Eco-Friendly Decomposition of Durian Waste for the Production of Valuable Materials Using Subcritical Water Treatment

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ABSTRACT

The quest for renewable energy sources to replace fossil fuels has encouraged researchers and policymakers to create innovative research programs around the globe. A rapid and eco-friendly decomposition of durian peel waste was performed under subcritical water conditions to produce valuable materials. Subcritical water treatment (Sub-CW) was conducted under reaction temperature (180-370°C at 5 min fixed time) and reaction time (1-60 min at 180 and 220°C). From the obtainable results its shows that the maximum yields of Total Organic Carbon (TOC) and Reducing Sugars (RS) were 6.51mg /g (360°C, 4min) and 249.57 mg GAE (180°C, 35 min) respectively. In addition, the yields from conventional methods were all lower than that of Sub-CW. Beside that the amount of solid residue obtained after Sub-CW was significantly decreased to almost less than 1%, this shows that Sub-CW is an efficient and green technique for solid waste treatment.

Keywords: Subcritical Water, Durian peel waste, Valuable material.

Aims Research Journal Reference Format:
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1. BACKGROUND TO THE STUDY

Malaysia is harvesting large amount of durian fruit every year for several purposes. In a previous study, Manshor et al. (2014) reported that, Malaysia produced approximately 320,164 MT of durian in 2013. Durian waste constitutes 65-70% of the entire fruit, this shows that the durian wastes have an average total weight of about 255,353 MT. Therefore, causes the increases in landfill loading rate (Foo and Hameed., 2012). As result of its less or no commercial value, durian residues are disposed in open spaces and/or in municipal waste stream causing environmental pollution. With more stringent and restrictive environmental regulations concerning the pollution from agricultural waste materials by regulatory agencies (Foo and Hameed, 2011). Therefore, it is beneficial to convert these residual wastes into useful materials. Alvarez and Saldaña (2013) reported that agricultural waste including durian peel to be very rich source of bioactive compounds, carbohydrates and other useful antioxidant compounds. An efficient, inexpensive, and ecofriendly way to use these fruit residues is by converting them into value added material. These products could be utilized as a substrate for fermentation process and many more useful products.
The commonly conventional techniques use for extractions of bioactive compounds are maceration, solid-solvent extraction and soxhlet extraction (Pourali et al., 2010).

The aforementioned techniques mainly involved the use of organic solvent which are toxic, time consuming and less efficient (Pourali et al., 2010). The drawback of those methods has led researchers to investigate alternative technology that could be utilized favourably in terms of cost, efficient, ease of operations and unpolluted techniques (Woo et al., 2014). In this days, several researchers explored the use of powerful technique called Sub-Critical Water (Sub-CW) treatment. Water that maintain its liquid state at heating temperature between 100 to 370°C, under enough high pressure (Yoshida et al., 2014). SCW in this state was reported to possess unique properties, such as its dielectric constant decreases to the same as ethanol, which make it acts as a solvent and it magnitude of ion product is high (Tavakoli and Yoshida 2008). SCW has been successfully utilized on various agricultural waste biomass for the production of value added materials such as production of soluble sugars from rice bran (Pourali et al., 2010), reducing sugar from sugarcane bagasse waste (Zhu et al., 2012) and biodiesel production (Woo et al., 2014).

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Therefore, the main aim of this work was to decompose the durian peel using Sub-CW as ecofriendly and rapid treatment technique to produced valuable materials.

2. METHODOLOGY

2.1 Materials and Methods

2.1.1 Maceration Extraction

Maceration was performed according to modified method reported by (Kim et al., 2010). 10 g of fresh durian peel was charged to each 100 mL of acetone, methanol and ethanol in a volumetric flask. The volumetric flask was wrapped with foil paper to prevent light penetration and then placed on magnetic stirrer with stirring speed of 2000 rpm for 24hr at ambient temperature for the extraction. The extracts where centrifuged (Centrifuge model 2420 Kubota co., Japan) at 1500xg for 10 min, then the mixture was separated using 0.4µm nylon filter in to aqueous solution and the remaining solid. All extraction for each liquid solvent was carried out in triplicate.

2.1.2 Soxhlet Standard Extraction

In this extraction method, standard soxhlet extraction apparatus was used (Al-Farsi and Lee, 2008). 10 g of sample was charged in to the soxhlet thimble and extraction was conducted using 250 ml of acetone, methanol or ethanol at their boiling temperature for 60, 90 and 120 min respectively. After each extraction the extraction solution was filtered with No. 1 filter paper, then evaporated at 60°C for 240 min then kept in refrigerator for further analysis. All extraction for each liquid solvent was carried out in triplicate.

2.1.3 Sub- CW Treatment

Sub-CW treatment was carried out in a standard stainless steel batch. Weighed amount of sample and distilled water were placed in to the reactor, then air was forced out of the reactor by purging argon gas. The reactor was capped and tighten properly, then dipped into a heated oil bath for reaction temperatures of 100 to 180°C and in preheated salt bath of 200-360°C for 4 min reaction time. After the preferred reaction time was reached, the reactor was then taken out from the heating bath and immediately cooled down by immersing in a cold water at ambient temperature (Pourali et al., 2009).

2.2 Reactor Content Isolation After Sub-CW Treatment

After sub- CW treatment, as can be seen in Figure 1. reactor contents were transferred into a glass test tube in a carefully manner to avoid any loss of the aqueous and remained solid. The products were isolated into two phase water soluble and residual solids. The separation procedure was briefly performed as follows; the glass test tube was centrifuged at 1500×g for 10 min, and then the supernatant and residual solid were separated by transferring of the aqueous solution to another test tube using Pasteur pipette. The aqueous phase was also centrifuged at 2000×g for 5 min for the second time and then filtered with a 0.2-µm filter paper, and then the aqueous product was kept in a freezer for further analysis. Finally, the residual solids were kept in a heating oven at 60°C for two days to dry up the remaining liquid and the final weight was measured and recorded.

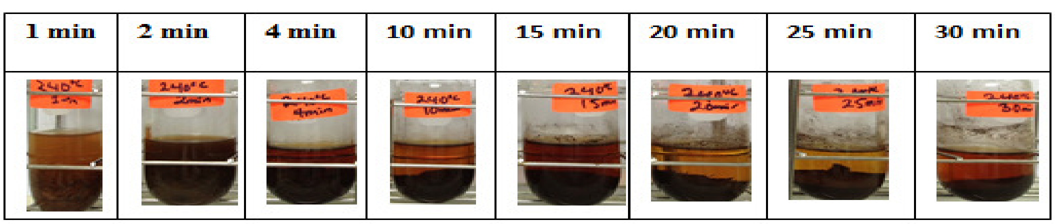

Fig.1: Photographs of Sub-CW treatment of durian peel as function of reaction time

2.3 Analysis

2.3.1 Reducing Sugar (RS) Determination

The Total reducing sugars of product were determined following modified photometric method (Mousavinejad et al., 2009). Briefly, 1 mL of standard or of the extract was mixed with 1 mL of 5% phenol solution, then the mixture was thoroughly shaken with tube mixer (TMS, AS ONE Co., Japan) at room temperature for 5 min. 5 mL of concentrated sulphuric acid was then added to the mixture and after waited for 25 min, the mixture absorbance was measured using UV–visible spectrophotometer at 490 nm. Then sugar contents were reported as glucose equivalents mg/g dry sample.

2.3.2 Total Organic Carbon (TOC) Determination
The TOC level in the supernatant phase was determined using an automatic total organic carbon analyser (Shimadzu, TOC-V CPH. Shimadzu co., Japan).

3. RESULTS AND DISCUSSION

3.1 Total Organic Carbon (TOC)

The influence of Sub-CW temperatures on TOC yield at 4 min retention time is presented in Figure 2. After phase isolation, soluble organic materials present in the water phase were measured using TOC analysis. As presented in Figure 2. at the beginning the TOC yields slightly increased from 1.874 to 3.30 mg/g when temperature increased from 100 to 180°C, then increased steadily to 3.67 mg/g with further increase of reaction temperatures to 260°C. Moreover, rapid increase of TOC concentration can also be observed with increasing temperature above 260°C and reached peak of about 6.51 mg/g at 360°C. This is in good agreement with results obtained in previous studies (Yoshida et al., 2014). This shows that most of the water soluble organic carbons are transferred to the liquid phase due to the decomposition of large macromolecules of the durian peel. It is found that with an increase in temperature the amount of solid residue decrease while TOC yield increase.

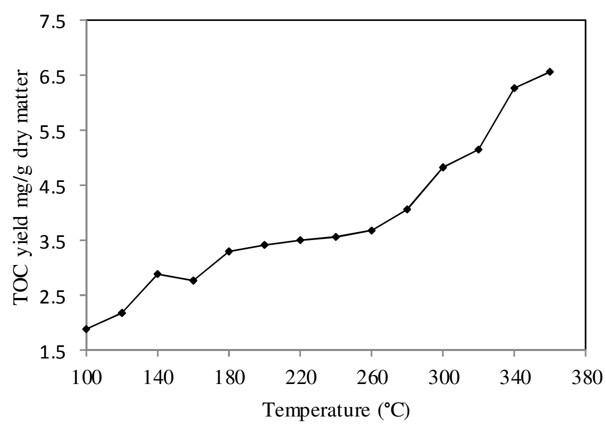

Fig. 2: Effect of Sub-CW reaction temperature on TOC production at 4 min reaction time

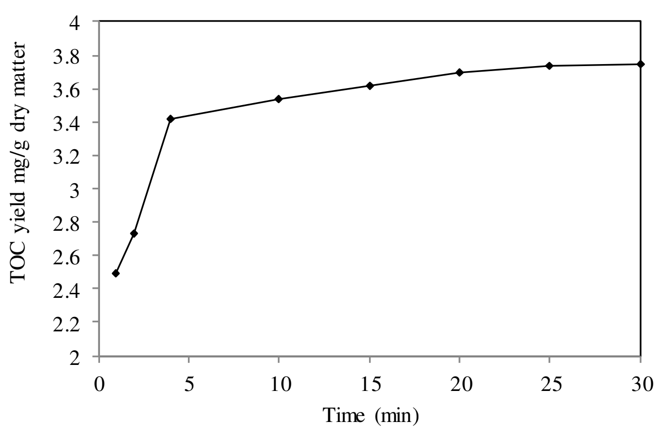

Fig. 3: Time course of TOC production at constant reaction temperature 180°C

TOC in the liquid phases was measured with different reaction times at 240°C temperature and the results are given in Figure 2. TOC yield increased sharply to 3.54 mg/g with an increase time 4 min. The results suggested that carbon component of the peel decomposed to water soluble components gradually by Sub-CW hydrolysis reaction (Tavakoli & Yoshida, 2008). However, with longer reaction time the amount of TOC yield almost remains the same. In a similar manner Sereewatthanawut et al., (2008) under Sub-CW condition produced amino acids and protein from deoiled rice bran. They reported the increase in TOC yield at the retention times below 30 min.

3.2 Reducing Sugar Yield (RS)

Sub-CW hydrolysis at different reaction temperatures was investigated at 4 min reaction time, to determine the influence of temperatures on RS production from durian peel waste. Daneshvar et al., (2012) reported that under Sub-CW condition carbohydrates can be converted into smaller soluble sugars for example mono-saccharides and oligomers. Figure 3. presents the effect of reaction temperature on the total amount of RS produced for reaction time 4 min. It showed a peak yield of 249.574 mg/g at 180°C. The significance increase could be attributed to the capability of Sub-CW to decompose hemicellulose part of durian peel in to smaller sugar components at temperatures below 200°C (Cardenas-toro et al., 2014). Furthermore, with further increased in reaction temperature from 180 to 360°C the yield dropped drastically to the lowest amount of about 18.469mg/g. The decreased in yield at high temperatures might be due to the degradation of soluble sugars into other compounds such as aldehydes, ketones and soluble polymers (Cardenas-toro et al., 2014).

The time course of RS produced at 180°C is also presented in Figure 4. The yield of the soluble sugars reached a peak at around 8 min. The results indicated that increasing the reaction time enhances the liquefaction of the sample matrix. However, decreased in the yield with further increasing the reaction time from 15 min can be observed, and then the yield remained constant throughout. This is consistent with previous result from (Abdelmoez et al., 2014). The constant in yield possibly may be due to the pyrolysis and decompositions of organic compound as mentioned earlier

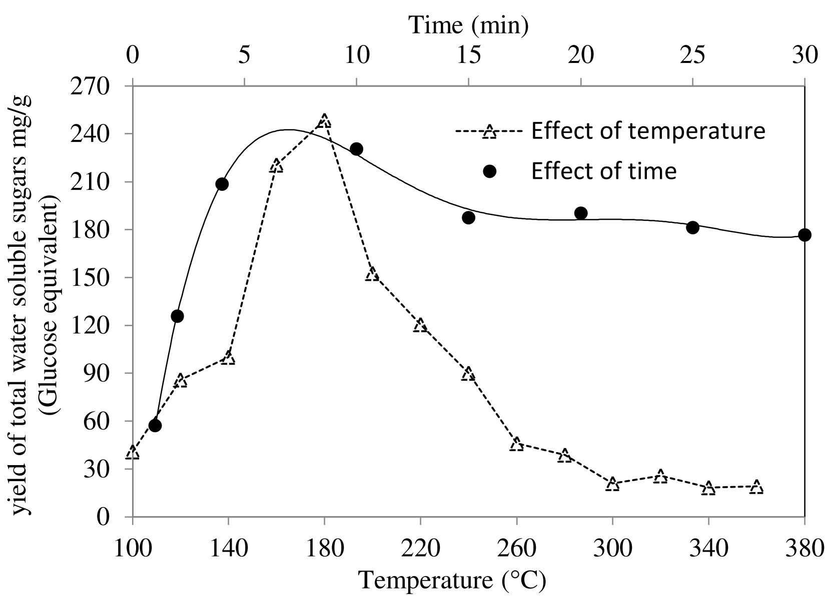

Fig. 4: Effect of Sub-CW reaction temperature on RS production at 4 min reaction time and Time course of RS production at constant reaction temperature 180°C

3.3 Comparison between Sub-CW Treatment with Current Solvent Extraction Methods

In the present study, comparisons were made for the performance between Sub-CW and other two organic solvent extraction methods; Standard soxhlet and maceration (Room temperature) extraction method. The results of the RS contents obtained from all utilized extraction methods together with their experimental condition are presented in Table 1.

Table 1: Comparison Between Extraction of Reducing Sugar by Sub-CW Method and Current Solvent Extraction Methods.

Extraction Methods	Solvent	Time (min)	Temp. (°C)	Reducing Sugars (RS) (mg GE/g)
Sub-CW	Water	4.00	180	206.44
Soxhlet	Acetone	90.0	57	82.653
	Methanol	60.0	64.7	8.500
	Ethanol	120.0	78.3	7.864
Maceration	Acetone	1440	24	199.519
	Methanol	1440	24	11.525
	Ethanol	1440	24	5.452

High amount of RS was obtained by Sub-CW at 180°C while requiring fewer amounts of water as a solvent, less time consuming compared to soxhlet and maceration. The significant enhancement of RS produced by Sub-CW might be attributed to the increase in solubility and decomposition of larger macromolecules including lignin, cellulose and hemicellulose (Carbohydrates) in the cell wall of durian peel. This could also be as a result of larger water ion product at these conditions that activated the hydrolysis to occur (Don et al., 2014). It can also see that high RS yield was obtained by maceration extraction method using acetone. Maceration method requires 1440 min (24 hr.) of extraction time which is impractical. However, from the reaction time, and ecological/environmental point of view Sub-CW is the cleanest alternative technique compare to the traditional solvent extraction methods (Pourali et al., 2009).

4. CONCLUDING REMARKS

In this study Sub-CW was successfully utilized by the decomposition of durian peel waste for production of valuable resources under different reaction temperatures and times. Maximum RS was produced at 180°C. However, it decreased drastically as the temperature increased above 180°C which could be possibly due to the decomposition and hydrolysis of the soluble sugars to other compounds. Furthermore, it shows that with increasing temperature, the TOC yield increased, this indicated that the process proved to be a good technique for conversion of biological waste into value addition materials. The RS are good energy precursors for fermentation process, bioethanol & biodiesel production. Hence Sub-CW is a powerful technique that can be applied in both agricultural and industrial waste for production of valuable resources at same time reducing landfill tipping cost and environmental pollutions.

Moreover, the amount of RS and TOC contained in the product obtained from Sub-CW process are much high than those obtained from all the various solvent extraction methods. Consequently, our study shows that Sub-CW is a promising techniques being a clean does not employs organic solvent, green alternative process for material recovery, environmentally friendly and less time consuming.

5. ACKNOWLEDGEMENT

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