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Some physical properties of Napier grass before and after chopping for producing biomass pellets

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Abstract

The objective of this research was to study some physical properties, before and after chopping of Pak Chong 1 Napier grass to produce biomass pellets. The experimental results of Napier grass before chopping were 39.67±26.68 leaves per stalk, 22.42±6.92 internodes per stem, weight per stalk of 0.64±0.24 kg, weight per stem of 0.53±0.19 kg, lengths of stalk, stem, apex and leaf were 429.5±52.58, 257.40±35.01, 172.04±36.96 and 70.42±15.33 cm respectively. Stem diameters at lower, middle and upper sections 19.42±2.43, 18.31±2.84 and 14.08±2.71 mm respectively. The lower and upper apical diameters were 10.83±1.55 and 6.25±1.21 mm respectively. Thicknesses of leaf at lower, middle and upper portions were 0.13±0.04, 0.14±0.05, and 0.19±0.67 mm respectively while widths of leaf at lower, middle and upper portions were 28.01±4.14, 34.88±4.71, and 29.01±4.94 mm respectively. The heating values of all parts of Napier grass were not significantly different. On the other hand, the experimental results of Napier grass after chopping indicated on optimum moisture content of 11.78 % w.b. by sun drying to produce biomass pellets. The coefficients of static friction on ply wood, rubber, mild steel and stainless steel plates were 0.78 0.69 0.79 and 0.62 respectively. Angle of repose was 57.54 degrees while bulk density was 39.46 kg/m^3. Average particle size was 2.47±1.13 mm. The percent through sieve by using a size through a resolution sieve of 2.00 to 0.85 mm was 72.53 % and the maximum heating value at moisture content of 8.37 % w.b. was maximum at 3606.33 cal/g.

Keywords: Physical properties, Napier grass, Biomass, Pellets

1. Introduction

Nowadays**,** Thailand is one of the countries that use the biomass extensively whether by direct burning, or increasing bulk density before burning such as for biomass pellets [1] and the charcoal briquettes, etc. [2] Moreover, they are also used to produce electricity and for food industry. Therefore, using biomass as renewable energy will play more roles to develop our country in the future. [3]

The biomass in Thailand includes husk, leaves of sugarcane, rice straw, corncobs, cassava bark from starch factory, coconut shell, and bagasse from sugar factory, etc. However, it is necessary to wait to obtain these biomass materials after the harvest of each crop. This affects the availability of raw materials to produce energy and causes lack of continuity in the production of biomass pellets.

If there exists a kind of plant that can be harvested thoughtout the year and minimum maintenance, it will be a better alternative for the production of renewable energy to reduce power shortages. This is the reason of considering Napier grass to be a source of renewable energy because it can be harvested 5-7 times per year (harvested 2-3 months per time). Moreover, the Napier grass can be harvested continually for seven years and the product is at 60-100 tons per rai per year. Therefore, in irrigable areas [4], the Napier grass has a good potential to be the base material for producing alternative energy and a good value added crops.

However, the physical properties of each agricultural material are different but specific, and they are important factors in the design of [5] equipment, machinery, material handling system, forming products or storages for other related agriculture materials. From this point, the study of physical properties is important in the critical analysis of data for the design of engineering services, which relates to material design requirements. To summarize, this study aimed to investigate the physical properties of Napier grass before and after chopping for being the basis for the decision making to use Napier grass to produce biomass pellets.

2. Materials and methods

This study aimed to investigate the physical characteristic of Napier grass before and after chopping to produce biomass pellets**.** The dimensions or parameters proportions**:** moisture, coefficient of static friction, angle, particle size, bulk density, and heating value were studied as

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the basis information for production or design related machinery. Therefore, the retention of Napier grass seeds; Pak Chong 1, three months of age (suitable range for harvesting) both before chopping (Figure 1) and after chopping (Figure 2) were used to be the samples.

2.1 Physical characteristic of Napier grass before chopping

2.1.1 Physical characteristic

To study the characteristics or dimensions of Napier grass before chopping, 200 samples of Napier grass were collected randomly to count the number of leaves per stalk and the number of internodes per stem. Moreover, the various parts of Napier grass were measured: weight, length, width and thickness.

The thickness of stem and leaf were divided into three parts, Lower, Middle, Upper, and the apical thicknesses were divided into two parts, Lower and Upper. Then measure the thickness at the middle of each section as shown in Figure 1.

The width of leaf was measured by dividing into three parts, Lower, Middle, Upper before measuring the width at the middle of each section. The moistures of the stems and leaves on wet basis while testing were at 72.83 and 81.56 percent respectively.

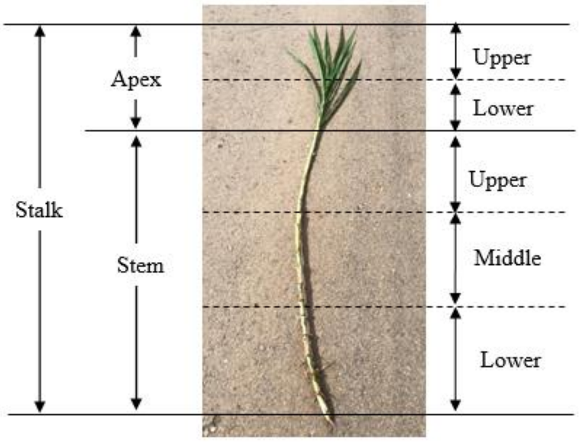

Figure 1 Physical characteristic of Napier grass before chopping

2.1.2 Heating value

Analysis of the heating value of Napier grass before chopping, the comparative method by weight was used to analyze each part of Napier grass: stalk, leaves, and ingredients between the stalk and leaves included the inner core and outer core before performing statistical analysis of variance by using ANOVA in a bomb calorimeter to test the heat value of the material.

2.2 Physical characteristic of Napier grass after chopping

The physical properties of Napier grass after chopping, which were chopped by rolling Napier grass harvester with twin blade on fly wheel, were studied by relating the moisture with the coefficient of static friction, angle, bulk density, particle size and the heat value. The data were collected five times (duration of 12 days) by the interval of one time in three days until no decrease of moisture. This method was a dehumidification process for drying the Napier grass.

Figure 2 Physical characteristic of Napier grass after chopping

2.2.1 Moisture content

Moisture affected various indicators whether they be the coefficient of static friction, particle size, bulk density and heating value that measured by collecting data on the tests. Moisture measurement was done by bringing Napier grass to test in the oven at temperature 103 °C for 24 hours and using the first equation for evaluating moisture content of the materials. [6]

$$MC_{w.b.} = \frac{LW}{WW} \times 100 \quad (1)$$

$MC_{w.b.}$ = Moisture content of material on wet basis (%w.b.)
LW = Losing weight of the material after drying. (kg.)
WW = Weight of the material before drying without the weight of container. (kg.)

2.2.2 The coefficient of static friction

The coefficient of static friction testing: setting platform up tested four different types of materials including wood, rubber, steel and stainless steel. When the material moved at the first time, the researcher read the angle scale and recorded. Then took the value for equation 2 for finding the coefficient of static friction. [5]

$$\mu = \tan\alpha \quad (2)$$

μ = The coefficient of static friction
α = Angle of friction (degree.)

2.2.3 Angle of repose

Angle of repose measurement was conducted by releasing the material to the ground independently. Then measured the length of the base and took the value for equation 3. [7]

$$\alpha = \tan^{-1}(360L/h\pi) \quad (3)$$

α = Angle of repose (degree.)
h = Height of the material (cm.)
L = Length of the base material (cm.)

2.2.4 Bulk density

Bulk density: the material was released into the container with constant volume filled containers. Then leveled the material face to smooth with the edges of the container and weighed the material in the container. The test was repeated 50 times for equation 4. [8]

$$\rho_b = \frac{m}{V} \quad (4)$$

ρ_b = Bulk density (kg/m^3)
m = Weight of the material (kg)
V = Volume of containers (m^3)

2.2.5 Particle size

Particle size analysis of Napier grass to find the average diameter of particle sizes range, this method was performed by pouring into a sieve on the top of a shaking Ro-tap with weight of 50 grams with 10 sizes of sieve. Then weighed to find the percentage pending on the sieve for finding the diameter of the particles from the equation 5. [9]

$$d_{gw} = \log^{-1}\left[\sum_{i=1}^{n}\left(w_i \log \bar{d}_i\right) \Big/ \sum_{i=1}^{n} w_i\right] \quad (5)$$

d_{gw} = Average diameter (mm.)
$\bar{d}_i$ = Diameter on the sieve (mm.)
w_i = Weight pending on the sieve (g)

Then analyzed the distribution of particle sizes by doing test on weight particles that remained on each sieve size to analyze the distribution of particle sizes.

2.2.6 Heating value

Analysis of the heating value of Napier grass after chopping: this method was performed by comparing the heating value and the relative moisture content changed in each day by using a bomb Michal Perimeter for testing the heating value of the material.

3. Results and discussion

3.1 Results of physical characteristic of Napier grass before chopping

3.1.1 Physical characteristic

Specific characteristic of Napier grass before chopping: the number of leaves per stalk averaged 39.67, number of internodes per stem averaged 22.42, weight per stalk and per stem averaged 0.64 and 0.53 kg respectively. In addition, the lengths of stalk, stem, apex, and leaf averaged 429.45 257.40 172.04 and 70.42 cm. respectively. The diameters of stem: lower, middle, and upper stem averaged 19.42 18.31 and 14.08 mm respectively. The lower and upper apical diameters averaged 10.83 and 6.25 mm respectively while the thicknesses of leaf: lower, middle and upper portions averaged 0.13 0.14 and 0.19 mm respectively. The widths of leaf: lower, middle and upper portions averaged 28.01 34.88 29.01 mm respectively. Thus, the results of physical characteristic have been summarized as shown in Table 1.

Dimensional shape, size and weight of Napier grass, such as parts of stalk, leaf, and apex were important in the design of the machine. [5]

Table 1 Physical characteristic of Napier grass before chopping

Physical characteristic	mean±s.d.	Range
1. Number of leaf per stalk.	39.67±26.68	119-8
2. Number of internode per stem.	22.42±6.92	46-9
3. Weight of stalk.(kg.)	0.64±0.24	1.15-0.15
4. Weight of stem.(kg.)	0.53±0.19	1.00-0.10
5. Length of stalk.(cm.)	429.5±52.58	320.22-144.25
6. Length of stem.(cm.)	257.40±35.01	233.10-65.24
7. Length of apex.(cm.)	172.04±36.96	522.00-293.20
8. Length of leaf.(cm.)	70.42±15.33	103.20-29.90
9. Diameter of stem.(mm.)		
Lower	19.42±2.43	27.40-14.11
Middle	18.31±2.84	22.94-10.65
Upper	14.08±2.71	28.96-8.93
10. Diameter of apex.(mm.)		
Lower	10.83±1.55	15.98-7.48
Upper	6.25±1.21	10.49-4.05
11.Thickness of leaf.(mm.)		
Lower	0.13±0.04	0.25-0.03
Middle	0.14±0.05	0.29-0.04
Upper	0.19±0.67	0.29-0.01
12. Width of leaf.(mm.)		
Lower	28.01±4.14	49.39-16.17
Middle	34.88±4.71	46.42-20.36
Upper	29.01±4.94	40.00-15.18

Note: Moisture contents of stem and leaf of Napier grass were at 72.83 and 81.56 %w.b. respectively.

3.1.2 Heating value of Napier grass before chopping

From the study of heating properties of Napier grass before chopping by considering the percentage of weight from each part of Napier grass, various proportions of stem and leaf gave corresponding heating values as shown in Table 2. When the data were analyzed statistically at 95% confidence level, heating value of Napier grass in each section did not differ statistically. Consequently, at the significance level of 0.05, various parts of Napier grass could be chopped together to produce biomass pellets.

Table 2 The proportion by weight in contrast with the heating value

Type (%weight)	Heating value (Cal/g)
Stem 100%	4099.85
Leaf 100%	4026.31
Stem 50% Leaf 50%	4081.99
Stem 75% Leaf 25%	4163.39
Stem 25% Leaf 75%	4107.36
Stem (inner) 100%	4092.51
Stem (outer) 100%	4056.84

Note: Moistures of stem and leaf at 2.28 and 8.10 % w.b. respectively.

3.2 The results of physical characteristic of Napier grass after chopping

3.2.1 Moisture content

Moisture content of Napier grass after chopping, the study performed by comparison period of drying on dehumidification (Table 3)

Table 3 can be exposed moisture content for a period of three days that moisture content reduced from 84.51 to 77.27 which decreased to 7.21 %w.b. It is clear that, the moisture content become lower differently from a period of six days, which reduced to 16.45 %w.b. (material begins to dry). The material has been continued to dry nine to twelve days, the moisture dropped to 11.78 and 11.67 %w.b. There was no

Table 3 Physical properties of Napier grass after chopping

Time (day)	Moisture content (%w.b.)	The coefficient of static friction (μ)				Angle of repose (degree)	Bulk density (kg/m³)
		ply wood	rubber	mild steel	stainless		
0	84.51	2.11	2.29	2.24	2.08	49.22	256.70
3	77.27	0.97	1.06	1.03	1.04	49.20	146.33
6	16.45	0.80	0.68	0.77	0.60	61.56	40.13
9	11.78	0.78	0.69	0.79	0.62	57.54	39.46
12	11.67	0.69	0.61	0.77	0.59	61.65	40.96
Reference	41.17						

different in moisture distance (moisture equilibrium point). It could be described, as reduction rate of moisture is at 8.08 percent per day in the period of six to nine days, which is appropriate period of drying. Accordingly, Napier grass is necessary to rely on 10–12 %w.b. to produce biomass pellets [10].

According to 41. 17 % w.b. of reference moisture wet basis, this reference will be dried for dehumidification in building that no heat transfers to the material in a period of 12 days before collecting data. It is clear that moisture content on outdoor drying become lower than indoor drying.

3.2.2 The coefficient of static friction

After chopping, the coefficient of static friction of Napier grass reduced. When the material was put on the rubber, steel and stainless steel, it was tested at five different of moisture as shown in Table 3. It is noted that when the moisture dropped, the coefficient of static friction would be also reduced. Due to reduction, it is caused by moisture content because if there were high moisture content in material, there would be a large amount of water, which can be as a bonding to hold it together. Therefore, testing affected the material with high friction as well. In the same way, when the moisture dropped, bonding between the water and material would reduce. It is clear that testing affected the material with low friction. Nevertheless, the appropriate to design equipment or machinery need rely on moisture content at 11.78 %w.b. (Table 3, Figure 3).

Moreover, coefficient of static friction can indicate stability of the material before taking the information to design and build hopper for the machine [5].

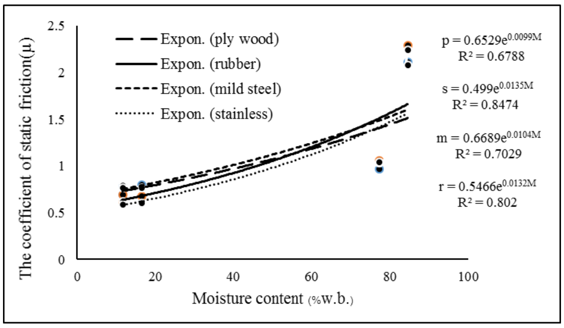

Figure 3 The coefficient of static friction

3.2.3 Angle of repose

The study found that Napier grass after chopping on five different of moisture as shown in Table 3, when the moisture dropped, it affected to angle of repose reduced. Drying period from one to three days, angle of repose is from 49.22 to 49.02 degrees, which is resembled. On the contrary, drying for dehumidification one to six days can increase the angle repose from 49.22 to 61.56 degree. After drying 6th day, there was not much change (Table 3, Figure 4).

In addition, the angle of repose can indicate stability of the material before taking the information to design and evaluate storage space.

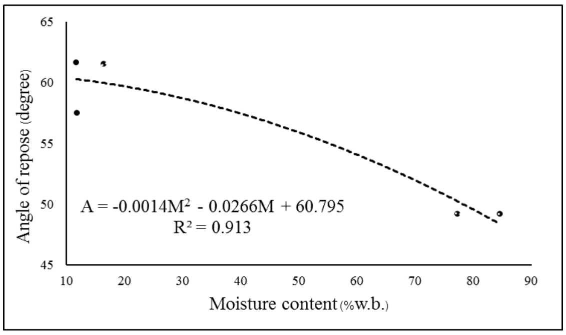

Figure 4 Angle of repose

3.2.4 Bulk density

Bulk density of Napier grass after chopping, it was tested after drying at five different of moisture as shown in Table 3. When the moisture dropped, bulk density tends to decrease as well. Drying period from one to three days, bulk density is from 256.70 and 146.33 kg/m^3, which differ from drying for dehumidification on six days at 40.13 kg/m^3. After drying 6th day, bulk density not much changed. This change occurred because of the relation between moisture content and bulk density. It is explained that when material has high moisture content, it would be high bulk density. On the other hand, when the moisture content is low, the weight of the water will evaporate from the material, which affected the bulk density decreased.

Thus, bulk density can indicate weight per volume of packaging before taking the data to design materials handling systems and packing materials. It included on using as preliminary data on machine design, which also affected to pellet the biomass (Table 3, Figure 5).

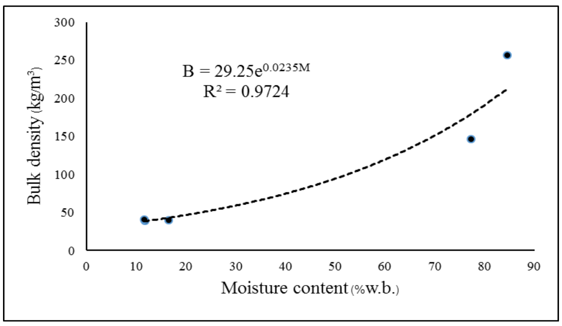

Figure 5 Bulk density

Table 4 Particle size and Heating value

Moisture content (%w.b.)	Particle size (mm) mean±s.d.	Percent through sieve (%) Size through a resolution sieve (mm)			Heating value (Cal/g)
		9.50 to 8.75	2.00 to 0.85	Less than 0.85	
66.22	5.97±1.04	76.33	23.40	0.00	2128.29
48.22	4.21±1.10	50.73	47.07	2.20	2475.07
10.63	2.53±1.12	15.93	71.20	12.87	3306.02
8.47	2.47±1.13	14.47	72.53	13.00	3604.59
8.37	2.55±1.12	17.27	73.33	9.40	3606.33

3.2.5 Particle size

The results can be explained the particle size of Napier grass after chopping as shown in Table 4. It founded that moisture content at 66.62 and 48.22 %w.b., the average of particle diameter was mean 5.97 and 4.21 mm, which was similar size of particles. In addition, when the moisture content was at 10.63 8.47 and 8.37 %w.b., the average of particle diameter was mean 2.53 2.47 and 2.55, which was similar particle size. From this testing, it can be seen that when the moisture dropped, the particle size was smaller as well. On the contrast, when moisture content was high, it caused of holding between water particles and Napier grass particles. Therefore, after shaken, the particles were not dispersed and did not pass under the sieve. It affected to calculation the size of the particles by weight because diameter was larger than normal.

However, the size of particles is an important factor related on forming biomass pellets including index such as durability and bulk density [10].

In terms of the percentage through sieve of particle sizes, it can describe the particle size of Napier grass after chopping in volume by 10.63 to 8.37 %w.b. Thereby, the proper moisture content to produce biomass pellets founded that particle size at 2.00 mm to 0.85 mm that was calculated at 71.2 to 73.33 percent.

3.2.6 Heating value

The data as shown on Table 4, it indicated the changes of moisture content compared with heating value which tends to be inversely. When the moisture was high, it affected to be lower heating value. Due to the fact that calculation of heating value with high moisture, part of heating was brought away from the materials. From this point, the heating value became lower. However, materials with low moisture were at 10.63 to 8.37 %w.b., which is proper moisture content and the heat was on 3604.59 to 3606.33 cal/g.

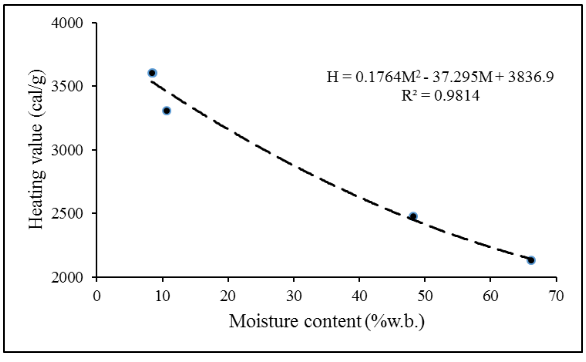

Figure 6 Heating value

4. Conclusions

This research studied and tested some physical properties of Napier grass (Pak Chong 1 seeds) before and after chopping to produce biomass pellets. From the study of physical properties before chopping, on shape and dimension of Napier grass and from the heating value calculation it was found that there was no statistical different at significance level of 0.05. As a result, all parts of Napier grass could be used the component to produce biomass pellets by chopping them together. While the study of physical properties after chopping, it indicated the relationship between the duration of drying and moisture content of Napier grass after chopping. Furthermore, if duration of drying was increased, moisture tended to decrease. This study indicated further that when the materials were dried for dehumidification up to the 9th day, the moisture was likely to approach the equilibrium moisture content. Accordingly, the relationship between the moisture content and coefficient of static friction was a directly proportional one. On the contrary, angle of repose, particle size, percent through sieve and heating value were inversely proportional to the moisture.

5. Acknowledgements

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