and its lid was sealed and perforated for the allocation and fixation of a copper tube, also sealed, and connected to a hose, with the same diameter as the pipe (¼ inch), also used as a coil for the condenser (Fig. 8a-8b).

Fig. 8a: Distiller mounted.

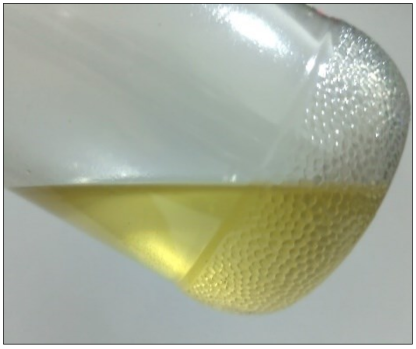
Source: by authors (2022).

Fig. 8b: Pyrolysis oil being distilled.

Source: by authors (2022).

Through the distillation process, two compounds were obtained, 30 g of a clean and clear fuel (Fig. 9a), resulting from the condensation of lighter gases; and 18 g of residue, with the consistency of dense and dark grease (Fig. 9b), remaining in the flask. The remainder of the prepared sample, 2 g of material, represents the removed impurities and non-condensable gases.

Fig. 9a: Oil obtained by distillation.



Source: by authors (2022).

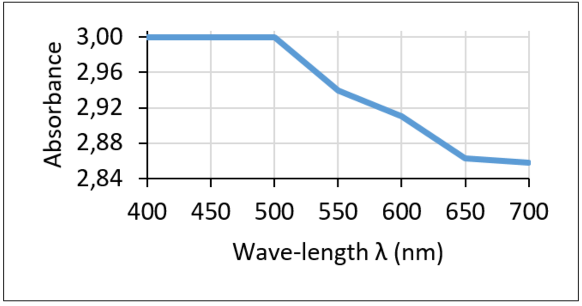
Fig. 9b: Distillation residues.

Source: by authors (2022).

The analysis of the obtained compound was performed by comparing the spectrophotometry results of a sample of purified commercial gasoline, as a reference. The measurements took place in the visible light spectrum range, from 400 to 700 nm of electromagnetic wavelength, between 50 nm spaces, with three repetitions for each measurement. From the data of these measurements, it is possible to observe the total absorbance of the radiation up to 500 nm, at which time it begins to decrease, in a sinuous way, until it stabilizes in the range of 650 nm, with lower energy absorbance at 700 nm (Fig. 10).

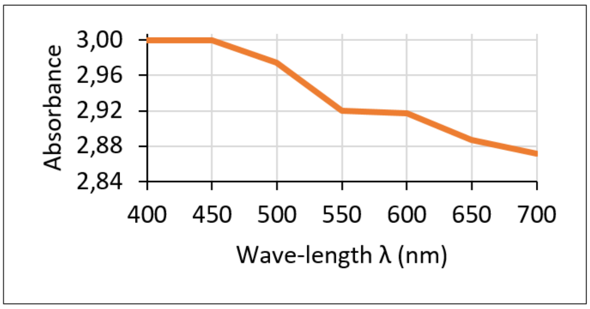
The spectrophotometry analysis of the pyrolysis oil followed the same conditions and steps as those performed with commercial gasoline. Thus, from the information acquired through the measurements, the behavior of the curve similar to that of commercial gasoline can be observed, with initial total absorbance, up to 450 nm, and then a drop in this aspect, until reaching 700 nm, the lowest absorbance point presented in the fuel (Fig. 11). However, in the electromagnetic range between 550 and 600 nm, there is a slight deceleration in the drop-in absorbance, and then it returns to the rate of reduction, tending to reduce even more in the infrared spectrum.

Fig. 10: Visible absorption spectrum of pure commercial gasoline.



Source: by authors (2022).

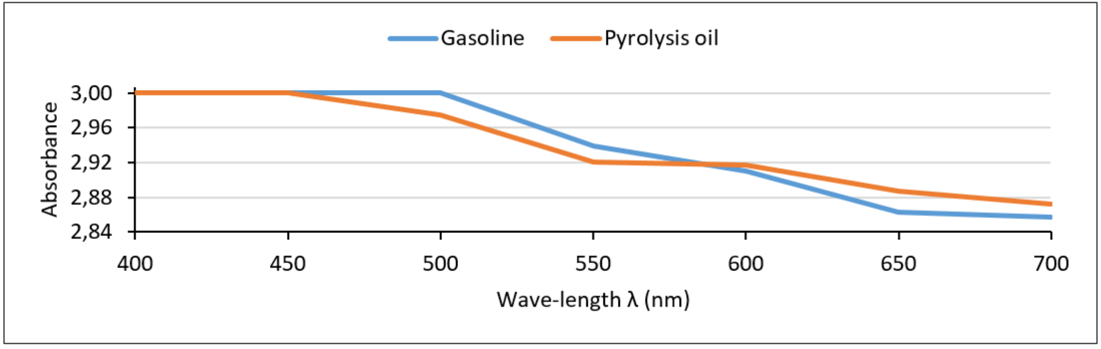
Fig. 11: Visible absorption spectrum of the pyrolysis oil obtained.



Source: by authors (2022).

By superimposing the curves of these two graphs (Fig. 12) it is possible to better verify the spectrophotometry similarity between analyzed compounds. It is observed, then, that the components presented in the electromagnetic range between 400 and 450 nm are the same for both the standard fuel, commercial gasoline, and the fuel obtained with polymeric cracking. Likewise, this occurs in the range of 585 nm, when the curves of the compounds intersect, indicating a common composition, as well as the tendency of the curves to meet again in the infrared spectrum, above 700 nm of the spectrum of this radiation. In the segment between 450 and approximately 585 nm, the pyrolysis oil has lower energy absorption than the same range of standard gasoline, thus indicating the obtaining of lighter and less energetic fractions of fuels in this range of the spectrum. However, in the segment between 585 and 700 nm, the pyrolysis compound absorbs more energy than the reference fuel, obtaining, in this range, fractions of heavier components and, therefore, more energetic components of this fuel.

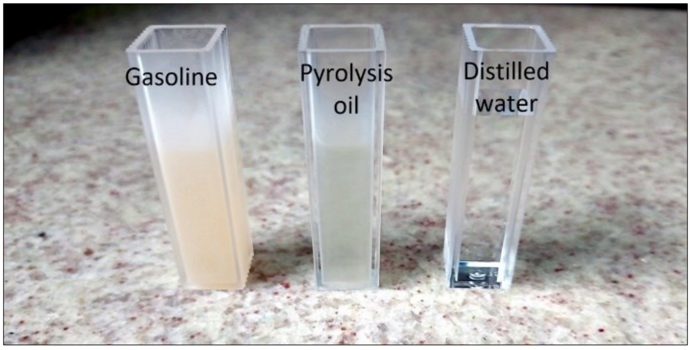
Fig. 12: Superimposed visible absorption spectra of pure commercial gasoline and obtained pyrolysis oil.



Source: by authors (2022).

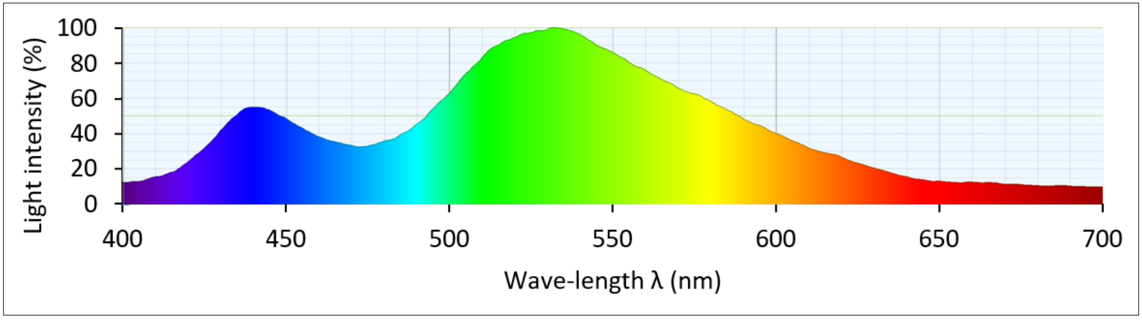
In order to validate the results obtained with the spectrophotometry analysis, a spectrometry study was also carried out, using the device set up for this purpose, on samples of distilled water, purified commercial gasoline and pyrolysis oil obtained (Fig. 13). Thus, aiming at a more consistent analysis, the visible light spectrum of the distilled water sample was initially obtained (Fig. 14), which served as a parameter to generate the spectra of the fuel compounds to be compared.

Fig. 13: Samples analyzed by spectrometry.



Source: by authors (2022).

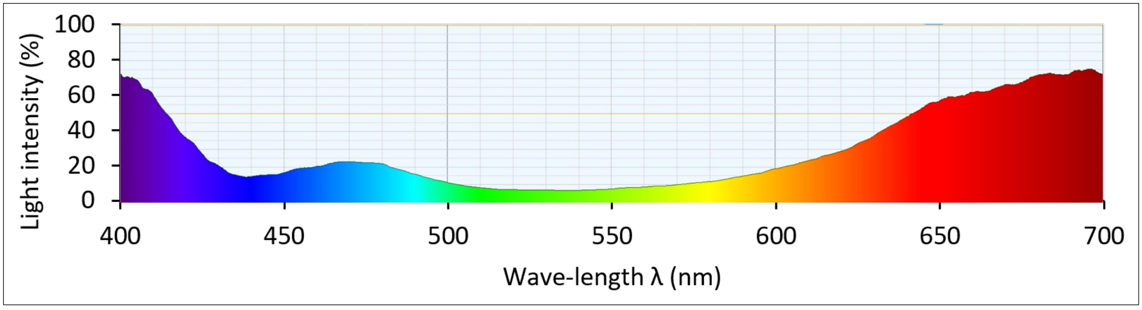
Fig. 14: Spectrum of visible light emission of distilled water.



Source: by authors (2022).

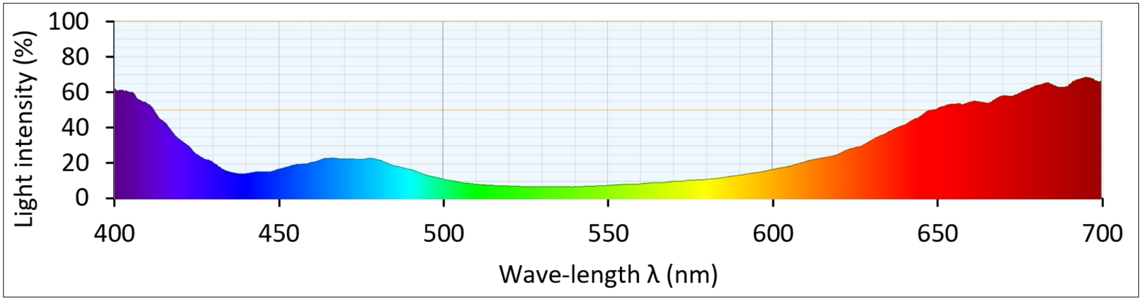
After calibrating the spectrometer, using distilled water, the spectra of the fuels under analysis were obtained. Thus, it can be observed in the spectrum of purified commercial gasoline (Fig. 15) a greater intensity in the ranges between 650 and 700 nm, corresponding to red light, and between 400 and 415 nm, consistent with violet light. In the other parts of the spectrum, greater absorption of green light is observed, between 500 and 540 nm. Compared to the gasoline spectrum, the pyrolysis oil spectrum (Fig. 16) presents very similar behavior and characteristics, with bands close to higher intensities and higher radiation absorptions in relation to the analyzed gasoline spectrum.

Fig. 15: Visible light spectrum of purified commercial gasoline.



Source: by authors (2022).

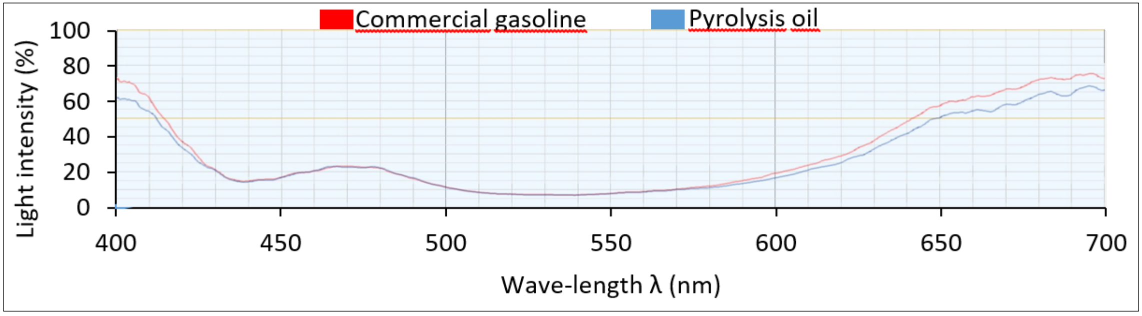
Fig. 16: Visible light spectrum of pyrolysis oil.



Source: by authors (2022).

With the superposition of the spectra of gasoline and pyrolysis oil (Fig. 17), the similarities between the visible radiation spectra of the two compounds can be seen more clearly, especially in the range from 460 to 540 nm. In this interval, a profound similarity between the spectra can be verified, indicating compatible compounds in the two analyzed fuels. However, there are small differences in the other parts of the spectra, with pyrolysis oil showing a little more energy absorption, thus indicating that it is a slightly heavier and more energetic compound, compared to gasoline. However, even with these discrepancies, the overlay of the graphs presents similar behaviors, indicating similar compositions, even in the divergent bands.

Fig. 17: Superposition of visible light spectra of purified gasoline and pyrolysis oil.



Source: by authors (2022).

CONCLUSION

In view of the results presented, it was found that the objectives of this research were fully met, however, some reservations must be pointed out. In this sense, it was observed that the prototype of the assembled pyrolysis reactor, despite being efficient and suitable for the proposal presented here, can be improved and have its costs even lower, replacing the aluminum pressure cooker, a relatively fragile material at high temperatures, by a paint can, made of steel and more resistant, without the need for sealing with a rubber ring. It was also observed that the condenser coil did not necessarily need to be made of a copper tube, and could be assembled with a plastic or rubber hose, since the high temperatures occur only inside the cracking unit and the condenser must be immersed in water at low temperatures.

Both the thermal variation and the variation of proportions added of black clay as catalyzed in the catalytic cracking process of polymers exerted influences on the quantities and characteristics of the by-products obtained in the experiments carried out, however, the process without the use of the catalyst did not obtain satisfactory results. Thus, even with the efficiency verified in the thermal insulation system, temperatures below 300 °C are not indicated for carrying out polymeric pyrolysis, at the cost of sacrificing the efficiency of the system and the return on fuels obtained.

After the spectroscopic analysis of the sample of the liquid compounds obtained, in comparison with the same analysis performed on commercial gasoline, similarities were verified in the spectral curves and, therefore, in their respective compositions, thus pointing to gasoline as one of the compounds acquired with the catalytic cracking process. However, more definitive analyzes and tests can be performed for a more accurate identification of the polymeric pyrolysis fuel composition.

Thus, it is concluded that the thermal catalysis cracking procedure presented in this study is feasible for its implementation on any scale, from a small reactor, as presented here, to a large commercial reactor. This feasibility was observed in relation to the economic aspect, since the model of the reactor suggested and assembled aims at the low cost of its construction and the materials used in it. In addition, the energy consumption observed in the best scenario among the tests carried out, confirms the aforementioned economic feasibility, since the relationship between the amount of fuels acquired with the pyrolysis process and the fuels consumed is very favorable for the pyrolysis oil, thus indicating that the energy expenditure is compensated by the procedure performed.

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