MULTI-CRITERIA ANALYSIS FOR SELECTING THE OPTIMUM BLEND IN THE CO-GASIFICATION PROCESS

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Abstract

Co-gasification is an efficient process for obtaining valuable by-products from blending different raw materials. However, selecting the optimum blend in co-gasification is complicated to establish as it depends on the criterion selected. Analytical Hierarchy Process (AHP) was used for obtaining the optimum blend in the co-gasification of olive pomace, almond shells and petcoke. H_2/CO ratio, reactivity at 50% of char conversion (R_{50}), carbon footprint of each gasification experiment and price of raw material were considered as four key factors when selecting the optimum blend in gasification. Fifteen alternatives were proposed (three raw materials and twelve blends) in this study. In addition, a sensitivity analysis was made to determine potential changes in the ranking of different alternatives. As a result, the priorities of the criteria under consideration were varied. Apart from an equal weighted scenario, 28 scenarios were considered for evaluating all possible interactions between the criteria.

1. Introduction

Nowadays, CO_2 concentration in the Earth`s atmosphere is at the highest levels recorded in human history. In 1880 (after the industrial revolution) CO_2 concentration in the atmosphere was 280 ppm, while in August 2019 it reached 409 ppm ("https://es.co2.earth,"). Therefore, CO_2 emissions should be decreased. In fact, by 2050 emissions must be cut by 80-95% compared to 1990 levels. Therefore, the European Union is striving to substantially reduce greenhouse gas emissions and promotes renewable energies as alternatives to fossil fuels. As there is ever- increasing global awareness about climate change, the carbon footprint concept is now commonly used both as a marketing tool and a way of raising awareness in society. Hence, European Union member states have developed ways of calculating the carbon footprint of products. However, despite the current trend in promoting sustainable energy sources to reduce greenhouse gas emissions, the world´s energy is still mainly generated by fossil fuels whose consumption is still rising. As a result, petcoke production (a refinery by-product) has increased. As this is normally used for electricity generation, it increases carbon emissions and exacerbates the climate change crisis. However, gasification is a well-known, more environmentally-friendly technology in which it can be converted into syngas (Murthy et al., 2014; Salkuyeh et al., 2016) which can then either be burnt directly or used for obtaining high added value products (Murthy et al., 2014). Despite significant progress in petcoke gasification technologies how effective such processes are is still under review. Moreover, the quality of petcoke in terms of H_2/CO ratio, is lower than that required to produce chemical compounds (Puig-Gamero, Argudo-Santamaria, et al., 2018). However, co-gasification of petcoke with other feedstocks such as biomass is one alternative that might streamline the process and improve syngas quality (Puig-Gamero, Lara-Díaz, et al., 2018). In addition, this could reduce fossil fuel depletion and CO_2 emissions (Joelsson & Gustavsson, 2010). Biomass is environmentally-friendly: it is plentiful, renewable, carbon-neutral, easily storable and transportable (Sikarwar et al., 2016) (Sikarwar et al., 2017). Nowadays, 14% of the world's primary energy consumption comes directly from biomass. In addition, it has been estimated that 4.8 Gt of oil equivalent biomass will be used as a fuel in 2050 (Ul Hai et al., 2019). As a result, many researchers have focused on co-gasification of biomass and petcoke when studying potential synergistic effects. Edreis E.M.A. et al., and Wang, G et all., studied the kinetic analyses and synergistic effect of CO_2 co-gasification of low sulphur petcoke and biomass wastes (Edreis et al., 2018; G. Wang et al., 2017). In this research gasification reactivity of petcoke was seen to improve by adding biomass. Wang.G et al., researched co-gasification of petcoke and biomass using steam as a gasifying agent (G. Wang et al., 2018). They also observed synergistic effects during co-gasification. However, these decreased when the biomass and gasification temperature increased. Moreover, they determined that alkali metal was the main variable behind the synergistic effect. Juntao Wei et al., also analyzed the effect gasification temperature and blend ratio had on reactivity of petcoke and biomass co-gasification (Wei et al., 2017). They saw that the synergistic effect on co-gasification reactivity was enhanced when total ash was generated and temperatures were under 1000 ºC. However, Ziqi Yang et al., published an interesting review about synergistic effects in thermochemical conversions of biomass with fossil fuels, concluding that co-gasification of biomass waste and petcoke is a promising alternative due to synergistic effects during co-gasification (Yang et al., 2019). However, none of them identified the optimum blend in co-gasification. Selecting such a blend is a complex decision which involving many variables, such as the quality and quantity of raw materials and products and technological and environmental issues. Thus, choosing the optimum blend must not only save time and money, but also avoid any negative environmental impacts (Qazi et al., 2018). In this respect, multi-criteria decision making (MCDM) compares and selects or ranks alternatives based on a multi-criteria evaluation (Hussain Mirjat et al., 2018). In this study, the Analytical Hierarchy Process (AHP), which is a popular MDCM method, was used to obtain the optimum blend. The AHP has been used in different research such as that on emissions from power plants (Chatzimouratidis & Pilavachi, 2007) or the impact the site of a solar power plant has (Giamalaki & Tsoutsos, 2019). Moreover, Philip Behrend et al., employed the AHP to compare different gasifier models in order to obtain the most appropriate one (Behrend & Krishnamoorthy, 2017). Bo Wang et al., studied the optimum energy conversion technology for processing agricultural residues using an AHP model and J.D. Nixon et al., studied the optimum option for recovering energy from municipal solid waste in India (Nixon et al., 2013; B. Wang et al., 2019). Nayyar Hussain et all., carried out a multi-criteria analysis on electricity generation for sustainable energy planning (Hussain Mirjat et al., 2018). Additionally, multi-criteria optimization for biomass gasification in a combined cooling, heating and power system was implemented by C.Y. Li et al.,(Li et al., 2018). However, there are no studies in which the multi-criteria analysis is used for obtaining the optimum blend in co-gasification. Hence, in this research, different blends of biomasses and petcoke are evaluated with respect to four criteria, which reflect economic (price of raw material) and environmental (carbon footprint in terms of CO_2 emissions) technical (gasification reactivity and H_2/CO ratio) aspects. For this purpose, the Analytic Hierarchy Process (AHP) was used, as it is a common tool in single- and multi-objective decision-making problems. Moreover, this kind of research can help gasification plant managers plan for the future, thereby saving time, money and reducing any harmful environmental impacts.

2. Methodology

2.1. Materials

Olive pomace (op) obtained from "Aceites Garcia de la Cruz" olive oil mill, Madridejos (Toledo, Spain), almonds shell (A) from Castilla-La Mancha and petcoke (P) from a refinery in Puertollano (Ciudad Real, Spain) were the raw materials used in this research. Figure 1 shows the mixture design used and Table 1 shows the composition of the blends prepared and the names used to identify them.

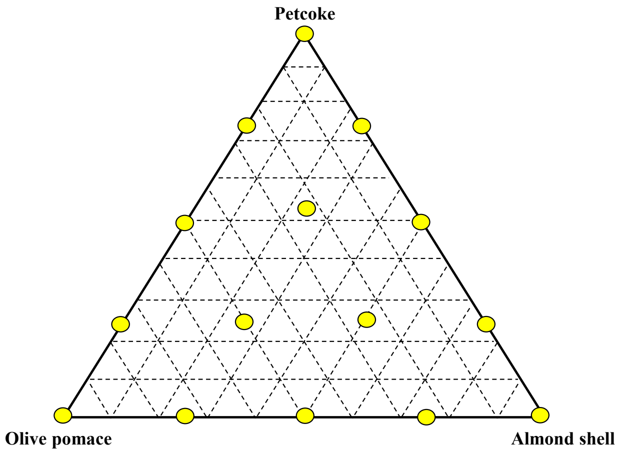


Figure 1. Schematic diagram of the mixture design for olive pomace, almond shell and petcoke.

Table 1. Olive pomace/almond shell/petcoke ratio used in the different blends studied.

Sample	*Petcoke (wt. %)*	*Olive pomace (wt. %)*	*Almond shell (wt. %)*
100P0op0A	100	0	0
0P100op0A	0	100	0
0P0op100A	0	0	100
0P25op75A	0	25	75
0P50op50A	0	50	50
0P75op25A	0	75	25
25P0op75A	25	0	75
50P0op50A	50	0	50
75P0op25A	75	0	25
50P50op0A	50	50	0
25P75op0A	25	75	0
75P25op0A	75	25	0
25P25op50A	25	25	50
25P50op25A	25	50	25
50P25op25A	50	25	25

2.2. Multi-Criteria decision making (MCDM): Analytical Hierarchy Process (AHP)

The analytical hierarchy process (AHP), introduced by Thomas Saaty (1980) (Saaty, 1990), is an efficient tool for making complex decisions, and it was used in this research for selecting the optimum blend during co-gasification. The AHP is an important method in MCDM and is based on the pairwise comparison of criteria and alternatives for determining priority scales. The decision-making problem is defined in a hierarchical structure in the AHP where this problem or goal is well-defined at the top with the main-criteria and sub-criteria further down and the decision-making alternatives at the bottom. The AHP was implemented with the following steps:

1. Defining a clear goal or decision-making problem; in this research this concerned selecting the optimum blend.
2. Identifying different criteria and sub-criteria. Here, the main criteria selected were the H_2/CO ratio, reactivity at 50% of char conversion (R_{50}), the carbon footprint for each gasification experiment and price of raw material. Thus, there were no sub-criteria.
3. Determining the alternatives. These were twelve blends and three raw materials (15 alternatives).
4. Establishing the hierarchical structure, breaking the decision-making problem down into goal, criteria and alternatives.
5. Developing the pairwise comparison matrix (A) for the main criteria. Matrix A is a $m^x m$ real matrix where m is the number of evaluation criteria considered. Each aij entry in matrix A represents the importance of the i criterion relative to the j criterion. The pairwise comparisons were measured according to a numerical scale from 1 to 9 developed by Saaty (Saaty, 1990). Table 2 shows how to interpret the scale.

Table 2. Table of relative scores.

Value	***Interpretation***
1	Equally important
3	Moderately more important
5	Considerably more important
7	Very considerably more important
9	Extremely more important
2,4,6 and 8	These values are used to assign intermediate value

6. Once the pairwise comparison matrix (A) is built, it must be normalized to obtain the normalized pairwise comparison matrix (A_{norm}). First, the values in each column are added. Subsequently, each value in the matrix is divided by the total value in its column. The resulting matrix is the A_{norm}.
7. Then, the criteria weight vector w is built by averaging the values in each row of A_{norm}.
8. The next step is to build a pairwise comparison matrix (B) for each of the m criteria. Matrix B is a $n^x n$ real matrix, where n is the number of alternatives evaluated. Each value in matrix B represents the evaluation of the alterative compared to the other ones with respect to each criterion. Then, the values in each column are added. Next, each value in matrix B is divided by the total value in its column, and then the average values of each row are calculated to obtain the score vectors which contain the scores of the alternatives evaluated with respect to the different criteria.
9. The matrix for option scores (matrix S) is obtained with the different vectors of the alternatives evaluated with respect to each criterion. It is a $n^x m$ real matrix.
10. Once the weight vector (w) and the score matrix (S) have been built, the vector v for the overall global score is obtained by multiplying S and w. The options ranking is carried out by ordering the global scores in descending order.
11. Finally, the consistency of each pairwise comparison matrix was checked. In general, a consistency ratio (CR) equal or less than 0.10 was considered valid. This parameter can be calculated as follows:

$$CR = \frac{CI}{RI} \quad [1]$$

where CI is the consistency index and RI is the Random Index.

$$CI = \frac{n_{max} - n}{n-1} \quad [2]$$

where n is the matrix size and the scalar n_{max} is the average of the vector elements in each matrix.

2.3. Thermogravimetric analysis coupled with analysis techniques for gaseous products

Thermogravimetric analysis coupled with analysis techniques for gaseous products (TGA-MS) was used herein to obtain reactivity at 50% of char conversion (R_{50}), the H_2/CO ratio and the carbon footprint. The gasification experiments were carried out in a TGA apparatus (TGA-DSC 1, METTLER TOLEDO) coupled with a mass spectrometer (Thermostar-GSD 320/quadrupole mass analyzer; PFEIFFER VACUUM). The steps taken in this process were: pyrolysis at temperatures ranging from 105 to 1000 ºC with a heating rate of 40 °C/min with a constant flow of 200 Nml/min in an Ar atmosphere and steam gasification at 900 ºC for 120 min. In this context, R_{50} was calculated with the following equation:

$$Ri = -1/wi \cdot dw/dt = (1/(1-xi)) \cdot dxi/dt \quad [3]$$

where x_i and w_i represent the conversion and the weight of char at any time, respectively.

Regarding the H_2/CO ratio and carbon footprint, gas yields were calculated by integrating the data obtained from the MS in gasification. The carbon footprint was calculated by following standard ISO 14069:2013. CO_2 and CH_4 were the main emissions considered when calculating the carbon footprint. Firstly, the climatic impact of the GHG emissions was assessed (by converting them into equivalent tonnes of CO_2) using the Global Warming Potential (GWP). The GWP values considered were 1 and 28 for CO_2 and CH_4, respectively (Montzka et al., 2011; C. Wang, 2019). Then, the carbon footprint was calculated as follows:

$$CF = +28 \cdot I_{CH_4} \quad [4]$$

where I_{CO2} and I_{CH4} represented the gas yields of CO_2 and CH_4, respectively.

3. Results and discussion

As mentioned above, different variables contribute to the effectiveness of gasification. The AHP is a valuable tool that enables both quantitative and qualitative aspects of different gasification variables to be assimilated in order to determine the most appropriate blend in any given situation. Firstly, the aim was defined as selecting the optimum blend. Then, the H_2/CO ratio, carbon footprint, char reactivity at 50% of conversion and price of raw materials were determined as being the most important factors influencing blend selection, and finally, fifteen alternatives were proposed (three raw materials and twelve blends). Figure 2 shows the final hierarchy structure established in this study, and breaks the decision-making problem down into goal, criteria and alternatives.

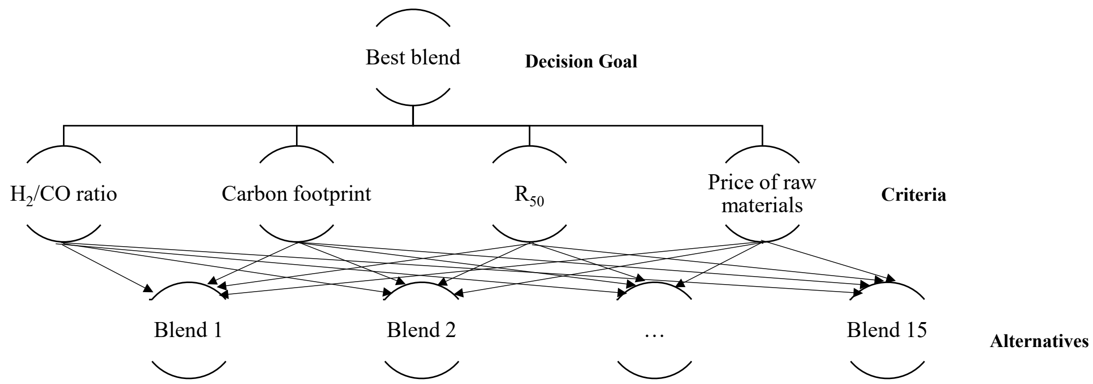


Figure 2. Hierarchical structure of the AHP for selecting the optimum blend in gasification.

3.1 Selection and description of criteria

In order to optimise reaction conditions and analysis methods, the variables which significantly influence the process (which can be found by experimenting and researching) must be known. Many variables contribute to the overall effectiveness of gasification. Here, the H_2/CO ratio, reactivity at 50% of char conversion (R_{50}), the carbon footprint for each gasification experiment and the price of raw material were considered to be four key factors when selecting the optimum blend in gasification and, thus, they were used when carrying out the AHP for the alternatives studied in this paper. In this study, the H_2/CO ratio and carbon footprint were obtained from the MS (semi-quantitative method), while R_{50} was obtained with a quantitative method (TGA). Likewise, the price of the raw material was also a quantitative value.

- **H_2/CO ratio of the gas produced during gasification (syngas quality)**

Synthesis gas or syngas is the valuable by-product from biomass gasification. It contains carbon monoxide, hydrogen, carbon dioxide and methane and traces of some other elements. Since it was first used in the nineteenth century by the London Gas, Light and Coke Company, it has become an important fuel (Sikarwar et al., 2017). Syngas can be used as a raw material in biofuels and chemical synthesis and in power generation. Gas composition is one of the most important criteria for obtaining quality gas for different applications. In power generation, essential gases are CO, H_2, CH_4 and hydrocarbons with a higher molecular weight than methane. However, to produce methanol and the Fischer-Tropsch synthesis, only CO and H_2 content are required. Gas composition can be controlled by the gasification conditions or by post-treatment of the gas product. In this context, higher temperatures give rise to a syngas rich in hydrogen and carbon monoxide. In addition, adding steam in gasification can yield a syngas rich in H_2. Hence, the gasification temperature selected was 900ºC and steam was used as the gasifying agent.

To sum up, the H_2/CO ratio is a key factor because it can determine the quality of the gas and how it is used. If the ratio is appropriate, it could be used to produce high-added value products such as methanol, ethanol or liquid hydrocarbons with the Fischer-Tropsch process.

- **Carbon footprint (CF)**

Nowadays, high greenhouse gas emissions (GHG) such as carbon dioxide, methane or nitrogen oxides derived from fossil fuel processes lead to global warming and harm public health (Im-orb & Arpornwichanop, 2016). Thus, new policy measures have made it obligatory to control and reduce these GHG. In this study, carbon footprint was used as an environmental indicator for calculating the overall amount of greenhouse gas emissions (equivalent emissions of CO_2) associated with gasifying each blend. Thus, higher greenhouse gas emissions, in turn, mean a higher carbon footprint. Therefore, in this study, carbon footprint was used as an environmental measurement and helped us know what blend was the most environmentally-friendly.

- **Reactivity at 50% of char conversion (R_{50})**

Char reactivity is a parameter which determine the kinetics in gasification, bearing in mind the degree of conversion. (Surup et al., 2019). Reactivity depends on temperature and gas composition and varies with the degree of conversion. In addition, char reactivity is also influenced by the amount of carbon and minerals in the raw material. In this sense, the higher the carbon content, the lower the reactivity. Char with a lower carbon content tends to contain a high amount of minerals such as calcium, magnesium, sodium and potassium, which can act as catalysts in gasification, thereby improving reactivity (Surup et al., 2019). Thus, char reactivity is a key factor when studying and comparing whether a blend improves or hinders gasification. Therefore, a representative value for reactivity must be selected in order to make a reliable comparison. In this paper, reactivity at 50% char conversion was deemed representative.

- **Price of raw materials**

This criterion was selected in order to factor in the economic variable. Nowadays, the economic point of view is still the most important one as projects must be profitable to be implemented. Moreover, it must be stressed that this study was aimed at obtaining the optimum blend in gasification and thus the capital cost associated with gasification was assumed to be the same for all blends. Therefore, the price of the raw material was the main variant in the economic assessment and a key factor when discarding less profitable blends. In this respect, the price of the raw materials under consideration was 0.07, 0.0709 and 0.0077 €/kg for almond shell (price obtained from (international)), petcoke (price obtained from Puertollano refinery, 2019) and olive pomace (obtained from *Aceites García de la Cruz* olive oil mill, 2018), respectively.

Table 3 summarizes the values obtained for the four criteria in gasification for each blend. It can be seen that selecting the best blend is complex and depends on the criterion. In this study, the blend 25P75op0A had the highest H_2/CO ratio. However, it also had one of the highest carbon footprints. Conversely, the blend 50P50or0A was the most environmentally-friendly one, but it had a low reactivity and H_2/CO ratio. As for the price criterion, the higher the olive pomace content in the blend, the lower the price. Thus, selecting the optimum blend was a complex matter, given that no one blend was optimal for all criteria. Therefore, the best blend would be the one with balanced values between the main criteria. Hence, a multi-criteria analysis was carried out for inter-relating all such criteria in order to obtain this blend.

Table 3. Values obtained for the four criteria: H_2/CO ratio, carbon footprint, R_{50} and price of raw material.

Sample	Criterion			
	H_2/CO ratio	**Carbon footprint (CDE*)**	**R_{50} (1/min)**	**Price of raw material (€)**
0P100op0A	0.0082	0.1247	0.1280	0.0077
0P0op100A	0.0030	0.1195	0.0730	0.0700
100P0op0A	0.0009	0.1126	0.0740	0.0709
0P25op75A	0.0151	0.1090	0.1280	0.0544
0P50op50A	0.0041	0.1646	0.0690	0.0389
0P75op25A	0.0107	0.0813	0.1080	0.0233
25P0op75A	0.0004	0.2841	0.0310	0.0702
25P25op50A	0.0134	0.0908	0.0180	0.0547
25P50op25A	0.0022	0.1003	0.0270	0.0391
25P75op0A	0.0556	0.2811	0.0340	0.0235
50P0op50A	0.0117	0.2177	0.0110	0.0705
50P25op25A	0.0305	0.0568	0.0080	0.0549
50P50op0A	0.0013	0.0234	0.0170	0.0393
75P0op25A	0.0031	0.1490	0.0390	0.0707
75P25op0A	0.0004	0.4063	0.0420	0.0551

CDE*: units equivalent of CO_2.

3.2 Determination of weightages of main criteria and sensitivity analysis

A sensitivity analysis for determining potential changes in the ranking for the alternatives was performed. Hence, the priorities of the criteria were varied. At this point, apart from an equal weighted scenario, 28 scenarios were considered to contemplate all possible interactions between the criteria. Table 4 shows the relative importance of each criteria in the different scenarios. Taking into account the numerical scale developed by Saaty (Saaty, 1990) and satisfying consistency requirements of each pairwise comparison matrix, one criterion was deemed to be the most important. In this respect, Scenario 2 (H_2/CO > CF > R_{50} > Price) means that H_2/CO was moderately more important (value 3) than CF, considerably more important (value 5) than R_{50} and very considerably more important (value

7) than price, and at the same time, CF was moderately more important than R50 and considerably more important than Price, and finally, R50 was moderately more important than Price, and so on. With scenarios of equal importance, for example, scenario 8 (H_2/CO > CF = R_{50} = Price), H_2/CO was deemed to be considerably more important (value 5) than the other criteria.

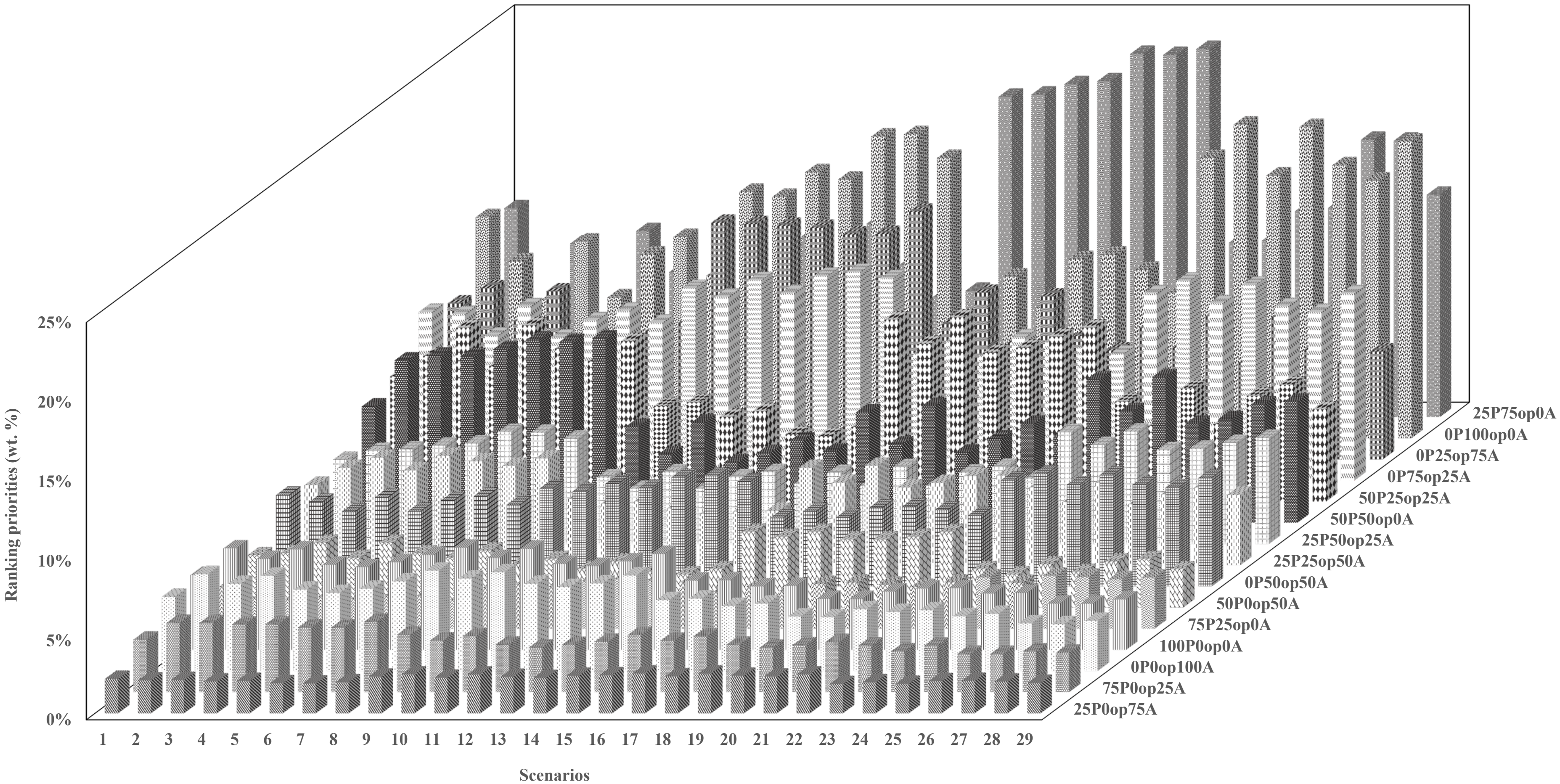
Table 4. Criteria of relative importance in different sensitivity analysis scenarios.

Scenario	Criteria importance	Scenario	Criteria importance
1	H_2/CO ratio = CF = R_{50} = Price	16	R_{50} > H_2/CO ratio > CF > Price
2	H_2/CO ratio > CF > R_{50} > Price	17	R_{50} > CF > H_2/CO ratio > Price
3	H_2/CO ratio > R_{50} > CF > Price	18	R_{50} > H_2/CO ratio > Price > CF
4	H_2/CO ratio > CF > Price > R_{50}	19	R_{50} > CF > Price > H_2/CO ratio
5	H_2/CO ratio > R_{50} > Price > CF	20	R_{50} > Price > CF > H_2/CO ratio
6	H_2/CO ratio > Price > R_{50} > CF	21	R_{50} > Price > H_2/CO ratio > CF
7	H_2/CO ratio > Price > CF > R_{50}	22	R_{50} > CF = H_2/CO ratio = Price
8	H_2/CO ratio > R_{50} = CF= Price	23	Price > H_2/CO ratio > CF > R_{50}
9	CF > H_2/CO ratio > R_{50} > Price	24	Price > CF > H_2/CO ratio > R_{50}
10	CF > R_{50} > H_2/CO ratio > Price	25	Price > H_2/CO ratio > R_{50} > CF
11	CF > H_2/CO ratio > Price > R_{50}	26	Price > CF > R_{50} > H_2/CO ratio
12	CF > R_{50} > Price > H_2/CO ratio	27	Price > R_{50} > CF > H_2/CO ratio
13	CF > Price > R_{50} > H_2/CO ratio	28	Price > R_{50} > H_2/CO ratio > CF
14	CF > Price > H_2/CO ratio > R_{50}	29	Price > CF = H_2/CO ratio = R50
15	CF > R50 = H2/CO ratio = Price		

3.3 Multi-criteria decision

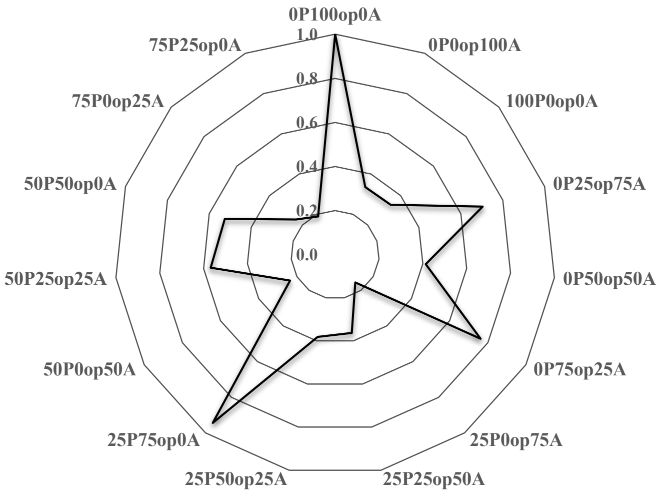
The pairwise comparison matrix for the main criteria and the criteria weight vector for all possible scenarios are shown in supplementary material (Table A1-A29). The next step was to check how consistent the matrix was. As explained in the methodology section, a consistency ratio (CR) equal to or less than 0.10 (10%) was considered valid. In this research, the CR was 6% in all scenarios, but the CR for scenarios 1, 8, 15, 22 and 29 was 0 %. Thus, the matrices can be deemed as consistent and, logically, satisfactory. Additionally, the pairwise comparison matrix for alternatives based on each criterion and their score vector are also shown in supplementary material (Table A30-A33). These matrices were calculated from quantitative and semi-quantitative data obtained in the experiments. Finally, the four score vectors, obtained previously, formed a new matrix. which was multiplied with the criteria weight vector obtained for each scenario to determine the general priorities for each alternative.

Figure 3 shows the AHP results for all scenarios. The AHP model compares the blend alternatives for each variable; in this study, three raw materials, nine binary blends and three ternary ones were considered. The optimal sample was seen to depend on the scenario studied, which meant criteria weightages were significant. However, in most scenarios, samples 0P100op0A and 25P75op0A the highest priority values. Therefore, sample 0P100op0A had the highest priority value in scenarios 1, 2, 4, 5, 6, 7, 9-15, 23-26 and 29, while sample 25P75op0A had the highest one in scenarios 5, 16-22 and 27-28. Only scenarios 3 and 8 were less influenced by these samples. As regards scenarios 3 and 8, the optimum blends were samples 50P25op25A and 50P50op0A, respectively. Hence, obviously, the criteria weightages had a significant relationship with the samples with the highest priority values. Consequently, sample 0P100op0A benefited when the highest weightage was for criteria H_2/CO, CF and price, while sample 25P75op0A was optimal for criteria R_{50} and price. In order to identify how the aggregate of all scenarios affected each sample, a normalized priority ranking was calculated by taking all scenarios into consideration.



25%
20%
15%
10%
5%
0%
Ranking priorities (wt. %)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Scenarios
25P75op0A
0P100op0A
0P25op75A
0P75op25A
50P25op25A
50P50op0A
25P50op25A
25P25op50A
0P50op50A
50P0op50A
75P25op0A
100P0op0A
0P0op100A
75P0op25A
25P0op75A

Figure 4 shows the normalized priority rankings for each alternative. It could be seen that the aforementioned blends had the highest priority values which were similar to each other, and they were followed by blend 0P75op25A. Finally, the least priority result was obtained with blend 25P0opo75A. Thus, on the basis of the AHP decision-making process, blends 0P100op0A, 25P75op0A and 0P75op25A were the most promising in gasification.



4. Conclusions

The Analytic Hierarchy Process (AHP) was used to obtain the optimum blend in co-gasification of olive pomace, almond shell and petcoke. Decision-making was defined in a hierarchical structure. In this respect, the aim of this study was defined as selecting the optimum blend. Then, H_2/CO ratio, carbon footprint, char reactivity at 50% conversion and the price of raw materials were determined to be the most important criteria influencing blend selection. Finally, fifteen alternatives were proposed (3 raw materials and 12 blends). In addition, 28 scenarios were considered by varying the criteria priorities in order to determine how sensitive the assigned weights and the results were. In this regard, the criteria weightages were significant as the optimum blends varied according to the scenario selected. Nevertheless, in most cases, samples, 0P100op0A and 25P75op0A had the highest priority values by far. Finally, the priority rankings for each alternative were normalized by taking all scenarios into account, the result of which was blends 0P100op0A, 25P75op0A and 0P75op25A were the most promising in gasification. In short, the AHP has proven to be a powerful tool for supporting decision-making in co-gasification.

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