Comparison of Sweet Melon (*Cucumis melo* L. var. *makuwa* Makino) Varieties and Their Hybrids

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Abstract

The research aimed to compare sweet melon varieties and their diallel hybrids, and to estimate heteroses for some important characters. Five oriental sweet melon varieties including Jianghuai honey #1 (JH#1), Fragrance princess (FP), Blue fragrance (BF), Golden fragrance (GF) and Golden jade (GJ) were crossed in a diallel fashion excluding reciprocals. The five parental varieties and 10 inter-varietal hybrids were arranged in a randomized complete block design with three replications. The results revealed that there were significant and highly significant differences among genotypes (5 parental varieties and their 10 hybrids) in all characters under studied. JH#1 had the highest fruit yield (36.05t/ha) among the parents, whereas JH#1 x FP was the highest value (40.13 t/ha) among the hybrids. Specific heterosis estimates were found positively significant for fruit width in BF x GF hybrid, flesh thickness in JH#1 x FP and BF x GF hybrids, fruit weight in JH#1 x FP and BF x GF, and yield in JH#1 x BF hybrid. The hybrid JH#1 x BF had the highest and significant ($P < 0.01$) heterosis percentage (46.21 %), whereas the hybrid FP x BF also had the high heterosis value (29.57 %), but it was not significant. FP had high performance per se in economic characters. For hybrid, JH#1 x FP had lower specific heterosis and mid-parents heterosis than JH#1 x BF hybrid, but it should be more appropriate than JH#1 x BF for a breeding program since JH#1 x FP hybrid had high performance per se than JH#1 x BF. Thus, FP variety, and the cross JH#1 x FP were suitable and potential for the breeding program.

Keywords: sweet melon, variety, hybrid, heterosis.

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1. Introduction

Oriental melons have been grown and consumed in Asia and Far East for thousands of years (Goldman, 2002). There are two types of oriental melon. One type is sweet, the other is non-sweet fruit and often used for pickling (Schultheis *et al*., 2002). The first and sweet type is called oriental sweet melon and its scientific name is *Cucumis melo* L. var. *makuwa* Makino. It has been widely grown in Korea, China and East Asia (Chen and Kang, 2013). Most of the cultivars tested had soluble solids of 12 – 13 °Brix (Schultheis *et al*., 2002). The sweet melon fruits can be oblong or round, and rind color is yellow, green, or white when ripe, depending on type. Fruits of most varieties are relatively small averaging less than 1 kg. Most have white flesh that is crisp (Lim, 2012). The second type is *Cucumis melo* L. var. *conomon*, and its common name is oriental pickling melon. These melons are small fruits with smooth, tender skin, white flesh, early maturity, and usually with little sweetness or odor.

They are used for pickling, but are also eaten fresh or cooked (Robinson and Decker-Walters, 1999). They are widely grown in Thailand and well known as Thai melon or Taeng Thai. Sweet melon plants and fruits are almost similar to Thai melon, but their fruit flesh is sweeter than Thai melon. Thus, the objectives of this study are to compare yield and horticultural characters of sweet melon cultivars and their hybrids and to determine heterosis in yield of the hybrids, under the same growing condition as Thai melon (climbing on the ground). The results of the study will be useful for breeding programs of both sweet melon and Thai melon.

2. Methodology

2.1 Hand pollination

Five sweet melon cultivars, all open-pollinated cultivars, namely Jianghuai honey#1 (JH#1), Fragrance princess (FP), Blue fragrance (BF), Golden fragrance (GF) and Golden jade (GJ) were grown as parental cultivars for crossing in the diallel fashion to obtain 10 hybrids. Each cultivar was planted in a 2-row plot, 10 m long with 50 cm plant spacing, and 60 cm row spacing, 1 plant per hill, totally 40 plants per plot, under trellising system using bamboo stakes. Hand pollination was performed according to the procedure described by Lertrat (1989).

2.2 Comparison of parental cultivars and hybrids

The 10 hybrids along with their 5 parent cultivars were planted in a randomized complete block design (RCBD) with 3 replications. Plants were grown in a single-row system and their vines were freely climbed on plot beds (using plastic mulch), plot size 1 x 3 m^2, plant spacing 0.5 m, 6 plants per plot. The experiment was conducted under standard furrow irrigation, cultural practices, and pest control practices. Data of each plot were separately recorded on plant length (cm), lateral branch per plant, fruit width and length (cm), fruit shape index (fruit length/fruit width), fruit flesh thickness (cm), fruit weight (g), fruit flesh sweetness and yield (t/ha). Data were analyzed statistically by analysis of variance according to the RCBD and mean comparisons were done using Duncan’s new multiple range test (DMRT). Specfic heterosis estimates were determined according to Gardner and Eberhart Analysis II (Gardner and Eberhart, 1966). Mid-parent heterosis was tested for significance by the functional analysis of variance (a single df comparison). The study was performed at Faculty of Agriculture and Natural Resources, Rajamangala University of Technology Tawan- ok, Chonburi province from June to September, 2015 (the second season).

3. Results

The analysis of variance showed that there were significant and highly significant differences among genotypes (5 parental varieties and their 10 hybrids) in all characters under studied.

3.1 Plant characters

Plant length: FP had the longest plant (208.06 cm) among the parents, whereas FP x GJ had the longest plant (218.89 cm) among the hybrids. BF, GJ and their hybrid (BF x GJ) all had short vines (145.00, 135.89 and 140.61 cm, respectively) (Table 1).

Lateral branches per plant: GF and JH#1 had the highest number of lateral branches per plant among the parents, whereas BF x GF had the top number of lateral branches per plant among the hybrids (Table 1).

3.2 Fruit characters

Fruit width: FP and JH#1 had the widest fruit (14.96 and 14.34 cm, respectively) among the parents, whereas JH#1 x FP had the widest fruit (14.69 cm) among the hybrids (Table 1).

Fruit length: GJ had the longest fruit (21.65 cm) among the parents, whereas FP x GJ had the longest fruit (21.74 cm) among the hybrids (Table 1).

Fruit shape index: Fruit shape index is a ratio of fruit length divided by fruit width. GJ had the highest value of fruit shape index (2.14), indicating its cylindrical fruit shape. Where, BF and FP possesed the round fruit with the fruit shape index of 0.80 and 1.19, respectively (Table 1).

Fruit flesh thickness: FP had the most flesh thickness (3.71 cm) among the parents, whereas JH#1 x FP had the most value (3.73 cm) among the hybrids (Table 2).

Fruit weight: FP had the largest fruit (1.90 kg) among the parents, whereas JH#1 x FP had the largest fruit (2.15 kg) among the hybrids (Table 2).

Fruit sweetness: The parental varieties had the fruit sweetness ranging from 5.41 to 7.40 °Brix of JH#1 and FP, respectively. Where, BF x GF hybrid possessed the sweetest fruit (8.07) (Table 2).

3.3 Yield

JH#1 had the highest fruit yield (36.05t/ha) among the parents, whereas JH#1 x FP had the highest fruit yield (40.13 t/ha) among the hybrids (Table 2).

Table 1 Means of 5 characters of the 10 inter-varietal hybrids of the 5 sweet melon varieties.

Varieties/hybrids	Plant length (cm)	Lateral branches per plant	Fruit width (cm)	Fruit length (cm)	Fruit shape index
JH#1	145.72 c	5.22 a	14.34 ab	18.93 abc	1.32 gh
FP	208.06 ab	4.00 bc	14.96 a	17.77 bcde	1.19 h
BF	145.00 c	4.89 abc	10.60 de	8.45 g	0.80 i
GF	173.05 abc	5.39 a	9.15 e	16.39 cdef	1.79 c
GJ	135.89 c	3.83 c	10.06 de	21.65 a	2.14 a
JH#1 x FP	162.28 bc	4.63 abc	14.69 a	18.57 bcd	1.27 gh
JH#1 x BF	163.50 bc	5.00 ab	10.93 cde	14.90 ef	1.37 fg
JH#1 x GF	162.00 bc	4.39 abc	9.05 e	16.13 cdef	1.78 c
JH#1 x GJ	148.06 c	4.11 bc	12.36 bcd	20.18 ab	1.64 de
FP x BF	179.61 abc	4.11 bc	10.77 cde	14.15 f	1.32 gh
FP x GF	218.89 a	4.61 abc	12.21 bcd	18.52 bcd	1.52 ef
FP x GJ	190.34 abc	4.00 bc	12.99 abc	21.74 a	1.67 cd
BF x GF	182.50 abc	5.39 a	9.68 e	13.57 f	1.40 fg
BF x GJ	140.61 c	4.00 bc	10.28 de	15.53 def	1.51 ef
GF x GJ	165.67 abc	4.91 abc	9.06 e	18.03 bcd	1.98 b
F-test	*	*	**	**	**
C.V. (%)	16.76	12.55	11.17	9.71	5.31

ns and ** = not significant and significant at $P< 0.01$, respectively.

Means in a column followed by the same letter are not significantly different at $DMRT_{0.05}$

3.4 Specific heterosis

Specific heterosis estimates for 6 characters were shown in Table 3. They were found positively significant for fruit width in BF x GF hybrid, flesh thickness in JH#1 x FP and BF x GF hybrids, fruit weight in JH#1 x FP and BF x GF, and yield in JH#1 x BF hybrid.

3.5 Mid-parents heterosis for yield

Means of parents, mid-parents, F_1 and mid-parents heterosis (%) for yield were shown in the Table 4. The hybrid JH#1 x BF had the highest and significant (P < 0.01) heterosis percentage (46.21 %), whereas the hybrid FP x BF also had the high heterosis value (29.57 %), but it was not significant. The other hybrids were also not significant in heterosis for yield.

Table 2 Means of 4 characters of the 10 inter-varietal hybrids of the 5 sweet melon varieties.

Varieties/hybrids	Flesh thickness (cm)	Fruit weight (kg)	Flesh sweetness (Brix)	Yield (t/ha)
JH#1	3.36 ab	1.64 bc	5.41 d	36.05 ab
FP	3.71 a	1.90 ab	7.40 ab	33.72 abc
BF	1.79 g	0.50 g	7.09 abc	13.96 f
GF	2.19 efg	0.75 fg	7.39 ab	29.24 bcde
GJ	2.34 defg	1.35 cd	6.22 bcd	29.81 abcd
JH#1x FP	3.73 a	2.15 a	6.79 abc	40.13 a
JH#1x BF	2.42 def	1.13 de	6.86 abc	36.56 ab
JH#1x GF	2.24 efg	0.86 ef	5.96 cd	32.74 abcd
JH#1x GJ	2.85 bcd	1.40 cd	6.17 bcd	25.36 cde
FP x BF	2.44 def	0.89 ef	7.06 abc	30.89 abcd
FP x GF	2.76 cde	1.36 cd	6.83 abc	36.32 ab
FP x GJ	3.19 abc	1.73 b	6.30 bcd	32.67 abcd
BF x GF	1.98 fg	0.74 fg	8.07 a	19.51 ef
BF x GJ	2.24 efg	0.87 ef	7.21 abc	23.12 def
GF x GJ	2.10 fg	0.87 ef	6.39 bcd	32.73 abcd
F-test	**	**	**	**
C.V. (%)	11.54	15.00	9.98	17.91

ns and ** = not significant and significant at $P< 0.01$, respectively.

Means in a column followed by the same letter are not significantly different at $DMRT_{0.05}$

4. Conclusion and discussion

From the study, varieties and inter-varietal hybrids that should be considered for a breeding program should have high yield, thick fruit flesh, small fruit cavity, sweet fruit flesh and marketable fruit size. FP variety had high potential for breeding program because it had high performance per se for those characters. For hybrid, JH#1 x FP had lower specific heterosis and mid-parents heterosis than JH#1 x BF hybrid, but it should be more appropriate than JH#1 x BF for the breeding program since JH#1 x FP hybrid had high performance per se than JH#1 x BF hybrid. In considering the suitable hybrid, the hybrid that gave high performance resulted from the all effects of genes (Pornsuriya, 2014). The inter-varietal hybrids in this study gave lower heterosis values than hybrids from parental lines (Kamer *et al*., 2015). In conclusion, FP variety, and the cross JH#1 x FP were suitable and potential for population improvement in the breeding program.

Table 3 Estimates of specific heterosis for 6 characters of the 10 hybrids of the 5 sweet melon varieties.

Hybrids	Fruit width (cm)	Fruit length (cm)	Flesh thickness (cm)	Fruit weight (kg)	Flesh sweetness (°brix)	Yield (t/ha)
JH#1 x FP	0.797	-0.464	0.264*	0.258**	0.477	0.201
JH#1 x BF	0.041	0.809	-0.026	0.075	-0.195	6.608*
JH#1 x GF	-1.293*	-0.659	-0.207	-0.264**	-0.443	-0.950
JH#1 x GJ	0.456	0.314	-0.031	-0.069	0.161	-5.859*
FP x BF	-1.338*	-1.004	-0.301*	-0.361**	-0.395	-0.801
FP x GF	0.661	0.664	0.018	0.041	0.027	0.888
FP x GJ	-0.120	0.804	0.018	0.062	-0.109	-0.288
BF x GF	1.132*	0.654	0.252*	0.251**	0.528	-5.946*
BF x GJ	0.164	-0.459	0.075	0.035	0.612	0.139
GF x GJ	-0.500	-0.660	-0.063	-0.027	-0.113	6.008
SE for S_{ij}	0.531	0.816	0.120	0.083	0.282	2.483

*, ** significant at $P < 0.05$ and $P < 0.01$, respectively.

Table 4 Means for yield of sweet melon parental varieties (P_1, P_2) and their hybrids (F_1), and heterosis (%) as compared with mid-parents.

Hybirds	Yield (t/ha)				Heterosis (%)	Significance of heterosis
	P_1	P_2	Mid-parents	F_1		
JH#1x FP	36.05	33.72	34.89	40.13	15.04	ns
JH#1x BF	36.05	13.96	25.01	36.56	46.21	**
JH#1x GF	36.05	29.24	32.65	32.74	0.29	ns
JH#1x GJ	36.05	29.81	32.93	25.36	-22.99	ns
FP x BF	33.72	13.96	23.84	30.89	29.57	ns
FP x GF	33.72	29.24	31.48	36.32	15.37	ns

FP x GJ	33.72	29.81	31.77	32.67	2.85	ns
BF x GF	13.96	29.24	21.60	19.51	-9.68	ns
BF x GJ	13.96	29.81	21.89	23.12	5.64	ns
GF x GJ	29.24	29.81	29.53	32.73	10.86	ns

ns and ** = Non-significance and significance of heterosis at $P< 0.01$, respectively, according to a single df comparison.

5. Acknowledgments

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Morphology, Structure, and Mechanical Properties of Natural Cellulose Fiber from Green Coconut (*Cocos nucifera* L.)

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Abstract

The objectives of this research was to investigate the morphology, structure, and mechanical properties of the green coconut fibers extracted from green coconut (*Cocos nucifera* L.) in the form of raw fibers by mechanical method. The research results showed that the fibers extraction from green coconut husk with stream explosion by using the steam pressure at 17 Bar and 207 ºC for 5 minutes was the best method for fiber extraction. The chemical composition of green coconut fiber consisted of 86.97% of cell walls, 84.93% of lignocellulose, 36.80% of lignin, 2.04% of hemicellulose and 46.70% cellulose. The aspect and physical properties of the green coconut fibers exposed that the fibers were bundle fiber, dark brown color, smooth surface and stiff. The fiber size was 123 deniers, 5-15 cm in length while the tensile strength was 0.40 gf/den and 15.97 % of elongation at break. The advantages of green coconut fibers are low price, abundantly available, renewable for sustainable agriculture and creative textiles.

Keywords: Natural fiber, Stream explosion, Mechanical extraction, Agricultural waste, Coir fiber

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1. Introduction

The advantages of natural fiber have been offering over the recent years and many advantages composites compared with composites with synthetic fiber reinforcement are low price, low density, abundantly available, renewable, and have no health hazard [1], [2]. Several alternatives of fiber sources, especially agricultural by-products include wheat straw [3], rice straw [4], Indian grass [5], Napier grass [6], pineapple leaves [7], banana tree [8], and sugar cane rind [9], have been used to produce cellulose fibers.

Coconut is one of the perennial plants and a member of the palm family, also known scientifically as *Cocos nucifera* L. It is considered an important industrial crop in tropical areas since it produces sustainable agricultural products [10]. Green coconut is a multipurpose plant since many of its parts can be used in various ways. For example, young coconut water and meat are edible, solid meat are used to produce coconut milk, and coconut shell are used as tools like coconut shell dippers and lanterns. Green coconut is a byproduct of solid coconut meat. Approximately 34% were used in Ceramic industry and commercial food preparation. Specifically in coconut water exports, green coconuts are being cut open for the juice inside. A great number of shells are left to waste. It is clear that by making practical use of green coconut fibers, considered as natural fibers from agricultural waste, we would gain multiple uses of it; as material in cement mixture since green coconut fibers provide proper physical and mechanical properties and as heat reduction substance and increasing construction capacity. It is also environment-friendly. Therefore, the use of green coconut fibers is crucial and apt for textile industry in terms of developing agricultural waste fibers to their highest use.

Hence, green coconut fibers development for special textile products for elderly is pivotal and highly interesting. As a result, we began our research by extracting fibers from coconut shells with mechanical method in which it helps produce special properties and higher efficiency than general natural fibers.

2. Methodology

2.1 Materials

Materials used in this study are fresh green coconut shells (figure 1) from a source with massive amount of green coconut; K-fresh Company LTD,.

(a) (b)

Figure 1 (a) Green coconuts (b) Wasted coconut shells

2.2 Methods

This study was conducted and separated into 3 parts as followed;

2.2.1 Green Coconut Fiber Extraction

1). Mechanical method on using steam explosion to extract fibers is a non-chemical and rapid way to extract fibers with the assistance of EUROTECH CO.,LTD. (Factory 2) 88/28 M.21 Bang Phli Yai subdistrict Bang Phli district Samut Prakan province.

2). Study on proper conditions of green coconut fibers extraction using steam explosion. We designed the experimental plan by researching the conditions of the steam pressure machine usage in mid-level pressure for energy-saving:

(1) Two levels of steam pressure at 17 Bar and 18 Bar.

(2) Two levels of temperature at 207 °C and 209 °C.

(3) Two different time periods at 5 minutes and 10 minutes.

3) Study on green coconut fibers extraction process using the steam pressure machine as in figure 2.

Figure 2 The steam pressure machine electric boiler Model: LDRO.05-2.5

The extraction processes consisted of 7 procedures as followed; the selection of inner coconut shells, water press, steam explosion, wash in fresh water, stretch the fibers, dry them and screen and select the fibers. These processes are seemingly uncomplicated, fast and cost-saving. Moreover, they are completely chemical-free and environment-friendly so the processes are conventional and considered as the sustainable methods on industrial-level natural fibers extraction.

2.2.2. Chemical Compositions of Green Coconut Fiber

The study on green coconut fibers chemical compositions using Detergent analysis referring to Van Soest – 1991.

2.2.3. Morphology, Structure, Mechanical Properties of Green Coconut Fiber

The study on 3 aspects of green coconut fibers' and qualities referring to the following textile standardized testing.

1). A test on the length of fibers according to ASTM D5332-92 Standard Test Method for Fiber Length and Length Distribution of Cotton Fibers.

2). A test on fibers fineness according to ASTM D 1577-07 Standard Test Methods for Linear Density of Textile Fibers and determined using a Scanning Electronic Microscope.

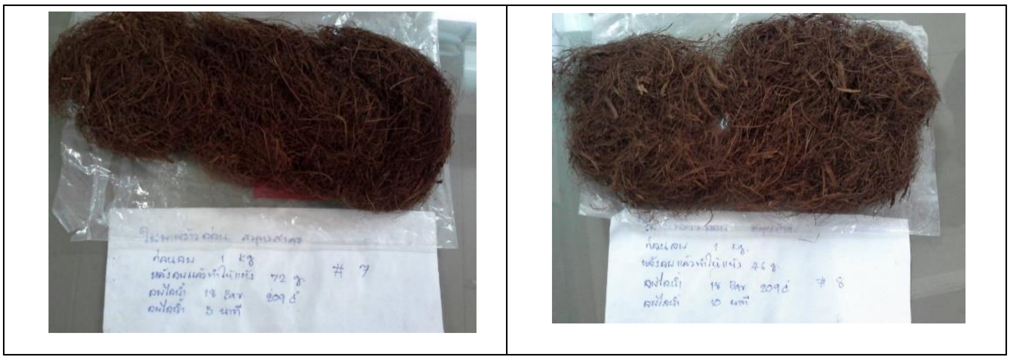
3). A test on tensile strength according to ASTM D 3822-01 standard Test Method for Tensile Properties of Single Textile Fibers.

3. Results

3.1 Morphology of Green Coconut Fibers

Green coconut fibers extraction using mechanical method of steam explosion, a chemical-free and fast extraction method, has produced extracted fibers by different extraction conditions as in figure 3.

(a) (b)

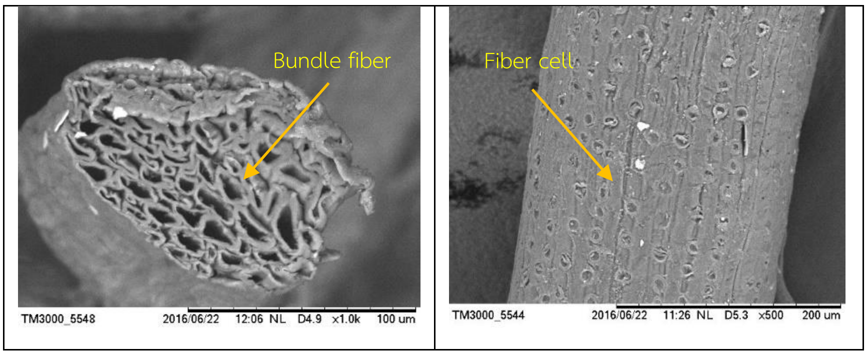


(c) (d)

Figure 3 Green coconut fibers extracted by steam explosion method (a) 17 Bar at 207 °C for 5 minutes (b) 17 Bar at 207 °C for 10 minutes (c) 18 Bar at 209 °C for 5 minutes (d) 18 Bar at 209 °C for 10 minutes

According to figure 3, fibers extracted from steam explosion are short at length, dark brown in color and has smooth texture but are very stiff. Hence the quality improvement should be done in order to produce better fineness or smaller fibers.

Upon extraction of green coconut fibers, the study found that fibers produced from green coconut shells are short in length and provide large and stiff fibers. Figure 4 show the morphology of bundle fiber from this study.



(a) (b)

Figure 4 Morphology of bundle fiber in green coconut (a) bundle fiber (x1.0k) (b) fiber cell (x500)

According to figure 4, green coconut surfaces has morphological characteristics: bundle fiber and has a cavity in the center of the fiber that form a thick outer layer to protect the cellulose inside and the long section of raw fiber showed the presence of fiber cell to be irregular and dirty.

3.2 Chemical composition of Green Coconut Fibers

The study on chemical composition in green coconut fibers results in Table 1.

Table 1 The chemical composition of green coconut fibers

Chemical composition	Percentage
Ash (Ash), %	0.98
Cell walls (NDF), %	86.97
Lignocellulose (ADF), %	84.93
Lignin (ADL), %	36.80
Cellulose (Cellulose), %	46.70
Hemicellulose (Hemicellulose), %	2.04

As in Table 1 The chemical composition of green coconut fibers found that the fibers contain almost 50% of cellulose, with 86.97% of cell walls which are composed of cellulose and 2.04% of hemicellulose as their outer skin. Also the fibers contain the high amount of lignin at 36.80%. Lignin is a pivotal composition of plant tissues, mostly found in cell walls since it helps strengthen plant's cell walls and is mostly combined with cellulose. This conforms to the research of Lee et al. [11] regarding chemical composition in plant's fibers. Generally, they consist of 40 – 60% cellulose, 20 – 30% hemicellulose and 15 – 30% lignin.

Table 2 Comparison between chemical composition of fibers from green coconut and other agricultural waste

Types of fibers	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Green coconut	47	2	37
Palmyra palm	53	30	17
Corn silk	45	35	15
Rice straw	30	50	15

As shown in Table 2 Comparison between chemical composition of fibers from green coconut and other agricultural waste, fibers produced from green coconuts contain nearly similar amount of cellulose compared to corn silk and Palmyra palm's fibers. It is highly possible that they are all products from the inner skin of agricultural fruits. When compared the Hemicellulose amount, we found that fibers from green coconut contain the fewest Hemicellulose but have the highest amount of lignin. This can be assumed that the amount of lignin in plants' tissues gives green coconut fibers the strongest capacity among other plant fibers.

3.3 Mechanical Properties of Green Coconut Fibers

The study on green coconut fibers' mechanical properties; length, fineness and tensile strength is shown below.

Table 3 Extracted green coconut fibers using steam explosion method's mechanical properties

Types of fibers	Size (denier)	Length (cm)	Tensile strength (gf/den)	Elongation at break (%)
17 Bar 207 °C 5 minutes	123	5-15	0.40	15.97
17 Bar 207 °C 10 minutes	126	5-15	0.58	22.11
18 Bar 209 °C 5 minutes	144	5-15	0.44	16.69
18 Bar 209 °C 10 minutes	153	5-15	0.21	19.80

According to Table 3 Extracted green coconut fibers using steam explosion method's mechanical properties, the research shows that green coconut fibers extracted at 17 Bar at 207 °C for 5 minutes produce the finest or smallest fibers. The fibers' average is 123 denier. The largest fibers produced here is from 18 Bar at 209 °C for 10 minutes and the average is 153 denier. Both have similar length at 5 – 15 centimeters. Fibers extracted at 17 Bar at 207 °C for 10 minutes have the highest tensile strength and elongation at break at 0.58 gf/den (22.11%). Fibers produced, from 18 Bar at 209 °C for 10 minutes, have the least tensile strength at 0.21 gf/den. It is certain that the most appreciated and proper method to extract green coconut fibers is by steam explosion using 17 Bar at 207 °C for 5 minutes. The advantages of steam explosion are less energy is consumed compared with mechanical method and no chemicals are used during the process.

4. Conclusion and discussion

The mechanical method of extracting green coconut fibers by steam explosion results the extracted fibers that are short, brown in color, have smooth texture but are stiff. Upon using scanning electron microscope, the outer surface of fibers is uneven and spongy. The most proper notion on green coconut fibers extraction is by using steam pressure at 17 Bar at 207 °C for 5 minutes which results the finest or smallest fibers and also the lowest energy consumption.

Green coconut fibers' chemical compositions contain nearly 50% of cellulose, 86.97% of cell walls, 2.04% of hemicellulose and 36.80% of lignin. The mechanical properties of the fibers are short, brown in color. The green coconut fiber can be used in textile applications and reinforced with agricultural fibers and care for the environment.

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