# Ultimate Properties of Different Ratio of Mix Leucaena leucocephala and Acacia mangium Fuel Pellets

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## ABSTRACT

The ultimate properties are important in order to determine the percentage of constituent elements of material which contributes to combustion. Combustion is one of the important elements to determine whether a material is suitable to be used as a solid fuel or not. Thus, the objective of this study is to evaluate the effect of ratio of the mixture of Leucaena leucocephala(LL) and Acacia mangium(AM)fuel pellets on ultimate properties. Five ratios were determined based on LL:AM namely 100:0; 30:70; 50:50; 70:30 and 0:100. The ultimate analysis parameters are carbon, hydrogen, nitrogen and sulfur. The carbon (C), hydrogen (H), nitrogen (N) and sulphur (S) elements were determined using a CHNS/O Analyser, and Perkin Elmer 2400 Series II base on ASTM D3176 standard. The averagepercentage of carbon has decreased from bottom to top portions, indicating that the bottom portion has recorded a higher percentage of carbon as compared to the top portion. The highest is in the mixture of 70:30 bottom portion (49.31%), and the lowest is in the mixture of 30:70 top portion (38.9%). Meanwhile, the average percentage of hydrogen has increased from bottom to top portions, indicating that the top portion has recorded a higher percentage of hydrogen as compared to the bottom portion. The highest is in A. mangium middle portion (9.23%), and the lowest is in the mixture of 70:30 bottom portion (5.87%). The average percentage of nitrogen has increased from bottom to top portions, indicating that the top portion has recorded a higher percentage of nitrogen as compared to the bottom portion. The highest is in the mixture of 50:50 top portion (19.18%), and the lowest is in the L. leucocephala bottom portion (12.26%). On the other hand, the average percentage of sulphur has decreased from bottom to top, meaning that the bottom portion has recorded a higher percentage of sulphur as compared to the top portion. The highest is in L. leucocephala bottom portion (0.49%), and the lowest is in the mixture of 70:30 bottom portion (0.11%). The mixtures have increased the percentage of nitrogen and carbon in the fuel pellets but have no increment in the percentage of sulphur and hydrogen. The 50:50 mixtures of the top portion of L. leucocephala and A. mangium fuel pellets has recorded the highest nitrogen contents (19.18%). On the other hand, the 70:30 mixtures of the bottom portion of L. leucocephala and A. mangium fuelpellets has recorded the highest carbon contents (49.31%).Based on the results of the ultimate analysis above, it can be concluded that L. leucocephala and A. mangiumhave the potential to be utilised as solid fuel individually or in the form of mixtures with the best compositions is at 70:30 for all the portions.

**Keywords**
ultimate analysis, carbon, hydrogen, nitrogen, sulfur,Leucaena leucocephala, Acacia mangium

*Article Received: 10 August 2020, Revised: 25 October 2020, Accepted: 18 November 2020*

## Introduction

Recently, the new industry has been focusing on energy production through the use of renewable sources emerged as a by-product of urgency to generate thermal and electrical energy, global warming (a result of increased emissions of greenhouse gases), rising fossil fuel prices and demand for energy independence out of conservative energy sources (Nuneset al., 2014). Besides, the increasing concentration in greenhouse gas emissions, as well as the rapid fluctuation in the transportation fuel prices has resulted in the exploration of renewable energy sources, which is more promising (Baños et al., 2011). There are three types of fossil fuel products used to produce energy which is coal, oil and natural gas, which are considered as non-renewable sources (or known as Conventional Energy product) since their resources cannot be replenished (Sulaiman et al., 2011). Fossil fuel now is the main energy source in the world (Cheng, 2010) produced to generate electricity to meet the great demand around the globe. However, Renewable Energy sources like biomass are being given attention as a potential for power generation due to sustainable aspect and also with the aim to reduce the greenhouse gases emission (Ashish and Mohapatra, 2013). Other than that, biomass is also one of the noticeable choices to be used as the raw material to generate electricity (Kirkels and Verbong, 2011). Therefore, biomass energy is sustainable, renewable, carbon-neutral, and can be perceived as the most basic essential energy in the world (Egnell et al., 2011).

Tiwari and Mishra (2012) stated that; Energy consumed on the entire Earth can be categorised into two types; the renewable energy sources and non-renewable energy sources. The natural sources, which can be reloaded or restocked over short phases of time which can deliver energy is the best definition of renewable energy sources. They are also known as non-conventional sources of energy. The example of renewable energy resources is the sun, wind, moving water, biomass, and geothermal. This sources can be utilised to generate power (electricity) and for other uses. Other than that, the energy sources that are produced from limited and fixed stocks of energy are called non--renewable energy sources. These energy sources are also termed as conventional sources of energy. This is due to the available supply which cannot be created, developed, bred or used on the premise of being sustainable in its utilisation rate. This is because these form of sources exist in a finite amount as well as greatly consumed faster than the actual time needed for nature to prepare the sources.

Malaysia is a unique country blessed with plenty of energy resources, be it Renewable Energy (RE) and Non-Renewable Energy (NRE) (Sulaiman et al., 2011). However, in Malaysia, public awareness about the needs of improving daily activity without being depending much on the non-renewable energy is still in the early phase. Besides, being as one of the countries that produce and supply oil, majority of Malaysian is in the comfort zone due to the attitude of being dependent on the energy sources (both on fuel and electrical energy purposes). Comparing to the coal and natural gas electric generation, the petroleum product of crude oil serves as the main supplier with 62.7% energy production, while the mix-generation plant likes coal and oil-based electric generation produce 19.0%, and coal and coke at 3.2 %, while natural gas yield is 15.1% (Sulaiman et al., 2011). Currently, the primary energy supply in Malaysia is being led by non-renewable energy resources (oil and natural gas), that have contributed to 32.1% and 46.0% respectively of energy generation (EC, 2012).

In order for the biomass to be used as fuel to produce energy, it has to be turned into fuel pellet. Pelletization or pelletisingis a process to turn the extracted-prepared material into the compressed cylinder shape. Basically, moulding machine produces a pellet with a diameter of 5-12 mm and 12 mm long. Pelletizing is proposed to enhance the wood performance by reducing the moisture content and thus, increasing the heating value of the wood pellets for the steam power plants and gasification systems applications. Due to its compressed characteristic, pellets consist of stable fuel with efficient and better heating characteristic rather than chip-product (Tiwari and Mishra, 2012). Middleton (2010) informed that there are widespread sources of pellet involving the use of sawdust and wood scrap from the hardwood and softwood, shells and nut hulls, agricultural by-products, paper, and cardboard. Along the way, the softwood, hardwood and mixture of several different wood species are used asmaterial for wood pellet known as the feedstock. The hardwood species are favourably used for the cordwood purpose due to its higher heating value and lower emission. Two types of trees grow wild throughout Malaysia, especially in the states of Kelantan and Perak that have the potential to be used as fuel, namely L. leucocephala and A. mangium trees. According to Walton (2003), L. leucocephala reproduces by seeds which could be distributed by a number of vectors and the distribution range of the seeds are generally taking some time due to the fact that most its new plants are controlled by grazing animals or taken over by grass competition. On the other hand, L. leucocephala reproductive capacity is extremely strong (Chen and Wang 2010).L. leucocephala characteristic is a perennial non-climbing, non-spiny shrub or tree (Walton, 2003) up to about 6 m tall with green-greyish-colour leaves, measuring about 25 cm long and bi-pinnate (DAFF, 2013). The shape of its flower heads is in spherical form, with creamy-yellow colour on stalks of about 5 cm long. The pods are flattened, measured up to 15 cm long in dense clusters. Each of the pods contains around 20 flat seed with glossy brown in colour, which will split when they are riped (DAFF, 2013). Due to its tropical species characteristic, L. leucocephala needs warm environment temperatures, about 25 °C to 30 °C for optimum growth, but it has a poor cold tolerance (Walton, 2003). L. leucocephala is a tropical species originated from Mexico and Central America (Chen and Wang,2010; DAFF, 2013; Walton, 2003) and it was widely distributed in southern Asia and neighbouring islands (Chen and Wang, 2010).L. leucocephala tend to favour limestone, other alkaline soils and volcanic soils. Still, it also can grow on a wide selection of deep, well-drained fertile soils (Walton, 2003). L. leucocephala has the ability to spread vigorously to adjacent areas if it is not heavily grazed or controlled (DAFF, 2013). L. leucocephala is declared as a weed in over 25 countries around the globe (Walton, 2003) due to its naturalised features throughout many areas of the Australian mainland and on a number of offshore islands (DAFF, 2013).

The second abundant plant in Malaysia is A. mangium. A. mangium generally grows to a height of 25-35 m with the diameter at breast height (DBH) of usually 60 cm (Dhamodaran and Chacko, 1999 ; Francis, 1986). The mean height of the A. mangium measured at the age of 1 year varied from 4 m to 9 m up until 26.2 m at the age of 10 years. The A. mangium measured from Girth Breast Height (GBH) varied from 11 to 18 cm, which represents mean annual increment (MAI). These values indicate that the A. mangium is a fast-growing species. However, A. mangium has vigorous growth for early-stage growth, which can go up until 10 years (Dhamodaran and Chacko, 1999). Still, the A. mangium tree growth is affected by seasonal conditions due to its characteristic of humidity, tropical lowland climatic zone characterised by a short winter dry season and high total annual rainfall, about 1500 to 3000 mm (Dhamodaran and Chacko, 1999). A. mangium tree is native (indigenous) to northeastern Queensland, Australia, and has fragmented natural distribution, which stretches from Indonesia (islands of Sula, Ceram and Aru) to Iriyan Jaya, Molluccan Islands and up to the western province of Papua New Guinea(Starr et al., 2003; Dhamodaran and Chacko, 1999). A. mangium has become one of the major tropical plantation forestry species in Asia, primarily in Indonesia, Malaysia, Philippines and Thailand. Its successful introduction to Malaysia in 1976 has led to its introduction to China, Fiji, Laos, Philippines, Sri Lanka, Thailand, Vietnam and some countries in the Africa continent (Dhamodaran and Chacko, 1999). Many countries have introduced this species for trial, re-planting and rehabilitation programme and A. mangium is the one among the Acacia species which is most widely planted. This is due to its fast-growing and fitness for heavily infested areas. Besides, A. mangium has the ability to control soil erosion and perform well at infertile soils, especially the soil which has low phosphorus element (Dhamodaran and Chacko, 1999; Francis, 1986). Thus, A. mangium has achieved a wide popularity in the private sector plantation programs in Kerala, India, as a multi-purpose fast-growing species (Dhamodaran and Chacko, 1999).

Fuel pellet analysis is derived based on the biomass characteristics, that are biochemical analysis, proximate analysis, and ultimate analysis. The physical analysis was included due to analytical changes observation on the pellet appearance and its texture. The main components of biomass basically are lignin, hemicelluloses, cellulose, mineral matter and ash. Wood made up of 40-50 % cellulose, 20-30% hemicelluloses and 20-30% lignin. However, the percentage varies from species to species. Wood is a solid lignocellulose material naturally produced in trees and certain shrubs (Tiwari and Mishra, 2012). Evaluation of biomass resources requires information about their composition, and this information can be conveyed in terms of biochemical analysis, proximate analysis and ultimate analysis. The wood sources ultimate analysis shows that it consists of 44-52 % of carbon, 5-7 % of the hydrogen, 0.5-0.9 % of nitrogen, 40-48 % of the oxygen and 1-3 % of ash present. Nitrogen and sulphur also appear to be ina small and insignificant amount in the material (Tiwari and Mishra, 2012).

Treeproperties play a big role in the heating value of wood pellet. Thus, in this research, the trees were divided into three groups (bottom, middle and top). The group segmentation in this context refers to the tree density proportion. The segmentation of the trees is referred to the standard segmentation of standing tree in forest mensuration, for commercial tree harvesting. Therefore, the segmentation of the tree will serve as the guideline or a template to define the segmentation of tree for biofuel purpose. Diameter Breast Height (DBH) was used to measure the diameter of a standing tree from certain distances above the ground level due to the root features of certain tree species being different from one to another. Bertram,etal. (2003) use 4.5 ft or 1.3 m as a DBH reference point from the ground level. Meanwhile, according to Anthonie and Alporslon (2007), in most countries, the point of measurement is located at 1.30 m above ground level, but at the height of 4.5 ft (= 1.37 cm) which is used in the USA and a height of 1.2 m in Japan and Korea. First branch or crown point indicates the first branch formings tree crown up until the tip of the tree, that is also known as the crown length (Bertram,etal., 2003).

On the other hand, the research which relates to the development ofrenewable energy is in gloomy mood due to the lack of interest to investigate the subject further, and also people involved in this particular research is relatively small in number. Thus, more study needs to be conducted to deliver more information about the uncovered potential and expanding the body of knowledge in terms of energy generation on the biomass renewable energy product. In biomass energy, fuel pellet is one of the biomass product utilised to produce energy. There are several advantages of fuel pellet product as compared to the unprocessed biofuel. This includes higher energy density, low transportation cost and storage cost, good quality, constant moisture, lesser emissions and better potentials to fire at lower loads, resulted in longer boiler utilisation times (Werther et al., 2000). Moreover, the modernisation of biomass incorporates technology progresses, including combustion, gasification and pyrolysis, to escalate the efficiency of biomass energy production (Frank et al.,2007). Aside from the electric generation application for the large industrial applications, the biomass energy is also being used in household applications such as improved cooking stoves and as well as biogas for the small cottage (Frank et al.,2007).

## Materials And Methods

The species of choices for this study was Ipil-ipil (L. leucocephala) and Akasia (A. mangium). Preparation of the raw material involved the harvesting of raw materials in the wild area (roadside). The wood supply was collected in the nearby area, Gerik district for Ipil-ipil (L. leucocephala) and Jeli district for Akasia (A. mangium) supply (Figure 1.0)

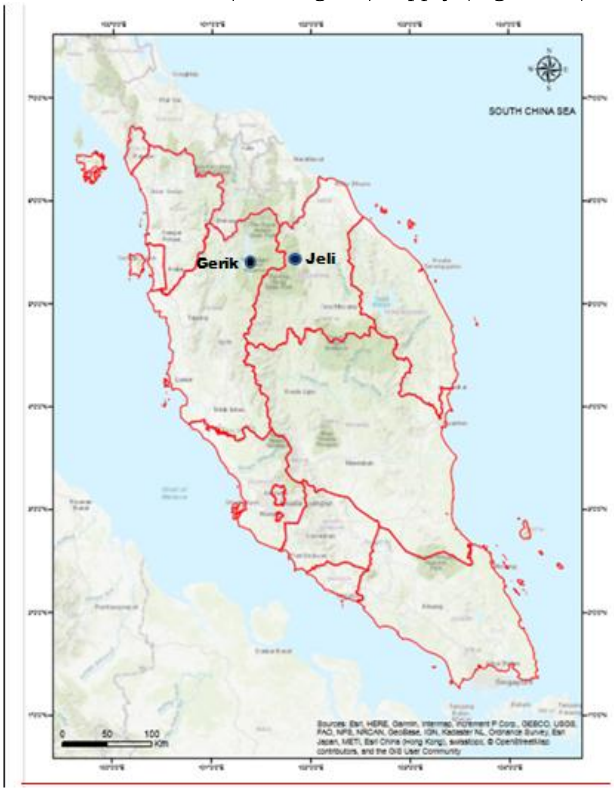


**Figure 1.0:** Sample collection areas

### Sample collection

The raw material (in the form of the standing tree) was collected randomly by using systematic random sampling in the wild area. The young trees preferences were harvested, which are estimated to be about 5-10 years old for each species. The diameter was measured in the range of 5 cm to 8 cm. Besides, the measurement reading was based on the diameter breast height (DBH). The sample was randomly selected through the entire perimeter of the pindown area (Jeli and Grik district< Malaysia). The sample size of the raw material harvested was about 30 trees for both species. Due to the sampling trees were obtained in the wild, and the younger tree was selected; thus, more trees were needed to prepare the materials so that they are sufficient prior to undergoing the selected test. About 2 kg of wood chips are needed to produce approximately 1 kg of pellet due to the removal of the moisture (water content) in the wood (Tiwari and Mishra, 2012). Thus, to produce the pellet and obtain the desirable weight (targeted bulk weight), the particles size needed twice weight than the targeted production. The younger tree was selected in order to avoid the defect existed on the targeted wood. Besides, the younger (5-10 years old tree) is more appealing in term of being free from decay or any physical defect stages. Furthermore, the need forthe selected tree to be free from any defect is essential to reduce any possible errorthat might affect the result of the research. In a real-time situation, the need for the pellet production to endure a lesser amount of time is essential to reach the harvested stage rather than the longer time due to the rotation of harvesting which has become frequent. Plus, the waiting period (the gap between production and preparation of the raw material) will be greatly reduced and sustained. Other than that, the amount of time taken will also be lessened during harvesting, as well as reducing capitals investment and the overall cost. Thus, in this research, the tree selection was focusing only on the young tree.

**Sample preparation**

Fractionator machine/shredder was used for the first crushing process. This machine was used to break down the manually chipped wood into the smaller form in size. The crushing process might produce an irregular size of particles, which need to be screened and assigned according to the size, based on the segmented part of the wood. These particles are different from the sawdust because the lignin content of these particles is abundant rather than the lignin available in the sawdust form. The first shredding has produced about 5 cm of length, reducing about a third of its actual length before being shredded. After the initial shredding process, there was a second shredding process done. This process produced a much smaller sample size by using the crusher machine. The crusher machine has produced about 1 to 2 cm particle length, compared to the previous 5cm shredded product. Consequently, the grinding process was conductedusing the Disc Mill Grinder machine. The machine has produced tiny particles from the crushing machine product into small-fine particle sizes.

The wood particles were also undergoing the drying process, which was the final process before the pelletising process. The drying process occurred when the moisture content in the wood particles was ranging about 16% to 18%. The moisture content was tested by using the Moisture Analyser machine.

Screening process begun after the crushing process was done. All the by-product of the crushing process went into the screening process. Screening process allows us to segregate the oversize and the undersize particle into its respective group size. There are two sizes available, that is 0.5 mm and 1.5 mm particles size. The screening process is important to alienate the unwanted substances, which presented in the particle heap, starting from splitting the process into the crushing step. The examples of the unwanted substances are foreign substances such as dust, dirt, oil from the machine, and every other thing except the wood particles itself. In this stage, the particles were secluded according to the two sizes and were left for air dry. The final step in this stage is the pelletising process.

**Sample analysis**

The ultimate analysis involves the estimation of important chemical elements that make up the biomass, namely carbon (C), hydrogen (H), nitrogen (N) and sulphur (S). The carbon (C), hydrogen (H), nitrogen (N) and sulphur (S) elements were determined using a CHNS/O Analyser, Perkin Elmer 2400 Series II (Sulaiman and Abdullah, 2014). The basic method for doing an ultimate analysis is to burn a sample of biomass in a platinum crucible in a stream of air to produce carbon dioxide and water, the mass fractions of which are determined by gas-analysis procedures.

**Data analysis**

The result obtained was analysed using the statistical analysis. The statistical toolsemployed were Analysis of Variance (ANOVA Two-ways), correlation and regression test. The analysis was performed to determine the significant factor (independent variables) on the pellet produced.

## Results And Discussion

The ultimate properties are important in order to determine the percentage of constituent elements of L. leucocephala and A. mangium which which contributes to combustion.

Individual L. leucocephala and A. mangium or the mixtureshave relatively high carbon content which is above 40% in the average, and low content of nitrogen, hydrogen and sulphur,which indicates a good property for solid fuel. Based on Tarasov et al., (2013), calorific value is influenced by carbon, hydrogen, oxygen, sulphur, nitrogen and ash contents present in the wood pellets, where carbon, hydrogen and sulphur were positively correlated, and nitrogen and oxygen were negatively correlated. High carbon content is required since it is an important element to facilitate combustion. The low content of nitrogen and sulphur is a good thing because it will be minimising the release of nitrogen and sulphur oxides into the atmosphere to reduce environmental pollution (Oesch and Faller, 1997). Carbon element playsan important role not only for biomass but also for any organic material. It has a major contribution to the overall heating value of biomass fuel. During photosynthesis, carbon comes from atmospheric $CO_2$ and becomes a part of the plants. Once the plant undergoes combustion process, it is mainly released back to the atmosphere in the form of $CO_2$.Figure1.1, demonstrates the average of carbon contents in the fuel pellets ofL. leucocephala and A. mangium individually or the mixtures. It shows that the average percentage of carbon has decreased from bottom to top portions, meaning that the bottom portion recorded a higher percentage of carbon as compared to the top portion. The highest value came from the mixture of 70:30 bottom portion (49.31%), and the lowest is in the mixture of 30:70 top portion (38.9%). However, the differentiation of carbon value from the mixing ratio of 100:0, 30:70, 50:50, 70:30 and 0:100 as well as bottom to middle and top portions are not significant ($p>0.05$).

Hydrogen is another important element of biomass and can be found in the carbohydrates and phenolic polymers. It contributes significantly to the heating value of biomass. Hydrogen is converted to $H_2O$ during combustion. The average percentage of hydrogen has increased from bottom to top portions, meaning that top portion recorded a higher percentage of hydrogen as compared to the bottom portion. The highest is in A. mangium middle portion (9.23%), and the lowest is in the mixture of 70:30 bottom portion (5.87%). However, the differentiation of hydrogen value from the mixing ratio of 100:0, 30:70, 50:50, 70:30 and

0:100 as well as bottom to middle and top portions are also not significant ($p>0.05$).

Nitrogen element is related to the plant nutrient. Normally plant absorbs nitrogen from the nutrients in the soil or the fertilisers which were applied to the plant for its growth. Nitrogen is partially emitted in oxide forms during combustion, which gives negative effects on global climate and human health. The average percentage of nitrogen has increased from bottom to top portions, meaning that the top portion has recorded a higher percentage of nitrogen as compared to the bottom portion. The highest is in the mixture of 50:50 top portion (19.18%), and the lowest is in the L. leucocephala bottom portion (12.26%). The differentiation of nitrogen value from the mixing ratio of 100:0, 30:70, 50:50, 70:30 and 0:100 as well as bottom to middle and top portions are also not significant ($p>0.05$).

Sulphur is also an important nutrient for plant growth like nitrogen. It has only a small fraction in biomass and presents in some organic structures like amino-acids, protein and enzymes. During combustion, sulphur is mainly transformed into SO2 which contributes to aerosol and smog formation, corrosion and acid rain. On the other hand, the average percentage of sulphur has decreased from bottom to top, meaning that the bottom portion recorded a higher percentage of sulphur as compared to the top portion. The highest is in L. leucocephala bottom portion (0.49%), and the lowest is in the mixture of 70:30 bottom portion (0.11%). The differentiation of sulphur value from the mixing ratio of 100:0, 30:70, 50:50, 70:30 and 0:100 as well as bottom to middle and top portions are also not significant ($p>0.05$).

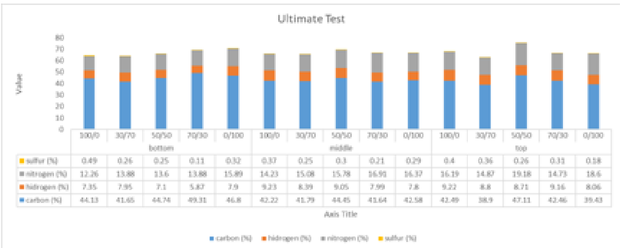


**Figure 1.1:** Ultimate properties of L. leucocephala and A. mangium pellets

The mixtures do not increase the percentage of nitrogen and carbon in the fuel pellets as well as the percentage of sulphur and hydrogen. The 50:50 mixtures of the top portion of L. leucocephala and A. mangium fuel pellets has recorded the highest nitrogen contents (19.18%). On the other hand, the 70:30 mixtures of the bottom portion of L. leucocephala and A. mangiumfuel pellets has recorded the highest carbon contents (49.31%). Based on the results of the ultimate analysis above, it can be concluded that L. leucocephala and A. mangium have the potential to be utilised as solid fuel individually or in the form of mixtures and the best compositions is 70:30 for all the portions.

## Conclusions

Based on the analysis, it can be concluded that carbon, hydrogen, nitrogen and sulphur of L. leucocephala and A. mangiumare influenced by portions (bottom, middle and top) as well as a mixing ratio. Thus, the ultimate properties that were recorded in this study show thatit has good fuel characteristics to be used as raw materials for solid fuel due to itshighmean percentage of carbon contents and low in nitrogen.

## Acknowledgements

The authors would like to extend their highest appreciation to Universiti Malaysia Kelantan for the approval to use the facilities at the Jeli Campus and to the Faculty of Earth Science for the kind permission to publish this article.

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