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Introduction of Novel Analysis Technique: Biomass Element Life Cycle Analysis (BELCA)

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Negative environment impacts from fossil fuel based resource lead to the search of alternative sustainable resources, such as biomass. Biomass technology is limited by the complex biomass characteristic and high transportation cost. A novel technique - Biomass Element Life Cycle Analysis (BELCA) is introduced to tackle these problems. BELCA acts as a platform to study the properties of each biomass, from plantation biomass to biomass generated within processes. This study allows better understanding of respective biomass characteristic which is needed in higher level of biomass utilisation and applications. Biomass characteristic is presented in a simple graphical approach to enhance the understanding and highlight their potential value. Combination of this method with biomass characteristic data bank will make the biomass selection easier. In this work, characteristic of palm biomasses based on literature are presented in radar chart. As the case study for LCA analysis, sago industry is studied to discover underutilised biomass generated within processes. Analysis on the sago biomass characteristic will be conducted with collaboration with sago industry partner and other industry via BELCA approach for better understanding of respective underutilised biomass. With the knowledge in underutilised biomass, biomass supply chain can be improved and support the implementation of respective biomass.

1. Introduction

High dependence of fossil fuel leads to over usage of natural resources leading to environmental pollution and resources limitation issue. Therefore, worldwide development has moves toward sustainability to minimise the usage of non-renewable resources. One of the highly anticipate approach is development and utilisation of bio-resources as alternative feedstocks to produce higher value downstream products. Exploration in bio-resources has leads to the success of implementation in few bio-resources, such as palm oil industry. Lam et al. (2009) claims that palm oil is the cheapest edible oil with potential to convert into biofuel. Yusoff (2006) summarised utilisation of palm oil biomass in energy generation and fertiliser production. However, development in biomass has been the focus at the moment due to arise of ethical issue on utilising food crops as feedstock for chemical product and energy (Lam et al., 2009). Nevertheless, successful implementation of biomass industry has yet to be accomplished due to high logistic cost for raw material (Pirraglia et al., 2013). Fluctuations in availability and quality of biomass are part of the limitation in the development as well. On the other hand, the complexity of biomass characteristic and poor understanding of each biomass species lead to an over unify biomass development phenomenon. For example, rapid breakthrough of palm oil biomass catches the interest of researchers and de-motivates them to study other biomass, leading to underutilization of other potential biomass species. Being one of the largest in palm oil production, Malaysia produces about 41 % in 2008 (Yoon et al., 2011), 39 % in 2009 (Shafie et al., 2012) and 47 % in 2010 (Mohammed et al, 2011) of world palm oil production. This over unify in palm oil industry might causes economically insecure if palm oil industry is replaced with new technology in future. Thus, this work is dedicated to tackle the issue of poor understanding and underutilisation of biomass.

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A systematic biomass analysis approach is introduced to investigate properties of each potential bio-resource in the system. Biomass Element Life Cycle Analysis (BELCA) is proposed from inspiration of previous work, the element classification in Biomass Demand-Resources Value Targeting (DRVT) (Lam et al., 2013) and Life Cycle Assessment (LCA)-in application such as capturing carbon footprint (Čuček et al., 2012). BELCA acts as a platform to investigate the potential value in each of biomass within a system. Key elements such as cellulose, hemi-cellulose, lignin, ash, moisture, calorific value, carbon, hydrogen, sulphur, nitrogen, size and etc. are used as the basis for biomass element classification. This approach is carried out with an assumption that no significant affects on biomass technology yield as long as the key elements of feedstock (single biomass or mixture) are within an acceptable range of respective technology. The main objective of BELCA is to analyse potential value of underutilised biomass and educates public of its potential to further develop its application. With proper analysis and data compilation, better understanding of underutilised biomass characteristic can be achieved. Discovery of potential underutilised biomass enables improvement over current biomass supply chain as alternative resources and source point to reduce raw material and logistic cost. As BELCA consists the nature of LCA, each process stages within an industry will be studied. Element classification with graphical presentation will be conducted on respective biomass to allow wider coverage in the search for alternative resources and minimises waste management. Utilising resources from existing technology waste is much economically efficient. With proper implementation, BELCA acts as a decision and management tools, allowing better planning and development. With the proposed BELCA approach, utilization of each potential biomass in the system can be well analysed, provide better understanding of the system resources and allows effective planning and development.

2. Objective

Aim of this research is to improve understanding of biomass characteristic through: i) discovery of underutilised biomass via element classification, ii) improvement of biomass supply chain via consideration of underutilised biomass.

3. Methodology and Discussion

General research methodology for the novel BELCA approach is presented in Figure 1. It shows the general steps for the proposed approach. The methodology steps are further discussed in latter part. Section 3.1 indicates the generic element analysis used in literature and Section 3.2 presents palm oil based biomass characteristic via graphical approach. In Section 3.3, sago production processes are studied as potential industry for BELCA implementation. Section 3.4 illustrates the implementation of BELCA in biomass supply chain.

3.1 Element Classification

In this scope, it is essential to utilise a simple and generally used approach to classify biomass into their respective characteristic. For example, Ultimate and Proximate Analysis are generally used to identify key element in biomass as shown in many literatures. Maia et al. (2014) studied banana leaves waste via thermal, ultimate and proximate analysis. The result shows similar characteristic to existing fuel-type biomass which suggests that banana leaves briquettes has potential to use as fuel for energy generation.

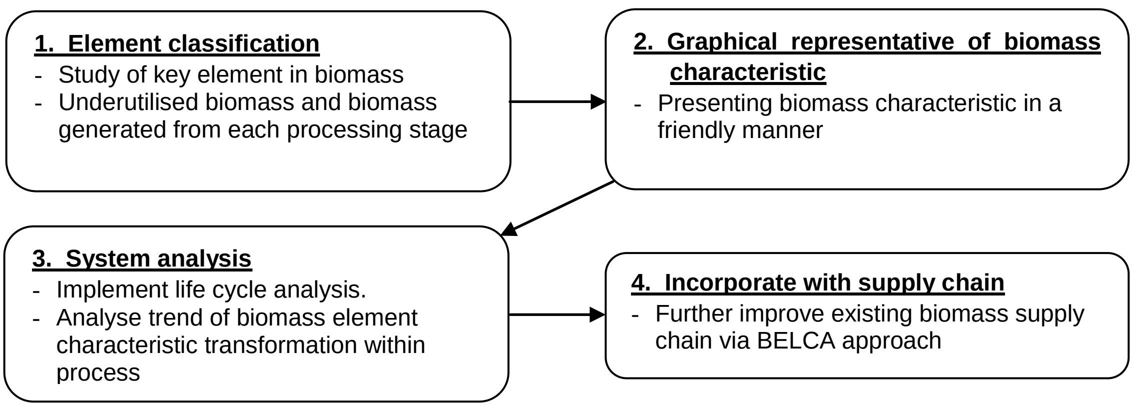

Figure 1: General research methodology for BELCA approach

Similarly, Braz and Crnkovic (2014) conducted same analyses on coffee husk, tucumã seed, sugar cane bagasse, peanut shell, rice husk and pine sawdust for pyrolysis process application; Miccio et al. (2014) conducted those analyses on olive husk for fluidised bed combustion process. Wang and Dibdiakova (2014) study ash characteristic of woody biomass of Normay spruce tree. Key elements to be considered in this work consist of, but not limited to, carbon (C), hydrogen (H), nitrogen (N), sulphur (S), oxygen (O), ash (ash), fix carbon (FC), volatile matter (VM), moisture content (MC), cellulose (Cell), hemicellulose (Hcel), and lignin (Lig). More elements should be considered in future work if it has significant effect in the process. As BELCA is an analysis for the life cycle of a system, element classification will be conducted not only on biomass from plantation, but also on biomass generated from processes. Few interesting underutilised biomass to be studied are tropical fruits biomass such as coconut shell, durian shell, and sago biomass.

3.2 Graphical presentative of biomass characteristic

With biomass element classification, understanding of properties and characteristic for underutilised biomass are expected to be improved. However, it is very important to educate and share the result to public. An eye-catching result presentation is vital to further engage research and development in underutilised biomass. Thus, Graphical approach such as radar chart is used to present the characteristic of each biomass based on key elements. Figure 2 and Figure 3 show the characteristic of several palm biomasses based on literature. C, H, N, S, O, ash, FC, VM and MC values is presented by Idris et al. (2012) for palm mesocarp fibre, palm kernel shell and empty fruit bunch; and by and Sait et al. (2012) for palm seed, palm leaf and palm leaf stem. Mohammed et al. (2011) presented Cell, Hcel and Lig value for palm mesocarp fibre, palm kernel shell and empty fruit bunch. From the figures, similar characteristic between palm mesocarp fibre and empty fruit bunch and between palm seed and palm leaf are well presented. This suggests that alternative biomasses species can be utilised as feedstock in respective process technology based on the similarity in biomass properties are highly possible. However, noted that some information is not available in literature as shown in Figure 3. Thus, more analysis will be conducted to fill in the gaps, as well as expend the data base to cover more biomass species. However, these step only essential if respective key elements are critical to process yield. Further verification for the effect of respective key element to the process is necessary.

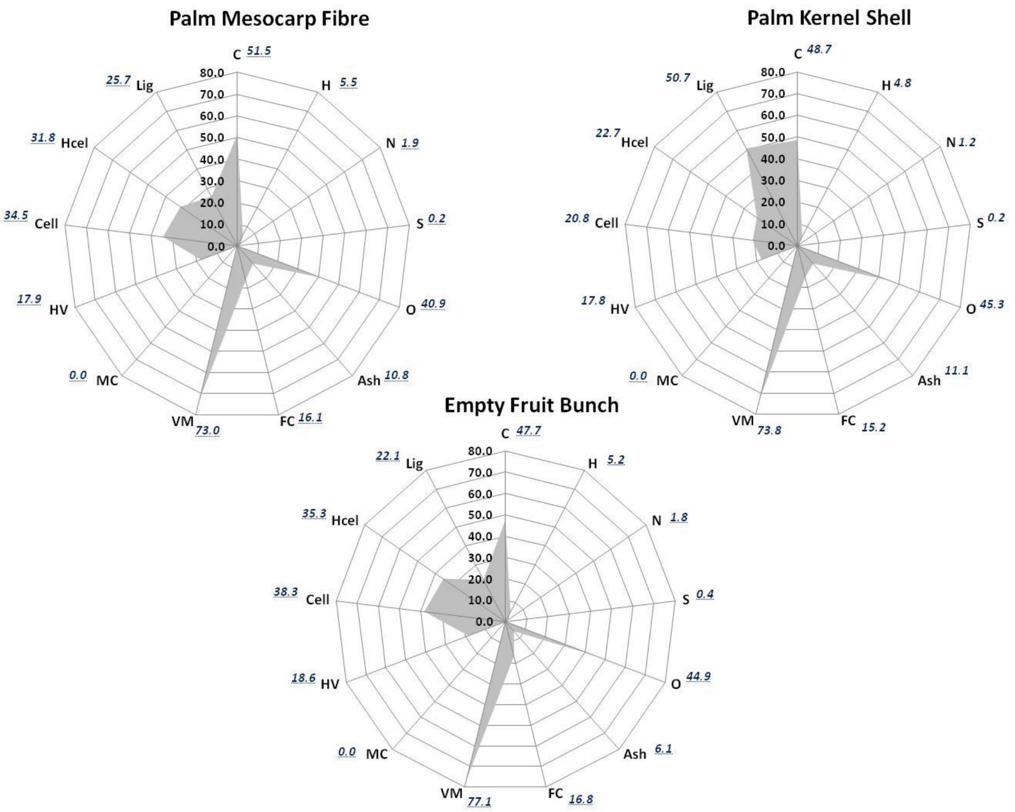

Figure 2: Radar chart for biomass characteristic with complete data from literature

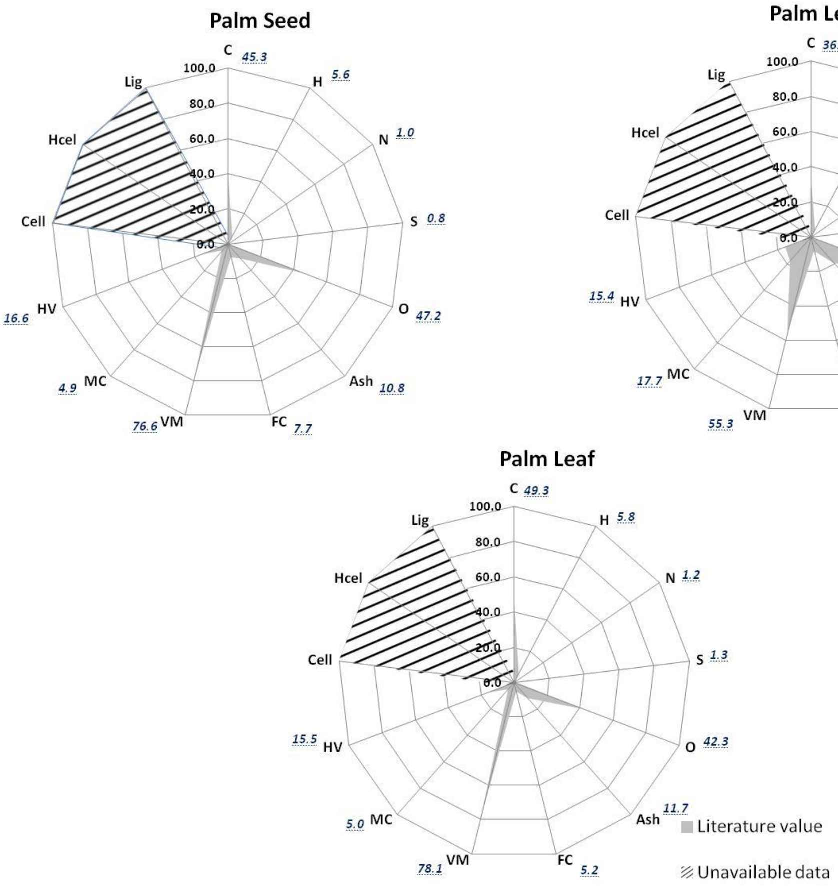

Figure 3: Radar chart for biomass characteristic with insufficient data from literature

3.3 System analysis

As BELCA included life cycle assessment, system analysis is essential to further improve respective industry from its current state. Therefore, studies on each process stages are required. Figure 4 shows process diagram of sago industry in Malaysia. Sago is a staple food which extracted from various tropical palm stems. Normally it presents in raw powder form and can be served in paste, pancake or rolled ball form. From Figure 4, there are several potential biomasses generated within the system to be utilised as valuable resource. BELCA approach allows additional understanding of each biomass and determines the merit of further research and implementation. Application of BELCA approach in sago industry will be conducted with industrial partner in Malaysia.

3.4 Incorporate with supply chain

This is the most important step to utilise the result from previous steps and incorporate into biomass supply chain for improvement. However, this segment of work is relatively independent work from previous study and categorised more into future work for improvement of DRVT biomass supply chain. The main objective is to allow the inclusion of BELCA approach in biomass supply chain in order to improve on biomass implementation. Nevertheless, the idea of DRVT approach can be expressed via BELCA. Figure 5 shows a demonstration of technology tolerance for process unit which originally uses empty fruit bunch as feedstock. This represents the biomass selection in DRVT supply chain model such that alternative biomass species can mix or replace original feedstock as long as the end feedstock is fall within the boundary. Similarly, this assumption will be validates in collaboration with industry partner.

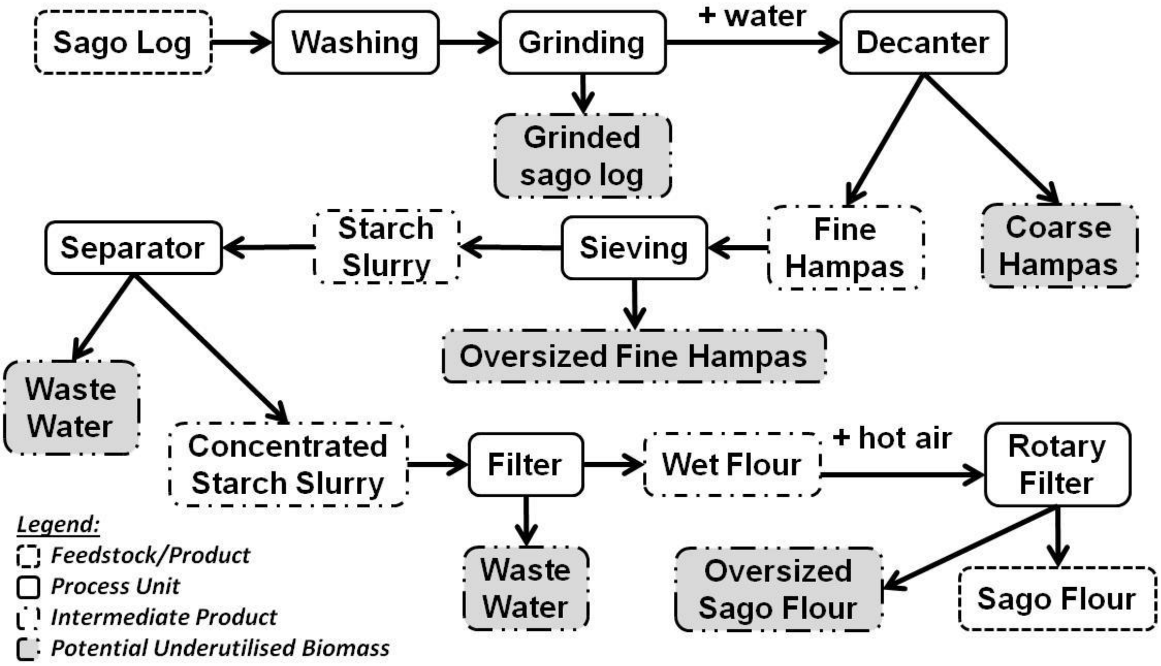

Figure 4: Process unit in sago industry

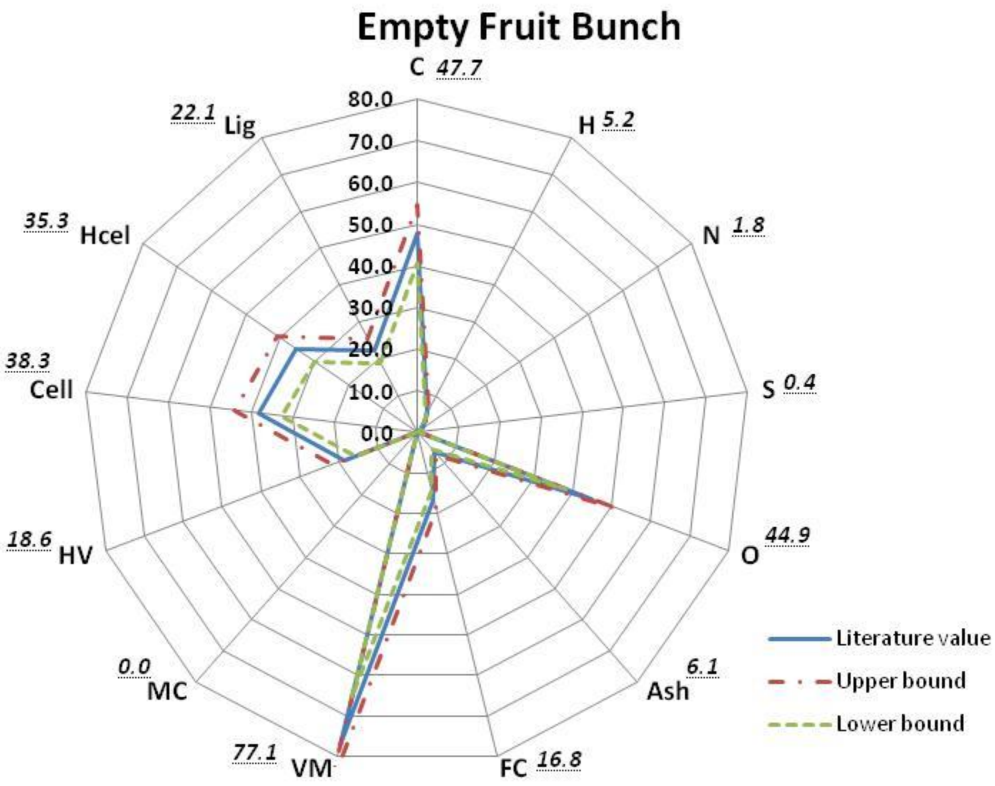

Figure 5: Tolerance of biomass feedstock in process

4. Conclusions and Future Works

In conclusion, novel BELCA approach is introduced to tackle the issue on poor understanding of valuable biomass and analyse potential value within each biomass for alternative application. An eye-catching graphical approach is used to show case the characteristic of biomass enhance interest of researchers to work on underutilised biomass. As the study includes biomass generated at each stage of processes, increases of waste recycle is expected, leading to cost reduction in waste management. With proper analysis of underutilised biomass via BELCA approach and incorporate into biomass supply chain management, an improvement of logistic issue in biomass industry is expected. Further study in biomass supply chain will be conducted with the inclusion of BELCA for verification. Biomass characteristic study will be conducted on tropical fruits such as durian shell, coconut waste and etc to expend data bank of biomass characteristic. This will allow wider biomass selection in future biomass development espeially in the sustainable network synthesis (Kostevšek et al., 2014).

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