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Effect of Portions and Particle Sizes on Proximate Properties of Oil Palm Fronds

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Abstract. The purpose of proximate analysis is basically to evaluate the fuel characteristics of raw materials. So, the aim of this study is to evaluate the effect of portions and particle sizes on proximate properties of oil palm fronds. The moisture analyser mx-50 machine was used in the identification of moisture content (MC) in the samples. Meanwhile, volatile matter (VM) was analyzed based on BS EN 15148:2009 standard. Ash content (AC) was obtained using BS EN 14775:2009 standard. On the other hand, fix carbon (FC) was obtained through the summation of percentage in all three (3) different values of moisture content, ash content and volatile matter subtracted from 100%. The average percentage of MC of bottom, middle and top portion of oil palm fronds for smaller particle size (0.5mm) were 11.91±0.25%, 12.23±0.14%, 12.59±0.23% respectively. On the other hand, the average percentage of MC of the same portion of oil palm fronds for bigger particle size (1.5mm) were 10.67±0.41%, 11.25±0.12%, 11.53±0.23% respectively. Meanwhile, the average percentage of VM of the same portion of oil palm fronds for smaller particle size (0.5mm) were 81.02±0.28%, 80.68±0.33%, 80.15±0.19% respectively. The average percentage of VM of the same portion of oil palm fronds for bigger particle size (1.5mm) were 82.48±0.32%, 82.48±0.32%, 81.26±0.26% respectively. The average percentage of AC of the same portion of oil palm fronds for smaller particle size (0.5mm) were 2.48±0.15%, 2.63±0.16%, 2.85±0.70% respectively and for bigger particle size were 2.23±0.11%, 2.46±0.71%, 2.67±0.50% respectively. Last but not least the average percentage of FC of the same portion of oil palm fronds for smaller particle size were 4.59±0.26%, 4.46±0.60%, 4.41±0.11% respectively and for bigger particle size were 4.62±0.33%, 4.57±0.15%, 4.54±0.02% respectively. Based on the results of proximate analysis above, it can be concluded that, oil palm fronds has a potential to be utilized as solid fuel.



1. Introduction

Oil palm frond is one of the most abundant oil palm agricultural residues in Malaysia. Oil palm fronds are found around the trunk in two spirals which are right-handed or left-handed. The leaves are found at the top of the plant arranged as a crown which may contain 40 or more fronds. The fronds lengths decrease from the bottom to the top level of crown, with an average of about 4 m in length. At cross-section, the frond shows a triangle shape with the width decreasing from the base to the end of the petiole and from the bottom to the top frond (Hishamudin, 1987). A fruit branch which contains thousands of fruits are held in the axils of the leaves and arranged in a rosette pattern around the crown (Rehm and Espig, 1991; Opeke, 1982). The fronds will be chopped down regularly either for pruning or for the harvesting purposes. The frond below fruit bunch need to remove in order to facilitate fruit picking. According to the previous study, the hydrogen value of palm oil fronds, ranging between 5.33% to 5.50% in average where the highest value 5.50% came from bottom portion of 1.5 mm particle size while 5.33% was located in top portion of 0.5 mm particle size (Daud and Law, 2010; Mohd Sukhairi, 2011). The decreasing trend was observed from the bottom to the top portion and large particle hold higher value compare to small particle size (Ng et al., 2003), that is why the chipped in the chipped board manufacturing came from bottom portion. Oil palm fronds currently are left to rot in between the row of oil palm trees in the plantation as soil conservation, increase the fertility of the soil, increase the amount of water retain in the soil, as erosion control and provide a source of nutrient. Oil palms waste are available in large quantity, sufficient for industrial raw materials in agro-based industries. Therefore, it also has a very good potential to be converted into renewable energy sources especially the oil palm frond. So, the important property to indicate whether biomass or agriculture waste could be a good material for solid fuel are proximate properties via proximate analysis. Proximate analysis was developed by Henneberg and Stohmann in Germany on 1860 (Hew, 2015) comprises of MC, VM, AC and FC.

The moisture content (MC) is a measure of the amount of water in the material (fronds). It can be presented in two forms which are as free water surrounded by the pores and interstices of the fuel and as bound water which is part of the chemical structure of the material (Borgman and Ragland, 1998). The moisture content can be set up by taking a small weigh of sample and oven drying it at 105°C for 1 hours until consistency in the sample's mass is obtained (British Standards Institution, 2010). The change in weight can then be used to determine the sample's percentage moisture content. General, moisture content is obtainable either on a wet basis, also known as the moisture content as received (the biomass moisture content as a percentage of the total as received mass), or on a dry basis, which is the moisture content as a percentage of the dry mass (Chaney, 2010). In this study, only dry basis were present as moisture content value. Moisture content is very important property and can greatly affect the burning characteristics of the biomass (Yang et al., 2005). According to Chaney (2010), during the combustion, moisture in the biomass will absorb heat by vaporization and heating of the resulting vapor will decrease the heating value of a given fuel. This can result in incomplete combustion of the volatiles and the deposition of unburnt carbon (smoke) in the stove's chimney, on the bottom of cooking pans and result it difficult to clean.

The second parameter for proximate property is volatile matter (VM). The volatile matter represents the components of carbon, hydrogen and oxygen present in the biomass that when heated turn to vapour, usually a mixture of short and long chain hydrocarbons (Chaney, 2010). It is determined by heating a dried ground sample of biomass in an oven at 900°C for 7 minutes (British Standards Institute, 2010). The amount of volatile matter in the biomass can then be calculated as percentage of the weight loss of the sample. In almost all biomass, the amount of volatile matter is higher than in bituminous coal. Biomass generally has a volatile content of around 70-86% of the weight of the dry biomass, compared to coal, which contains only about 35% volatile matter (Loo and Koppejan, 2008). Consequently, the fractional heat contribution of the volatiles is more for biomass. This makes biomass a more reactive fuel than coal, giving a much faster combustion rate during the devolatilisation phase (Loo and Koppejan, 2008). The volatile content is hard to quantify as it affect the thermal behavior, structure and bonding

within the fuel, of the solid fuel (Loo and Kopperjan, 2008). Low-grade fuels, tend to have a low volatile content resulting in smouldering combustion (Chaney, 2010).

Next is ash content (AC), ash is the non-combustible component of biomass and the higher the fuel's ash content, the lower its calorific value (Loo and Kopperjan, 2008). The ash content is determined by heating a dry sample of biomass in an open crucible in a furnace at 815°C for 3 hours (British Standards Institute, 2010). Depending on the type of biomass, the ash content can vary between 0.8% for groundnut shells to as high as 23% for rice husks (Chaney, 2010). Ash is known to cause problems in combustion systems, notably because of slagging and fouling, and its tendency to increase the rate of corrosion of metal in the system (Loo and Kopperjan, 2008). Ash can also have a significant influence on the heat transfer to the surface of the fuel, as well as affecting the diffusion of oxygen to the fuel surface during char combustion (Kim et al., 2010). After the volatiles and moisture have been released, ash and fixed carbon are remain. The relative proportion of volatiles, moisture, ash and fixed carbon are often quoted for biomass fuels. The percentage of fixed carbon is normally determined by subtracted quantify with moisture content, volatile matter and ash contents (Chavalparit et al., 2013). Essentially, the fixed carbon of a fuel is the percentage of carbon available for char combustion. Chaney, (2010) stated that, fixed carbon not equal to the total amount of carbon in the fuel (the ultimate carbon) because there is also a significant amount released as hydrocarbons in the volatiles. Fixed carbon gives an indication of the proportion of char that remains after the devolatilisation phase.

2. Materials And Methods

The oil palm fronds that were used for this study was collected from eastern part of Malaysia which located in Felda Kemahang 1, Tanah Merah, Kelantan, Malaysia (Figure 1.0). The oil palm fronds with no defect and decay-free were selected. Later, they were transported to Universiti Malaysia Kelantan (UMK), Jeli Campus for further processing. The leaflets were removed from the fronds and then it were divided into three section which are bottom, middle and top portion. Then, the fronds skin were peeled and sliced in longitudinal direction. These sliced fronds were then compressed using a roller type equipped with a servomotor having power supply with a capacity of 750 W to increase their density before undergoing sun-drying. In order to remove the excess of moisture content from their fiber, drying process were involve. This process can also enhance their durability against fungi and insects attacks. Each portions of fronds were dried in oven under condition of 72° C for 12 hours. The drying temperature of the samples must be moderate to avoid breaking up the lignin structure as well as to keep the moisture content range between 9-12%. In addition, this process also helped to increase the efficiency to move on for grinding process. The samples were then grinded by disc mill machine to split them into very fine sawdust forms in between 0.5-2.0 mm particle size. This grinding partially breaks down the lignin, increases the specific area and contributes to better binding. In this study, only two size of particle were selected which are 0.5mm and 1.5 mm. Generally, the small particle size have the higher specific area, huge number of contact points and more exposed surface area. Next is screening process to remove those unwanted material, undersize and oversize particles. The screening vibrator machine was used to separate the sample. Initially, the machine separate the particles into four different sizes, which are 0.5, 1.0, 1.5 and 2.0 mm. Then, only the required size were selected which were ≤ 0.5 mm and $\geq 1.5 < 2.0$ mm. Particle size ≤ 0.5 mm will be considered as 0.5 mm size and particle size 1.5mm and greater but less than 2.0 mm will be considered as 1.5 mm size.

The proximate analysis was carried out particularly based on its moisture content (%), volatile matter (%), ash content (%) and fixed carbon (%). Moisture content (MC) basically expressing the amount of water present in a sample. The moisture analyser mx-50 machine was used in the identification of moisture content in the samples. The moisture content was expressed in percentage by subtracting the weight of the dry sample from the weight of the moist sample, and then dividing by the weight of the dry sample and multiply by one hundred. Meanwhile, the volatile matter (VM) were analyze based on

BS EN 15148:2009 standard. The sample was put crucible with lid and weighted to nearest 0.01 g and placed in a furnace under the oxygen free condition at 900°C for 7 minutes. After that, remove the crucible with lid from furnace and allow to cool to room temperature. When cool, the crucibles were weight to the nearest to 0.01 g. The volatile matter was also expressed in percentage by subtracting the weight of the residue from the weight of the sample (air dried), and dividing by the weight of the sample (air dried) and multiply by one hundred. the other hand, ash content (AC) was obtained using BS EN 14775:2009 standard. 1 g of sample were put in a fused silica crucible without lid and burned in furnace under the temperature 815 °C for 3 hours. The AC also was expressed in percentage by dividing weight of ash with weight of sample and multiply by one hundred. Finally, FC was obtained through the summation of percentage in all three (3) different values of moisture content, ash content and volatile matter subtracted from 100%. Analysis of variance (ANOVA) was carried out to access the comparison for physical, proximate, ultimate and energy content of oil palm fronds for different portion and particle size and continued with the analysis of post-hoc test through Tukey's tests. The correlation between these properties was determined by correlation test.

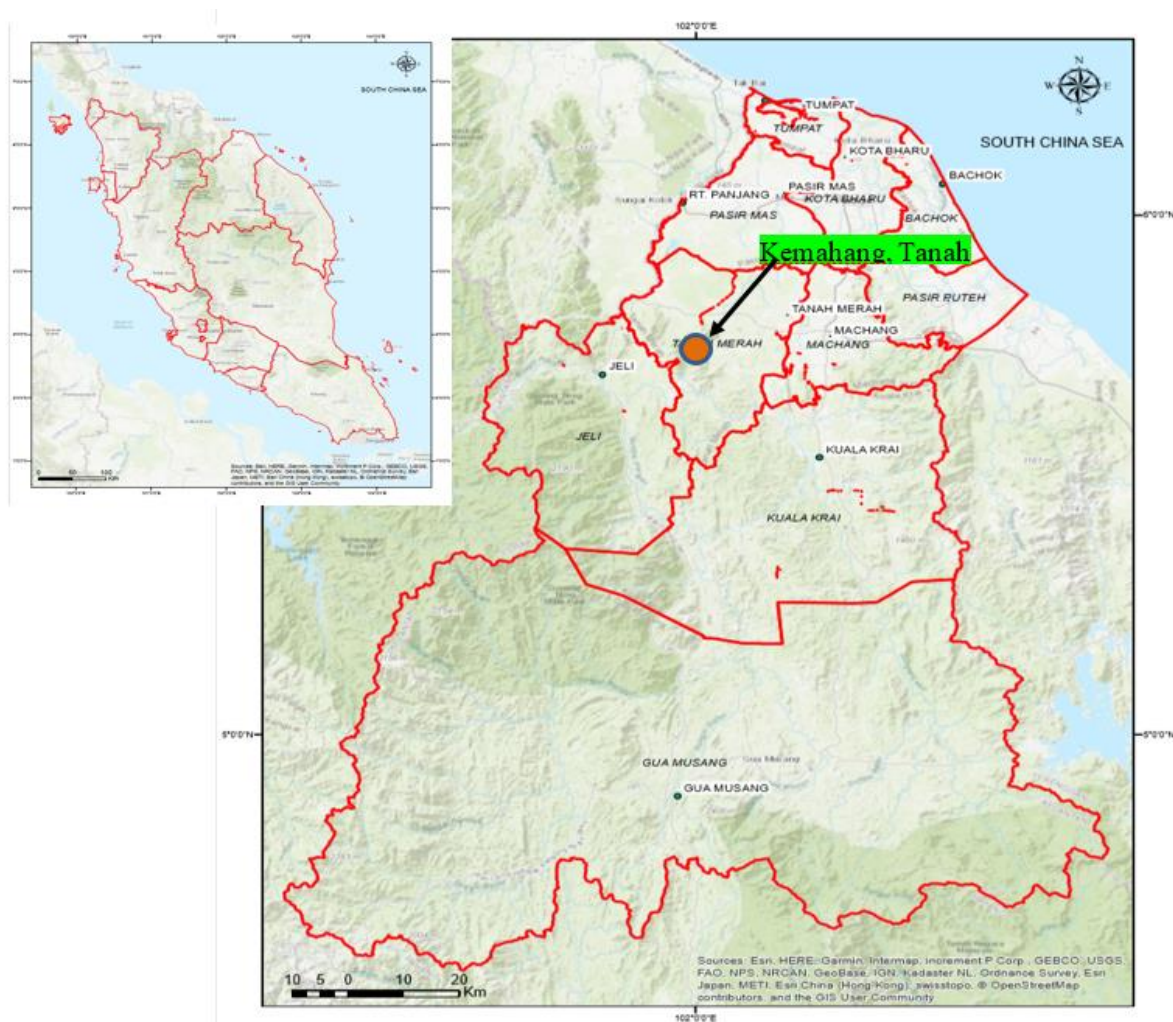


Figure 1. Study area

3. Results and Discussion

The purpose of proximate properties analysis is basically to evaluate the fuel characteristics of raw materials. Moisture content, volatile matter, ash content and fixed carbon content were analyzed in this proximate properties according to three different portions (bottom, middle and top) and two different particle sizes (0.5 and 1.5 mm) respectively. Table 1.0 shows the mean value of proximate properties for raw oil palm fronds.

Table 1.0: Mean value of proximate properties for raw oil palm fronds.

Portion	Particle Size (mm)	Proximate Properties (%)			
		MC	VM	AC	FC
Bottom	0.5	11.91±0.25	81.02±0.28	2.48±0.15	4.59±0.26
	1.5	10.67±0.41	82.48±0.32	2.23±0.11	4.62±0.33
Middle	0.5	12.23±0.14	80.68±0.33	2.63±0.16	4.46±0.60
	1.5	11.25±0.12	81.72±0.34	2.46±0.71	4.57±0.15
Top	0.5	12.59±0.23	80.15±0.19	2.85±0.70	4.41±0.11
	1.5	11.53±0.23	81.26±0.26	2.67±0.50	4.54±0.02

Note: MC = Moisture content
 VM = Volatile matter
 AC = Ash content
 FC = Fixed carbon content

Figure 2 showed the mean value of MC for raw oil palm fronds according to the portion and particle size. It shows that, MC values increased from bottom to top portions and 0.5 mm possessed the highest mean values in each portions compare to particle size 1.5 mm. The highest MC mean value is 12.59% from top portion of 0.5 mm, while the lowest mean value was observed from the bottom portion of 1.5 mm particle size with the value of 10.67%. This trend indicate that the value of MC increase from bottom to top portion and highest in small particle size compare to large particle size. The high MC in top portion was due to the abundant amount of the parenchyma ground tissue (Abdullah, 2011) as compared to the middle and bottom portions. The parenchyma behaves like a sponge and hold high moisture (Paridah and Anis, 2008). The other reasons because top portion has less matured cell as compared to other two portions that able it to hold more moisture in their cell. These finding was in agreement with previous study done by few researchers, where they reported that, MC of oil palm biomass are increasing from the bottom to the top portions because the top portion got lacking in fibre cell in the vascular bundle compare to the middle and bottom portion (Erwinsyah, 2008; Lim and Fuji, 1997; Mohd Sukhairi, 2011). Meanwhile, Killman and Koh (1988), reported that MC increases from peripheral zone to inner zone along the oil palm trunk and this is due to the distribution of the vascular bundles, where from inner zone to peripheral zone, the population of the vascular bundles was drastically increased. The same situation have been happening to MC value between portions of the oil palm fronds,

where the population of vascular bundles and quantity of *parenchymatous* tissue influence the MC value. The MC value obtained is suitable for pelletizing in fuel pellet production because based on Razuan *et al.* (2011), high moisture level up to 15% caused the pellets to collapse immediately when emitted from the mould, whereas a low as 5% MC caused the pellets to crack instantly. Thus, the property of MC recorded in fresh frond is considered as good raw material for making fuel pellets. In terms of particle size, the results showed that, the smaller particle size 0.5 mm has higher MC as compare to bigger (1.5 mm) particle size. According to Sonthi and Nitipong (2013), the ability of small particle size to absorb water is better than large particle size. These result also was in agreement with Mani *et al.* (2004) on corn stover, where they reported that, the reduction of particle size from 12.5 mm to particle size of 3.2 – 0.8 mm, increased MC from 6.2 to 12.0%. Studied by Hew (2015) on *Leucaena leucocephala* also found that the value of MC higher in small particle size as the stored amount of water in large particle size was loss faster during sample preparation compare to small particle size. This results also reinforced by the analysis of variance (ANOVA), where there was a significant difference for MC between portions and particle sizes of oil palm fronds.

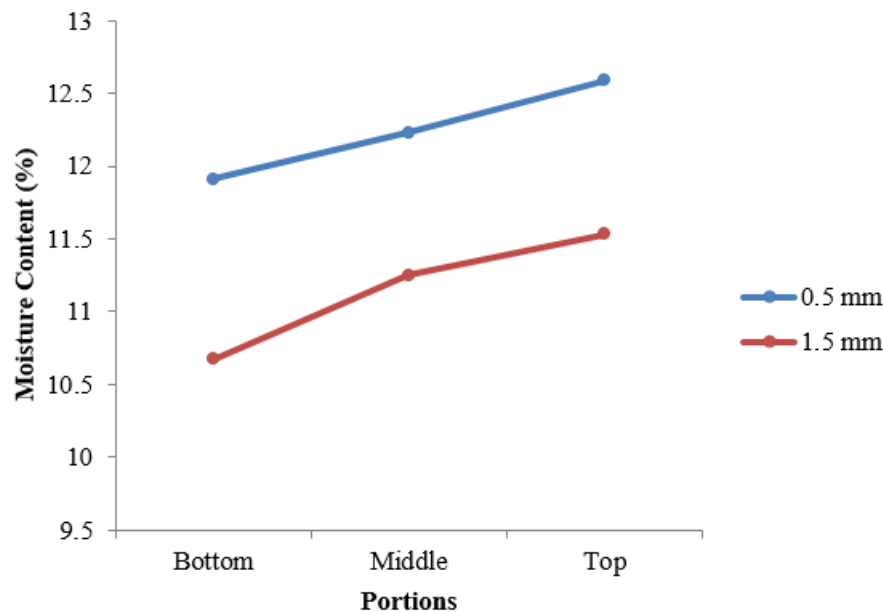


Figure 2. Trend on moisture content by portions and particle sizes of raw oil palm fronds.

Meanwhile, the mean percentage of VM for raw oil palm fronds recorded ranged between 79.95% and 82.68%. This is in-line with findings from Vassilev *et al.*, (2010), where they found that, biomass generally contains of high levels of volatile matter ranging from 64 to 98% as compared to fossil coal which typically below 40%. This high quantity of volatile matter indicates an inflammable property of the oil palm fronds biomass (Chavalparit *et al.*, 2013; Ho, 2015). However, percentage of VM of this study a little bit higher as compared to finding from Abdul Rahman *et al.* (2014), where they reported that, VM on oil palm fronds was 76.26%. Figure 2 illustrated the mean value of volatile matter for each portion and particle size. It showed that, the value of VM were decreased from bottom to top portions and large particle size possessed the higher value for each portion compared to small particle size (Figure 2). From the results, it showed that the value of the bottom portion with 1.5 mm particle size possessed the highest VM with mean value of 82.48%, meanwhile the top portion with 0.5 mm particle size recorded the lowest with the mean value of 80.15%. According to Eriksson *et al.* (2004), VC was inversely proportional to MC, high MC will decreased the VM as it need much time to ignite. This

statement was supported the above result for VM since top portion and small particle size were possessed the higher MC compared to other portions and particle size and resulted the low VM respectively. The ANOVA results also proved that VM post significant difference base on portion and particle sizes of oil palm fronds.

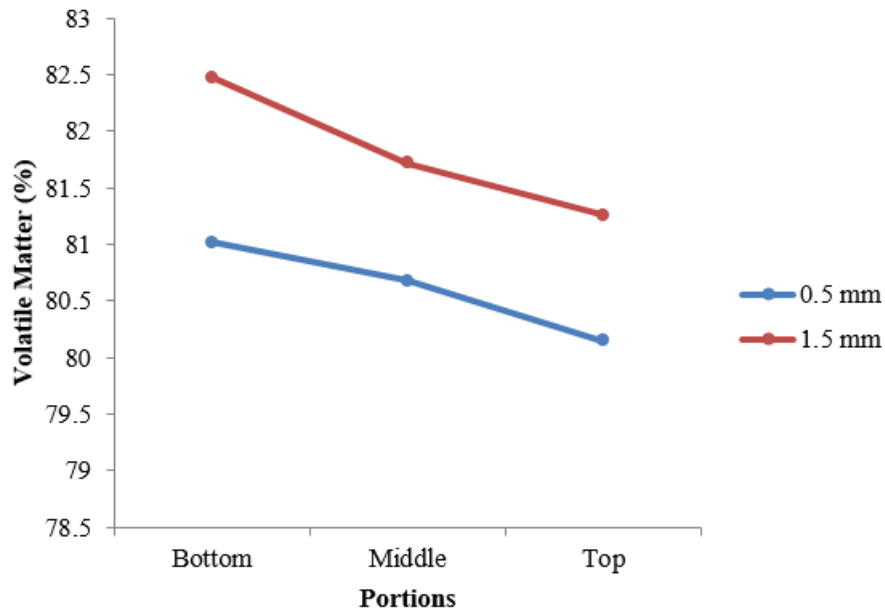


Figure 3. Trend on volatile matter by portions and particle size of raw oil palm fronds.

The percentage of AC is the percentage of residue of ash after burning in furnace under temperature condition of 815°C for 1 hours. The value of ash content of raw oil palm fronds was recorded ranging from 1.97% to 3.64%. Ash content of oil palm fronds is significantly low as compared to other oil palm wastes such as oil palm shell with 6.7% (Kim et al., 2010) and empty fruit bunch with 5.43% (Sia et al., 2009). Jenkins et al. (1998) reported that 1% increase in ash yields a significant decrease in the heating value (approximately 0.2 MJ kg). This decrease occurs because ash does not substantially contribute to the overall heat released by combustion, although elements in ash might be catalytic to the thermal decomposition. The trend on mean percentage for AC in each portions and particle sizes were shown in Figure 3. Based on that figure, the trend of AC was increase from bottom to top portion and 0.5 mm particle size had the highest mean value of AC for each portion compare to 1.5 mm particle size. The highest mean value of AC was found in top portion of 0.5 mm with 2.85 % and the lowest was recorded in bottom portion of 1.5 mm with the mean percentage of 2.23 %. Kumar et al. (2011) studies on eucalyptus wood fuel properties found that, the higher amount of potassium (k) and magnesium (Mg) on the top portions of the tree resulted in higher percentage of AC compared to other portions of the tree. The top portion of fronds is the actively metabolizing position, where the nutrition from the soil is fixed prior to relocation to other parts of plant, so AC is highest in the top portion. On the other hand, small particle size tend to have higher amount of AC and this was believed to be due to the inorganic matter lean to be concentrated in small particle size and cause the high AC in small particle size (Brigeman, et al., 2007). This was reinforced by the ANOVA results, where there was a significant difference for AC between portions and particle sizes.

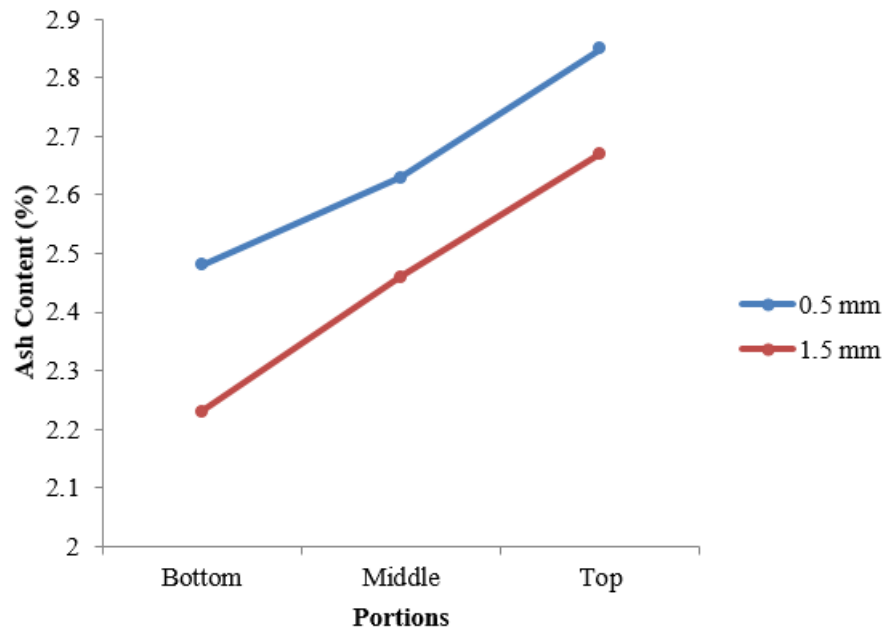


Figure 4. Trend on ash content by portions and particle sizes of raw oil palm fronds.

Fixed carbon also known as non-combined carbon is the fraction remaining after VM is completely released with the exception of ash and moisture which burns forming char (Oberberger and Thek, 2004). Hence, the value of FC were obtained by subtracted quantity with moisture content, volatile matter and ash contents value for each sample. The results showed that, the highest value was from bottom portion of 1.5 mm particle size with 4.62% while the lowest value was observed from top portion of 0.5 mm particle size with the value of 4.41%. Figure 5 shows the trend of FC for each portion and particle size where descending trend were observed for both portion and particle size but the differences is not significant ($P > 0.01$). It means that, FC of oil palm fronds were not influenced by portions and particle sizes.

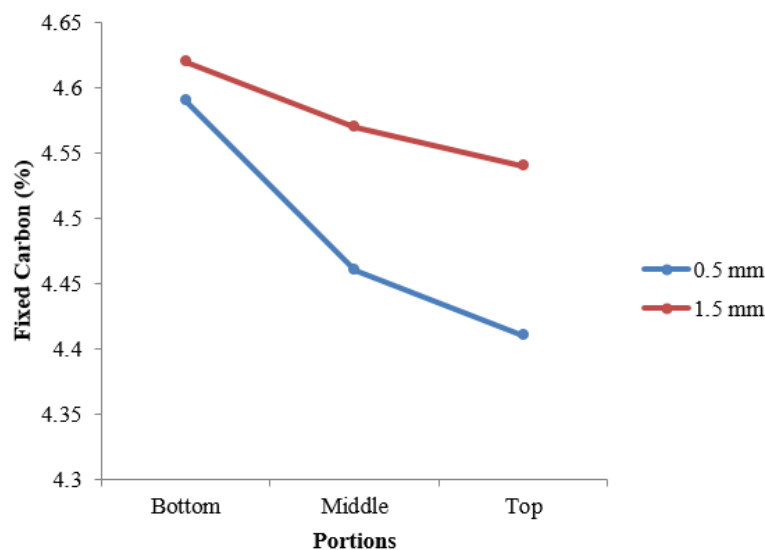


Figure 5. Trend on fixed carbon content by portions and particle sizes of raw oil palm fronds.

Obernberger and Thek (2004) stated that, the FC content value is also useful to indicate the calorific value as the higher of FC, the easier the ignition, and thus the lower the residence stage until combustion is completed. When biomass materials are heated in a combustion process, the VM releases first and burn in gaseous state. While the FC are left behind as char, which burns later in solid state. In this study, bottom portion and large particle size hold the higher value compare to other factor, so this can be indicated that, bottom portion with 1.5 mm particle size able to hold higher calorific value. Based on the analysis of variance (ANOVA), MC, VM and AC of raw oil palm fronds were significantly ($p < 0.01$) influenced by frond portions (bottom, middle and top) but it was not significantly ($P > 0.01$) influence by FC. Moisture content, VM and AC of raw oil palm fronds were also significantly influenced by the particle size. There were significance different at $p < 0.01$ for MC and VM whereas for AC there were significant different at $p < 0.05$. This indicated that both, frond portions and particle size influences the MC, VM and AC. However, FC content exists of no significant difference to portions and particle sizes due to no encouragement of FC content to the portions and particle sizes of the oil palm fronds although there was differences in value for the testing result. So, meaning that, FC content does not different much from bottom to top portions and it was also not differ much whether it is small (0.5mm) or big (1.5mm) particle size.

4. Conclusion

Based on the analysis it can be concluded that, MC, VM and AC of raw oil palm fronds were significantly influenced by frond portions (bottom, middle and top) but it was not significantly influence by FC. MC, VM and AC of raw oil palm fronds were also significantly influenced by the particle size. However, FC content exists of no significant difference to portions and particle sizes of the oil palm fronds although there are differences in value for the testing result. So, meaning that, FC content does not different much from bottom to top portions and it was also not differ much whether it is small (0.5mm) or big (1.5mm) particle size. However, the proximate properties of oil palm fronds that was recorded in this study shows that, it has good fuel characteristics to be used as raw materials for solid fuel because it has high of mean percentage of VM and FC and low in MC and AC.

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