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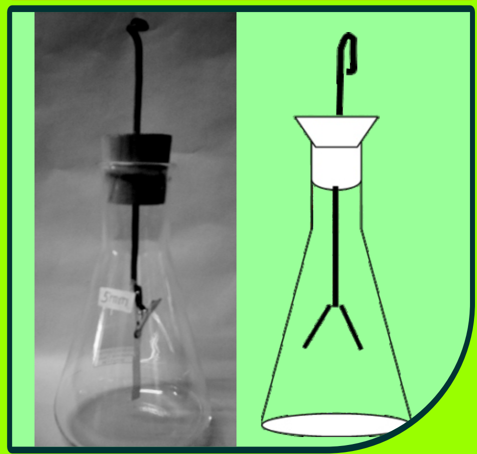

Patubas is an Ilonggo word for "product" or "fruit". It is a fitting description for this multidisciplinary research journal which is indeed, a product or fruit of labors of researchers or the "seekers" of truth in its varied dimensions.

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2. Manuscript submitted shall be related to areas specified above. It shall be written either in English or Filipino.
3. Publishes descriptive, relational, and experimental research studies.
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    a. Title Page
    b. Abstract (150 words or not more than one page)
    c. Introduction
        c.1. Background, Rationale and Related Studies
        c.2. Objectives
        c.3. Theoretical/Conceptual Framework and Hypotheses (if applicable)
        c.4. Significance of the Study
        c.5. Scope and Limitation of the Study
    d. Methodology
    e. Results and Discussion
    f. Conclusions and Recommendations
    g. Acknowledgment
    h. References
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PREFACE

CENTRAL PHILIPPINE UNIVERSITY
5000 ILOILO CITY, PHILIPPINES

OFFICE OF THE PRESIDENT

MESSAGE for PATUBAS

Research is an integral part of any academic institution. For one, it addresses a need of a university. Another, it gives extra credit to the faculty or staff and eventually the university once it reaches publication.

However, research does not stop once the institution or the proponents have reaped its fruits. What should be remembered here is the need to go beyond the results of the study. Let us look at an even larger scale --- the society --- and ensure that it, too, can be greatly benefited.

As CPU's contribution to the community, the university highly encourages her faculty and staff to go into research and to aim for publication whether in a local or international journal.

Patubas, CPU's multi-disciplinary journal, is helping researchers get the boost that they need to continue pursuing timely and relevant studies. In its recent release, Patubas is publishing five articles on various fields: Literature, Education, Communication, Theology and Science and Technology.

May this latest edition of Patubas open more opportunities to bridge knowledge gaps and to seek needs that should be met. May this also encourage and inspire many of us to pursue research. More importantly, may the researches that we want to pursue better CPU and the society.

Teodoro C. Robles

TEODORO C. ROBLES, Ph.D.
President

Tel. (63-33) 329-1971 local 2100; 320-3824 (DD) Fax (63-33) 320-3685

EFFICACY OF DIFFERENT GREEN MANURES AND COMMERCIAL ORGANIC FERTILIZERS ON THE GROWTH AND YIELD OF POTTED LETTUCE AND CABBAGE AND THEIR RESIDUES ON LETTUCE AND PECHAY

Ma. Victoria C. Seredrica

ABSTRACT

Two studies were conducted at CPU campus, Iloilo City from October 2009 to April 2010. The first one compared the effects of IMO-5, commercial compost, leaf green manures and inorganic fertilizer. Plants without fertilizer served as basis for comparison. The second study evaluated the growth and yield of pechay and lettuce in pots with residual fertilizer. Pechay was used instead of cabbage because of its shorter growth period than cabbage. The treatments consisted of acacia (*Albizia saman* (Jacq.) *Merr.*) (T1), ipil-ipil (*Leucaena leucocephala* (Lam.) de Wit) (T2), and madre de cacao (*Gliricidia sepium*) (Jacq.) *Walp*.) (T3) leaf manures, IMO-5 (T4), and commercial compost (T5). The inorganic fertilized (T6) and unfertilized (T7) plants served as positive and negative controls, respectively. These were laid out in randomized complete block design with three replications. Results from the first study showed significantly most leaves from fertilized lettuce except those added with madre de cacao. Likewise in cabbage, the fertilized plants were significantly taller and produced significantly more leaves than the unfertilized. Lettuce and cabbage with inorganic fertilizer, however, recorded the highest return on investment (ROI) of 89% and 125%, respectively.

Results from the second study revealed that lettuce grown in soil with residues of green manures and commercial organic fertilizers had more leaves, were taller, and out yielded the unfertilized plants and those previously applied with inorganic fertilizer. Results further showed that pechay with different manures had statistically similar leaf count and height but had significantly outperformed those with inorganic fertilizer (T6) and without fertilizer (T7). However, lettuce and pechay with residues of compost (T5) showed the highest ROI of 411% and 318%, respectively. Based on the results of the first study, it is concluded that it is profitable to use inorganic fertilizer (T_6) in lettuce and cabbage production. However, it was the residue from commercial compost (T_5) that sustained soil productivity and profitability of the second crop.

***Keywords**: green manures, organic fertilizers, residual fertility, urban gardening*

INTRODUCTION

People nowadays are more concerned with their health. Nutrition can be in the form of fruits and vegetables. However, with the increasing population, areas allotted to the growing of plants are getting smaller and smaller. This problem can be addressed by urban gardening. Urban gardening is one way of growing vegetables in vacant lots and roof tops and even in cemented areas as long as sufficient containers or even recycled containers are available. Since it is small scale production, it can be managed organically. According to the Department of Agriculture (DA) (Cotthem, 2015) a mixture of urban agricultural production technologies can enable cities to produce their own food, complementing the government's efforts in the countryside to maintain food security in the country.

Cabbage (*Brassica oleracea* L.) and lettuce (*Lactuca sativa* L.) are high value crops with great demand in the market. Crucifers contain phytochemicals which help fight colds and flu, help shrink tumors and malignancies, and with very strong anti-cancer properties (Undan, *et al.*, 2002). For lettuce, this is a good source of dietary fiber, Calcium, magnesium, phosphorus and selenium, and a very good source of Vitamin A, Vitamin C, Vitamin K, Thiamin, Riboflavin, Vitamin B6, Folate, Iron, Potassium and Manganese (Self Nutrition Data; USDA). These benefits can further be enhanced when crops are grown without the use of chemicals which can adversely affect human health. This was further supported by the government through Republic Act No.10068, otherwise known as Organic Agriculture Act of 2010 that promotes organic agriculture in the Philippines (FAO).

Organic farming takes local soil fertility as the key to successful production. Most fertile and productive soils have a high content of organic matter which is the seat of microorganisms responsible for many biological transformations in soils. Generally, the soil contains 2-5% organic matter and about 5 percent nitrogen (PCAARRD, 2012). Organic manures have low nutrient content and, therefore, need to be applied in larger quantities which can be easily managed when used in container gardens. In contrast, soils which are fertilized with inorganic fertilizers year after have low organic matter content, decreased soil pH and cation exchange capacity (CEC). Physical properties, especially soil water relations, are also greatly affected (Pernes-Debuyser & Tessier, 2004).

Leguminous tress such as ipil-ipil (*Leucaena leucocephala*), acacia *(Albizia saman)* and madre de cacao (*Gliricidia sepium*) are the commonly used green manure crops. Leaf biomass from these trees are good sources of organic matter. A study on alley farming at the International Institute of Tropical Agriculture (IITA) revealed that repeated addition of prunings of Leucaena and *Gliricidia plays* an important role in maintaining high soil organic matter and nutrient status. The study measured the long-term effects of the addition of *Leucaena* and *Gliricidia* prunings on soil properties and crop yield. As compared to a tree-less control plot, the alley farming plots recorded 80% higher soil organic matter after six years of cropping (Kang and Ghuman, 1989). The inputs of organic matter from plant residues and exudates provide carbon and energy sources for soil organisms. Net increases in soil organic matter improve soil aeration, temperature, moisture, and aggregate stability, and provide a resilient resource base for a wide variety of soil organisms through the maintenance of a rich and varied source of OM (Lehman, R. M. *et al*., 2015).

A study by Seredrica and Patricio (2011) showed that in lettuce, the use of ipil-ipil leaf manure resulted in the highest ROI of 103.71% while those of the unfertilized plants was -70.10%. In cabbage, all treatments with leaf manures gave a negative ROI (-14.45% to 100%). Meanwhile, the result of the study by Detaro (2008) and Antipatia (2009) on the use of IMO-5 (organic fertilizer containing indigenous microorganisms) at one kg/pot in lettuce had an ROI of 39.56% and 5%, respectively, while that of Catalan (2009) showed that the application of organic fertilizer at one kg/pot recorded an ROI of 10%.

Seredrica and Patricio (2011) recommended that to increase yield of potted cabbage, the amount of ipil-ipil and madre de cacao as leaf manures should be increased along with an increasing amount of soil in order to support the growth and yield. For this reason, this study was conducted to verify the above results.

Objectives of the Study

The general objective of study I was to compare the effect of IMO- 5, organic compost and leaf green manures on the growth and yield of potted leaf lettuce and cabbage.

Specifically, this aimed to determine the:

1) horticultural characteristics of lettuce and cabbage; and,

2) productivity and profitability of growing lettuce and cabbage using leaf green manures and composts.

As to study II, the general objective was to determine if lettuce and pechay can still grow on residual fertility of the different organic manures.

Specifically, this study was conducted to determine and compare the:

1) horticultural characteristics of lettuce and pechay; and,

2) productivity and profitability of lettuce and pechay.

Time and Place of the Studies

These studies were conducted from October 2009 to April 2010 at the vacant lot at the back of the LEB building, Central Philippine University, Jaro, Iloilo City.

METHODOLOGY

The experimental treatments consisted of acacia (*Albizia saman* (Jacq.) Merr.) (T1), ipil-ipil (*Leucaena leucocephala* (Lam.) de Wit) (T2) and madre de cacao (*Gliricidia sepium* (Jacq.) Walp.) (T3) leaf green manures, IMO-5 (T4), commercial compost (T5), inorganic fertilizer (T6) and the control (T7). These were laid out in a randomized complete block design (RCBD) with three replications.

Seven pots were used for every treatment. Big-sized plastic pots (30 cm dia) ($0.07m^2$/pot) for cabbage were added with 14 kg of 2:1 part garden soil and sand incorporated with two kg of the designated leaf manures allowed to decompose for a month. Medium- sized pots (25.4 cm dia) ($0.05m^2$/pot) for lettuce were placed with 7 kg of 2:1 soil medium plus a kg of each of leaf manures which were mixed separately. For treatments with IMO-5 and organic compost, the potted media were mixed with two kg and one kg of each material a day prior to transplanting for big-sized and medium-sized pots, respectively. The amount of inorganic fertilizers was based on the recommendation of 240-60-60 N,P_2O_5 and K_2O using T-14 and Urea for cabbage and 200-60-60 N,P_2O_5 and K_2O for lettuce.

Seeds were sown in a mixture of 1:1:1 garden soil, sand and humus. Cabbage was transplanted at one seedling/pot while lettuce was transplanted at four seedlings/pot. Plants were watered daily and protected from spittle bugs, cabbage worms and aphids using neem extract while alternaria blight was controlled using moringa and coleus extracts.

One month old seedlings of cabbage and lettuce and leaf samples after harvest were processed for plant tissue analysis. Soil analysis was also done before planting and after harvest. One kg soil sample from each treatment was set aside for analysis of residual fertility.

For the study on fertilizer residues, pechay and lettuce were used after cabbage and lettuce, respectively. Pechay was used after cabbage and not cabbage after cabbage because it takes three months to harvest cabbage while pechay can be harvested in one month only. There were four seedlings transplanted per pot.

The data collected were plant height, number of functional leaves, days to head formation, head diameter, and yield. The ROI was calculated by dividing the net income by production cost. All data collected except for plant tissue, soil analysis and ROI were statistically analyzed using ANOVA for RCBD. Significant treatment mean differences were determined using the DMRT at the 5% level of significance.

RESULTS AND DISCUSSION

Study I

Lettuce

Plant height, leaf count and weight/m^2. Results from the first study (Table 1) showed that lettuce height was not significantly influenced by the kind of fertilizers used. However, leaf production was affected with significantly more leaves in all fertilized pots than other treatments except from pots added with madre de cacao whose leaf count was comparable to the unfertilized plants. Furthermore, the highest yield was obtained from plants fertilized with acacia at 1.25 kg/ m^2. This was significantly higher than the yields of other fertilized plants which ranged from 0.85 to 1.00 kg. The soil analysis in Table 2 showed a high percentage of organic matter (OM) in soil incorporated with acacia and consequently high nutrient N (5.58%) in tissue analysis of lettuce.

Cost and return analysis. The highest ROI of 83% (Table 3) was obtained from lettuce fertilized with inorganic fertilizer which are 9%, 45%, 46%, 48%, 51% and 64% higher than those plants in pots incorporated with acacia, commercial compost, IMO-5, ipil-ipil, and the control treatments, respectively. The lowest ROI (19%) was obtained from plants applied with madre de cacao which could be explained by the lowest leaf count. These results showed that acacia leaf green manure can be a good substitute for inorganic fertilizer.

Table 1. Final Height, Leaf Count and Yield of Lettuce.

Treatment	Height	Leaf Count	Yield/m^2
	-cm-		-kg-
Acacia	22.49 [ns]	6.26 [a]	1.25 [a]
Ipil-ipil	21.57	5.90 [ab]	0.97 [b]
Madre de cacao	22.09	5.43 [bc]	0.85 [b]
IMO-5	22.43	6.06 [ab]	1.00 [b]
Commercial compost	21.13	5.96 [ab]	0.88 [b]
Inorganic fertilizer	21.45	6.13 [ab]	0.90 [b]
Control (unfertilized)	19.91	5.06 [c]	0.58 [c]

[ns] not significant at the 5% level of probability

[abc] Treatment means followed by the same letter superscript are not significantly different at the 5% level of significance.

Table 2. Soil Analysis of Growing Medium before First Planting and Tissue Analysis of Organic Fertilizer Sources, Lettuce and Cabbage as First Crop

Treatment	% OM	% N		
	Growing Media	Green Manures/ Organic Fertilizers	Lettuce	Cabbage
Acacia	4.62	4.43	5.58	3.07
Ipil-ipil	3.12	4.78	4.83	3.09
Madre de cacao	4.38	3.62	4.56	2.80
IMO-5	3.18	0.26	4.18	2.68
Commercial compost	3.21	0.90	4.10	2.58
Inorganic fertilizer*			4.63	3.04
Control (unfertilized)	0.47		3.48	1.56

* T6 – no soil analysis was done because inorganic fertilizers have to be applied during planting and during the growth period of the crop

Note: Lettuce seedlings, 2.53% N; Cabbage seedlings, 1.66% N dry basis

Table 3. Cost and Return Analysis for Lettuce

Treatment	Yield kg/m^2	Gross Income	Production Cost	Net Income	% ROI
Acacia	1.25	P275.00	P 157.53	P 117.47	74
Ipil-ipil	0.97	213.30	157.53	55.47	35
Madre de cacao	0.85	187.00	157.53	29.47	19
IMO-5	1.00	220.00	160.27	59.73	37
Commercial compost	0.88	193.60	139.72	53.88	38
Inorganic*	0.90	198.00	108.21	89.79	83
Control	0.58	127.60	96.63	30.97	32

Price = P220/kg

Cabbage

Leaf count and final height. Leaf count (Table 4) for cabbage did not significantly differ among treatments while plant height was highly significantly affected by the fertilizer used. The tallest plant were those applied with inorganic fertilizer but were as tall as those added with ipil-ipil and IMO-5 while the shortest were the plants without fertilizer.

Table 4. Leaf Count and Final Height (cm) of Cabbage

Treatment	Leaf Count	Height
		-cm-
Acacia	15.66[a]	25.79[d]
Ipil-ipil	17.33[a]	30.33[ab]
Madre de cacao	16.46[a]	27.45[cd]
IMO-5	15.66[a]	29.30[abc]
Commercial compost	16.86[a]	28.34[bcd]
Inorganic fertilizer*	17.26[a]	31.46[a]
Control (unfertilized)	12.80[b]	21.47[e]

[ns] not significant at the 5% level of probability

[abcde] Treatment means followed by the same letter superscripts are not significantly different over each other at the 5% level of significance.

Days to heading, head diameter and yield of cabbage. Plants with IMO-5, commercial compost and inorganic fertilizer had significantly earlier head formation (Table 5) than the other treatments. On the other hand, the significantly widest head and heaviest heads were obtained from plants fertilized with acacia and ipil-ipil. In Table 2, the higher N content from acacia and ipil-ipil leaf tissues had supplied the N needed for three months growing period of cabbage that yielded 2.75 kg and 2.68 kg/m^2, respectively. The results of the study of Hara and Sonoda (1981) revealed that the contribution of 10 ppm S was important in increasing cabbage-head formation. As presented in Table 6, soil analysis showed that acacia and ipi-ipil contain 22.58 to 41.76

ppm S in SO_4^{2-} form that were absent in the inorganic fertilizer used. Cabbage from the control treatments were stunted and formed no heads (unproductive) due to lack of nutrients to support its growth.

The return on investment was quite good with cabbage added with inorganic fertilizer that recorded a lower cost of production and a higher yield that gave the highest ROI of 125% (Table 6). Although, plants fertilized with acacia and ipil-ipil leaf green manures had the highest yield, these had the highest cost of production resulting in ROI of 66 to 70%. A negative ROI was obtained from the unfertilized cabbage because there was no head produced.

Table 5. Days to Heading, Head Diameter and Yield of Cabbage/m^2

Treatment	Heading	Head Diameter	Yield
	-days-	-cm-	-kg/m^2-
Acacia	40.30^{b}	11.96^{a}	2.75^{a}
Ipil-ipil	37.40^{cd}	11.74^{a}	2.68^{a}
Madre de cacao	38.46^{bc}	9.79^{c}	1.80^{c}
IMO-5	34.66^{e}	10.65^{b}	1.82^{c}
Commercial compost	35.53^{de}	8.92^{d}	1.40^{d}
Inorganic fertilizer*	35.80^{de}	11.04^{b}	2.18^{b}
Control (unfertilized)	58.20 ^{a}	0.00^{e}	0.00^{e}

^{abcde} Treatment means followed by the same letter superscript are not significantly different over each other at the 5% level of significance.

Table 6. Soil Analysis before First Crop and Pure IMO-5 and Commercial Compost Analysis.

Treatment	pH	P	SO_4^{2-}	Fe	OM
			ppm		%
Acacia	7.27	42.06	22.58	1.93	4.62
Ipil-ipil	7.23	14.61	41.76	1.88	3.12
Madre de cacao	7.01	40.65	35.08	1.68	4.38
IMO-5	6.97	60.98	122.76	1.63	3.18
Commercial compost	6.98	51.45	140.86	1.65	3.21
Control (unfertilized)	7.45	22.35	81.07	61.14	0.47
Pure Commercial Com	7.64	34.74	192.54	423.28	2.10
Pure IMO 5	7.71	26.75	151.56	192.45	1.72

Table 7. Cost and Return Analysis for Cabbage

Treatment	Yield kg/m^2	Gross Income	Production Cost	Net Income	% ROI
Acacia	2.75	P330.28	P194.28	P136.00	70
Ipil-ipil	2.68	321.60	194.28	127.00	66
Madre de cacao	1.80	217.14	194.28	22.86	12
IMO-5	1.82	219.04	184.76	45.64	23
Commercial compost	1.40	169.14	152.38	16.76	11
Inorganic	2.18	261.71	116.19	145.52	125
Control	0.00	0.00	96.19	-96.19	-100

Cabbage = P120/kg

Study II

Lettuce after Lettuce

Height, leaf count and yield of lettuce after lettuce. Results from the second study showed that at 4 WAT, lettuce with madre de cacao leaf manure had significantly the most leaves (Table 7) but were comparatively similar to plants applied with IMO-5, commercial compost, acacia and ipil-ipil. The least leaves were recorded from unfertilized plants and those previously applied with inorganic fertilizer.

The final heights at 4 WAT showed lettuce with IMO-5 residue as tallest but the mean height was comparable to those with commercial compost and ipil-ipil residue. Plants grown in pots previously added with inorganic fertilizer were the shortest.

Significantly highest yields of lettuce/m^2 were obtained from soils with residues of organic fertilizers. This means that the use of organic fertilizers had improved soil health and sustained biological productivity. This is further supported by the results of the soil analysis after planting lettuce and tissue analysis of lettuce as second crop (Table 8).

Table 7. Final Height, Average Leaf Count and Yield of Lettuce after Lettuce Four Weeks after Transplanting

Treatment	Height	Leaf Count	Yield
	-cm-		$-kg/m^2-$
Acacia	17.90^{cd}	7.80^{ab}	2.18^{a}
Ipil-ipil	19.29^{abc}	7.73^{ab}	2.26^{a}
Madre de cacao	18.56^{bcd}	8.03^{a}	2.16^{a}
IMO-5	20.83^{a}	7.96^{ab}	2.61^{a}
Commercial compost	19.86^{ab}	7.96^{ab}	2.53^{a}
Inorganic fertilizer	12.89^{e}	6.76^{b}	0.90^{c}
Control (unfertilized)	17.10^{d}	7.40^{b}	1.49^{b}

[ns] not significant at the 5% level of probability

[abc]Treatment means followed by the same letter superscript are not significantly different over each other at the 5% level of significance.

Table 8. Soil Analysis of Growing Medium before and after First Crop and Plant Tissue Analysis of Lettuce and Pechay as Second Crop

Treatment	% OM on Growing Medium			% N	
	Before Planting	After First Crop		Second Crop	
		Lettuce	Cabbage	Lettuce	Pechay
Acacia	4.62	2.84	3.78	3.45	4.99
Ipil-ipil	3.12	3.82	2.68	3.19	5.09
Madre de cacao	4.38	3.95	2.52	3.21	4.45
IMO-5	3.18	1.49	3.63	3.03	4.03
Commercial compost	3.21	3.06	2.87	2.52	4.42
Control (unfertilized)		1.68	2.02	3.26	4.21
Pure Commercial Com	0.47	1.59	0.09	2.68	3.87

Lettuce with IMO-5 realized the highest gross income (Table 9) followed by those grown with commercial compost. However, the highest net income was obtained from plants with commercial compost residue that resulted in the highest ROI of 411%. Plants with inorganic fertilizers had the lowest gross and net incomes. This could be due to the destructive effect of inorganic fertilizer on the soil structure. Potted lettuce fertilized with organic fertilizers and those without fertilizer had ROI that ranged from 244 to 411%.

Table 9. Cost and Return Analysis for Lettuce after Lettuce

Treatment	Yield Kg/m^2	Gross Income	Productio n Cost	Net Income	% ROI
Acacia	2.18	P479.60	P140.00	P339.60	242
Ipil-ipil	2.26	497.29	140.00	357.20	255
Madre de cacao	2.16	475.20	140.00	335.20	239
IMO-5	2.61	574.93	141.33	432.87	306
Commercial compost	2.53	556.60	112.00	444.60	397
Inorganic	0.90	198.00	88.00	110.00	125
Control	1.49	327.80	78.66	249.14	317

Price = P220/kg

Pechay after Cabbage

The tallest pechay ($p < 0.05$) were grown from pots with residues of organic fertilizers (Table 10) while the shortest were from pots previously fertilized with inorganic fertilizer and the unfertilized plants.

Furthermore, pechay grown in soil with residues from ipil-ipil leaf green manure, IMO-5 and commercial compost had significantly the most leaves but were comparable with those grown from residues of acacia and madre de cacao.

Table 10. Final Height, Leaf Count and Yield of Pechay after Cabbage/m^2 Three Weeks after Transplanting

Treatment	Height	Leaf Count	Yield
	-cm-		-kg-
Acacia	18.45[a]	7.43[ab]	2.39[a]
Ipil-ipil	18.30[a]	8.13[a]	2.31[ab]
Madre de cacao	18.80[a]	7.43[ab]	2.02[bc]
IMO-5	18.51[a]	7.93[a]	1.95[a]
Commercial compost	18.55[a]	7.66[a]	2.32[ab]
Inorganic fertilizer	15.17[b]	6.73[b]	0.95[d]
Control (unfertilized)	15.62 [b]	6.63[b]	1.16[d]

[ns] not significant at the 5% level of probability

[abc]Treatment means followed by the same letter superscripts are not significantly different over each other at the 5% level of significance.

Although the cabbage plants in Study 1 were grown for almost three months, data in Table 8 show that the residues of organic matter were sufficient to significantly increase the yield of pechay. These organic sources had provided carbon and energy sources for soil organisms in carrying out their biological activities in the soil and improved soil properties conducive to crop production (Lehman, *et* *al*., 2015). The highest ROI of 318% (Table 11) was recorded from pechay grown with commercial compost and is much better than the ROI of cabbage (11%) in the first crop. This was followed by those from the control treatments (128% ROI) and acacia at 102% ROI.

Based on the results of the first study, it can be concluded that it is profitable to use inorganic fertilizer (T_6) in lettuce and cabbage production. However, it was the residue from commercial compost (T_5) that favourably sustained soil productivity and profitability of the following crop.

Table 11. Cost and Return Analysis for Pechay after Cabbage

Treatment	Computed Yield (kg/ m^2)	Gross Income	Productio n Cost	Net Income	% ROI
Acacia	2.39	P286.80	P141.90	P144.9 0	102
Ipil-ipil	2.31	277.20	141.90	135.30	95
Madre de cacao	2.02	242.40	141.90	100.50	71
IMO-5	1.95	234.00	127.61	106.39	83
Commercial compost	2.32	278.40	66.66	211.74	318
Inorganic	0.95	114.00	62.85	51.15	81
Control	1.16	139.20	60.95	78.25	128

Price /kg = P120

CONCLUSIONS AND RECOMMENDATIONS

Based on the foregoing results, it can be concluded that lettuce and cabbage respond favorably to the use of IMO 5, commercial compost, and leaf green manures from acacia, ipil-ipil, and madre de cacao as substantiated by their highly positive agronomic performances and yields. Although lettuce with acacia can result in significantly highest yield, the use of inorganic fertilizer, can give the highest ROI. Improved height, more leaves, bigger heads, and higher yields are attainable in cabbage with the application of organic fertilizers. However, the use of inorganic fertilizer can offset the advantages of organic fertilizer with its higher ROI. Furthermore, continues application of inorganic fertilizers year after year resulted in negative effects on soil properties like decreased soil pH and cation exchange capacity (CEC), low organic matter and also affecting soil water relations (Pernes-Debuyser & Tessier, 2004).

Results from the second study, however, contradicted the superior advantage of inorganic vis-à-vis organic fertilizers. Lettuce and pechay with residues of green leaf manures and commercial compost produced more leaves, taller plants, higher yield, and greater ROI than the unfertilized and those previously applied with inorganic fertilizer.

It is recommended that organic fertilizers which include commercial compost, IMO-5 and green leaf manures from ipil-ipil, acacia, and madre de cacao should be used as organic fertilizers when growing lettuce, cabbage, and pechay. For optimum yields and ROI, however, commercial compost and IMO-5, respectively, are recommended.

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EXTENT OF DETERIORATION AND FORMATION OF TOXIC SUBSTANCES IN COOKING OIL (COCONUT OIL) WHEN HEATED REPEATEDLY ABOVE SMOKE POINT

Ma. Mercy A. Japitana

ABSTRACT

Commercial cooking oil sample (Refined, Bleached and Deodorized-Coconut Oil or RBD-CNO) was subjected to heat treatments. Twelve samples of four treatments and three replicates for each treatment: namely, the untreated (UN), heated once (T1), heated twice (T2) with intermittent cooling and, heated thrice (T3) with intermittent cooling were analyzed for fatty acid profile, free fatty acid value, peroxide value and the presence of PAH. Data were statistically analyzed using one way analysis of variance (ANOVA). Significant treatment mean differences were established using DMRT. The fatty acid profile showed that only linoleic acid decreased in quantity constantly up to the third heating. Free fatty acid and peroxide values showed an increasing trend. All of the 22 PAH included in the analysis were present in all treatments in small quantities. The only PAH which showed an increasing trend in the 4 treatments was 1,6,7-trimethylnaphthalene, the quantities of the rest remained the same. The decrease in the amount of linoleic acid in the free fatty acid profile indicated that unsaturated fatty acids decompose on heating and this could be the source of peroxides, but saturated fatty acid components were stable at high temperature.

***Keywords**: fatty acid profile, free fatty acid, peroxide, poly aromatic hydrocarbons.*

INTRODUCTION

In the preparation of food cooking by frying with oil is inevitable. Most Filipino households practice the reuse of cooking oil up to the nth time until the color of the oil becomes dark brown, viscosity increased and rancid odor developed.

In the process of frying, smoke point is the temperature at which a cooking fat or oil smokes or burns, and begins to break down releasing free radicals. This is also the point when natural nutrients in oils and phytochemicals are destroyed (Good, 2012).RBD-CNO, cooking oil (Dayrit, *et al*., 2007) commonly used in the Philippines has a smoke point of 232^0C while the unrefined, the likes of VCO (Virgin Coconut oil) smokes at 170^0C (Coconut Oils Facts 2017). Every time oil is heated, smoke point is decreased and reusing it for several times lowers the smoke point to about the frying temperature (Wikipedia, 2009). As the oil is reused deterioration and chemical reactions takes place at lower temperatures.

In reusing cooking oil (RBD-CNO), the researcher would like to find out to what extent does it deteriorate? Are toxic products, peroxides and poly-aromatic hydrocarbons formed? Does the amount of peroxide increase as heating above smoke point is repeated? The study would determine the stability of RBD–CNO cooking oil and its safety of reuse in cooking of food.

Objectives of the study

This study aimed to determine the deterioration and the formation of toxic substances in cooking oil that was subjected to different heat treatments. Specifically this study aimed to determine the following:

1. changes in the fatty acid profile and free fatty acid value; and,

2. the peroxide value and presence of polyaromatic hydrocarbons (PAH), before heating and every time it was reheated above smoke point up to the third time.

Significance of the Study

This study will be beneficial to:

1. households as food is prepared for the family two to three times a day;
2. restaurants, food chains, caterers, canteens where the general public eat; and,
3. side walk food vendors who engage in deep fried food.

Awareness of the toxic substances formed when cooking oil is reused is important to these sectors as they are responsible for food preparation. This experiment would establish the health risk in reusing cooking oil and its possible connection to recurring diseases.

Scope and Limitation of the study

The analysis included in this study were fatty acid profile, free fatty acid value, peroxide value and determination of PAH determination value in cooking oil-RBD-CNO, before it was heated and every time it was reheated. The heating was above smoke point (232^0C) for 30 minutes. There were four treatments: heated once, heated twice and heated thrice and the untreated. There were three replicates for each of the treatments.

This study did not include frying of food, as components of food would add reactants to the cooking oil. For different food products, a variety of reactants maybe added to the cooking oil.

METHODOLOGY

Materials and Preparation of Samples

The sample was bought from a grocery store. Twelve 250 mL portions were measured as were measured as samples for four treatments with three replicates each. The four treatments were the UN (untreated), T1 (heated once), T2 (heated twice with intermittent cooling to room temperature), T3 (heated three times with intermittent cooling to room temperature). The temperature used for the treatment was 250^oC and maintained for 30 minutes, then the oils were stored in amber bottles and refrigerated prior to analysis.

Fatty Acid Profiling

A portion of the four samples of three replicates were brought to SEAFDEC, Tigbauan, Iloilo for fatty acid profiling. Methylation of samples to fatty acid methyl esters (FAME) was done by saponification of sample with 0.5N KOH/methanol and subsequent trans-esterification with borontrifluoride (Metcalfe, *et al*., 1966). The fatty acid profile was analyzed using Shimadzu Gas Chromatograph Model GC-17A, with Supelco Omega wax 320 capillary column, having a dimension of 30m x 0.32mm x 0.25μm. The standard used in the GC analysis was cod liver oil. The fatty acid composition was expressed as percent normalized value.

Free Fatty Acid

A portion of oils in the four treatments with three replicates was analyzed by the researcher for free fatty acid value at the laboratory of the Chemistry Department of Central Philippine University, Jaro, Iloilo City by titrimetry, based on AOAC (1990) 940.28 modified method. The free fatty acid was analyzed by titration of a measured amount of sample with a standard sodium hydroxide solution using phenolphthalein as the indicator. The results were computed and expressed as % butyric acid.

Peroxide Values

Another portion of oils in the four treatments and three replicates was analyzed for peroxide value at the laboratory of the Chemistry Department of Central Philippine University, Jaro, Iloilo City using titrimetry, AOAC (1990) Official Method 965.33. Peroxide value was measured by the reduction of excess iodide with peroxide in the sample and subsequent oxidation of the molecular iodine by titration with standardized sodium thiosulfate to iodide. Iodine reacts with thiosulfate; thiosulfate losses one electron. One equivalent of iodine is equal to one equivalent of thiosulfate. The amount of peroxide was expressed as milli equivalent peroxide per kilogram oil.

Determination of the Presence of Polyaromatic Hydrocarbons (PAH)

Representative samples of each treatment with the three replicates were brought to the Oil Spill Response Program, University of the Philippines Visayas, Freshwater Aquaculture Station, Miag-ao, Iloilo for the analysis of poly aromatic hydrocarbons (PAH) by gas chromatography-mass spectrometry (GC-MS). The amount of poly aromatic hydrocarbons in mcg/mL was determined using the method EPA-8270-C which is the determination of semi-volatile organic compounds by GC-MS. The extraction of PAH was done using the method EPA-3540, solid phase extraction of PAHs using SPE tube DSC-Si (EPA Method 3535A). The instrument used was GC: Clarus 600 Gas Chromatograph; MS: Clarus 600T Mass Spectrometer. Analysis parameters used: Oven temperature program, initial temperature, 80^0C for 0 min. Ramp 1, 8.0^0C /min to 240^0C, hold for 20 min. Ramp 2, 8.00^0C/min to 250^0C, hold for 20 min. Injection Volume: 1.0μL; splitless; Carrier gas: He gas; transfer length: 60m; MS scan: Time 8.100 min to 61.2500 min, Mass 50.00 to 450.00El+; Solvent delay: start 0.00(min), End 8.00(min).

Statistical Analysis

Results on fatty acid profile, free fatty acid and peroxide values and amount of PAH were statistically analyzed by one way analysis of variance (ANOVA) at the 5 % level of significance.

Significant differences between or among pairs of means were determined using the Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

The sample used was a commercially-sold cooking oil and the physical appearance was clear and pale yellow in color. As the oil was heated, the color darkened and viscosity increased (Fig. 1). Thickening was the result of evaporation of the more volatile components of the oil (Choe, *et al*., 2007).

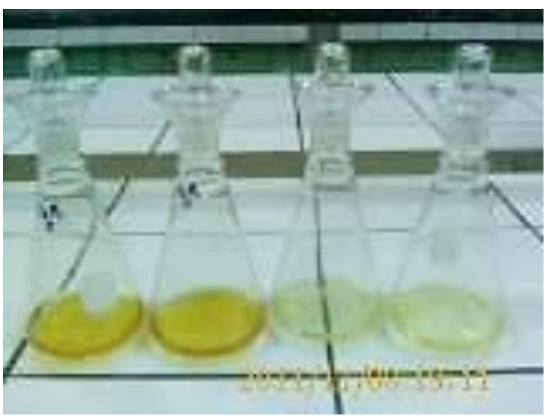

Figure 1. Color of the oil before and after heat treatments

Fatty Acid Profile

As shown in Table 1, six fatty acids were identified in the samples, and there were some which were not identified as the determination was limited to the standard being used which is cod liver oil. Four of these fatty acids namely, Lauric, Myristic, Palmitic and Stearic, were saturated, while two, Oleic acid and Linoleic, were unsaturated. Among these fatty acids present Lauric acid is the highest in percent composition, consistent with the study of Dayrit, *et al*., (2007), that coconut oil is made up of mostly medium chain fatty acids and small quantities of oleic and linoleic acid. Only linoleic acid significantly decreased in quantity on repeated heating while the rest did not show any substantial change in amount. This is because linoleic acid is unsaturated and is readily oxidized in the double bonds. Saturated fatty acids are stable to thermal decomposition as compared with unsaturated fatty acids. DMRT results showed that the amount of linoleic acid in the unheated sample was significantly higher compared to those in Treatment 1, Treatment 2, and Treatment 3 but there was no significant difference in the amount among the heated samples. The finding also shows that coconut oil is not easily deteriorated by heating.

Table 1. The fatty acid profile (expressed as % normalized value)

Fatty Acid	Abbrev. Symbol	% Fatty Acid Mean ± SD			
		UN	Treatment 1	Treatme	Treatment
Lauric	C12	31.01 ± 4.91	34.43 ± 1.64	36.83 ± 1.14	33.75 ± 5.04
Myristic	C14	21.74 ± 1.24	21.44 ± 0.30	22.82 ± 1.92	21.68 ± 0.82
Palmitic	C16	16.61 ± 2.40	15.14 ± 0.85	15.52 ± 1.59	16.00 ± 1.83
Stearic	C18	8.17 ± 1.63	7.16 ± 0.26	6.99 ± 0.42	8.11 ± 2.28
Oleic	C18:1n9	13.37 ± 1.54	11.94 ± 0.43	11.65 ± 0.93	11.75 ± 2.44
Linoleic	C182n6	4.39 ± 0.30[a]	3.23 ± 0.32[b]	1.81 ± 1.57[bc]	2.14 ± 0.57[bc]
Unidentified		4.72 ± 1.62	6.65 ± 0.94	4.38 ± 3.80	6.58 ± 1.61
Total		100.00%	100.00%	100.00%	100.00%

*Linoleic acid is significant while the rest is not significant at α=5% by one way ANOVA

[abcd] Treatment means having the same letter superscript are not significantly different at 5% level of probability by DMRT.

Percent Free Fatty Acids

Free fatty acids are products of the breakdown of fat molecules by hydrolysis. Its presence in large quantities in the sample signifies deterioration. Hydrolysis of oil would breakdown triglycerides to free fatty acids and glycerol. The presence of free fatty acids at high levels is undesirable as it gives an unpleasant odor to the oil. Hydrolysis is brought about by reaction of water vapor in the air to the oil during the process of repeated heating and intermittent cooling. According to the study of Dayrit, *et al.,* (2007), the range for FFA in RBD in several commercially available cooking oil which included the sample that was used in the study, were within

0.008% to 0.076% and the average of 0.021%. The Philippine Coconut Authority (PCA) recommended value is 0.2% (Dayrit, *et al.,* 2007).

As shown in Table 2, the amount of free fatty acids in the samples increased from the untreated to the third reheating. There was significant difference for all the treatments. Results showed that the free fatty acid content of the untreated oil is 0.03% and increased steadily up to more than 0.1% on the third heating. Repeated heating of the oil brought about hydrolysis but maximum amount of free fatty acid did not exceed the limits set by the (PCA). When the pairs of mean of different treatments were compared by DMRT, results showed that all data were significantly different from each other. Again the result of this analysis shows that RBD-CNO is stable at high temperature due to its unsaturated nature.

Table 2. Percent Free Fatty Acids expressed as % Butyric Acid

Sample	% Free Fatty Acid (% Butyric Acid) MEAN ± SD
Untreated	0.0314 ± 0.0002[a]
Treatment 1	0.0482 ± 0.0002[b]
Treatment 2	0.0665 ± 0.0003[c]
Treatment 3	0.1129 ± 0.0003[d]

*Significant at α=5% by one way ANOVA

[abcd] Treatment means having the same letter superscript are not significantly different at 5% level of probability by DMRT.

Peroxide Value

Peroxides (hydroxyl peroxides) are produced from the oxidation of double bonds in unsaturated fatty acids in an oil molecule. Hydroxyl peroxides are groups of compounds that are highly reactive, which could react with lipids in the cell resulting to cell damage (Trevisan, *et al*., 2001). Lipid peroxidation results to products such as malondialdehyde and 4-hydroxy nonenal that are mutagenic and carcinogenic (Marnett, 1999).

The data in Table 3 showed that the amount of peroxide in the sample had an increasing trend. The study of Dayrit, *et al*., (2007), for RBD-CNO gave an average peroxide value of 0.98 meq/kg oil and a range of 0.27 to 3.39 meq/kg for fresh RBD-CNO. Asian Pacific Coconut Community (APCC) set a limit of 3.00 meq/kg oil. Results obtained in the study showed peroxide value of 2.01 meq peroxide per kg of oil for the untreated and increased to 10.64 meq peroxide per kg oil on the third treatment. ANOVA showed significant difference between means at 5% α. Comparing pairs of mean by DMRT, the differences were significant between treatments. The results showed that toxic substances like peroxide is produced and increases on repeated heating.

Table 3. Peroxide Value *Expressed as milli equivalent of Peroxide per Kilogram Sample*

Samples	Peroxide Value (meq of peroxide per kg of oil) MEAN±SD
Untreated	2.01 ± 0.04^{a}
Treatment 1	7.84 ± 0.02^{b}
Treatment 2	9.66 ± 0.04^{c}
Treatment 3	10.64 ± 0.03^{d}

*Significant at α=5% by one way ANOVA

^{abcd} Treatment means having the same letter superscript are not significantly different at 5% level of probability by DMRT.

Polycyclic Aromatic Hydrocarbons

The quantities of the 22 most commonly encountered, supposed to be most harmful PAH in micrograms per milliliter, a unit that can also be expressed in parts per million (ppm) are shown in Table 4. The only PAH that significantly increased in amount up to the third reheating was 1,6,7-trimethyl naphthalene at 5% α. No reference could be found on the allowable limit for these PAH. For the rest of the PAH analyzed, there were no increasing trend on repeated heating. Statistical test showed no significant differences on the mean for all the treatments.

According to the Official Journal of the European Union COMMISSION REGULATION (EU) No 835/2011 of 19 August 2011 amending Regulation (EC) No 1881/2006 as regards to the maximum levels for polycyclic aromatic hydrocarbons in foodstuffs, the maximum amount of benzopyrene for oils and fats intended for human consumption is 2.0 microgram per kilogram of oil which is about 0.002 ppm. Benzopyrene, a proven carcinogenic and toxic PAH that is found in meat barbecue, was not detected in the analysis. The European union also stated in the same document that the sum total of benzopyrene, benzanthracene, benzofloranthene and crysene, should be at 20 μg per kg of oil which is about 0.02 ppm. The data gotten in this study showed a total average amount of 0.05 μg/mL or 0.05 ppm for benzanthracene and benzo fluoranthene only, which is higher as compared to the amount of the four PAH prescribed by the European Union.

The Agency for Toxic Substances and Disease Registry (ASTDR) in the United States released a Public Health Statement in August of 1995, Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAH) set a limit for the amount of daily PAH intake to 0.3 mg of anthracene, 0.06 mg of acenaphtene, 0.04 mg of fluoranthene, 0.04 mg of fluorene and 0.03 mg of pyrene per kilogram body weight. Data obtained by MS-GC for these PAH is below the ASTDR limits (Table 4). Benzopyrene was not included in the ASTDR limits. No other data could be found for allowable limits of daily intake in humans for the rest of the PAH included in the determination. Generally, the formation of PAH does not show an increasing trend on repeated heating but, the results showed that small quantities of this PAH is already present in coconut oil even before it was heated. These findings would further vouch that reuse of RBD-CNO for frying is not advisable.

Table 4. Polycyclic Aromatic Hydrocarbons

PAH	Polycyclic Aromatic Hydrocarbons (μg/mL) MEAN ± SD			
	Untreated	Treatment 1	Treatment 2	Treatment 3
1.) Acenaphthylene	<0.0125	<0.0125	<0.0125	<0.0125
2.) Acenaphthene	0.0078 ± 0.0001	0.0078 ± 0.0001	0.0085 ± 0.0012	0.0080 ± 0.0001
3.) Anthracene	0.0729 ± 0.0963	<0.0038	0.0055 ± 0.0098	<0.0038
4.) Benz[a]anthracene	0.0233 ± 0.0219	0.0093 ± 0.0028	0.0331 ± 0.0388	0.0350 ± 0.0219
5.) Benzo fluoranthene	0.0189 ± 0.0148	0.0081 ± 0.0037	0.0517 ± 0.0499	0.0353 ± 0.0253
6.) Benzo pyrene	0	0	0	0
7.) Fluoranthene	0.0043 ± 0.0044	0.0004 ± 0.0008	0.0063 ± 0.0038	0.0044 ± 0.0077
8.) Fluorene	0.0065 ± 0.00004	0.0064 ± 0.0001	0.0069 ± 0.0005	0.0066 ± 0.0002
9.) Naphthalene	0.0694 ± 0.0025	0.0679 ± 0.00001	0.0680 ± 0.0001	0.0686 ± 0.0012
10.) Phenanthrene	0.0192 ± 0.0207	0.0032 ± 0.0036	0.0668 ± 0.0514	0.0026 ± 0.0032
11.) Pyrene	0.0083 ± 0.0085	0.0017 ± 0.0009	0.0023 ± 0.0006	0.0044 ± 0.0046
12.) 1,4,5,9-tetramethyl Naphthalene	0.0406 ± 0.0292	0.0183 ± 0.0028	0.0610±0.0308	0.1155 ± 0.1672
13.)1,6,7-trimethylnaphthalene	0.0175 ± 0.0004	0.0173 ± 0.0007	0.0176 ± 0.0009	0.0191 ± 0.0004
14.)1-methylnaphthalene	<0.0413	<0.0413	<0.0413	<0.0413
15.)1,6-dimethyl naphthalene	0.0132 ± 0.0001	0.0133 ± 0.00001	0.0132 ± 0.0001	0.0134 ± 0.00001
16.) 2,8-dimethyldibenzothiophene	0.0399 ± 0.0219	0.0515 ± 0.0365	0.0667 ± 0.0182	0.0370 ± 0.0219
17.) 2-methylanthracene	0.0361 ± 0.0330	0.0550 ± 0.0587	0.0253 ± 0.0093	0.0262 ± 0.0133
18.) 3,6-dimethylphenanthrene	0.0190 ± 0.0017	0.0175 ± 0.0014	0.0218 ± 0.0034	0.0178 ± 0.0018
19.) 4-methyldibenzothiophene	0.0250 ± 0.0039	0.0284 ± 0.0088	0.0349 ± 0.0141	0.0317 ± 0.0143
20.) 1-methyl-9H-Fluorene	0.0575 ± 0.0615	0.0354 ± 0.0247	0.0315 ± 0.0272	0.0803 ± 0.0965
21.) 9,9-dimethyl-9-H Fluorene	0.0034 ± 0.0024	0.0033 ± 0.0025	0.0049 ± 0.0040	0.0062 ± 0.0058
22.) 1,12-dimethylbenz[a] anthracene	0.2039 ± 0.1610	0.2590 ± 0.1325	0.9063 ± 1.0029	0.8624 ± 0.4274

*1,6,7-trimethylnaphthalene is significant while the rest is not significant at $\alpha=5\%$ by one way ANOVA

SUMMARY CONCLUSION AND RECOMMENDATIONS

Summary

This study aimed to determine the deterioration and detect the formation of toxic matter in cooking oil that was repeatedly heated to establish the stability and safety of reuse in the cooking of food, which could relate to the recurrence of some diseases associated with food preparation practices.

Cooking oil, (RBD-CNO) was used in the study. Twelve bottles of cooking oil were prepared which underwent four treatments of three replicates each. These samples were analyzed for fatty acid profile, free fatty acid, peroxides and PAH.

Among the fatty acids in the fatty acid profile, only linoleic acid had significantly decreased in quantity on the third reheating which showed that unsaturated fatty acids deteriorated more and oxidized faster than saturated fatty acids.

There were increasing trends in the amounts of free fatty acids and peroxide values which were significant at 5% α by one way ANOVA. All treatment means for both parameters were significantly different from each other at 5% level of probability by DMRT.

Except for 1, 6, 7-trimethyl naphthalene, the other PAH analyzed in this study did not show an increasing trend in the result, which means that there were no significant changes in the amount of PAH in the untreated up to the third reheating treatment.

Benzopyrene, the PAH that has been proven a carcinogen found in charcoal grilled meat (ATSDR, 1995), was not detected in the analysis.

Conclusions

The cooking oil RBD-CNO used as sample in the study exhibits minimal deterioration as the fatty acid profile showed that only linoleic acid (unsaturated fatty acid) decreased in quantity on the third heating. Free fatty acid was found to increase on repeated heating significantly but did not exceed the standard of 0.2% set by the Philippine Coconut Authority. The result revealed that there is minimal deterioration of the sample. The increase in the amount of peroxide on repeated heating, from 2.01 meq peroxide per kilogram sample to 10.64 meq peroxide per kilogram of oil on the third heating signifies that the reuse of cooking oil in the frying of food is inadvisable. This is a cause for concern as this product is carcinogenic and causes serious diseases.

The amount of PAH is also a cause for concern as some of them are carcinogenic and all of them are suspected carcinogens. Although Benzopyrene is not detected in the samples, some of the amounts of Benzanthracene and Benzo fluoranthene exceeded the amounts set by the European Union. Repeated heating of oil did not show an effect on the amount of PAH as statistical test showed no significant increase for almost all of the PAH determined except for 1, 6, 7 trimethylnaphthalene. However, it should be noted that the untreated already contained levels of PAH that are higher than the limits set by EU.

Recommendation

It is recommended that: awareness should be created among the different sectors involved in the preparation of food like the restaurants and food vendors on the ill effects of the reuse of cooking oil. For food preparation involving deep frying of food, there should be alternative ways to do the process but if unavoidable, should be used oil properly so that it does not find its way back to the consumers.
Households should also be informed about peroxides in reused cooking oil and its ill effects like cancer and heart diseases. It is further recommended that when frying foods use just enough amount of oil so there will be no excesses for reuse. There are also cookwares that make frying possible with a small amount of cooking oil

Further studies could be done on: the peroxide formation and presence of PAH on cooking oils that are reused in cooking of food and compare peroxides and PAH in unsaturated cooking oils like canola, olive oil and RBD-CNO.

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TECHNICAL AND ECONOMIC EVALUATION OF THE JACK-DRIVEN BRIQUETTING MACHINE

Aries Roda D. Romallosa

ABSTRACT

This study was conducted to evaluate the technical and economic performance of the designed briquetting machine that utilizes a hydraulic-type bottle-jack for better compression in producing briquettes. The machine can compact 16 cylindrical (with a hole at the center) briquettes in one pressing or about 200 to 240 pcs/hr. The jack creates the needed pressure by thrusting the molders up to fully compact the materials. With the aid of one spring on both sides, which jointly holds together the molder and jack flooring supports, the piston of the jack when loosened is pulled back to its normal position allowing a semi-automatic type of operation. The briquettes produced by the machine functioned well as fuel when subjected to cooking and boiling tests indicating its potential as alternative source of energy. This was also highlighted by a higher percentage (81%) of willingness by waste reclaimer-respondents to buy them as fuel for various cooking and heat applications. The production cost per hour for briquettes ranged from about Php32 to Php34 or Php0.13 to Php0.16 per briquette. Leveling-up of operation may even increase production giving annual potential earnings of about Php29,000.00 to Php69,000.00. The quality of the three briquettes produced slightly varied and some of the parameters analyzed like bulk density, heating value, moisture, N and S closely met or have met the requirements of DIN 51731.

Keywords: *briquetting machine, technology, briquette production, briquettes, biomass, energy conservation*

INTRODUCTION

Background and Rationale

Briquetting involves the compression of a material into a solid fuel product of any convenient shape that can be utilized as fuel just like the use of wood or charcoal. The conversion of combustible materials found in the waste stream was found to be a better way of turning waste into wealth (Adegoke, 2002). It is one of several compaction technologies in the general category of densification in which the material is compressed to form a product of higher bulk density, lower moisture content, and of uniform size, shape, and material properties. One must have something to make the materials stick together during compression like the use of paper, which has excellent adhesive properties; otherwise, it will just crumble into pieces (from http://www.cd3wd.com/cd3wd_40/vita/ briquette/en/briquette.htm; Demirbas & Sahin, 1998; Immergut, 1975). In producing briquettes, a hole at the center of the fuel is believed by many to improve the combustion characteristics of the briquette because it encourages rapid drying, easy ignition and highly efficient burning due to the draft and insulated combustion chamber that the hole creates (Chaney, Clifford & Wilson, 2008; from http://www. paceproject.net/ UserFiles/File/Urban% 20Living/make% 20briquettes.pdf). Many parameters are also considered on the determination of the quality of briquettes produced which include production rate and economic analysis and thermophysical properties and chemical composition of the materials used for briquette production

(Stolarski, *et al.,* 2013; Singh & Kashap, 1985; Chin & Siddiqui, 2000; Vassilev, *et al.*, 2010; Voicea, *et al.*, 2013).

Some briquetting technologies developed include wooden compound levers, hydraulic pistons, car jack presses, and solar or pedal powered versions (Stanley, 2003; Chaney, Clifford & Wilson, 2008). Pressing is achieved through a simple lever mechanism and this design does not require special parts as opposed to screw presses and hydraulic jack presses (Stanley, 2003). Another one uses a hydraulic bottle-jack positioned at the bottom in order to compress the materials to be briquetted in an upward manner (Beaverton Rotary Foundation, 2013).

At the national level, researchers of the Forestry Products Research and Development Institute (FPRDI), based in UP Los Baños, Laguna, fabricated a modified manual briquetting machine that produces 10 pieces of cylindrical briquettes with center hole in one pressing. The charcoal briquettes were produced from coconut shell charcoal fines with cassava starch as binding material. In St. Paul University in Dumaguete City, Negros Oriental their briquetting machine employs a hydraulic bottle-jack positioned at the bottom. It was observed, however, that the water dripping from molders during the compression also went to the hydraulic press. The machine can produce 20 cylindrical briquettes (with no hole) in one pressing. Another visit to the fabrication site of RU Foundry and Machine Shop Corporation in Bacolod City also revealed another low-density charcoal maker. The machine likewise uses a car jack press principle in which compression is done by revolving the screw press in a downward manner. It can produce twelve cylindrical briquettes in one pressing.

Central Philippine University (CPU) also developed different briquetting technologies in the past years (Belonio, 2000; Paclibar, 2002). The technologies gave more emphasis on the use of purely biomass wastes (carbonized rice husk) including the use of binding materials such as cornstarch and animal manure. But with the increasing generation of urban wastes such as paper (Paul et al., 2007), a more flourishing fuel for heat energy may be provided in the market. Hence, paper was considered as an add-on material for briquette production. It led to the development of hand-pressed briquette molders (Paul, Lange & Romallosa, 2009; Romallosa & Hornada, 2011) through CPU's Approtech Center for the value-adding test to produce alternative fuels and raw materials (AFR) for industrial purposes and for household energy supply.

The output of the study led to the fabrication of minimal number of units for use by the members of the Uswag Calajunan Livelihood Association, Inc. (UCLA), which is located in Brgy. Calajunan, Mandurriao, Iloilo City. The units were then field tested and utilized by the members in their briquette production (Romallosa, *et al*., 2011).

The limitations from the commercial briquetting technologies developed were considered in the criteria for designing an improved version of a briquetting machine. These include among others the portability of the machine, location of the jack, shape of the fuel including the number of pieces that can be produced in one pressing.

This study was conducted to evaluate the technical and economic performance of the briquetting machine. It also covered the verification of the operating performance of the machine through actual field production test by identified members of UCLA, physico-chemical quality of briquettes produced, fuel potential, product acceptance, and economic analysis of briquette production.

METHODOLOGY

Technical Description of the Jack-Driven Briquetting

Machine

The hydraulic-type bottle-jack press briquetting machine as shown in Figure 1 consists of four major parts: briquette molders, cover, hydraulic jack and frame.

Briquette molders. The new machine was constructed with sixteen cylindrical holes. Each molder was constructed using a schedule 20 galvanized iron (GI) pipe having an inside diameter 57 mm (2-1/4 in.) and a height of 10 cm (4 in.). It was welded in the middle with a 10 mm diameter plain round bar to create the hole needed for the briquettes. Each hole was also drilled with twelve 5 mm (1/4 in.) diameter holes distributed evenly along the circumference of the pipe. A 4 mm (1/8 in.) thick metal plate was inserted at the bottom and this is supported by 4 pieces of 8 mm diameter round bar welded to connect this sliding metal plate to another plate where the hydraulic jack pushes it up during compression. The said sliding plate is responsible for holding the materials for compression.

Cover. The cover of the machine held the materials when the hydraulic jack was compressing it up. It was made of a 13 mm (½ in.) thick metal plate. It was welded with three hinges to allow easy opening of the cover. During operation, it was locked by two bolts welded on the opposite side of the hinges.

Hydraulic jack. A 10-ton capacity bottle-type hydraulic jack was utilized for this machine. It was placed under the metal plate that supported the legs of the briquette molder. The jack was supported by a 13 mm (½ in.) thick metal plate braced by I-bars to withstand the forces created during compression. The metal plate was welded on the four legs of the machine that served as support.

Frame. The frame served as the legs and support of the machine. It was constructed from a 48 mm x 48 mm (1-1/2 in. x 1-1/2 in.) angle bar. The machine was 650 mm high. The cover measured 300 mm x 300 mm while the protruding leg measured 410 mm x 410 mm. It approximately weighed 65 kg.

Figure 1. The final design of the hydraulic-jack driven briquetting machine.

Principle of Operation

The machine produced briquettes through the compressive force delivered by the hydraulic jack. The materials (paper, sawdust and carbonized rice husk) were first prepared separately, after which, they were placed into each of the cylindrical molders until totally filled. The molders were then closed and locked by the bolts then the hydraulic jack was pumped. While the materials were being molded, excess water would come out of the holes of the molders. The metal plate that served as the molder support protected the jack from water drips during operation. The different legs that supported the molders were also responsible in distributing the load from the jack since these legs were also welded on the same metal plate pumped up by the jack. Once the materials had been compressed, the cover was oscillated to open position. Pumping of the jack was continued until the briquettes were pushed out of the molders. After this, the jack was released forcing the two springs to automatically pull down the molder support back to the jack's normal position. This mode of operation had eliminated any activity that would require the user to lift anything making it very easy to operate. The user would only require human power in pumping the hydraulic jack. The use of the machine is presented in Figure 2.

Figure 2. Briquetting of wastes showing "from left to right" the placement of mixtures in the molder, compaction of the materials, and removal of briquettes produced from the molders.

Briquette Production and Evaluation

Laboratory test. Three different types of briquettes utilizing biomass and urban wastes were produced for this study using the 4x4 briquetting machine. The briquettes were made of the following mixing proportions: Briquette 1: paper (100%); Briquette 2: paper (50%) + sawdust (50%); and Briquette 3: paper (50%) + CRH (25%) + sawdust

(25%). The dry weight of biomass and urban wastes and their combinations were all fixed to 3000 g. The weighed materials were mixed manually in pure form or with add on materials in a container based on the recommended mixing ratio until homogenized. Then they were placed in the briquetting machine for compaction and the fuels produced were sundried after until 20 to 30% moisture was attained making them ideal for the boiling water and cooking rice tests.

Performance evaluation of briquettes was done in four test runs. Boiling of 2000g or 2 li of water using the three different types of briquettes produced and charcoal as fuels were performed simultaneously using a concrete stove. During this test, the initial weight of fuel used, number of pieces of briquettes or charcoal used as fuel and the total length of operation was recorded and monitored. After boiling test, the weight of ash produced was also measured. The same procedure was followed for the cooking test using 750g of rice.

Dried briquettes were sent to Bauhaus-Universität Weimar in Weimar, Germany for other physico-chemical tests. The identification and characterization of chemical and phase composition of a given solid fuel was the initial and most important step during the investigation and application of such fuel (Stanislav, *et al*., 2010).

Actual field production test. Verification of the performance of the machine was done through an actual field production test for 15 days (Figure 3). UCLA members who had been trained on briquette production through participation in previous studies or attendance in trainings conducted were commissioned for this test. Field production test was performed to determine the average volume of briquettes they could produce under simulated work conditions wherein each participant was compensated based on the actual number of briquettes produced. The same mixture of materials as in the laboratory test was utilized for this field test.

Figure 3. The actual field production test in UCLA Center (left) and the briquettes produced hanged for drying (right).

The actual field production test was performed in UCLA Center located just 100 m across Iloilo City's controlled disposal facility in Brgy. Calajunan, Mandurriao. The Center has an approximate floor area of 144 m^2 and was made from light construction materials such as plywood for its flooring and *nipa* shingles for its roofing.

Eight units of the jack-driven briquetting machine were utilized for this test. Two persons working as a team operated each machine. On the other hand, two additional persons were assigned for the pulping of waste papers. This set-up wherein a certain team is assigned to pulping and another assigned is only to briquetting indicates a specialized type of work. This manner is common in work places to attain higher production.

Production of briquettes was done in modes that represent different possible types of productivity. These included a team/worker who produced briquettes based on the following rates:

- Paid for every 4 pieces of briquettes produced per day
- Paid on a fixed rate by producing 150 pieces per day with bonus for every 4 additional briquettes formed
- Paid on a fixed rate with no required number of briquettes produced

These three different rates were representative of three different possible productivities for workers, hence, the total production divided by the number of days and number of participants would illustrate on a realistic average production rate per person. The first mode represented an output-oriented worker who can increase his income if he can produce more. The second mode represented a worker, who was willing to earn that much, but if he wanted to increase his fixed income, then he can produce more so that he can have a bonus. The third mode represented a worker who does not really mind the volume he can produce as long as he is paid a fixed amount of money. The estimation of the fixed rate at 150 pieces per day was based on the average briquettes produced during previous briquetting tests conducted.

Product acceptance by users through survey. A survey was conducted to determine the acceptance of the UCLA members and other waste reclaimers found in the vicinity of Calajunan Disposal Facility on the use of the newly developed briquetting machine including their views on the utilization of briquettes as substitute fuel for cooking. UCLA has about 250 members living near the vicinity of the dumpsite; however, there are also non-UCLA members recovering wastes in the site. From this number, the sample size was determined using an online program (from http://www.raosoft.com/samplesize. html) at 0.95 reliability. The formula yielded a sample size of 152, however, 160 respondents were included in the survey. These respondents were identified using the incidental sampling technique (Altares, *et al*., 2003). In this method, the interviewer simply asked the waste reclaimers who were present in Calajunan Disposal Facility during the time of survey (Figure 4). The respondents were asked about their personal background, waste management/waste picking background, housing condition, kitchen/cooking devices, and their acceptability/use of briquettes.

Figure 4. Conduct of survey on product acceptance of the technology developed.

Instrumentation

The following instruments and equipment were used in the conduct of the study: 20-kg Fuji spring-scale balance, 1-kg compact scale, 50-kg pocket spring-balance, 22 and 25 cm diameter cooking pots, 56-cm big pail, 60-cm wash basin, thermocouple thermometer, moisture meter, steel tape, Vernier caliper, timer, pulping machine and concrete charcoal stoves.

RESULTS AND DISCUSSION

Operating Performance of the Machine

Shown in Table 1 are the results of the operating performance of the machine when subjected for testing in the laboratory. These are the same parameters analyzed as those from the previous study (Romallosa & Hornada, 2011) such as the weight of waste paper and biomass materials used. Longer pulping time was needed for Briquette 1 since this type of fuel utilized pure paper; hence, more time was also needed to disintegrate the structures of paper. Briquettes that utilize less paper needs less electrical energy consumption since the pulping machine used requires a 1-Hp motor to operate it. However, more time would also be needed if more materials were mixed as fuel. It was observed that when pure paper was used, the materials really penetrated through the surface of the molders creating more friction especially when they were being compressed. However, when paper was mixed with additional materials like sawdust and CRH, the operation became less strenuous especially on the use of the machine.

Data in Table 1 revealed a no significant difference at the 5% level of probability when the machine was evaluated in terms of production rate expressed as number of briquettes produced in an hour. The production rate range from 205 to 239 pcs/hr. Regardless of the mixtures used, the machine could produce almost the same number of briquettes. With the improved device, more briquettes can really be produced when numerically compared to that of the hand press briquetting technology previously developed (Romallosa & Hornada, 2011). The higher number of briquettes produced was due to the increased number of molders, i.e., from 5 to 16 molders in one pressing. The addition of a hydraulic jack made the operation easy in terms of physical effort needed and less complication in maneuvering it. Human power is only needed in the manipulation of the lever of the jack during the operation.

Briquette 3 statistically obtained the highest ($P<0.01$) production rate at 4.56 kg/hr followed by

Briquettes 2 and 1 with values of 3.98 and 3.30 kg/hr, respectively. Briquette 3 were heavier due to the use of three different materials (paper, sawdust and CRH) that made it heterogeneous. Mixing of these materials prior to molding them has reduced the presence of voids. It can be noted also that for Briquette 3 and even for Briquette 2, the amount of water during mixing has reduced because the add-on materials absorbed them. These moistened the mixtures only. Once these materials were compressed, less moisture was removed, therefore, the briquettes produced were thicker and heavier. In the case of the pure paper briquettes, the production rate in terms of weight per hour was less because the pulped papers placed in the molders contained higher water content, so during compression, most of the water together with some pulped papers were forced out through the tiny holes found at the periphery of the molders. After compaction, the paper briquettes produced were less dense; hence, the weight was also less (16 g).

Table 1. Operating Performance of the Machine in Terms of Technical Requirements and Output in Producing Briquettes.

Parameters Measured	Briquette 1 (P)	Briquette 2 (P + SD)	Briquette 3 (P + SD + CRH)
Total dry wt. mixture, kg	3	3	3
Dry wt. of paper (P), kg	3	1.5	1.5
Dry wt. of sawdust (SD), kg	-	1.5	0.75
Dry wt. of carbonized rice husk (CRH), g	-	-	0.75
Pulping time, min	8.61	4.96	2.46
Mixing time, min	-	1.79	2.14
Briquetting time, min	43.47	37.08	36.65
Total operating time, min	52.07	43.83	41.25
Briquettes produced, pcs	189	150	164
Dry wt. per briquette, g	16	21	20
Dry wt. of briquettes produced, g	2.86	2.91	3.13
Production rate, pcs/hr[1]	217 [ns]	205	239
kg/hr[2]	3.30 [c]	3.98 [b]	4.56 [a]

[1] cv = 8.00%

[2] cv = 5.54%

[ns] Not significant

[abc] Any two means on the parameter measured (in a row) followed by the same letter superscript are not significantly different at the 1% level of probability

Field Production Briquetting Test

Results of the 15-day actual field production test revealed a slightly different production rate. No statistical analysis was made since the amount of materials used was only summed up after the 5-day test for each briquette type. Moreover, the purpose of the field test was to observe and record the performance of the workers in terms of briquette outputs rather than the amount of materials used. As shown in Table 2, the amount of dry mixtures used varied from 796 kg to 1,152 kg maximum dry weight mixture. The analyzed production rate in terms of pcs/hr confirmed the non-significant results during the laboratory testing. This means that the highest production rate for Briquette 3 (as revealed in Table 1) might only be coincidental such as the capability of the person to be familiar right away with the operation. When the data was analyzed numerically, it was still Briquette 3 which had the highest production rate, followed by Briquette 2 (137 pcs/hr) and Briquette 1 (105 pcs/hr). When analyzed in terms of weight of briquettes produced per hour, the data also substantiated the results at the laboratory level.

The actual field testing likewise made possible the observation of the durability of the machine. The parts that gave in due to the wear and tear of the use of the machine were the welded hinge of the cover and the springs that pull together the molder support and jack flooring when the hydraulic jack was loosened.

Table 2. Operating Performance of the Machine through Actual 15-day Field Production Test* by Identified Members of UCLA.

Parameters Measured	Briquette 1 (P)	Briquette 2 (P + SD)	Briquette 3 (P + SD + CRH)
Total dry wt. of mixture, kg	796	1,152	924
Total dry wt. of paper (P), kg	796	576	462
Total dry wt. of sawdust (SD), kg	-	576	231
Total dry wt. of carbonized rice husk (CRH), kg	-	-	231
Ave. daily operating time, hr	6	6	6
Total briquettes produced in 5 days, pcs	50,410	65,759	71,753
Average daily briquettes produced per person, pcs/day	630	822	897
Total dry wt. of briquettes produced in 5 days, kg	807.00	921.00	861.00
Average daily dry wt. of briquettes produced per person, kg/day	10.09	11.51	10.76
Average production rate per person, pcs/hr	105	137	149
kg/hr	1.68	1.92	1.79

*15-day field production test at 5-days each for every briquette type

Quality of Briquettes Produced

In general, results of the study presented in Figure 9 and Table 3 revealed that properties of fuel briquettes depend mainly on the type of material they are made from and on the type of the briquetting machine used to produce them. These are supported by the findings of (Stolarski, *et al*., 2013). The machine produced briquettes that are cylindrical in shape and with a hole at the center, similar with other briquettes previously developed and produced from other places (Njenga, *et al.,* 2009; Chaney, Clifford & Wilson, 2008; Stanley, 2003; Beaverton Rotary Foundation, 2013). This designed machine can be added to the energy conversion technologies that had been developed and adopted under local conditions in order to utilize the abandoned biomass wastes in the country (Baconguis, 2007). The three different biomass materials were utilized using the improved machine since these were the mixtures that were recommended during the previous study (Romallosa & Hornada, 2011).

As presented in Figure 9, the three types of briquettes were different in color. They are cylindrical in shape with a hole in the center. The briquettes on the first column appeared mostly white because the waste papers were the only components of this fuel. On the other hand, the briquettes found at the center had light brown color with traces of white spots. This was due to the presence of 50% waste paper and 50% sawdust. For the third column, the presence of CRH in the mixture made black the dominant color of the fuels with specks of white and light brown materials.

The briquettes have a diameter within the 5-cm range and a thickness that varied from 1.54 to 2.34 cm while the inner hole was about 1.20 cm. Briquettes with more mixtures (Briquettes 2 and 3) were heavier than the pure paper. The value for the weight and volume per briquette were necessary data for the computation of the bulk density of the fuels. With a hydraulic jack, the bulk density of the briquettes was recorded to be highest for Briquette 1 at 0.49 g/cc (486.60 kg/m^3) followed by Briquette 3 (0.46 g/cc; 461.90 kg/m^3) and Briquette 2 (0.39 g/cc; 389.31 kg/m^3). The higher density observed in the 100% waste paper briquettes may be due to its homogenous nature, which may have enabled the material to form a stronger bond, resulting in a denser and more stable briquettes (Olorunnisola, 2007) compared to those from the two other mixtures. The use of the jack-driven machine has also improved the bulk density by about 0.32 g/cc or by 246% when compared to those made using the previous machine developed (Romallosa & Hornada, 2011). The bulk densities of the briquettes produced were also numerically similar with the results of the studies of (Stolarski, *et al*., 2013) and Demirbas and Sahin (1998) which produced briquettes made from agricultural, forest origin biomass; and waste paper using a horizontal crank-and-piston briquetting press (bulk density ranged from 469 to 542 kg/m^3) and Shimadzu hydraulic press (bulk density reported to be 0.32 g/cc or 320 kg/m^3).

Figure 9. Types of briquettes produced using biomass and urban wastes, from left to right: paper, paper and sawdust and paper, sawdust and CRH.

Table 3. Quality of Briquettes Produced.

Parameters Measured	Briquette 1 (P)	Briquette 2 (P + SD)	Briquette 3 (P + SD + CRH)
Physical Characteristics			
Color	White with spots of black prints	Light brown with white spots	Black with white and light brown spots
Shape	Cylindrical with hole	Cylindrical with hole	Cylindrical with hole
Diameter, cm	5.37	5.53	5.48
Height, cm	1.54	2.34	1.96
Inner holed diameter, cm	1.20	1.21	1.21
Weight per briquette, g	16	21	20
Volume per briquette, cc	33.15	53.30	43.97
Bulked Density, g/cc	0.49	0.39	0.46
kg/m^3	486.60	389.31	461.90
Heating value, Btu/lb	6,439	7,153	5,872
Proximate analysis			
Ash yield, % dm	21.0	14.6	31.0
Moisture, %	5.6	7.1	5.8
Ultimate analysis			
Hydrogen, % dm	5.1	5.9	4.8
Nitrogen, % dm	<0.1	<0.1	<0.1
Sulfur, % dm	0.035	0.036	0.028

Heating value is a major quality index for fuels (Demirbas & Sahin, 1998). Fuels such as briquettes need a heating value of about 11.66 MJ/kg (5,000 Btu/lb) for it to be able to sustain combustion (Yaws, 1999; Lee, 2007). The waste paper mixed with sawdust briquettes produced using the jack-driven machine had a heating value of 7,153 Btu/lb. The pure paper briquettes obtained a heating value of 6,439 Btu/lb while that of paper mixed with sawdust and CRH was 5,872 Btu/lb. All three mixtures recommended had a heating value that can sustain combustion (Yaws, 1999; Lee, 2007) making them an ideal and feasible fuel for cooking and other heat-related applications.

The calorific power or heating value of the material is influenced by the species and the moisture content (Voicea, *et al.*, 2013). The results of this study, however, do not agree that a lower moisture may lead to higher heating value; the heating value was rather influenced more by the materials used especially sawdust since it has a higher heating value compared to pure paper and CRH. When the heating value of the briquettes were compared to that of the German standards (DIN 51731) for compressed natural wood briquettes at 7,248 Btu/lb, results revealed that Briquette 2 had the closest numerical value (7,153 (Btu/lb). This indicates that this low-cost technology can also create fuel briquettes that can closely meet the standards set for products that are mostly manufactured by companies using high technologies.

The proximate analysis of the briquettes included the ash yield, and moisture while the ultimate analysis covered the organic forming elements in biomass (Vassilev, *et al*., 2010), namely: hydrogen (H), nitrogen (N) and sulfur (S). Ash yield is the inorganic oxides that remain after complete combustion of materials (Speight, 2008). Results show that the third briquette had the highest ash content at 31.0% followed by Briquette 1 at 21.0%. Briquette 2, which is a mixture of paper and sawdust, contained the lowest amount of ash at 14.6%. It can be noted that agricultural biomass like rice husk (such as found in Briquette 3) yields higher ash, thus, contains much more ash-forming elements than most of forestry biomass like sawdust (Stolarski, *et al*., 2013); (Vassilev, *et al*., 2010). This parameter is an important characteristic influencing the burning technology, emission of solid particle, and the handling and use of ash (Voicea, *et al*., 2013). The ash content of Briquette 2 (paper and sawdust) is numerically comparable with that of a bituminous coal at 15.7% (Vassilev, *et al*., 2010).

The moisture of the briquettes produced ranged from 5.6 to 7.1% of its dry matter (dm) weight. The use of a hydraulic jack in the compression of the briquettes and the presence of many holes on the side of the molders (Stanley, 2003) were instrumental in squeezing out excess water decreasing the moisture content by almost 4% when compared to briquettes pressed manually (Romallosa & Hornada, 2011). The moisture recorded also met the DIN 51731 standards that require fuels to have moisture of less than 12%.

The content of H in the three briquettes produced ranged from 4.8 to 5.9% with Briquette 2 having the highest. (Voicea, *et al*., 2013) mentioned that H is an important characteristic that influences the calorific power and the value should be high; hence, the higher H value in Briquette 2 also correspond to higher heating value among the three mixtures. For the N content, which influences the emission of nitrogen oxides (NO_x) and corrosion (Voicea, *et al*., 2013), all three briquettes obtained the same value of less than 0.1% of its dry matter weight. The value obtained for S, which influences the emission of sulfur oxides (SO_x) and corrosion were at almost the same value ranging from 0.028 to 0.036% of the dry matter weight. The briquettes produced contained lower N and S when compared to other biomass briquette fuels such as mixed paper, refuse-derived fuel and bituminous coal (Stolarski, *et al*., 2013); Vassilev, 2010; Demirbas & Sahin, 1998). The results for N and S also conform with the standards set under DIN 51731 standards of <0.3% and <0.0.08%, respectively. This implies that the briquettes produced, when used as fuel for heating operations, would emit less NO_x and SO_x which are pollutants in the atmosphere.

Alternative Fuel Potential of Briquettes

All tests presented in Table 4 were done using the same size of the usual charcoal stove used by a household and the results were compared with that of charcoal. The number of pieces of fuel used for each test was based on the number of fuel the stove can contain. Twelve pieces of briquettes were used for each type in each test while that of charcoal made use of 24 pieces of fuel since these were smaller than the briquettes. With this number of fuel, boiling of water was fastest ($P<0.01$) in Briquettes 1 and 2 at almost 13 min for both. The data obtained using cylindrical briquettes with a hole also yielded similar results with that of the hand-pressed briquettes (Romallosa & Hornada, 2011). The ranking as to which briquette boils water the fastest was similar with that of the previous study showing once again that the briquettes performed better than charcoal.

When the fuels were tested for cooking 750 g of rice, the paper briquettes exhibited significantly ($P<0.01$) the fastest cooking time at 19.88 min over the other two types of briquettes at about 23 min. Again, charcoal resulted in the longest cooking time (25.43 min).

Personal Profile of Respondents Users

One hundred sixty (160) respondents who were mostly (89.4%) residing in Brgy. Calajunan, Mandurriao were interviewed to determine the briquette acceptance. Results shown in Table 6 revealed that 69% were members of UCLA while the others who were present in the disposal facility during the time of interview were non-members or those waste reclaimers who did not signify voluntary participation in the association. Their average age is 37.52 years and most of the respondents are women (59.4%). In terms of their highest educational attainment, almost the same percentage (27 and 25%) were elementary and high school undergraduates; although there were waste reclaimers with college degree also (6.9%). Most of the waste reclaimers found at the facility are married (74%) with more than 50% having 3 or more children.

Table 4. Operating Performance of Briquettes as Fuel.

Parameters Measured	Briquette 1 (P)	Briquette 2 (P + SD)	Briquette 3 (P + SD + CRH)	Charcoal
Boiling Test				
Wt. of water used, g	2,000	2,000	2,000	2,000
No. of fuels used, pcs	12	12	12	24
Wt. of fuels used, g	257	250	295	244
Start-up time, min	1.07	1.16	1.52	1.87
Boiling time, min [1]	12.59 [a]	12.46 [a]	16.02 [b]	19.38 [c]
Total operating time, min	52.07	43.83	41.25	55.00
Cooking Test				
Wt. of rice cooked, g	750	750	750	750
No. of fuels used, pcs	12	12	14	17
Wt. of fuels used, g	252	249	340	204
Cooking time, min [2]	19.88 [a]	23.01 [b]	22.63 [b]	25.43 [c]

[1] cv = 4.60%

[2] cv = 5.69%

[abc] Any two means on the parameter measured followed by the same letter superscript are not significantly different at the 1% level of probability

Table 5. Distribution of Respondents according to Their Personal Profile (n=160).

	Frequency	Percent
Age		
23 years old and below	30	18.8
24 – 46 years old	89	55.6
47 years old and below	41	25.6
Total	**160**	**100.0**
Mean Age = 37.52 years old		
Residence		
Brgy. Calajunan, Mandurriao, Iloilo City	143	89.4
Brgy. So-oc, Arevalo, Iloilo City	10	6.2
Brgy. Pakiad, Oton, Iloilo	4	2.5
Gender		
Female	95	59.4
Male	65	40.6
Total	**160**	**100.0**
Highest Educational Attainment		
Elementary undergraduate	44	27.5
Elementary graduate	24	15.0
High School undergraduate	40	25.0
High School graduate	29	18.1
College undergraduate	12	7.5
College graduate	11	6.9
Total	**160**	**100.0**
Civil Status		
Married	118	73.8
Single	24	15.0
Live-in	15	9.4
Number of Children		
3 and below	90	56.2
4 to 6 children	37	23.1
7 and above	29	18.1
No answer	4	2.5
Total	**160**	**100.0**
Mean Number of Children = 3.71		
Classification of Respondents *(n=160)*		
UCLA Member	111	69.4
Non-UCLA Member	49	30.6
Total	**160**	**100.0**

Fuel Related Parameters

When the respondents were asked about their cooking facility and related information, results in Table 6 show that charcoal stove followed by the wood stove were the two commonly used cooking devices as claimed by 72.5% and 58.7% of the waste reclaimers, respectively. With these devices, wood and charcoal were also the main fuels utilized while others can afford to use LPG. Six respondents indicated that they were using briquettes and rice husk as fuel for cooking. These fuels were mostly sourced from the dumpsite (76.2%) while others were buying it (52.5%) or getting it from nearby places (14.4%). The results further show that a great majority (88.1%) of the respondents were already familiar with the use of briquettes as cooking fuel. Their familiarity may be attributed to the posted list of activities and many actual field tests that had been conducted and performed at the UCLA Center, which is just approximately 100 m away from the Calajunan Disposal Facility. These activities may have encouraged some (17%) of the waste workers to produce their own briquettes.

When each of the respondents were later provided with 3 kg of briquettes produced by selected participants during the 15-day actual field test held in UCLA Center, more than 83% indicated that they were using them for cooking rice and food and for boiling water. Others (31%) claimed that they were using them for cooking food for their animals.

In terms of acceptability of the technology, 93.1% of the respondents signified its usefulness as substitute fuel for cooking. Should these fuels be introduced in the market later on, 81.2% are willing to buy them as cooking fuel in their respective households. The outcome of this survey is a positive indicator of the potential of briquettes as substitute fuel for various cooking and heat applications.

Table 6. Distribution of Respondents according to Different Parameters (n=160).

Parameter	Frequency	Percent
Type of Cooking Device *(Multiple Response - MR)*		
Charcoal stove	116	72.5
Wood stove	94	58.7
Stone	14	8.75
LPG stove	13	8.1
Steel bars	9	5.6
Type of Fuel Used *(MR)*		
Wood	139	86.8
Charcoal	110	68.7
LPG	13	8.1
Briquettes	4	2.5
Rice husk	2	1.2
Source of Fuel *(MR)*		
Dumpsite	122	76.2
Bought	84	52.5
Nearby places	23	14.4
Familiarity with Briquettes as Cooking Fuel *(n=160)*		
Familiar	141	88.1
Not familiar	19	11.9
Production of Own Briquettes *(n=160)*		
Yes	27	16.8
No	133	83.1
Ways of Utilizing Briquettes Provided *(MR)*		
For cooking rice	149	93.1
For cooking food	144	90.0
For boiling water	134	83.7
For cooking food of animals	50	31.2
Usefulness of Briquettes as Substitute Fuel *(n=160)*		
Yes	149	93.1
No	11	6.9
Willingness to Buy Briquettes if Sold in the Market *(n=160)*		
Yes	130	81.2
No	4	2.5
Not sure	26	16.2

Economic Analysis

The cost analysis in producing briquettes is presented in Table 7. The improved briquette molder entailed additional cost as compared to the hand-press molder. The total cost of investment was Php37,000.00 while the fixed cost gave the same value for the three types of briquettes. The production of pure paper briquettes, however, entailed a higher variable cost of Php229.12 per day when compared to the other two briquettes which needed only Php214.56 per day. This was mainly due to the higher cost of electricity needed for pulping operations. Considering all the costs incurred at an assumed 8-hour operation per day, the cost of producing any of the three recommended briquettes ranged from about Php32.00 to Php34.00 per every hour of operation or Php0.13 to Php0.16 for every briquette produced. The design and development of this machine can be an answer to the limited commercial production of biomass briquettes in the country that would help convert combustible materials found in the waste stream into wealth (Primer on Biomass Briquette Production, 2010; Adegoke, 2002).

Table 7. Cost Analysis in Briquette Production.

Parameters Measured	Briquette 1 (P)	Briquette 2 (P + SD)	Briquette 3 (P + SD + CRH)
Investment Cost, Php	37,000.00	37,000.00	37,000.00
Fixed Cost, Php/day			
Depreciation [1]	30.41	30.41	30.41
Interest on Investment [2]	8.11	8.11	8.11
Repair & Maintenance [3]	3.38	3.38	3.38
Insurance [4]	1.01	1.01	1.01
Total	**42.91**	**42.91**	**42.91**
Variable Cost, Php/day			
Labor Cost [5]	200.00	200.00	200.00
Cost of Electricity [6]	29.12	14.56	14.56
Total	**229.12**	**214.56**	**214.56**
Total Cost, Php/day	272.03	257.47	257.47
Operating Time, hrs/day	8	8	8
Operating Cost, Php/hr	34.00	32.18	32.18
Php/pc [7]	0.16	0.16	0.13

[1] Straight line method with 10% salvage value and life span of 3 years

[2] 24% of investment cost (IC)

[3] 10% of IC

[4] 3% of IC

[5] The average daily earnings by waste picking is Php123.80 (Ikuse, *et al.*, 2014)

[6] 1.12 kW/hr @ 2 hrs pulping operation/day for Briquette 1 and 1 hr for Briquettes 2 and 3 @ Php13.00/kW-hr

[7] Operating cost divided by production rate in pcs/hr from Table 1

Potential Daily Production and Earnings

Data in Table 8 shows the computation for the potential earnings in the production of briquettes based on the production rate presented in Table 1 and operating cost in Table 7 with all data converted on a daily basis. When the briquettes are sold after mark-up at Php15.00/kg multiplied by the production rate for each briquette, the sales or revenue that may be generated would range from Php396.00 to Php548.00 per day. Subtracting the earned revenue with the cost of operation would give the producer potential daily earnings of Php124.00 to Php290.00, a value quite significantly higher when compared to the majority of waste reclaimer's surveyed daily income of Php124 (Ikuse, *et al.,* 2014). When computed on an annual basis, one person may earn Php29,000.00 to Php69,000.00 just by producing briquettes. Higher earnings may be realized if more members of an organization would work together for their income-generating project.

Table 8. Potential Daily Production and Earnings in Briquetting of Wastes.

Parameters Measured	Briquette 1 (P)	Briquette 2 (P + SD)	Briquette 3 (P + SD + CRH)
Production Rate [1], kg/day	26.40	31.84	36.48
Operating Cost [2], Php/day	272.00	257.44	257.44
Sales [3], Php/day	396.00	477.60	547.20
Potential Earnings:			
Php/day [4]	124.00	220.16	289.76
Php/yr[5]	29,760.00	52,838.40	69,542.40

[1]Obtained from Table 1 multiplied by 8-hr production per day

[2] Obtained from Table 7 multiplied by 8-hr operation per day

[3] Revenue for briquettes when sold at a mark-up price of Php15.00/kg (@ Php0.25 per briquette after mark-up)

[4]Sales less operating cost

[5] Potential earnings in Php/day multiplied by 20 days production per month for 12 months

CONCLUSIONS AND RECOMMENDATIONS

It can be concluded, in general, that the designed jack-driven briquetting machine has technically improved in terms of operating performance and production of briquettes based on the laboratory and actual field production tests conducted. Specifically, the bulk density of the briquettes was improved to a value comparable to other briquettes produced made from agricultural, forest origin biomass and waste paper that use a horizontal crank-and-piston briquetting press and Shimadzu hydraulic press.

The physico-chemical quality of the produced briquettes implies optimism as to their potential when utilized as fuels for heating operations due to their heating value that can sustain combustion. Its utilization for briquette production has also presented economic viability as an income-generating project.

Based on the findings and conclusions of the study, the following are recommended:

In spite of Briquette 3's high potential earnings, it is recommended that paper (Briquette 1) or a combination of paper and sawdust (Briquette 2) be utilized for briquette production using the designed jack-driven briquetting machine due to their better physico-chemical properties like bulk density, heating value, proximate and ultimate analyses.

Connection of the lever of the hydraulic-type bottle-jack to an electric motor for mechanized operation leading to higher production rate. Improvement of the hinge of the cover so that it would be able to withstand the pressure received during compression. Allow better catchment for water drips for cleaner operation by improving the height of the guide on the perimeter on the plate and by adjusting the inclination of the plate so that the water would easily flow into the spout provided. Attachment of rollers or wheels for easy mobility of the machine.

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CONSTRUCTION AND TESTING OF AN IMPROVISE LEAF ELECTROSCOPE (ILE)

Rex S. Rubidy

ABSTRACT

This study aimed to construct and test the improvised leaf electroscope (ILE) for Physics Laboratory experiments. It was only limited on the construction and testing of ILE. The finished products replaced the existing electroscope and provide hands – on learning experience to the students. The Improvised Leaf Electroscope was made of Erlen Meyer flask as chamber. Its major parts were the following: a) the metal rod which will serve as the stem and the knob b) cork stopper which will hold the aluminum leaves mounted on the metal rod, and c) aluminum foil which will serve as the leaves. The materials needed are locally available and less expensive. Nine samples of ILE were constructed in order to test which samples can produce the highest approximate angle of deflection. Three various ways of test were made with three trials for each testing. Results reveal that copper rod is the best metal stem to use with an approximate measured angle of deflection of 26^0. The appropriate length of the rod is 6 inches with 46^0 approximate measured angles of deflection. And the suitable width of aluminum leaves is 0.5 cm with 30^0 approximate measured angle of deflection. In order to improve the operation of the ILE, it is highly recommended to produce a good quality of plastic rod and woolen cloth in order to attain maximum results and not to depend on the imported rod and cloth.

INTRODUCTION

Background of the Study

Most modern applications of electricity involve moving electric charges or current electricity. Historically, however, the first studies of electricity involved static charges, or electrostatics.

Electricity comes from the Greek word *elektron* which means “amber”. Amber is a petrified tree resin, and the ancients know that an amber rod rubbed with a piece of cloth, will attract small pieces of leaves or dust. A piece of hard rubber, a glass rod, or a plastic ruler rubbed with a cloth will also display this “amber effect,” or electricity (Giancoli, 1998).

Electrostatics is the study of electrical charges and their characteristics. To experimentally investigate electrostatics, some charge−detecting or measuring device is needed (PASCO Scientific. 1999). A useful instrument for studying electrostatic phenomena is the electroscope. This instrument is consist of two thin leaves of gold foil attached to one end of metal rod which is terminated at the other end by a metal sphere. When the metal sphere is charged, part of the charge goes to the gold foils, causing them to repel and diverge. The greater the charge on the leaves, the greater the divergence (Smith & Cooper, 1979).

According to Noah Dorsey "The simple electroscope is consist of a metal case within which, and near its center, is supported in a vertical position by a well-insulated metal strip where a narrow strip of thin foil, preferably of gold leaf is attached to its top.

This strip is usually referred to as the leaf. The strip of metal and the leaf constitute the insulated system of the electroscope. When the insulated system is electrically charged by a suitable switch passing through the wall of the case, the leaf is repelled by the strip, and is deflected from its normal, vertical position. In opposite sides of the case are windows through which the position of the leaf can be observed. Such observation is usually made by means of a microscope mounted with an ocular micrometer (from http://inventors.about.com/library/inventors/blelectroscope.htm.)

The Braun electroscope as, illustrated in Figure 1 which is used in various experiments in Physics Class, is a deflection arm electroscope.

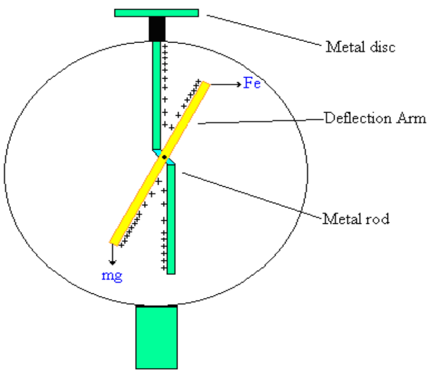

Figure 1. Deflection arm electroscope (Braun electroscope)

The electroscope is made of a metal disc connected to a metal rod inside a circular cylindrical ring. The metal rod is insulated from the outer ring by a rubber gasket; this is to shield the electroscope from the influence of external charges. The deflection arm which has a metal pin through its center of gravity is connected directly to the metal rod, thus it is free to rotate about its center axis. The metal rod is also bent such that the gravitational force acting on the deflection arm causes the arm to reside vertically on the right side of the metal rod the same with the top, left side and at the bottom.

When a positively-charged probe is touched to the metal disc, the positive charges will be induced on the surface of the metal rod and the deflection arm. Then Coulomb forces result in a repulsive force between the like positive charges. This then results in a clockwise directed torque on the deflection arm at the top and the bottom. The deflection arm is then rotated to a certain distance until the Coulomb force is in equilibrium with the gravitational force (F=mg) acts on the arm. The amount of deflection is proportional in some manner to the amount of charge induced on the electroscope.

A classical "gold leaf" electroscope is shown in Figure 2. The design is consist of a metal disc on top, a metal rod, and two strips of gold leaf at its lower end. The leaves are protected from air current and a simple scale in degree is provided for measurement. The charged probes are placed near the metal disc, and the leaves would diverge because of the Coulomb force.

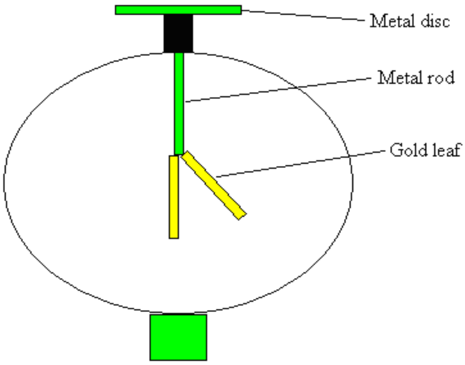

Figure 2. The Classical Electroscope

An electroscope developed by Sargent-Welch Scientific Company is used in the Physics Laboratory of Central Philippine University. This electroscope consisting of aluminum leaves is mounted on a metal rod held by a rubber stopper in a 250 mL Erlenmeyer flask. The round sides of the flask give ample space for the leaves to diverge when charged. The leaves are glued/pasted at the end of the stem.

As per Physics Stockroom Inventory Records for school year 2009 – 2010, a total of 17 units of Leaf Electroscope are in the list. Unfortunately, these 17 units of electroscope are also all in the damaged list. At present, there is no available electroscope that can be used by the students from the Colleges of Agriculture, Resources and Environmental Sciences; Arts and Sciences; Computer Studies; Education and Engineering.

With this situation, an improvised instrument is a must in order for the students to have hands–on learning experience in electrostatics. Thus, an improvised leaf electroscope was designed and developed. Apart from hands-on learning experience for the students, the developed improvised electroscope will also give ease and convenience to the lectures and demonstrations of the faculty members teaching electrostatics.

This improvised electroscope is very much cheaper than the one already available in the Physics Stockroom. If the department will purchase one set of the leaf electroscope, it will cost about P4, 900.00 as of July 15, 2009 price quotation. The Improvised Leaf Electroscope (ILE) will approximately cost only P900.00. This improvised instrument has an advantage over the old one in terms of the availability of the aluminum leaves. The old electroscope uses imported aluminum leaves from the U.S.A. that cannot function if the aluminum leaves have scratches while the leaves of the improvised electroscope can be easily replaced because the material needed is locally available.

Objectives of the Study

The main objectives of the study are to construct and test the improvised leaf electroscope (ILE) for Physics Laboratory experiments.

Specifically it aims to:

1. identify the basic components needed for a given system and function;
2. construct an improvised electroscope that will use locally available materials;
3. determine the cost of constructing an Improvised Leaf Electroscope (ILE); and,

4. conduct testing and evaluation of the system in terms of split distance between leaves and angle of deflection.

Scope and Limitation of the Study

The Improvised Leaf Electroscope was primarily designed for Physics Laboratory experiment in Central Philippine University. This instrument was designed based on the specifications and limitations of the materials. The primary material used was locally available. In order to determine the effect of a charged body, vinyl plastic strip was used.

This study was limited only to the construction and testing of an Improvised Leaf Electroscope. It made use of the presently available plastic strip and woolen cloth in the Physics Stockroom in order to test its functionality.

The length of the metal rod was based on the dimension of the Erlenmeyer flask used with an approximate volume of 250 ml and with a measured height and width of 14.5 cm x 8.5 cm, respectively. The rod was set to 10.16 cm (4 inches) for the minimum and 15.24 cm (6 inches) for the maximum length. In order to achieve the best result, the rods used did not go beyond the value set for its length.

The construction, testing and evaluation of the Improvised leaf electroscope was made at EN203, Physics Stockroom in the College of Engineering, Central Philippine University, Jaro, Iloilo City, Philippines. These were conducted by the Researcher, Stockroom Assistants of the Physics Laboratory, and College Physics Students.

Significance of the Study

Central Philippine University would save money from this study because this instrument is cheaper compared to the ones purchased from the Laboratory Suppliers.

The finished product would replace the existing electroscopes and provide hands–on learning experience to the students taking up Physics subjects.

The output of this study would comply with the Association of Christian Schools, Colleges and Universities, Accrediting Agency, Inc. (ACSCU) accreditation requirement on improvisation of laboratory equipment and for technology transfer program of the University through its Outreach Program.

Time and Place of the Study

The study was conducted from March 2015 to August 2015 at the Physics Stockroom, EN312, College of Engineering, Central Philippine University, Jaro, Iloilo City.

METHODOLOGY

Description of the Improvised Leaf Electroscope (ILE)

The improvised leaf electroscope, as presented in Figure 3, has the following major parts:

a. Chamber – It was made from an Erlenmeyer flask that encloses the entire parts except for the metal knob. The flask used had an approximate volume of 250 ml with a height of 14.5 cm and a bottom diameter of 8.5 cm.

b. Metal knob – This is where the plastic strip with a woolen cloth is closely pointed at to allow the transfer of electrons.

c. Cork stopper – This is where the metal knob and the metal rod were drilled at to make sure that these parts would not touch the circumference of the chamber. It has a diameter of 3 cm.

d. Metal rod – Part of the electroscope where two aluminum foil leaves are attached. The materials used for this study were aluminum, brass and copper. It has a fixed diameter of 0.33 cm but its length ranged from approximately 10 cm to 15cm.

e. Aluminum foil leaves – This part is responsible for showing whether there is an electrical charge flowing through the angle of deflection stand. The dimensions of the leaves varied from a width of 0.5 cm to 1 cm with a fixed length of 4 cm.

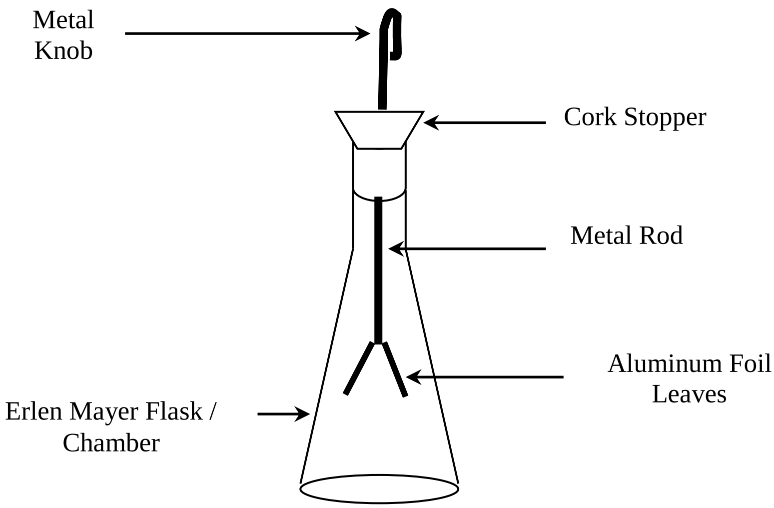

Figure 3. Schematic diagram of the improvised leaf electroscope showing its different parts

Charging the Electroscope by Induction

In order to determine the maximum approximate angle of deflection, the newly developed equipment was subjected to three tests. For the first test, three different kinds of metal rod namely, the aluminum rod, brass rod and the copper rod were used. Next, different sizes of the aluminum leaves which measure 0.5 cm, 0.7 cm and 1.0 cm were utilized. Lastly, the length of the metal rod used for this trial varied at 10.16 cm (4 inches), 12.7 cm (5 inches) and 15.24 cm (6 inches). The length of the aluminum leaves for the three tests was fixed to 4 cm. These were done to determine which sample can create the highest approximate measured angle of deflection.

The approximate measured angle of deflection was determined by mathematically based on the law of cosine ($\cos C = \frac{a^2 + b^2 - c^2}{2ab}$). The leaves will diverge during charging and the approximate distances between the two leaves were verified by taking a picture using a digital camera. Then the distance between the two leaves was measured using a ruler.

Evaluation and Testing of the Finished Design

Final evaluation of the improvised leaf electroscope was made at the EN312 Physics Stockroom. It was conducted by the Stockroom Coordinator with the help of the Laboratory Assistants of the Physics Laboratory. Testing was made by the Researcher, Physics Teachers and Students during the week of continuous operations.

Instrumentation

During the evaluation and testing of the improvised leaf electroscope, the following instruments were used:

Plastic rod. This rod was made of PVC tube. It is used to charge the electroscope by first rubbing it with a woolen cloth for a minimum of 1 minute.

Cork borer. It is used to bore cork stopper that was used to hold the metal knob and rod in place.

Ruler. This was used to measure the length of the aluminum foil.

Micrometer Caliper/Vernier Caliper. This was used to measure the width of the aluminum foil.

Digital camera. This was used to capture the approximate split distance between the two leaves.

Data Collection

During the performance evaluation of the improvised leaf electroscope, the following data were gathered:

1. Charging of the electroscope in terms of the different kind of metal rod versus the fixed length of the aluminum leaves.
2. Charging of the electroscope in terms of the different width of the aluminum leaves versus the fixed length of the metal rod.
3. Charging of the electroscope in terms of the different length of the metal rod versus the fixed length of the aluminum leaves.
4. Approximate angle of deflection formed by the foil in different width of the foil and different length of the rod used.
5. Specifications and dimension of the design.
6. Investment cost of the improvised leaf electroscope

RESULTS AND DISCUSSION

Principle of Operation

The electroscope is a sensitive detector of charge. It works on the principle that like charges repel. All kinds of friction can be shown to produce electrification by testing the rubbed object with this instrument. Before doing some testing, it should be made sure that there is no charge on the electroscope. The evidence that the electroscope has no charge is that the leaf hangs straight downward as shown in Figure 4. By rubbing the plastic strip with a woolen cloth and bringing the strip close to (but not touching) the knob of the electroscope, the electrons in the knob are repelled towards the leaves. Since, like charges repel, and since the leaves are free to move, they diverge as shown in Figure 5. When the plastic strip is removed from the knob of the electroscope, the electrons runs through the metal rod and the leaves would hang straight down together as shown in Figure 4.

Figure 4. Uncharged electroscope. The leaves hang straight down together.

Figure 5. Charged electroscope. The leaves diverge.

Approximate Measured Angle of Deflection

Data in Table 1 show that copper rod has the highest approximate split distance between the two leaves at 1.8 cm. which is numerically much higher compared to that of aluminum rod at 1.3 cm. and brass rod at 1.5 cm.

In terms of the approximate angle of deflection, copper rod also obtained the highest numerical value at 26^o. This was followed by the brass rod with a 22^o angle of deflection and aluminum rod with 19^o.

Table 1. Approximate Measured Angle of Deflection as Influenced by Different Kinds of Metal Rod Used as Stem

Test	Type of Rod	Length of the Leaf	Approx. Split Distance between the Two Leaves	Approx. Measured Angle of Deflection
		cm	cm	o
1	Aluminum	4	1.3	19°
2	Brass	4	1.5	22°
3	Copper	4	1.8	26°

Results in Table 2 show that out of the 3 samples of aluminum leaves with the width of 0.5 cm, 0.7 cm and 1.0 cm, the 0.5 cm width gave the highest approximate split distance between the two leaves at 2.1 cm and the 1.0 cm width attained the lowest value at 0.8 cm.

In terms of the approximate measured angle of deflection, the 0.5 cm width also gave the highest value at 30° while that of the 1.0 cm width was 11°. This shows that width is inversely proportional to the approximate measure angle of deflection which means that as the width of the leaves increases, the approximate measured angle of deflection decreases. Copper rod with a length of 6 in. were used in this particular test.

Table 2. Approximate Measured Angle of Deflection are Affected by Different Width of the Aluminum Leaves Used

Test	Width of the Aluminum Leaf	Length of the leaf	Approx. distance between the two leaves	Approx. angle of deflection
		cm	cm	o
1	0.5 cm	4	2.1	30^o
2	0.7 cm	4	1.6	23^o
3	1.0 cm	4	0.8	11^o

Table 3 presents the approximate measured angle of deflection as influenced by different length of the copper metal rod as stem. Copper rod was already used here because this was the metal that produced the highest angle of deflection as presented previously in Table 1. As shown in Table 3, out of the 3 samples used in testing the improvised leaf electroscope, the 6 in gave the widest split distance between the two leaves at 3.1 cm. followed by the 5 in. length at 2.5 cm. That of the 4 in. rod was only 1.8 cm.

When it comes to the approximate measured angle of deflection, the 6 in long rod also gave the highest numerical value at 46^0 which is much higher compared to the other two samples; the 5 in. rod deflected up to 36^0 while that of the 4 in. rod's deflection was 26^0 only. This test shows that the length of the copper rod was directly proportional to the approximate measured angle of deflection which means that as the length of the rod increases, the approximate measured angle of deflection also increases.

Table 3. Approximate Measured Angle of Deflection as Influenced by Different Lengths of the Copper Rod Used as Stem

Test	Length of the Copper Rod	Length of the leaf	Approx. Split Distance between the Two Leaves	Approx. Measured Angle of Deflection
1	4 in.	4 cm.	1.8 cm.	26^0
2	5 in.	4 cm.	2.5 cm.	36^0
3	6 in.	4 cm.	3.1 cm.	46^0

Construction/Fabrication Cost of Improvised Leaf Electroscope

The Improvised Leaf Electroscope has a very low investment cost of Php580.50 per unit compared to the other equipment already available inside the Physics Laboratory that has an investment cost of Php4,900.00 per unit. The benefit from using this improvised equipment is that it uses locally available materials but can operate and function in the same manner as the branded leaf electroscopes. It also shows that the market price of one unit of Improvised Leaf Electroscope was very much cheaper compared to the other equipment already available in the Physics Stockroom (Table 4).

Table 4. Construction/Fabrication Cost of Improvised Leaf Electroscope

A. Product Costing	
Direct Cost:	
Metal Rod	50.00
Erlenmeyer Flask	170.00
Cork	25.00
Alligator Clip	10.00
Total Direct Cost, Php	255.00
Indirect Cost:	
Labor	300.00
Contingency Cost (10% of direct cost)	25.50
Total Indirect Cost, Php	325.50
Production Cost:	
Total Direct Cost	255.00
Add: Total Indirect Cost	325.50
Production Cost per Unit, Php (Investment Cost	580.50
B. Product Pricing	
Production Cost per Unit, Php	580.50
Add: 20% Mark-up of the Production Cost, Php	116.10
Mark-up Price per unit, Php	696.60
Market Price, Php	750.00

SUMMARY, CONCLUSION, AND RECOMMENDATION

Nine improvised leaf electroscopes were constructed to test which samples can produce the highest approximate measured angle of deflection. Three various ways of tests were made with three trials for each testing.

In the first test, the researcher used three different types of metal rod (aluminum, brass and copper). During the second test, three copper rods of different length (4in, 5in and 6in) were constructed to determine which would get the highest result in measured angle of deflection. In third testing, three copper rods of the same length with various width of the aluminum leaves (0.5cm, 0.7cm and 1.0cm) were considered. All construction and tests were done at the Physics Stockroom located in En312.

Results revealed that the newly developed improvised leaf electroscope has the lowest operating cost per day of Php0.78. In case the aluminum leaves will be worn-out, the Improvised Leaf Electroscope has the cheapest value for repair and maintenance of Php0.19 compared to the other brands having the same function and operation.

It can be concluded, that copper rod is the best metal stem to use with approximate measured angle of deflection of 26^0. The appropriate length of the rod to use is 6 inches with 46^0 measured angles of deflection. The suitable width of the aluminum leaf is 0.5 cm. with 30^0 approximate measured angles of deflection. This study also shows relationship between length of the rod and width of the aluminum leaf. The length of the rod is directly proportional to the angle of deflection. As the length of the metal rod increases, the angle of deflection also increases while the width of the aluminum leaf is inversely proportional to the angle of deflection. As the width of the aluminum leaves increases the angle of deflection decreases.

It can also be concluded that copper rod with 6 inches length of the metal stem and 0.5 cm width of the aluminum leaf is the appropriate measurement and combination for future mass production.

Furthermore, the description of the electroscope in this study is similar to those of Noah Dorsey and Jean Antoine Nollet, physicists who invented one of the first electroscope.

Based on the findings and conclusion of the study, the following are recommended to improve the operation of the improvised leaf electroscope:

1. Good quality of plastic strips/rod (used to generate heat by rubbing) is needed to produce the widest split distance between the two leaves, which will also create the highest approx. measured angle of deflection. The plastic strips/rod used in this experiment were acquired outside the Philippines.
2. It is highly recommended to conduct a study on construction and testing of different kinds of plastic strips/rod to be used in electrostatic and electroscope experiments to minimize if not totally eliminate the use of materials bought outside the Philippines.
3. Good quality woolen cloth (material used to rub the plastic strip) is needed to attain maximum results.

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