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Bio-oil production from waste potato peel and rice hush

Produção de bio-óleo a partir de resíduo de casca de batata e casca de arroz

Marcelo da Silva Batista[1], Camila Oliveira Guimarães[2], Lívia Carneiro Marra[3] e Maikel Laurence Maloncy[4]

[1] Professor Associado I do Curso de Engenharia Química e do Programa de Pós-Graduação em Tecnologias para o Desenvolvimento Sustentável da Universidade Federal de São João del-Rei, Campus AltoParaopeba em Ouro Branco-MG.
marcelobatista@hotmail.com
[2,3] Graduandas em Engenharia Química - Universidade Federal de São João del Rei , Campus Alto Paraopeba em Ouro Branco-MG.
kmilinha@hotmail.com; livinha@msn.com
[4] The Hague University of Applied Science – Holanda
m.l.maloncy@hhs.nl

Abstract

Pyrolysis is one of the most effective, economic and useful ways to produce bio-oil in the absence of oxygen. This article presents a study about the production of bio-oil from pyrolysis of waste potato peel and rice husk. This study aimed to evaluate the influence of the average particle size of the waste potato peel, and compare the results with another raw material, the rice husk. Three particles size were analyzed: (a) 0,500<Ø<1,400 mm, (b) 1,400<Ø<3,350 mm, and (c) Ø>3,350 mm. The best result with liquid (water and bio-oil) was 29.18% and it was obtained from the smaller particle size. The results obtained from potato peel and rice husk were compared for grain sizes (a) and (b). It was observed that the rice husk with the smaller size is more effective for bio-oil production (44.29% of liquid). However for the large particles sizes, the most effective raw material was the potato peel presenting a result of 27.74% of liquid

***Keywords**: Pyrolysis. Bio-oil. Potato peel. Rice husk*

Resumo

A pirólise é uma das formas mais eficazes, econômicos e úteis para a produção de bio-óleo na ausência de oxigênio. Este artigo apresenta um estudo sobre a produção de bio-óleo a partir da pirólise de resíduos de casca de batata e casca de arroz. Este estudo teve como objetivo avaliar a influência do tamanho médio de partícula de resíduos da casca de batata, e comparar os resultados com outra matéria-prima, a casca de arroz. Três tamanhos de partículas foram analisados: (a) 0,500<Ø<1,400 mm, (b) 1,400<Ø<3,350 mm, e (c) Ø>3,350 mm. O melhor resultado em líquido (água e o bio-óleo) foi 29,18%, obtido a partir do menor tamanho de partícula. Os resultados obtidos a partir de casca de batata e casca de arroz foram comparados para os tamanhos de grão (a) e (b). Observou-se que a casca de arroz com o menor tamanho é mais eficaz para a produção do bio-óleo (44,29% de líquido). No entanto, para os maiores tamanhos de partículas, a matéria-prima mais eficiente foi à casca de batata apresentando um resultado de 27,74% de líquido.

***Palavras-chave**: Pirólise. Bio-óleo. Casca de batata. Casca de arroz*

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1 INTRODUCTION

Nowadays, the oil reserves of easy access are becoming exhausting and the new reserves are located in inhospitable regions, such as deserts, icy regions and large depths below marine waters (MORTENSEN et al, 2011). Because of that, there has been a huge effort to develop a new technology to explore this traditional fuel which has made the price of this energetic source grow and emerge alternative energy sources.

In this context, fuels derived of biomass called biofuels are considered energetic materials with great potential since they are produced in a short production cycle and are renewable sources.

The first generation biofuels are produced from fermentation of sugar or starch (bio-ethanol) or manufactured from vegetable oils (bio-diesel). A few years ago emerged the second generation biofuels which originated from agricultural waste, wood scraps and other organic waste products (VALLE et al, 2010).

The bio-oil is a second generation biofuel and because of that do not interfere or compete with agricultural products since it is made of waste of materials. The concept of this type of fuel is the conversion of rejected organic materials into more valuable products. In this perspective, the bio-oils certainly represent an attractive alternative for Brazil, which has a very significant agricultural production, and where there is consequently a substantial waste and organic waste (ONAL et al, 2011).

The technology of biomass pyrolysis is an economic and advantageous way to get liquid fuel (bio-oil) at atmospheric pressure and in the absence of oxygen and this can be also done continuously and on a large scale. The bio-oil is considered a clean energy and has a high energy density and very low amount of sulfur and nitrogen (ROCHA et al, 2005). It is noteworthy that in the pyrolysis process, there is the generation of byproducts of good energy content which are biogas and biochar. The gas obtained on the pyrolysis process is predominately composed of carbon oxides (CO, CO_2) and methane (CH_4). On the other hand, the liquid fraction generated (bio-oil) consists of organic acids, esters, alcohols, ketones, aldehydes, phenols, alkenes, furans, guaiacols, seringols, sugars and various oxygenates (JAYASINGHE et al, 2012).

The potato is considered one of the main vegetables currently cultivated in Brazil within the production is estimated in about of 3.785.257 tons in the year 2013 with an average growth of 1.6% over the past 5 years (IBGE, 2013). The area planted annually is around 170.000 ha with a production exceeding 2.5 million ton / ha. The south and southeast regions produce more than 95% of Brazilian production contributing approximately 98% of the area planted with potatoes in Brazil (ARRUDA, 2004). In worldwide terms, Brazil is the tenth largest producer of potato.

The potato is the raw material on the production of starch, alcohol (wine) and traditional foods of Brazilian homes. One form that has grown a lot in recent years is the "chips" form (fries packed). It is estimated that in this manufacturing process of this type of food product are disposed over 300.000 tons of potato skins per year. Since this huge waste generation and for being an organic product this type of waste is certainly a good source of bio-oil (FERNANDES et al, 2008). According to YORINORI (2012) the potato as food is consumed in different ways such as: 85% in the fresh form, 10% in the chips form and 5% preprocessed form.

Another source with a good potential of bio-oil production is the rice husk. Brazil production is approximately 11 million tons of rice husks per year and that material represents 20% of the grain weight. The rice husk is composed of 10% of silica (SiO_2), and the remainder is organic material such as cellulose, hemicellulose and lignin (CAMPOS et al, 2013). DINIZ (2005) in his doctorate thesis showed that the production of bio-oil from rice husk can be performed in a fixed bed at lower temperatures if compared to others organics sources and being the temperature about 420°C. The oil obtained was not toxic and presents a good energetic level with the advantage of not produce polluting gases. It occurs when the rice husk is burned in furnaces or steam boilers since this raw material presents a good calorific value 3384 Kcal/Kg (COELHO et al., 2002). A big disadvantage of the rice husk is the low density and high hygroscopicity which has a bad effect in costs of transport.

In this article the production of bio-oil by pyrolysis from potato skin was studied in order to evaluate the influence of the average size of this raw material in the yield of fuel (gases, liquids and solids). For comparison of results it was also evaluated yield of pyrolysis from rice husk.

2 METHODOLOGY

The Figure 1 shows a sequence of operations of a typical industrial production of potato in the form of chips. It can be seen that in the peel step are generated skin potatoes which is the material used to produce bio-oil in this article.

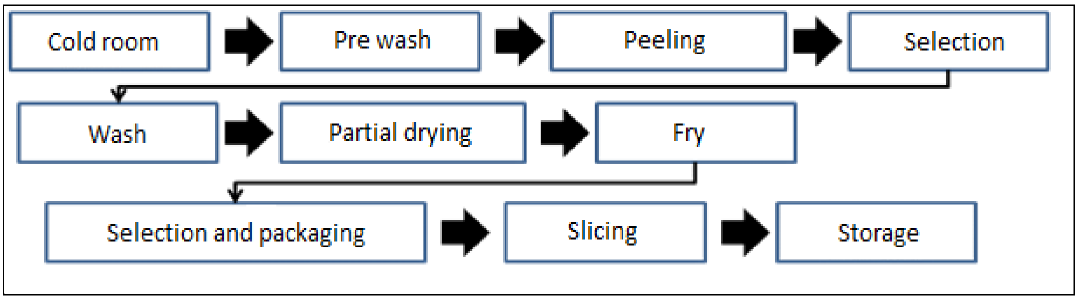

Figure 1 - Flow chart of the production of potato chips

The potato skin used in this article was provided by the Frithais Company (Conselheiro Lafaiete - MG – Brazil) which produces chips potato. Initially the preparation of the raw material was performed. This preparation consists of drying the potato skins in an oven at the temperature of 120 °C for about 3 hours. Under these drying conditions, the mass loss is due only to the water removal (ÖNAL et. al., 2011).

The dried particles were separated by size ranges with a granulometric sieves in vibrating table for a period of 10 minutes. These particles were classified in six different particle sizes such as: (i) less than 0.150 mm, (ii) between 0.150 mm and 0.300 mm, (iii) between 0.300 and 0.500 mm, (iv) between 0.500 mm and 1.400 mm, (v) between 1.400 and 3.350 mm (vi) greater than 3.350 mm.

The fast pyrolysis of potato skin and rice husk was performed in a reactor of stainless steel (AISI 306) 280 mL and at atmospheric pressure. The heating (~ 100°C/min) was also performed with a resistor of 2000 Watts of power that was tailored for the steel reactor. In order to avoid heat losses, the reactor was surrounded with rock wool. The temperature was measured and controlled by a PID controller connected to a thermocouple. In each batch were used approximately 30 g of dry potato skin or rice husk. Nitrogen was used as carrier gas with a flow rate of approximately 50 ml / min throughout all the process. The residence time in the pyrolysis end temperature was 2 to 3 min for each experiment. At the exit of the reactor the liquid product (bio-oil + water) was condensed in tubes immersed in an ice bath. So as to evaluate the influence of the potato skin size in liquid yield obtained on bio-oil production, three particle sizes were defined by : (a) between 0.500 mm and 1.400 mm , (b) between 1.400 and 3.350 mm , and (c) greater than 3.350 mm. The yields of solid (coal), liquid (bio - oil + water) and gas were calculated by following equation.

$$Yield\ (\%) = \frac{m_i x100}{m_{total}} \qquad (1)$$

m_{total} = mass of dry potato skin or rice husk used in batch; mi = mass obtained of solid or liquid or gas; mass of gass = m_{total} – mass of sólido+liquid.

3 RESULTS AND DISCUSSION

The results of particle size classification of dried potato skins are presented in Table 1. This table shows that the potato skin received from the company- Frithais concentrated in larger particle size ranges which 80% of the material is above 1.40 mm. Only 1.5 % of the materials are in the range of smaller size below 0.30 mm. The remaining material (18.5%) presented the intermediate size granulometric classification which is 0.30 to 1.40 mm. Because of this results was chosen to work with granulometric ranges that presents a bigger amount of material and the three size classes chosen for production of bio-oil were: class (a), between 0.500 mm and 1.400 mm (with 16.8% of the material received), class (b) between 1.400 and 3.350 mm (with 55.5% of the incoming material) and class (c) greater than 3.350 mm (with 24.5% of material received).

Table 1 - Particle size distribution of the residue of potato peel

Granulometric range	Mass of potato skin (g)	Percentage weight (%)
Less than 0.150 mm	0.06	0.4
Between 0.150 mm and 0.300 mm	0.18	1.1
Between 0.300 mm and 0.500 mm	0.29	1.7
Between 0.500 mm and 1.400 mm	2.80	16.8
Between 1.400 mm and 3.350 mm	9.21	55.5
Greater than 3.350 mm	4.07	24.5

While the pyrolysis experiments of potato skin were performed, it was observed that the production of gas inside the reactor starts between 60ºC e 70ºC and that the gas outlet is attenuated when reaches temperatures higher than 80°C. Liquids and gaseous products were obtained by fast pyrolysis in temperatures between 550ºC a 580ºC. The table 2 shows the fractions yields of gas, liquid and solid in the three particle sizes that were evaluated.

By Table 2 can be seen that as the size of potato skin was increased there was a decrease in the yield of the liquid fraction and consequently less bio - oil was produced. In the other hand, this increased causes higher yield of gaseous fraction while the yield of the solid fraction remained almost constant. ONAY E KOÇKAR (2001) working with pyrolysis from safflower seed also observed a decrease in the bio-oil yield when the particle size is increased. For these researchers this income drop is explained by the heat transfer within the particles which during the pyrolysis occurs more slowly in materials with larger particle size. So the heating of the larger particle size is less uniform what causes a longer time to reach the treatment temperature. On the other hand, the lower granulometry (between 0.500 and 1.400 mm) presented more uniform heating and thus showed the best performance in liquid (29.18%).

Table 2 - Measured gas, solid and liquid, using different particle size and temperature between 550-580 °C

Experiment	Size (mm)	Gas yield (%)	Liquid yield (%)	Solid yield (%)
1	Class (a): between 0.500 and 1.400	40.04%	29.18%	30.78%
2	Class (b): between 1.400 and 3.350	39.91%	27.74%	32.35%
3	Class (c): greater than 3.350	55.31%	16.21%	28.48%

ÖNAL et al (2011) conducted a fast pyrolysis at 550 °C using potato skins with an average particle size of 0.80 mm and obtained different yields of gas (32.05%), liquid (47.50%)

and solid (20.45%). Comparing this results with the Table 2 (in range size: between 0,500 mm and 1,400 mm) is observed that the yield of liquid obtained in Table 2 was much lower (29.18%). Beyond that, the yield of solid observed by ÖNAL et al (2011) was lower than that observed in Table 2. These differences in yield can be explained by different conditions and techniques used in this experiment and by ÖNAL et al (2011). It is also observed that the ratio of potato skin mass per reactor volume used in this study (0.107 g of potato skin/ cm^3 of reactor) was much greater than the ration used by ÖNAL et al (2011) in experiments (0.025 g of potato skin/cm^3 of reactor).

The results of pyrolysis from potato skin were compared with results of pyrolysis from rice husk. So, experiments with rice husk to produce bio-oil were performed in the same conditions (mass, temperature, reactor and others) that were used for potato skin. For the rice husk were evaluated two particle sizes: (a) between 0.500 and 1.400 mm, (b) between 1.400 and 3.350 mm. The results are shown in Figures 2, 3 and 4.

In Figure 2 can be seen that the yield of solid products of pyrolysis of the potato skin and rice husk has changed a little with the variation of the particle size of the waste. It is also noted that yields of solid in this two types of particles are very similar.

Figure 3 shows that the pyrolysis from rice husk performed with the smaller range of size (class (a)) generated a large amount of liquid and therefore bio-oil. This residue showed a liquid yield of 44.3% while the potato skin showed a yield of 29.2%. On the other hand, for the greater range size (class (b)) the performance of the potato skin and rice husk reduced but the decreased of the income of the rice husk was significantly higher. For this class of particle the liquid yield of the potato skin (27.7%) was slightly higher than the yield of the rice husk (25.4%). This effect can be explained by the intense generation of gaseous fraction occurred in the pyrolysis of the gross particles (potato skin) which is showed in Figure 4. In addition to it, in the size range between 0.500 mm and 1.400 mm the pyrolysis process of the potato skin produced much more gas and in the other size range the production of gas is almost the same for the both biomass.

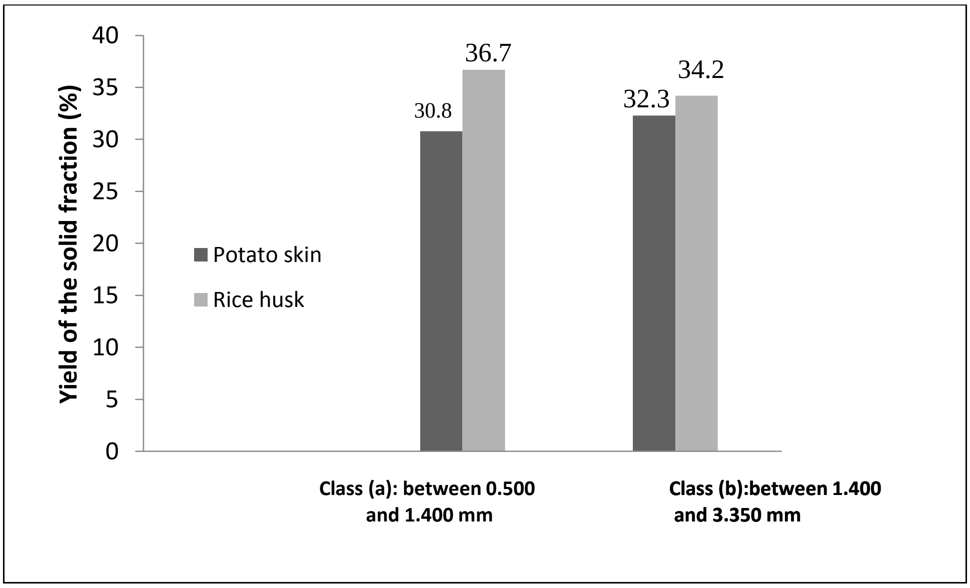

Figure 2 - Yields of solid fraction product obtained from the pyrolysis of potato skin and rice husk in two particle sizes: (a) between 0.500 and 1.400 mm and (b) Between 1.400 and 3.350 mm.

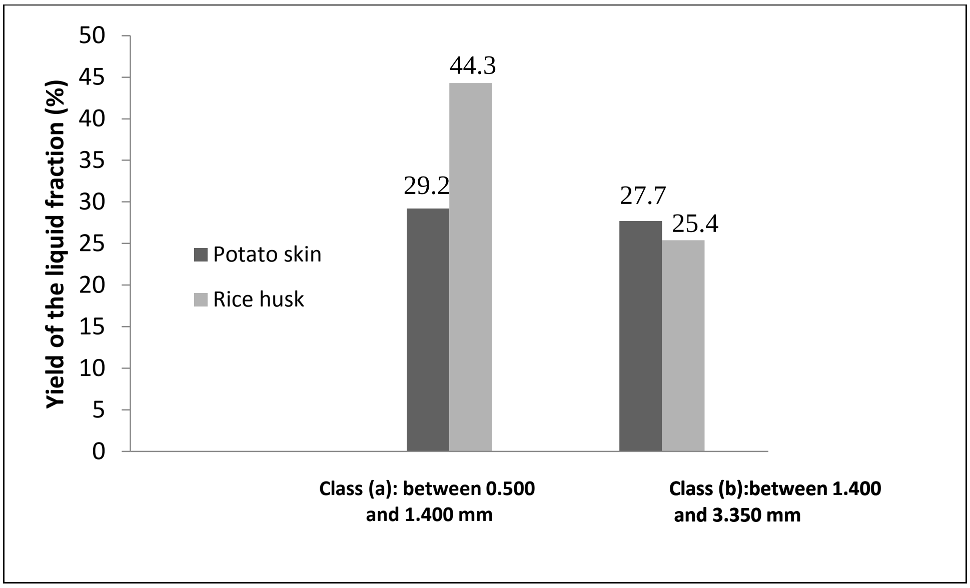

Figure 3 – Yields of liquid fraction product obtained from the pyrolysis of potato skin and rice husk in two particle sizes: (a) between 0.500 and 1.400 mm and (b) Between 1.400 and 3.350 mm.

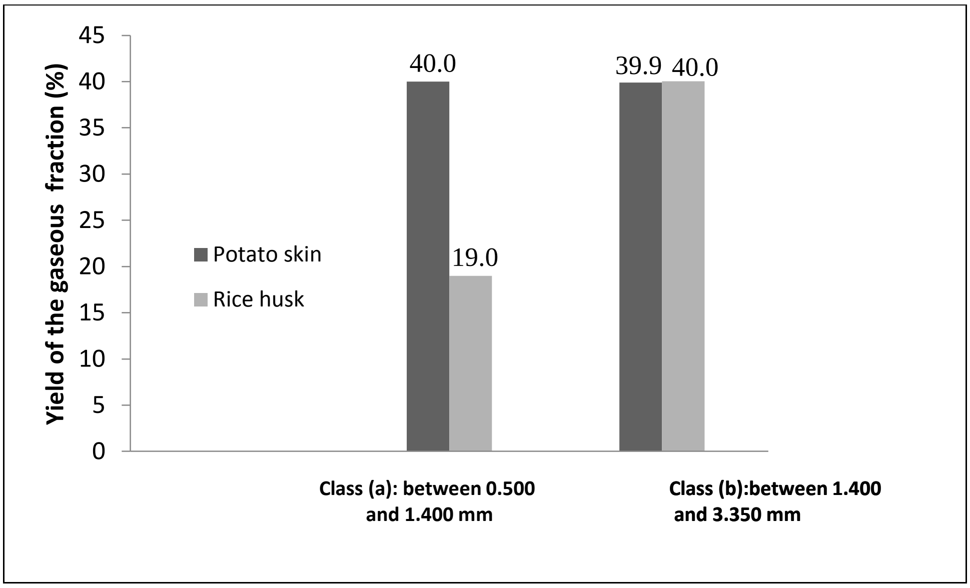

Figure 4 – Yields of gaseous fraction product obtained from the pyrolysis of potato skin and rice husk in two particle sizes: (a) between 0.500 and 1.400 mm and (b) Between 1,400 and 3,350 mm.

4 CONCLUSION

From the results obtained and the conditions used in experiments it is possible to conclude that the majority of the potato skin particles is on the range size of: between 1.400 mm and 3.350 mm. In fast pyrolysis of potato skin in batch reactor, the particle size influences the yield of liquid and gaseous products. It was observed that for smaller sizes of particles (between 0.500 mm and 1.400 mm) was obtained the best yield for liquid products (29.2%).

The results of pyrolysis of potato skin were compared to the pyrolysis of rice husk. The yield of the solid was similar for pyrolysis of potato skin and rice husk, and showed a little changed with the variation of the particle size of the waste. The pyrolysis of rice husk for the smallest range of particle size presented 44.3% in liquid yield while the potato skins showed 29.2% yield. On the other hand, for the larger size range of organic residues (between 1.400 mm and 3.350 mm) it was found that although the performance generation liquid has fallen to potato skin (27.7%) it was superior than the yield presented by the rice husk (25.4%).

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