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The comparison between total phenolic content and antioxidant activity of gyokuro, sencha and matcha from some tea store in Chiang Rai and Bangkok

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Abstract

The objective of this study is to compare the total phenolic content and antioxidant activity between gyokuro, sencha and matcha from Chiang Rai and Bangkok. This research is very helpful for customers to choose the best green tea based on scientific studies. The result, sencha samples from Bangkok noted that sencha contains the most total phenolic content (179.07 ± 1.15 mgGAE/1g extract, gyokuro (91.64 ± 0.15 mgGAE/1g extract) and matcha (78.51 ± 0.45 mgGAE/1g extract), and sencha is shown to have the highest antioxidant activity (IC_{50} equal to 0.0077 ± 0.0001 mg/ml), gyokuro (IC_{50} 0.0140 ± 0.0006 mg/ml) and matcha (IC_{50} 0.0191 ± 0.0005 mg/ml). Samples from Chiang Rai noted that sencha contains the most total phenolic content (105.56 ± 0.31 mgGAE/1g extract), matcha (101.08 ± 0.12 mgGAE/1g extract) and gyokuro (72.91 ± 0.07 mgGAE/1g extract). Sencha has the highest antioxidant activity (50% inhibitory concentration (IC_{50}) equal to 0.0084 ± 0.0001 mg/ml), matcha (IC_{50} is equal to 0.00168 ± 0.0005 mg/ml) and gyokuro (IC_{50} is equal to 0.0232 ± 0.0004 mg/ml. Based on the amount of total phenolic content and antioxidant activity, it can be concluded that sencha is the best type of green tea for consumption. Most green tea samples contain higher antioxidant activity than the BHT standard, especially the sencha sample from Bangkok has higher antioxidant activity than the BHT standard by around 2-folds. Many factors are involved in the amount of total phenolic content and antioxidant activity such as sunlight, storage duration, pH value, oxygen, temperature, ingredients in products etc.

Keywords : Camellia sinensis, Green tea, Total phenolic content, Antioxidant activity, DPPH

1. Introduction

Green tea is one of the most popular tea consumed as beverage, and has been known to have many benefits to the human body. Green tea is different from other teas, because its leaves are not fermented like black tea and oolong tea. Instead, green tea is prepared by having its leaves pass through a few steps, starting from the tea leaves being harvested from the *Camellia sinensis* plant, then through the quickly heated process by pan firing or steaming, and finally dried to prevent too much oxidation from occurring that would turn the green leaves brown and alter their fresh-picked flavor. There are many factors that can be reasons why there are many kinds of green tea because it depends on variety of *Camellia sinensis* used, growing conditions, horticultural procedure, manufacturing time of harvest and leaf grades (Zhang *et al*., 2018). There are many brands of beverage with different kinds of green tea products, such as gyokuro, sencha, matcha, etc. All of these types of tea leaves are also called green tea, but each contains different levels of antioxidant, as well as differing levels of antioxidant activity. Thus, from this research we want to determine which kinds of green tea contains the most antioxidant and can be the most effective one for human health benefits.

Green tea is a kind of beverage that many people are interested in because there are a lot of benefits as it contains healthy bioactive compounds. Catechin is available in flavonoid group about 60-70%. Most of catechin includes (-)-epigallocatechin-3-gallate (EGCG), (-)-epigallocatechin (EGC), (-)-epicatechin-3-gallate (ECG) and (-)-epicatechin (EC) (Khan& Mukhtar, 2018). Green tea is contained with polyphenol antioxidants, including a catechin called Epigallocatechin gallate (EGCG). EGCG is one of the most powerful antioxidant in green tea. *Camellia sinensis* has a lot of beneficial properties such as anticancer, anti-inflammation, antioxidant effects and etc. Anti-oxidation effects of green tea are mainly involved in inhibition of free radicals and lipid peroxidation. The study showed that drinking green tea four glasses per day within 4 months can lead to reduce the urinary levels of 8-hydroxydeoxyguanosine (Musial, Kuban-Jankowska and Gorska-Ponikowska, 2020).

In this research, 3 kinds of popular green tea were chosen based on customer recommendation and preference, namely the gyokuro, sencha and matcha. There are different from its manufacturing and production processes. Gyokuro: the plants are shaded from direct sunlight for approximately 3 weeks before the spring harvest. Once harvested, the leaves are rolled and dried naturally (Gyokuro dewy-colored Japanese green tea, 2019) then sencha: after the sencha leaves are picked, they are steamed immediately and taken away for preparation. Sencha is then dried after the steaming process and, when dried enough, rolled into a variety of shapes until it is completely dried and shriveled (Sencha, 2021). Matcha's manufacturing process differs from gyokuro in that the leaves are not rolled at all. After steaming gyokuro leaves, they are thoroughly dried, then ground into a super-fine powder, and that powder is known as matcha (Matcha, 2021).

In this research green tea samples are taken and from 2 places. First place, the green tea sample were purchased from a tea store in Amphoe Mueang, Chiang Rai province (material green tea were grown in Chiang Rai province). The second place, the green tea samples were purchased from the tea store in Bangkok which are imported from Japan.

2. Objectives

2.1 To compare the amount of total phenolic content of gyokuro, sencha and matcha green tea by using Folin-Ciocalteu

2.2 To compare antioxidant activity of gyokuro, sencha and matcha green tea using DPPH radical scavenging (DPPH method).

3. Materials and methods

This research has based on Rusak G, Sola I & Vujcic Bok V (2021)'s protocol because it is involved in studying matcha and sencha green tea extracts with regards to their phenolics pattern and antioxidant and antidiabetic activity during in vitro digestion, and also it is the latest review. And to find the crude extraction of each type of green tea is based on Hui Ru tan (2019) and L.K. Takao (2014)'s protocol (Hui Ru Tan *et al*., 2018; Takao, Imatomi and Gualtieri, 2015)

3.1 Chemicals and materials

All chemicals and reagents are from (OHAUS Adventurer, USA), (PYREX, Germany), (MARTIN CHRIST, Germany). Enzymes are from SIGMA-ALDRICH, Switzerland), (ACROS ORGANICS, China) and (KEMAUS, Australia). Samples of gyokuro, sencha and matcha are purchased from the same tea stores in Chiang Rai and Bangkok.

3.2 Preparation of green tea extract

Each sample of gyokuro, sencha and matcha is prepared by mixing 10 grams of each sample mix 100 mL of deionized water at 80^{o}C, stirred for 5 minutes then filtered by Whatman No.1 filter paper and vacuum pump unit. Filtered green tea extract is kept in refrigerator at 0^{o}C. Then filtered green tea extract is submitted to freeze-dry for 3-days and wait until all the substance of each extracted green tea is completely dry. Next, the separation process between liquid and each extracted green tea sample has done by rotary evaporator, and wait until liquid from each extracted green tea sample has completely evaporated. Then the crude extraction of each green tea sample is collected.

3.3 Methods for total phenolic content by using Folin-Ciocalteu

1) Prepare Folin-Ciocalteu reagent at a concentration of 10% in 100 mL of distilled water.

2) Prepare Sodium carbonate (Na_2CO_3) at a concentration of 2.5% (w/v) in 100 ml of distilled water

3) Prepare Gallic acid at a concentration of 3 mg/mL in distilled water.

4) Prepare sample at a concentration of 10 mg/mL in distilled water, and diluted at concentration 0.3125 and 0.0781 mg/mL. Dilute the gallic acid and sample by distilled water to be concentrated at 0.3, 0.15, 0.075, 0.0375, 0.0188, 0.0094 and 0.0047 mg/mL then pipette the substance from each concentration in the amount of 20 μL and mix with 100 μL of Folin-Ciocalteu reagent and shake, then keep in the darkness for 5 minutes. Next, add 80 μL of Sodium carbonate anhydrous (Na_2CO_3), shake and keep in the darkness for 20 minutes. Finally, measure the light absorbance by UV- visible spectrophotometer at 760 nm. Each sample is dome triplicate and use distilled water as reference solution.

3.4 Methods for antioxidant activity by using DPPH method

The antioxidant activity of green tea samples is measured by 2,2-diphenyl-1-picrylhydrazyl (DPPH). The DPPH is prepared at concentration of 0.004 g/ 1 mL in EtOH 100 ml. Prepare standard BHT in EtOH (50mg/1mL) and dilution at different concentrations (1, 0.5, 0.1, 0.05 and 0.025 mg/mL). Prepare tea extract in EtOH at different concentrations (1, 0.5, 0.1, 0.05 and 0.0025 mg/mL).

In each concentration, the test will include 1 tube of reference solution and 3 tubes of control solution, 1 tube of blank sample and 3 tubes of sample solution then add DPPH into each tube at different concentrations, shake and keep in the dark for 30 minutes and wait for the reaction to be completed. After that, light absorbance is measured by UV-visible spectrophotometer at 517 nm. All the tests were carried out in triplicate. Then Calculate % inhibition at 50% by comparison with BHT standard solution, then calculate IC_{50}. IC_{50} stands for 50% inhibitory concentration which means concentration value of tested sample that can inhibit 50% of reaction.

% inhibition = [(Abs Control – (Abs Sample – Abs Blank sample))/Abs Control] X 100

3.5 Statistical analysis

All results are evaluated using Program SPSS (MFU) version 21.0. Results gathered from the comparison of the amount of total phenolic content and antioxidant activity in 3 types of green tea are done by one-way ANOVA. Let the confidence interval be 95% ($P \leq 0.05$).

4. Results

Green tea extraction Each the material green tea 10 g were mixed with distilled water 100 mL and stirred at 80^{o}C for 5 minutes. After the process of freeze-drying is done, the crude extract of green tea from Chiang Rai has shown the yield of gyokuro, sencha, matcha extracts

are 19.34, 20.16, and 30.75 % yield, respectively. While, the crude extract from Bangkok has shown gyokuro, sencha, matcha extracts are 15.59, 17.33, and 28.98 % yield, respectively (Table 1). Matcha has more yield in terms of crude amount per extraction than other kinds of green tea due to its finely ground powdered appearance. Because matcha is a finely ground powdered appearance, it is easier to be processed and thus yields more crude extract than other types of green tea.

Table 1 Results of green tea extraction

Green tea samples	Amount of initial substance (grams)	Final amount of crude extraction (grams)	%yield
Gyokuro in Chiang Rai	10	1.9343	19.3430
Sencha in Chiang Rai	10	2.0159	20.1590
Matcha in Chiang Rai	10	3.0745	30.7450
Gyokuro in Bangkok	10	1.5591	15.5910
Sencha in Bangkok	10	1.7331	17.3310
Matcha in Bangkok	10	2.8980	28.9800

Total phenolic content

Total phenolic content (TPC) of green tea extract from Chiang Rai; the result shows that sencha contains the highest level of total phenolic content, having a mean of 105.5575, matcha and gyokuro, having the means of 101.0803 and 72.9142. Additionally, the result generated from the One Way Analysis of Variance also confirms that the difference in the type of tea significantly lead to the difference in the level of total phenolic content at 95 percent confidence level, having the P-value of <0.001 which is lower than 0.05. Green tea extract from Bangkok, sencha contains the highest level of total phenolic content, having a mean of 179.0741, gyokuro and matcha, having the mean of 91.6373 and 78.5108. The result generated from One Way Analysis of Variance also suggests that the difference in the types of tea significantly lead to the difference in the level total phenolic content at 95 percent confident level as the P-value is equal to <0.001 (Table 2). The result indicated that sencha show the highest level of total phenolic content both from Chiang Rai and Bangkok, and the TPC of sencha from Bangkok show the highest level , and more than gyokuro and matcha almost two folds.

Table 2 The difference in the level of total phenolic content (mg GAE/1 g extract) of green tea, each three types from Chiang Rai and Bangkok

Independent Variable		$\bar{x}$	S.D.	df	F	P
Green tea Types (Chiang Rai)	Gyokuro	72.9142	.07050	8	24655.821	<0.001
	Sencha	105.5575	.30730			
	Matcha	101.0803	.12211			
Green tea Types (Bangkok)	Gyokuro	91.6373	.15365	8	17261.767	<0.001
	Sencha	179.0741	1.15411			
	Matcha	78.5108	.45003			

Note: df is the degree of freedom, which refers to the maximum number of logically independent values, which are values that have the freedom to vary, in the data sample. F-value is calculated as variation between sample means / variation within the samples. The higher F- value means higher the variation between sample means relative to the variation within the samples. The higher the F-value means, the lower corresponding P-value. A p-value is a statistical measurement used to validate a hypothesis against observed data. A p-value of 0.05 or lower is generally considered statistically significant.

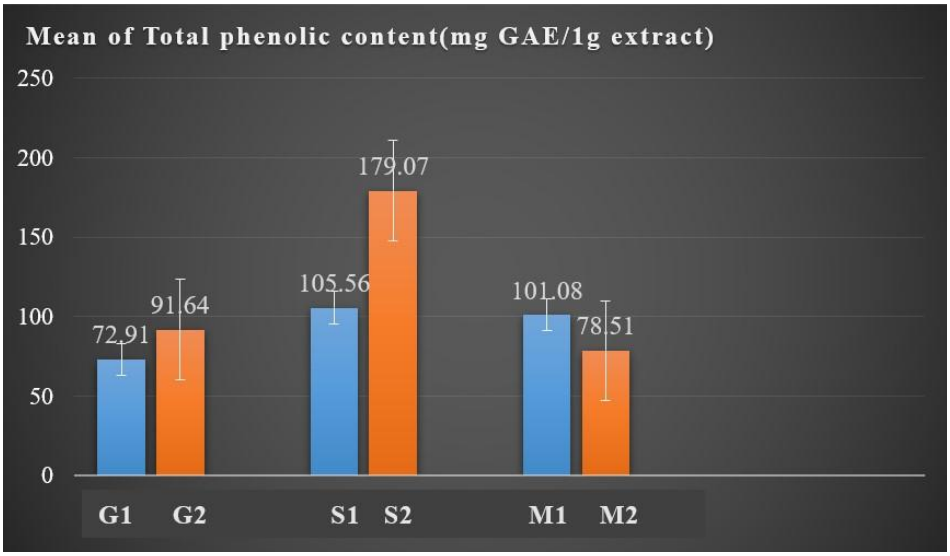

Figure 1 The total phenolic content of three types of green tea from Chiang Rai and Bangkok (Mean ± SD, n=3); G1, S1 and M1 refers to gyokuro, sencha and matcha from the same tea store in Chiang Rai. G2, S2 and M2 refers to gyokuro, sencha and matcha from the same tea store in Bangkok.

Antioxidant activity

All green tea extract from Chiang Rai and Bangkok are subjected to test antioxidant activity by using DPPH method. The green tea extract from Chiang Rai showed the antioxidant activity in IC_{50} range 0.0083-0.0233 mg/mL. Sencha extract showed the highest antioxidant activity in IC_{50} at 0.0083 mg/mL, matcha and gyokuro, having the means of 0.0167 and 0.0233 mg/mL. Moreover, the result generated by One Way Analysis of Variance also shows that the difference in the types of green tea significantly leads to the difference in the level of IC_{50} at 95 percent confidence level as P-Value is equal to <0.001 which is lower than 0.05. The antioxidant activity of green tea extract from Bangkok, the sencha extract showed the highest antioxidant activity in IC_{50} at 0.0080 mg/mL, gyokuro and matcha, having the means of 0.0140 and 0.0190 mg/mL. The result generated from One Way Analysis of Variance also confirms that the difference in the types of green tea significantly leads to the difference in the level of IC_{50} at 95 percent confidence level as the P-Value is equal to< 0.001 which is lower than 0.05 (Table 3).

Table 3 The difference in the level of IC_{50} (mg/mL) of three types of green tea from Chiang Rai and Bangkok

Independent Variable		$\bar{x}$	S.D.	df	F	P
Green tea Types (Chiang Rai)	Gyokuro	0.0233	.00058	8	508.333	<0.001
	Sencha	0.0083	.00058			
	Matcha	0.0167	.00058			
Green tea Types (Bangkok)	Gyokuro	0.0140	.00100	8	136.500	<0.001
	Sencha	0.0080	.00000			
	Matcha	0.0190	.00100			
BHT (Standard)		0.0172	0.0005			

Note: df is the degree of freedom, which refers to the maximum number of logically independent values, which are values that have the freedom to vary, in the data sample. The F-value is calculated as variation between sample means / variation within the samples. The higher F- value means higher the variation between sample means relative to the variation within the samples. The higher the F-value means, the lower corresponding P-value. The p-value is a statistical measurement used to validate a hypothesis against observed data. A P-value of 0.05 or lower is generally considered statistically significant.

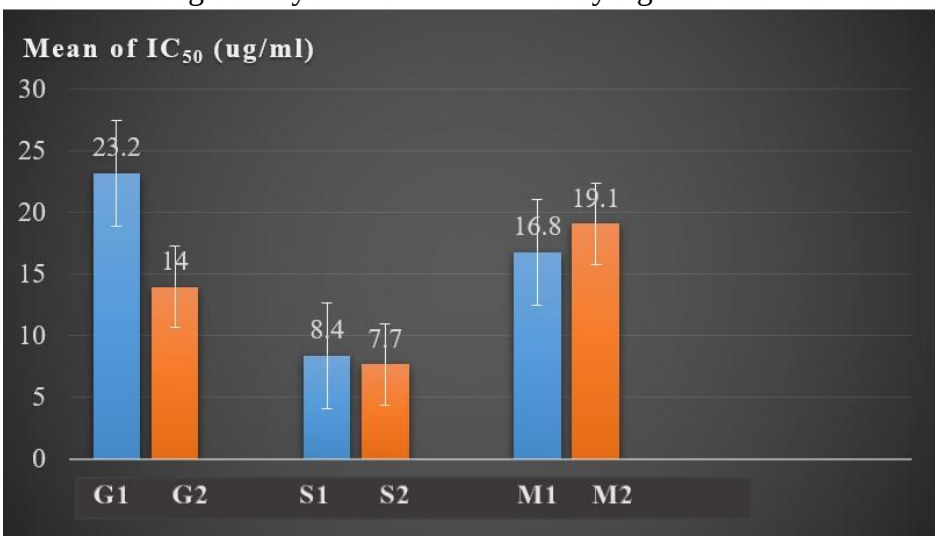

Figure 2 The antioxidant activity of three types of green tea from Chiang Rai and Bangkok (Mean ± SD, n=3); G1, S1 and M1 refers to gyokuro, sencha and matcha from the same tea store in Chiang Rai. G2, S2 and M2 refers to gyokuro, sencha and matcha from the same tea store in Bangkok.

5. Discussion

Matcha has more yield in terms of crude amount per extraction than other kinds of green tea due to its finely ground powdered appearance. Because matcha is a finely ground powdered appearance, it is easier to be processed and thus yields more crude extract than other types of green tea, as shown in the result of this experiment.

We concluded that sencha contains the most total phenolic content and has the highest antioxidant activity. Due to the manufacturing process, sencha is grown in sunlight directly

and is different from gyokuro and matcha, which are grown under shade. The cultivation process of sencha is involved in photosynthesis reaction because it is grown in sunlight directly, different from gyokuro and matcha. Photosynthesis can produce secondary metabolites, in this thesis secondary metabolites are focused on phenolic and flavonoid which are founded in green tea. Secondary metabolites are divided in many classes and many biosynthetic pathways. In this thesis focus only on pathways of phenolic compounds which are important substances involved in antioxidant activity of green tea.

Phenols are found in green tea and occur in the pathways, starting from photosynthesis that is involved in the glycolysis reaction, which converts glucose into pyruvate. Then pyruvate oxidation converts pyruvate into acetyl -CoA, next acetyl-CoA is converted into malonyl-CoA by the enzyme acetyl-CoA carboxylase. Malonyl-CoA builds polyketide synthesis, finally lead to the production of phenols and flavonoid (Michael Wink, 2010; Maike Petersen, Joachim Hans and Ulrich Matern, 2010), this reaction is the reason sencha has the highest antioxidant activity and the most total phenolic content. In conclusion, sencha is cultivated via exposure to sunlight directly; sunlight help stimulate the process of photosynthesis, which produces secondary metabolites, which are phenols and flavonoid that can be found in green tea. Meanwhile, gyokuro and matcha are grown under shade, in which photosynthesis does not take place. That is the reason gyokuro and matcha have lower antioxidant activity and contain less total phenolic content (Figure 3).

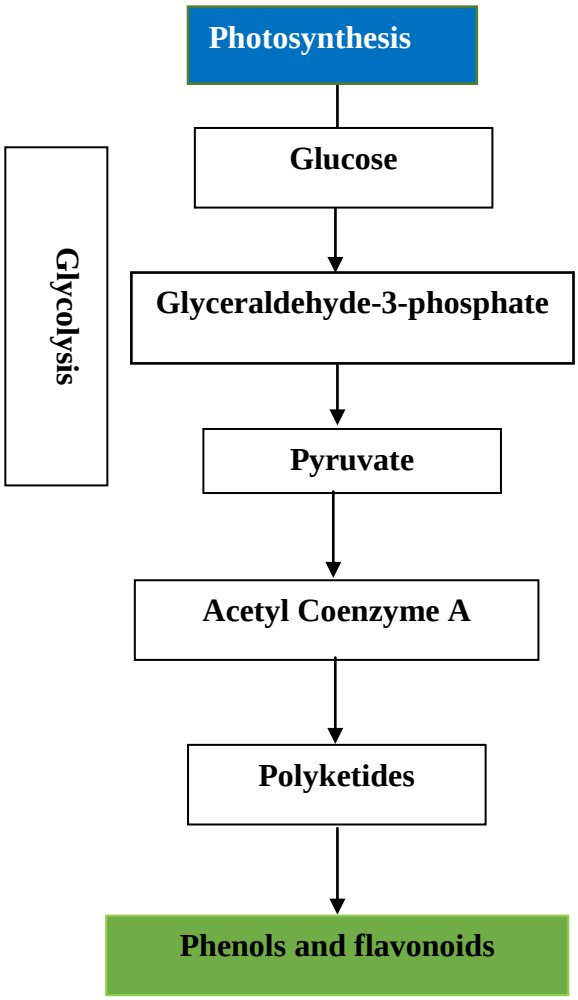

Figure 3 The main pathways leading to secondary metabolites

Flavonoid and catechins being the main substances that can be found in green tea. They are produced via shikimate pathway, which starts from photosynthesis. The shikimate pathway starts from eryhthrose-4-phosphate and phosphoenolpyruvate that are converted to chorismate which is the precursor of many aromatic secondary metabolites. The shikimate pathways are closely related to many aromatic amino acids such as L-tryptophan, L-phenylalanine and L-tyrosine (Michael Wink, 2010; Maike Petersen, Joachim Hans and Ulrich Matern, 2010). From this shikimate pathway is another reason sencha has the highest antioxidant activity and contain the most total phenolic content (Figure 4).

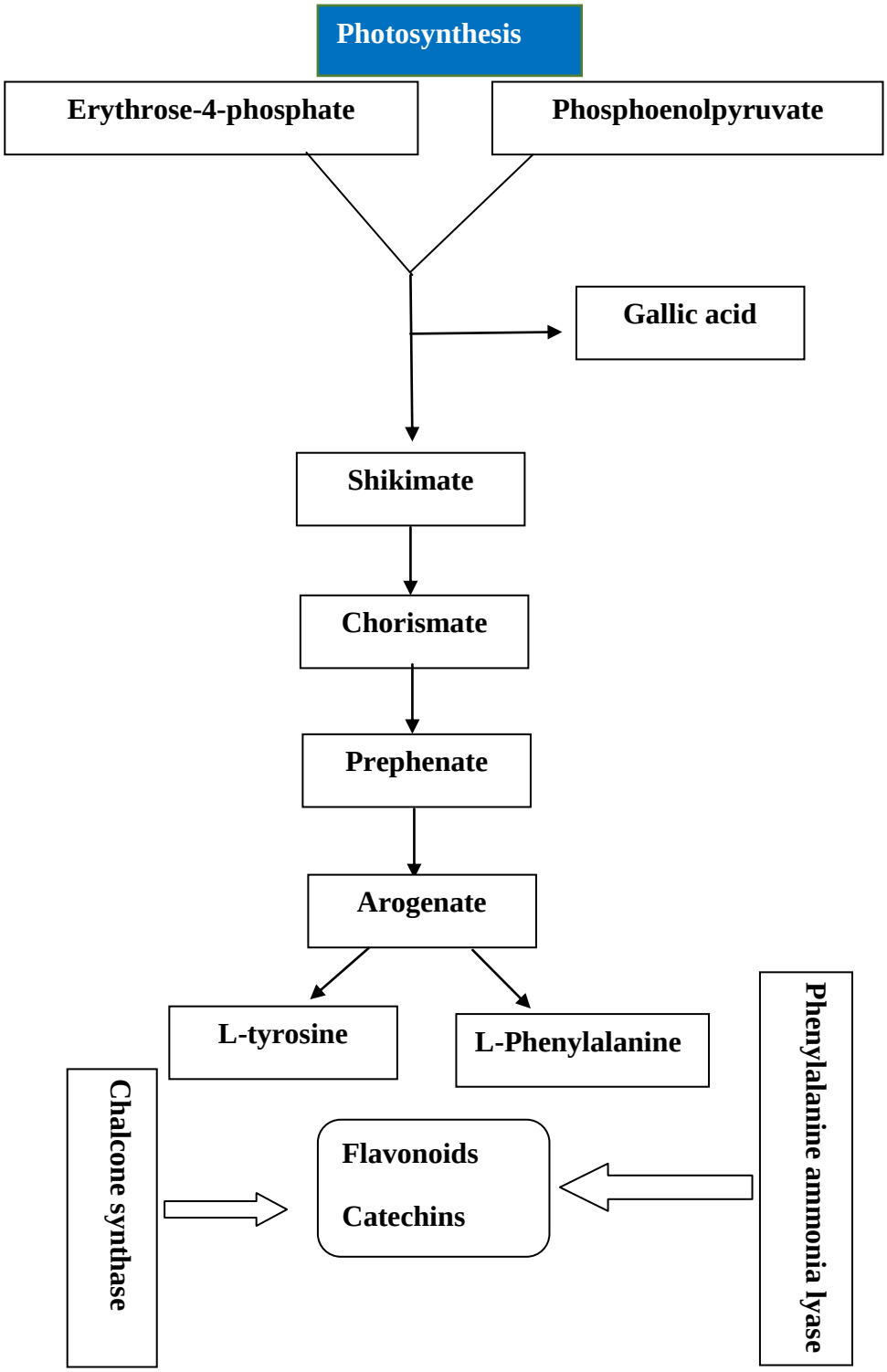

Figure 4 Several pathways of secondary metabolites

The main reason gyokuro and matcha has less amount of total phenolic content and less antioxidant activity than sencha is because both gyokuro and matcha do not go through photosynthesis reaction, because both are grown under shade. Another reason gyokuro and matcha from Chiang Rai and Bangkok or the same kind of green tea but from different places has different results is due to other factors, mainly temperature, pH, oxygen availability and presence of metal ions (Sang *et.al*, 2015), meaning catechin is highly stable in acidic pH and higher temperature can lead to unstable of tea polyphenol (Liang *et.al*, 2017). Leaf grades, plantation elevations and geographical locations are involved, and can lead to higher or lower total antioxidant activity and more or less amount of total phenolic content, meaning fresher green tea leaves and low elevation of green tea growth have higher antioxidant activity and contain more amount of total phenolic content than old green tea leaves and high elevation of green tea growth (Musial, Kuban-Jankowska and Gorska-Ponikowska, 2020). Sencha sample from the tea store in Bangkok (Originated from Japan) contain higher amount of total phenolic content and has higher antioxidant activity than sencha sample from Chiang Rai (grown in Amphoe Mueang, Chiang Rai) due to many factors, such as sencha leaves from Bangkok are fresher, grown at lower elevation, smaller size of tea leaves than sencha leaves from Chiang Rai. Total phenolic content and antioxidant activity depends on all of these factors (Musial, Kuban-Jankowska and Gorska-Ponikowska, 2020).

6. Conclusion

"Sencha" is the best green tea to drink because sencha contain the highest amount of total phenolic content mainly catechin, and highest antioxidant activity. This research uses deionized water as the solvent, because deionized water can be consumed, and thus served as the perfect solvent in terms of projecting the beneficial effects of green tea on the human body. With many different types of green tea in the market today, this research will most definitely be helpful for customers to make s good wise decision on which kind of green tea would benefit them most health-wise.

The gyokuro and matcha products in daily are mainly used in beverages but matcha is more commonly found in bakery ingredients. Although the result of total phenolic content and antioxidant activity from both Chiang Rai and Bangkok differ only slightly in results, gyokuro is more expensive than matcha.

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The role of urban trees: stomatal characterization, carbon sequestration, and socio-cultural conservation

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Abstract

The Philippines is one of the countries vulnerable to the effects of climate change. Anthropogenic activities induce emissions of greenhouse gases that elicit environmental impacts including, but not limited to, flood risk and air pollution. Green spaces and trees in cities serve as the city's lungs that aid in the reduction of pollutants and greenhouse gas emissions. The ecosystem services of trees are often neglected due to a lack of evidence in a local setting. The ability of trees to sequester carbon is essential in lowering carbon emissions by naturally removing carbon from the atmosphere. Highly populated areas are more prone to these effects due to the increasing demand of economic activities. In Angeles City, the urban trees along the Friendship Highway are presently under removal vulnerability attributable to the city's development activities. The purpose of the study is to provide more information about the role trees play in urban landscapes, specifically in Angeles City. Specifically, the study aims to a) microscopically describe the foliage structure and leaf stomata, b) estimate and assess the carbon content of the rain trees, and c) determine its importance in terms of socio-cultural conservation. In terms of air quality, a rise in PM2.5 (+89.29%) and PM10 (+83.33%) from measurements obtained in areas with significant vehicle traffic. From the sample of 20 rain trees, more than 177 kilograms of carbon dioxide was sequestered. Findings from the study offer relevant and science-based evidence in support to save the threatened trees.

Keywords : rain trees, air quality, carbon storage, Friendship highway

Introduction

Climate change is a natural occurrence exacerbated by human-induced emissions of greenhouse gases (Rajak, 2021). Caused mainly by the burning of fossil fuels, the most prevalent anthropogenic greenhouse gas is carbon. Over the years, the atmospheric CO2 concentration has increased dramatically. Nevertheless, trees are an essential pathway for CO2 to transition from atmospheric gas to solid form. As such, the role of forestry activity became relevant in reducing high levels of greenhouse gases and an approach to mitigate climate change (Superales, 2016). Thus, the ability of trees to sequester carbon is essential in lowering carbon emissions by naturally removing carbon from the atmosphere.

Urban greening has evolved into a biological ecosystem with various environmental management roles. Green spaces and trees in cities serve as the city's lungs that aid in the reduction of pollutants and greenhouse gas emissions, carbon sequestration, temperature regulation, minimize rainwater runoff, sound dampener from vehicles, and offer recreational, social, psychological, and aesthetic gains to the city (Sicard et al., 2018). Since plants are stationary, they are frequently subjected to pollution and thus can act as crucial sinks and monitors to air pollutants. Also, plant morphology varies predicated on microclimatic variables; the physical characteristics of plants constitute effective determinants of habitat quality (Alushi & Veizi, 2020). Moreover, numerous studies cited that urban green spaces

and urban trees can reduce air pollution and greenhouse gas emissions (Livesley et al., 2016; Sirakaya et al., 2018; Sicard et al., 2018). According to Olivera-Lora et al (2019), attitudes toward residential trees may significantly influence the management of green spaces with substantial implications for urban sustainability.

Friendship Circumferential Road, famously known as Filipino-American Friendship Highway, is located in Angeles City, Pampanga, at 15°07'49.9"N 120°34'25.8"E. The 3.7 kilometers long road is home to 259 urban trees. Residential subdivisions, commercial buildings, and other businesses make up a large portion of the location (Pingul et al., 2021). The urban trees along the Friendship Highway are presently under removal vulnerability attributable to the city's development activities. It was concluded in a study that countries with higher energy intensity also produce higher carbon emissions (Liddle & Lung, 2010). The notion that the energy consumption of a country determines its economic activities remains relevant. With that, highly urbanized areas are more prone to carbon emissions and the effects of climate change (Nowak, 2000). Consequently, automotive emissions have been identified as one of the most prevalent contributors to urban air pollution, which is now a growing concern due to urbanization (Allahnouri et al., 2018). In such a context, urban trees can efficiently attenuate the implications of impurities, notably air pollutants; by fixing carbon through photosynthesis and holding it as biomass, the trees function as a CO2 sink. As a result, roadside trees are projected to improve air quality (Hukum Singh et al., 2020).

The ecosystem services of trees are often neglected due to a lack of evidence in a local setting. Many types of research have divulged the crucial role of trees in maintaining a good quality of air, especially in urban areas (Livesley et al., 2016). Nonetheless, there is still an increasing need to show a research-based viewpoint. Grasping the contributions of urban trees to the community is a step in improving the stewardship and concern of the citizens (Song et al., 2018). Alongside urban trees, numerous studies favor the need and benefits of urban green spaces (Escobedo and Nowak, 2009; Pataki et al., 2011). These researches highlight the ecosystem services of urban green areas, particularly in ameliorating air pollution and greenhouse gas emissions (Sicard et al., 2018). The presence of urban green spaces was also reported to contribute to the regulation of air temperature, mitigation of storm-water runoff, and carbon sequestration (Sicard et al., 2018; Livesley et al., 2016). On the other hand, urban trees and green spaces also provide cultural services as part of their ecosystem services. These include cultural services such as reduced noise pollution and recreational, social, psychological, and aesthetic provisions (Sicard et al., 2018). Furthermore, urban green spaces constitute a lower carbon dioxide concentration due to the presence of vegetation (Fares et al., 2017).

A diverse range of studies from different countries researches carbon estimation (Negi et al., 2003; Kiran & Kinnary, 2011; Superales, 2016). Most of them used allometric equations to estimate the carbon sequestration properties of various tree species. Two methods are commonly utilized to measure carbon sequestration a) ash method and b) regression method. According to Negi et al. (2003), species with the most carbon stored are more efficient in carbon sequestration.

Roadside plantations are the initial layer of protection against urban automobile pollution; these trees are also susceptible to strain. Trees in the proximity of stressful settings show a variety of physiological changes. Particulates within the atmosphere can be further deposited, retained, or incorporated in the plant structures (Allahnouri et al., 2018). In an analysis conducted by Abbasi et al. (2018), the paper stated that among plant organs, foliage is more vulnerable to external stressors as they conduct out the majority of the plants' physiological processes, including photosynthesis. Having said that, leaves have a higher

ability to respond to altering environmental factors. Hence, assessing the different responses and modifications of foliage to air pollution could be a realistic representation of plant species productivity in urban conditions.

By collecting dust particles onto the leaf surface, trees function as a natural filtration system, optimizing air quality (Allahnouri et al., 2018). According to the study of Nowak et al., (2018) trees absorb gaseous air pollution predominantly through leaf stomata absorption, but then again, the plant surface additionally filters certain pollutants. Stomata are structures of the leaves located at the upper or basal epidermis of leaf epidermal cells. It opens or closes as a general response to its environmental conditions, like the light intensity and osmotic adjustments, allowing Carbon dioxide to oxygen conversion via photosynthesis to infiltrate the plant for photosynthetic activity. The preponderance of stomata on a leaf is localized on the dorsal side; however, some genera have some on the ventral surface (Alushi & Veizi, 2020).

Albizia saman (syn. *Samanea saman (Jacq.) Merr*.) is a Fabaceae family flowering tree with an umbrella-shaped canopy. Rain trees are native to Mexico, Peru, and Brazil, but they have also spread to South and Southeast Asia, as well as Pacific islands. Rain Tree plants' initial development is slow, but their survival rate is high, therefore they've been chosen to be planted along urban roadsides for several years (Sharma & Jamble, 2019) giving shading for people passing along the roadways (Ayodele et al., 2003). The rain tree (*A. saman*) is a well-known and widely planted massive tree in the Philippines. They are nitrogen fixers and are valued for their long-lasting, environmentally friendly hardwood, which may be utilized for furniture, hand-carved bowls, and ornamental items (Anil et al., 2018). Sia Su et al. (2018), carried out research on Major Roadsides in Metro Manila, Philippines. *S. saman* (in Ortigas Ave.) is among the few species of trees with a higher Air Pollution Tolerance Index (APTI) that has been classified as air pollution tolerant.

Objectives

The scarcity of records and scientific studies further adds to the trees' disadvantage. Thus, the study emphasizes the importance of rain trees as urban trees planted along Friendship Highway. Research for this study yielded no information on stomatal characterization, carbon sequestration, and socio-cultural conservation by rain trees along Friendship Highway. Specifically, the study aims to a) microscopically describe the foliage structure and leaf stomata, b) estimate and assess the carbon content of the rain trees, and c) determine its importance in terms of socio-cultural conservation. The aim of this study is to illuminate these uncharted topics and provide a local and research-based perspective about the threatened trees in Angeles City.

Materials and methods

A total of 21 samples were collected along the Fil-Am Friendship Highway and at the greenspace within Villa Teresa Village in Angeles City on January 5, 2022. The trees were sampled using opportunistic sampling throughout the treatment site (Fil-Am Friendship Highway), beginning at the intersection of J.P. Rizal Street Fil-Am Highway, Barangay Cutcut, Angeles, Pampanga with a distance of 1.3 kilometers (Figure 1).

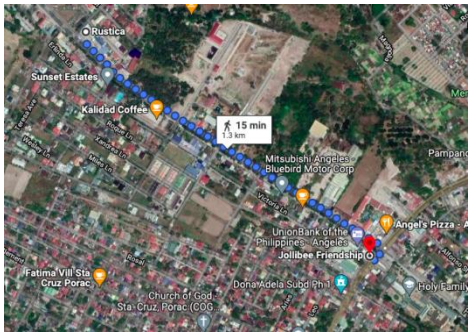

Figure 1 Map of the study site

Tree identification

For the tree identification, the researchers used the Philippine Medicinal Plants database and the study of Pingul et al., (2021) as references. The form of the tree (Figure 2A), leaves (Figure 2B), flowers (Figure 3D), and fruits (Figure 3C) were assessed to classify the tree as *A. saman*. Species identification verification was done by an expert from the Department of Biological Sciences, Angeles University Foundation.

Figure 2 A-B Showing the (A) form of the DM17 Tree and leaves (B) from DM01 both identified as *A.saman* in Fil-Am Friendship Highway

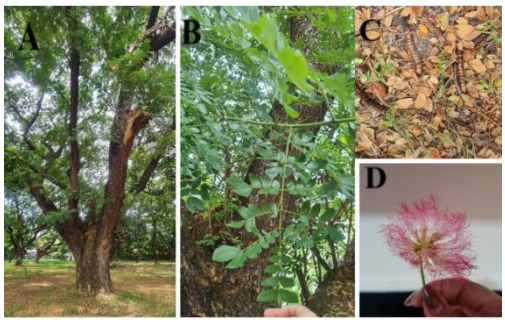

Figure 3 A-D Photo showing the (A) form, (B) leaves, (C) fruits, and (D) flower the identified *A. saman* control tree situated in Villa Teresa Clubhouse

From the selected trees, three chunks of 2.54 cm x 12.7 cm of barks were peeled off from three different regions. The part where bark samples were collected was sealed with clear nail polish to avoid infection on trees. On the other hand, an equal amount of healthy, mature leaves well exposed to sunlight were collected in each rain tree. The collected samples were labeled according to the collection site and kept in a plastic bag to prevent the leaves from withering. Additionally, the diameter at breast height (DBH) of each tree was measured along with environmental parameters such as particulate matter levels.

After collecting samples, necessary data were gathered by measuring the fresh weight, dry weight, and ash weight of the samples. Using a weighing scale, the fresh weights of bark (Figure 4A) and leaf (Figure 4B) samples were measured. Dry weight was measured after heating the samples (Figure 4C-D) in the oven under 108-112 °C for 18 hours. Subsequently, dry samples from the oven were subjected to further heat for combustion for an additional 4 hours to measure the ash weight.

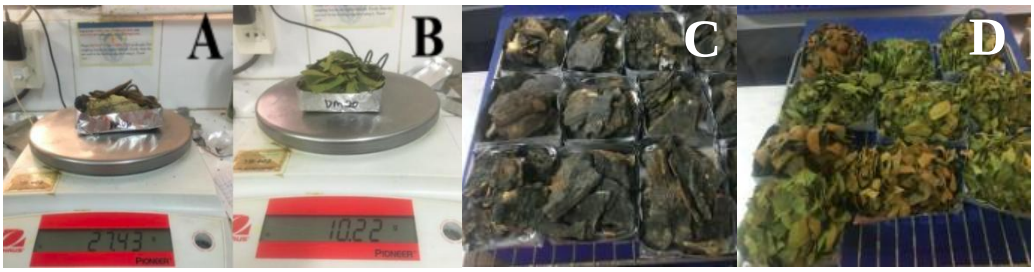

Figure 4 A-D Weighing of bark (A) and leaf (B) samples, and the dried bark (C) and leaf (D) samples

Computations of Properties

For the computation of data, the researcher based on the allometric equations from previous studies (Superales, 2016; Negi et al., 2003). The formula used for each property are as follows: **Moisture Content (%)** = [(Fresh Weight - Dry Weight) / Fresh Weight] x 100, **Organic Matter Content (%)** = [(Dry Weight - Ash Weight) / Dry Weight] x 100, and **Dry Matter Content (%)** = (Dry Weight / Fresh Weight) x 100.

Carbon Content and Storage Estimation

The allometric equation used to compute the carbon content from organic matter is as follows: Carbon % = 100 - (Ash weight + 53.3), wherein 53.3 is the molecular weight of O_2 in $C_6H_{12}O_6$ (Negi et al., 2003). To get the carbon content in grams, the percentage of carbon was divided by the organic matter that was previously calculated. Correspondingly, to estimate the carbon dioxide storage in each tree, the carbon content will be multiplied by 3.6663, the carbon dioxide to carbon ratio (Superales, 2016).

Air Quality Assessment

A digital meter (Estore 9 in 1 Air Quality Detector) was used to assess the air quality of the control and the locations of the subject trees. The air temperature, Particulate Matter (PM) PM1, PM2.5, and PM10 levels were then evaluated.

Stomatal Characterization

For the stomatal characterization, only five trees were observed; 4 trees from the highway were included, specifically tree numbers 68, 111, 155, 161, and 1 control tree inside the Villa Teresa Village. The specimen was drawn from 7:30 am to 2:00 pm, generally when the stomata are often open. Laboratory work was done immediately after collection. The stomatal micromorphological properties of the leaf sample were the leaf parameters evaluated.

Following the methods of the studies of Des et al. (2021); Mudakir et al., (2021); and Vauzia et al. (2020), the replica approach was employed, which involved rubbing clear nail polish over the bottom and upper surfaces of the leaves in the middle and allowing it to settle. The nail polish-covered portion is then attached to a clear scotch tape and carefully

pulled before being put on the glass slide. The findings were photographed using a Samsung Galaxy Note 20 camera after being examined under a Novel Optics light microscope at a magnification of 40x10.

Adapted from the study of (Des et al., 2021; Mudakir et al., 2021), the ocular micrometer was used to measure the size of the stomata and the length of trichomes. To calculate the stomatal density, identify the area of the field of view; in this case, the area field of view is 0.00159043 (mm2). The formula of stomatal density is as follows: **Stomatal density** = the number of stomata / Area Field of View. Using the calibrated ocular micrometer, micro-morphologic data were recorded at appropriate magnification.

Determination of stomata distribution

Similar to the study of Des et al. (2021), the stomata were categorized as amphistomatic (stomata are located on both plant leaves), epistomatic (stomata are visible on the top side of the leaf only), or hypostomatic (stomata just present on the bottom side of the leaves).

Socio-cultural conservation

The socio-cultural conservation values of urban trees were assessed using survey questionnaires through Google Form. The survey was done with the approval of the Ethics Review Committee of the Angeles University Foundation. A convenient way of selecting the respondents was applied due to the limitations imposed by the pandemic. Hence, the respondents were initially the 94 first-year to fourth-year Biology students and nine full-time faculty members of AUF's Biology Department; 48 out of the total 103 respondents agreed to participate and answered the survey.

At the vanguard of advocating for trees, their knowledge, attitude, and perception of the benefits, issues, importance, and management of urban trees were assessed. This study adopted the survey questionnaire used in the study by Rollins (2008). Furthermore, the survey data was analyzed using Microsoft Excel, specifically its Data Analysis tool, and descriptive statistics were used to calculate the mean scores for each question. The results were tabulated and presented through graphs and tables.

Results and Discussion

As shown in Table 1, the results of the aboveground biomass of the samples per location were compiled wherein MC % = moisture content, DM % = dry matter content, and OM % = organic matter content.

Table 1 Average aboveground biomass of rain trees in the two study area

Location	**Bark**			**Leaf**		
	MC%	DM%	OM%	MC%	DM%	OM%
Friendship Highway	34.11%	89.35%	16.31%	54.48%	3.71%	44.52%
Villa Teresa Village	10.12%	89.88%	10.46%	54.32%	4.35%	45.68%

In terms of carbon content, the average samples from Fil-Am Friendship highway are 2217.40 grams and 199.45 grams for leaves and bark, respectively. Furthermore, the control sample from Villa Teresa Village garnered 972.90 grams of carbon from the leaves, while 254.96 grams of carbon from the bark samples. Figure 5 shows the average amount of carbon content in grams. Collectively, there is an average of 1575.85 grams of carbon content from the rain trees in Fil-Am Friendship highway, while there are 1227.86 grams of carbon content from the rain trees in Villa Teresa Village.

The average value of the carbon content of Mahogany sapling from the study of Superales (2016) was 16.64 grams and 8.10 grams for leaf and bark samples. The average of the computed values from the sample rain trees are considerably larger since they are more mature compared to the saplings. It can also be noted that among the two parameters, the carbon content from leaf samples are consistently greater than in the bark samples in both results.

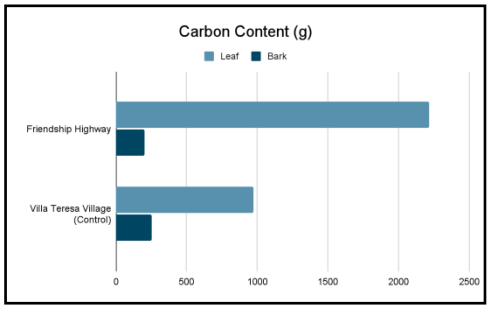

Figure 5 Average carbon content in leaves and bark sample

The average amount of carbon dioxide storage of the rain trees on Fil-Am Friendship highway is 7912.37 grams and 721.06 grams for leaves and bark, respectively (Figure 6). The average carbon dioxide captured by each rain tree is 5777.54 grams. For the control sample in Villa Teresa Village, the average carbon dioxide storage in the leaves is 3566.94 grams, while 934.76 grams for the bark. Altogether the control sample in Villa Teresa Village captured 4501.71 grams of carbon dioxide.

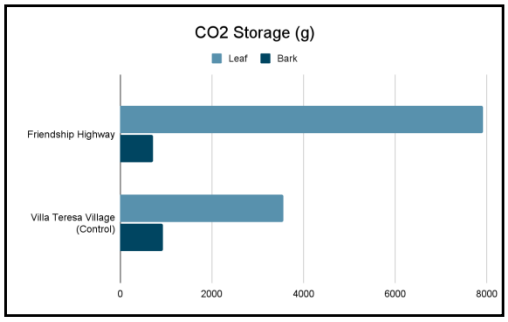

Figure 6 Average carbon dioxide storage in leaves and bark samples

Results show that 20 rain trees in Fil-Am Friendship Highway sequestered 177013.99 grams or 177.01 kilograms of carbon dioxide. On average, one tree accounts for 5777.54 grams of 5.77 kilograms of carbon dioxide. On the other side, a single rain tree in Villa Teresa Village sequestered 4501.71 grams or 4.50 kilograms of carbon dioxide. The results suggest that the average rain tree in Fil-Am Friendship Highway sequestered more carbon than a single rain tree in Villa Teresa Village. From that, it can be interpreted that the carbon emissions from human activities and vehicular traffic on Fil-Am Friendship Highway, a public road in Angeles City, elevated the carbon dioxide levels of the rain trees located along the highway. At the same time, the carbon dioxide levels of the rain tree in Villa Teresa Village are lower because it is located in a green space on the street inside the village.

Air quality

The average or mean of the air quality parameters taken from the four sites along the Fil-Am Friendship Highway is greater than the air quality recorded at the control site. A rise in PM2.5 (+89.29%) and PM10 (+83.33%) from measurements obtained in areas with

significant vehicle traffic is anticipated. The treatment site has a reduced average air temperature (-12.07%) compared to the control site, which can attest to the statement of Nowak (2002) claiming that one-way urban trees influence air quality is through temperature reduction, as their canopies play a role in cooling the air temperatures.

The average PM 2.5 level recorded in Fil-Am Friendship highway is 9.4 µg/m3. While 12.6 µg/m3 and 5.7 µg/m3 for PM 10 and PM 1 levels, respectively. In contrast, recorded PM levels in Villa Teresa Village are seven µg/m3, nine µg/m3, and four µg/m3 for PM 2.5, PM 10, and PM 1, respectively. This reveals that higher PM levels were recorded in Fil-Am Friendship highway compared to Villa Teresa Village (Figure 7). In reference to the study conducted on the roadsides of Vadodara City, particulate matter levels in roadside trees are higher compared to the ones that are not located in major roads (Beckett et. al., 2000; Kiran & Kinnary, 2011).

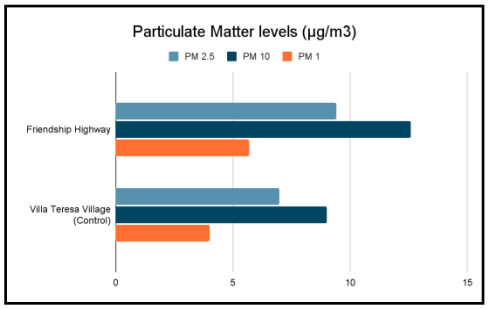

Figure 7 Particulate matter levels in Friendship Highway and Villa Teresa Village

Surface structure

In the *A. saman* leaves, it is observed that in the adaxial portion, the irregular or polygonal epidermal cell is very prominent (Figure 8A). The trichomes on the upper surface are difficult to locate since the number of trichomes ranges from zero to a few, and the stomata are also nonexistent (Figure 8B). Stomata and Trichomes, on the other hand, are observed and abundant on the bottom or abaxial surface of the leaves (Figure 9C-D). The outcomes of research by Ayodele et al. (2003) also presented the corresponding result where the stomata of *A. saman* is described to be only present in its lower surface and not on the upper.

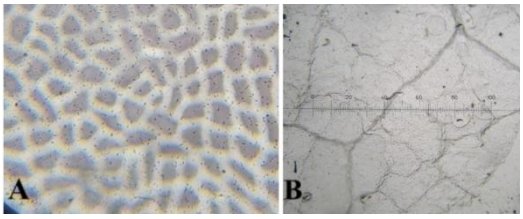

Figure 8 A-B Photo of the adaxial epidermal surface of *A. saman* (A.) polygonal to irregular cells and (B.) a few trichomes

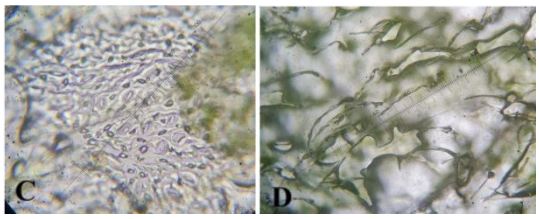

Figure 9 C-D Photo of the abaxial epidermal surface of *A. saman* showing the (C) imprint of the stomatal cell and (D) its trichomes (more, longer)

Stomata on *A. saman* trees located over the 5 sites were consistent with each other, all of which were hypostomatic, indicating that stomata were exclusively found on the underside leaf surface as illustrated in Figure 2A and 2C. Des et al., (2021) said in their research that stomata are more localized on the bottom side of the leaf in general; this is a known mechanism enabling trees to conform to their surroundings and minimize transpiration.

Stomatal density

The data show that the stomata density of *A. saman* leaves growing along the Fil-Am Friendship Highway in Angeles City is higher than the trees of the same species situated in the Villa Teresa Subdivision. In leaf samples obtained in the control site in the Villa Teresa Clubhouse, the average density of *A. saman* stomata reached 16766.94/mm2. While on the roadside of the Fil-Am Friendship Highway in Angeles City, 22635.37 / mm2 was recorded (Table 2). This is attributable to the reality that the Fil-Am Friendship Road is often congested, significantly boosting the highway's car flow. This growth does have a consequence of increasing vehicle density and CO emissions, affecting air quality and prompting the stomata to respond by raising the quantity of stomata in the vicinity. This agrebes with Vauzia et al. (2020), who also observed the stomatal density of trees, specifically *Swietenia macrophylla* (Mahogany), growing on the side of a road heavily traveled motorists is higher than in a non-congested area. It was also stated that this is a type of adaptation, as polluted stomatal cells promote the formation of new and more stomata, allowing the photosynthetic process to continue efficiently.

Table 2 The average result of stomatal density on Fil-Am Highway and Villa Teresa Subd.

Location	Stomata Density (/mm²)
Fil-Am Friendship Highway, Angeles City	**22635.37**
Villa Teresa Subd. Angeles City	**16766.94**

Stomatal size

The stomatal size of the leaf samples ranged between 19.14µm to 26.10µm, with DM20 exhibiting the maximum size, followed by DM17 and DMO1, and DM12 having the least dimensions (Table 3). The result is in contradiction to conventional finding, that demonstrates that the stomatal size of foliage susceptible to pollution is significantly less than those that are not, notably presented in the work of Shrestha et al., (2017) but this is not generally the fact, as stomatal size varies greatly amongst species of plants. For example, species bearing leaves adapted for greater gas exchange rate exhibit smaller stomata as well as quicker dynamic features (Drake et al., 2013). However, Bertolino et al., (2019) highlighted in their article that small stomatal size can minimize gsmax, the maximum potential gas exchange in a circumstance at which all stomata are completely open. Reduction

in gsmax resulting in reduced SS has also been related to increased water conservation, as documented for plants subjected to drought.

Table 3 Average Stomatal Size of each tree site. (DM no: stands for the tree code of the sampled trees in Fil-Am Highway)

Tree Code	Stomatal Size (µm)
DM20 AVERAGE	**26.10**
DM17 AVERAGE	22.62
DM01 AVERAGE	22.62
CONTROL AVERAGE	21.75
DM12 AVERAGE	19.14

Open and close stomata

In terms of proportion, the Rain tree leaves gathered in Villa Theresa have the most open stomata when contrasted to all other trees along the Fil-Am Friendship Highway (Table 4). This outcome is congruent with the observations of Des et al., (2021) who also reported that leaves that are not always subjected to contaminants have a higher frequency of open stomata than those that are. Because pollutants can block or obscure the stomatal openings which can lead to the photosynthetic activity being hindered, and the mesophyll tissue being harmed.

Table 4 The percentage of open and close stomata on each tree site

TREE	OPEN	CLOSE
DM20	46%	54%
DM17	60%	40%
DM12	50%	50%
DM01	55%	45%
CONTROL	77%	23%

SOCIO-CULTURAL CONSERVATION VALUES

Among the 48 respondents, 33 (69%) reside in an urban environment, while 15 (31%) live in rural areas. On the other hand, no comparisons are made between these two groups; rather, the purpose of the survey is to assess the knowledge, attitude, and perception of the respondents about the benefits of trees in general and the concerns, importance, and management of the trees, most specifically the urban trees along the Friendship Highway.

Awareness of trees in the vicinity

Figure 10 & 11 reflects the immediate environment of respondents in terms of the relative abundance of trees. The awareness also extends in the radius of a 10-minute walk where (~97%) of respondents show awareness of tree abundance spatially-wise (See Figure 12).

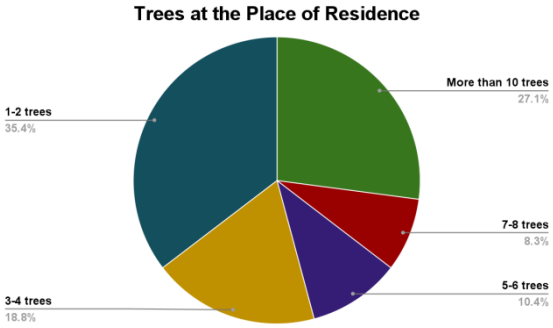

Figure 10 Pie chart showing the range of numbers of trees within the property of the respondents

Figure 11 shows that 18.8% (9 out of 48 respondents) have more than 100 trees on their street (trees in the city/municipality properties), 6.3% (3 out of 48) have 81-100 trees, 4.2% (2 out of 48) have 61-80 trees, 10.4% (5 out of 48) have 41-60 trees, 20.8% (10 out of 48) have 21-40 trees, and 39.6% (19 out of 48 respondents) have 1-20 trees. This demonstrates that the quantity of street trees in front of their homes in their city or municipality varies.

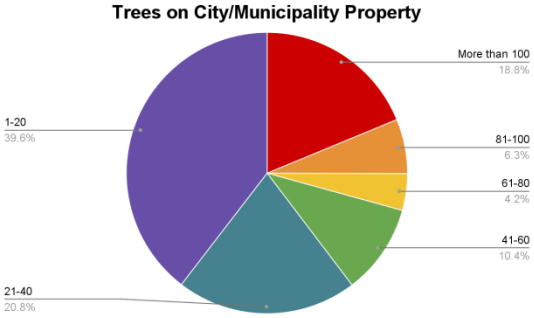

Figure 11 Pie chart showing the range of numbers of trees within the city/municipality property of the respondents

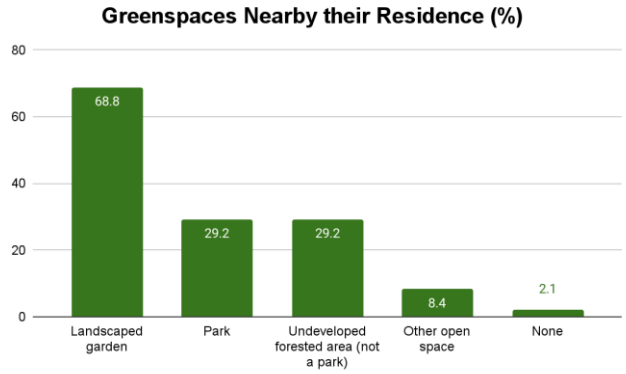

Figure 12 Bar graph showing the percentages of greenspaces that can be found nearby their place of residence (within 10 minutes walk)

In the last question in the first section of the questionnaire, respondents were asked to indicate if they felt the number of trees in their residence seemed to have increased, decreased, or remained the same. Figure 13 reveals that about 66.7% (32 of 48 respondents) believe that the number of trees has declined, 12.5% (6 of 48) believe that trees have increased, 12.5% also believe that trees have remained the same, and 8.3% (4 of 48) are

unsure. This indicates that over half of the respondents believe the number of trees in their neighborhood has decreased over time.

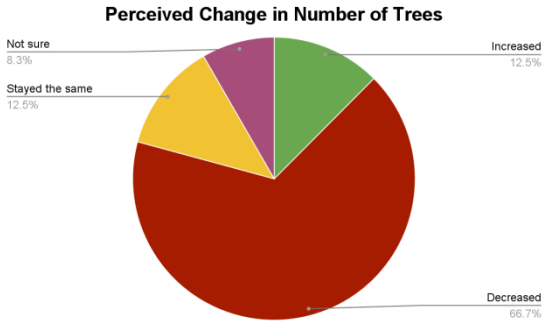

Figure 13 Pie chart showing the percentage of trees of the perceived change in number of trees within the vicinity of the respondents

Perceived Benefits of Urban Trees

The public's support for urban trees is influenced by their perceived benefits. Respondents were given a list of possible benefits of urban trees in the second section of the questionnaire and asked to indicate whether they thought each statement was a "minor benefit," "major benefit," "not a benefit," or "not sure." The formula n-1/n was used to obtain the interval range of the 4-point Likert scale questionnaire to interpret the verbal description of the obtained mean scores for every question.

The mean scores were obtained from scoring each response as 4 = major benefit, 3 = minor benefit, 2 = not a benefit, and 1 = not sure. It reveals that the following are the most strongly perceived benefits of urban trees (with mean scores ranging from 3.25 to 4.0, indicating significant benefit): Cool homes in summer (3.98); Improve the appearance of property (3.57); Improve the appearance of neighborhood (3.67); Provides a sound barrier (3.29); Make commercial areas more attractive (3.48); Reduce flooding from rain (3.90); Reduce erosion (3.90); Provide nutrients to soil (3.95); Remove carbon from atmosphere (3.95); Provide habitat for birds and other wildlife (3.90). The lowest perceived benefit was "improve property values" with a mean of 3.10 that fell below the range of 2.5-3.25, indicating a minor benefit, although over 50% of respondents said it was a major benefit.

Respondents were given the option of commenting on other potential benefits. These unstructured responses were examined. The following are some examples: *Sources of fruits; Trees as main contributors to the many factors and processes around us; Provide shade;* and *Improve air quality.*

Perceived Concerns of Urban Trees

Perceived benefits and concerns impact public support for urban trees. In terms of perceived concerns, the survey gave a list of potential concerns and asked respondents to score each statement as 4 = major concern, 3 = minor concern, 2 = not a concern, and 1 = not sure. Overall, concerns were ranked substantially lower than advantages. Those criteria with mean scores ranging from 2.5 to 3.25 among the possible concerns suggest that they were minor concerns. These are: Blocks views; Damage from falling branches; Effort to remove leaves from gutters; Risk of forest fire; and Cause moss to grow on roofs. These respondents' perceived minor concerns may be the result of personal encounters, and these issues might be

addressed with adequate guidelines and supervision that officials must implement to protect not just the residents but also these trees.

In addition to these findings, respondents were provided the opportunity to write in any additional comments or concerns. Other concerns mentioned are that it *may cause damage to infrastructure near it*, and *strong winds can uproot trees, causing damage to properties*.

Perceived Importance of Urban Trees

As previously indicated, perceived benefits and concerns about city trees will impact public support for urban trees, particularly those along the Friendship Highway. According to the discussion above, most respondents' perceived benefits outweigh their perceived concerns, therefore we may expect these findings to lead to widespread support for urban trees. The survey's fourth portion asked respondents to rate a series of statements by indicating whether they thought they were "very important," "somewhat important," "not at all important," or "not sure."

Figure 14 shows that urban trees are valued highly, with the highest levels of support for trees in parks, trees at work, and trees on other city streets, which received between 80% and 90% of respondents who rated them "very important," while trees in the yard and trees on city property of their homes received 79.2% and 70.8%, respectively.

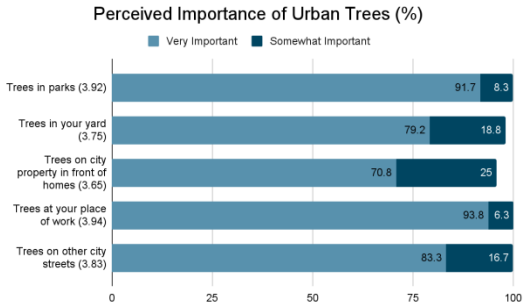

Figure 14 Bar graph showing showing the “very important” and “somewhat important” responses in percentage of how they felt about the importance of urban trees

Priorities for Managing Urban Trees in Friendship Highway

The final section of the questionnaire examined public support for tree-related programs and services provided by the officials and policymakers of Angeles City, Pampanga. Respondents indicated each statement as "low priority," "medium priority," "high priority," or "not sure.” Findings suggest solid support for the majority of programs, with the following receiving the greatest priority (mean values range from 3.25 to 4.0, signifying high priority): Ensuring some trees are retained in new developments (3.92); Hazard assessment for urban trees on private properties (3.72); Hazard assessment for urban trees on city property (3.90); Ensuring compliance with tree removal bylaws (3.92); Protecting significant trees (3.96); and, Providing consultation on street tree issue (3.90).

Overall, the survey findings reveal the respondents' knowledge, attitudes, and perceptions about the advantages of trees in general, as well as their concerns, importance, and priorities for tree management in urban settings, specifically trees along the Friendship Highway. Almost all of the respondents are aware of the ecological services provided by trees on their property and value them for themselves and their community. On the other hand, more than half of the respondents believed that the number of trees in their

neighborhood had decreased over time, indicating that there is a pressing need to save these trees. The presence and value of trees are strongly supported by respondents in this study, emphasizing that urban trees should be kept and safeguarded.

The respondents' support stems from their perceptions of the benefits of urban trees. Aside from improving the aesthetics of the property and neighborhood, most respondents believed that the most important benefits of urban trees are supplying nutrients to the soil and removing carbon from the environment, both of which received a 3.95 mean. Other ecological benefits of urban trees, such as minimizing floods from rain, reducing erosion, and providing a home for birds and other species, were also recognized by respondents. These responses reveal a deep awareness of natural processes and a commitment to environmental management in a city setting.

The majority of respondents emphasized the importance of trees in parks, yards, in front of their homes, at work, and on other city streets. Finally, almost all of the initiatives for urban tree management received strong support from respondents, implying that they want our politicians to take stringent climate action to protect these trees, particularly those along highways that are at risk of being cut down.

Conclusion

Highly urbanized city like Angeles City is undoubtedly home to large amounts of carbon emissions. Notably, highways that are bombarded with commercial establishments and vehicular traffic contribute to high levels of carbon emissions. And a city's initial layer of defense against traffic pollution is the urban trees and such factors influence several physical characteristics of plants, with different species exhibiting variable sensitivity. Due to this, the rain trees along the Fil-Am Friendship Highway are found to be efficient in sequestering the carbon from said sources. From the 20 rain trees, more than 177 kilograms of carbon dioxide were sequestered. In estimation, the 259 urban trees along Fil-Am Friendship highway have the potential to sequester up to 1494 kilograms or 1.49 tons of carbon dioxide.

In terms of the air quality evaluation, when compared to the control site it showed that there is a greater concentration of PM2.5 and PM10 but a lower average air temperature on Fil-Am Friendship Highway, implying that urban trees like *A.saman* can improve air quality by lowering the temperature of the site. Foliar microstructure investigation revealed that Rain Tree leaf stomata are exclusively located on the underside and are hypostomatic in nature. Stomata dimensions revealed fluctuation in leaf samples collected close to the road, including increased stomatal density, size, and a lower frequency of opened stomata as opposed to more remote distances, which can be attributed to the tree's exposure to higher proportions of pollutants. Stomatal characteristics of leaves in Villa Teresa, on the contrary, exhibited reduced stomatal density, size, as well as a larger percentage of open stomata. As the researchers' advocacy to speak for the trees, the findings from this research can be used as a piece of science-based and data-driven evidence as to why trees should be saved and protected.

Socio-cultural conservation values obtained from the survey show the support of the respondents for having these urban trees amidst the rapid urbanization that is occuring. This support for urban trees stems from the perceived benefits and importance of these trees to urban life. It is worth noting that respondents perceived trees to improve the appearance of their property and of their neighborhood. According to the majority of respondents, trees also have ecological benefits, such as cooling homes in the summer; supplying nutrients to soil and habitat for birds and other species; preventing flooding and erosion; and eliminating carbon from the atmosphere. These responses indicate a firm understanding of natural

processes as well as a commitment to environmental stewardship. The value of urban trees was also perceived as important, particularly those around workplaces and in parks. Furthermore, all of the programs for managing urban trees on Friendship Highway received a "high priority" rating from respondents, indicating strong support for all of the programs. These significant findings demonstrate the relevance of these trees in the respondents' perspectives and may be useful to local officials and environmental advocates in the future in protecting and preserving these urban trees.

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Investigating the Hardness Properties of Superhard Materials (B-C-N)

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Abstract

We present the computational report with the first-principles calculations based on the DFT concepts, which were performed to solve the Kohn-Sham equations by the self-consistent field method. The crystal structures of BC_2N in the *Pmm2* and *C2/m* phases were initially observed. The energy-calculation result indicated that the *Pmm2* phase is a more stable phase due to the minimum free energy. Besides, the elastic constants were calculated so that the bulk modulus and hardness will be analyzed between the two phases. The elastic constants of both phases of BC_2N exhibited the brittle-material condition. We also proposed the positive value of Vickers hardness that the BC_2N in the *Pmm2* phase gave the hardest condition at 74.8 GPa, while it was just found at 32.2 GPa in the *C2/m* phase.

Keywords : Hardness, Structure, Boron-based compound, Physical properties

1. Introduction

Nowadays, technological innovations seek to find a new type of extremely hard material known as superhard material, Wentorf (1980). The condition of superhard material can be determined from an interesting material with the Vickers hardness value exceeding 40 gigapascals (GPa), Dubrovinskaia (2007). Superhard materials have widely interested in robot and vehicle industries that require strength and durability. Robotic materials require both soft material for skin or outside and hard material for bone or inside, Jing (2020). Steel is one of the most selected materials for use in robot builders. This metal is a smart choice if you're building a robot that needs to stand up to harsh conditions. It's possible to harden the steel to between 100,000 and 300,000 pound-force per square inch (psi) in many cases. The most widely used superhard material applications from cutting and polishing tools to wear-resistant coatings, while diamonds are still the hardest-known diamonds. This material is even synthetic for many years, and the theory of attempts to improve upon it. However, even diamonds have limitations, not effective for cutting ferrous metals.

In another way, iron is also included due to the chemical reaction that produces cubic iron carbide, Kaner (2005). Boron nitride (BN), the second hardest material with a structure similar to that of diamonds, can be used to cut ferrous metals, but it does not occur naturally and must be conditionally synthesized. The compressions under pressure and temperature conditions are so high that they are quite expensive. The new super-hard material is not only great science interesting, but also very useful to design a new superhard material. One has to understand what makes diamonds so special. In diamonds, tetrahedral-bound sp^3 carbon atoms form a three-dimensional covalent highly symmetrical network of other carbon-containing materials It has a shorter, stronger carbon bond. By studying the experiment report of Solozhenko (2001), a cubic phase of BC_2N was synthesized by direct conversion of graphite-like BN–C solid solutions at 25 GPa and 2100 K. The hardness, Young's modulus, fracture toughness, and structure of this phase were examined using micro-indentation and transmission electron microscopy. The hardness and elastic modulus values of the c-BC_2N are intermediate between diamond and cubic boron nitride, which made the hardest known solid after diamond. By the theoretical study of Li (2009), an ab initio evolutionary algorithm was employed to resolve the crystal structure of the observed

superhard BC_2N and uncovered two polymorphs with rhombohedral and orthorhombic symmetries, with which the experimental x-ray diffraction pattern was reproduced. Analysis of the total energy results and the simulated energy-loss near-edge spectroscopy suggested that the rhombohedral structure is the best candidate for the superhard BC_2N. They also demonstrated that earlier proposed high density and low-density forms are likely from this single rhombohedral phase. Later, hexagonal BC_2N was shown as a superhard material, reported by Sadeghi (2020), identified to be comparable to or even harder than cubic boron nitride (c-BN) due to the full sp^3 bonding character and the higher number of C–C and B–N bonds compared to C–N and B–C.

2. Objectives

Based on the literature review of BC_2N, structural, electronic, and elastic properties of the B-C-N compounds are the main points of interest in this research. Ab initio calculation based on the concepts of density functional theory (DFT) is mainly used as a theoretical instrument for evaluating the physical properties of these interesting materials. Besides, the calculated result will be compared and discussed in the next part of this report. Therefore, the objectives of this study would be specified to the investigating of structural, electronic, and elastic properties of the B-C-N compounds using ab initio calculation.

3. Calculation method

In this computational report, the first-principles calculations based on the DFT concepts are performed to solve the Kohn-Sham equations by self-consistent field method (SCF) as implemented in Cambridge Serial Total Energy Package (CASTEP) code. To study the DFT calculations in the ternary compound (B-C-N) systems, the generalized-gradient approximation functional of Perdew-Burke-Ernzerhof (GGA-PBE) is used in term of exchange-correlation functional term in the Kohn-Sham equations at the ambient-pressure condition for the suitable exchange-correlation functional term for the formation of lightweight compounds. The lattice parameters and bulk modulus of BC_2N are also calculated from the GGA-PBE results; which are mainly used as exchange-correlation functional for finding the high-pressure properties of the undoped and doped systems. The maximum energy of the plane-wave basis set is used at 500 eV, which is suitable cutoff energy to cooperate with ultrasoft-pseudopotential. Monkhorst-Pack grid sizes are used, while k point is initially finite as the condition of $k = 0.04$. The energy minimization with Brodyden-Fletcher-Goldfarb-Shanno (BFGS) scheme is used for the calculation of geometry optimization. External forces and pressure tensors on optimized structures are controlled through the Hellmann-Feynman theorem. The BFGS optimization was considered to be completed when the total energy difference was less than 2×10^{-6} eV/atom, Hellman–Feynman forces were less than 0.006 eV/Å, maximum atomic displacement within 0.0002 Å, and all of the stresses within 0.003 GPa. The average bulk modulus can be evaluated from elastic constants by Voigt-Reuss-Hill (VRH) method.

4. Results and discussion

First of all, the structural investigation of the crystal structures of BC_2N in the *Pmm2* and *C2/m* phases was initially observed as shown in Figure 1. The calculated lattice parameters (*a*, *b*, and *c*) in the *Pmm2* phase were found as (2.534, 2.562, 3.640), while it was found as (3.636, 3.636, 4.174) in the *C2/m* phase. Volumes of the unit cells are 23.66 and 52.94, respectively. This showed that the *Pmm2* phase exhibits a higher gravimetric density. For total energy consideration, it was found that the *Pmm2* phase gave lower free energy at -658.90 eV per a formula unit (f. u.), while the *C2/m* phase gave a higher energy value at -658.49 eV/f. u., indicating that the *Pmm2* phase is a more stable phase at ambient pressure

due to the minimum free energy. However, we considered the physical properties in both phases due to the minimal energy difference of 0.51 eV.

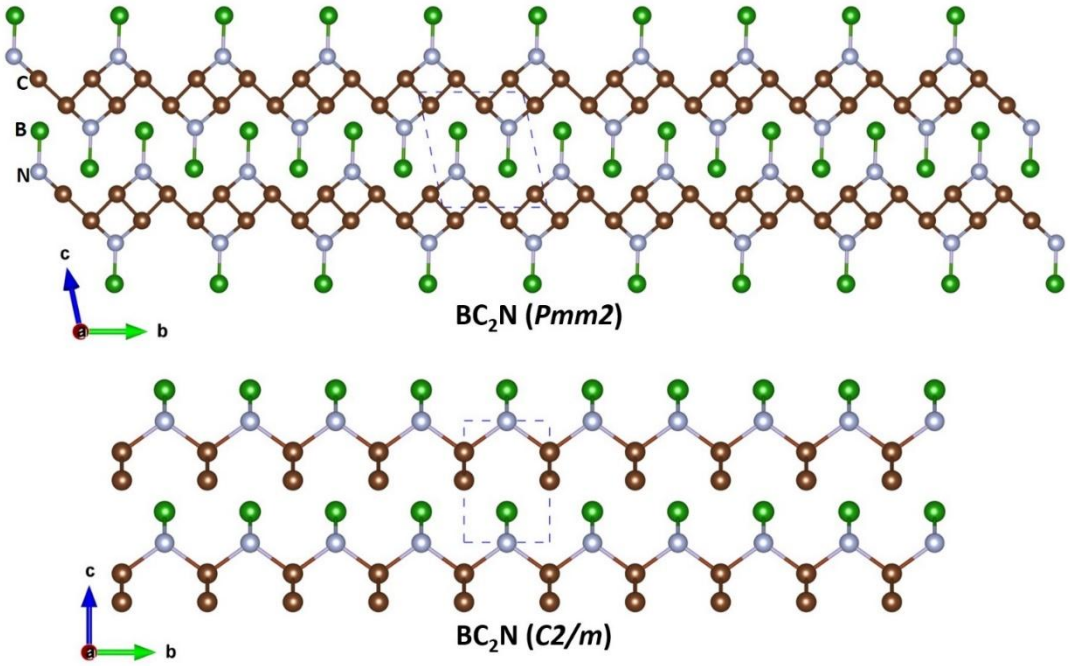

Figure 1 Structural virtualization of BC_2N in the *Pmm2* and *C2/m* phases.

Next, the elastic constants were calculated so that the bulk modulus and hardness will be analyzed between the two phases. We would like to obtain extensive detail on the elastic properties such as elastic constants (C_{ij}), bulk modulus (B), shear modulus (G), and Young's modulus (Y) were studied for determining the full physical properties of BC_2N in the *Pmm2* and *C2/m* phases. The elastic parameters at the ambient pressure phases were tested by using PBE functional as shown in Table 1. It was found that the PBE functional gave a good agreement with the previous experiments more than using the local-density approximation (LDA). The elastic properties of materials such as B and G can be estimated by using the Voigt–Reuss–Hill procedure. The Voigt and Reuss values are the upper and lower limits of crystalline constants, while the mean value from the Voigt (B_V, G_V) and Reuss (B_R, G_R) approximation is the Hill (B_H, G_H) modulus, which the Hill modulus is shown in Table 1. The type of material can be classified as brittle material if the ratio of B/G is less than 1.75, and it is a ductile material if the ratio is greater than 1.75. Considering the B/G ratio in Table 1, this indicates that both phases of BC_2N are the condition of the brittle material.

Table 1 The calculated elastic properties in a unit of gigapascal (GPa).

Phase	C_{11}	C_{22}	C_{33}	C_{44}	C_{55}	C_{66}	C_{12}	C_{13}	C_{23}	B	G	B/G	H_V
BC_2N (Pmm2)	1009	892	873	420	478	369	17	138	122	370	414	0.89	74.8
BC_2N (C2/m)	463	995	842	395	209	188	47	172	135	289	225	1.28	32.2
BC_5 (P3m1)	870	870	1032	378	378	378	149	77	77	374	364	1.03	57.9

Tian (2012) proposed that the positive value of Vickers hardness (H_V) for the hardness materials can be corrected as

$$H_V = 0.92\left(\frac{G}{B}\right)^{1.137} G^{0.708} \qquad (1)$$

Using equation (1), the H_V values exhibit the property as the interior of the superhard material. When compared to the well-known compound (BC_5), it can be concluded that the

different space groups have a direct influence on the Vickers hardness of BC_2N. Our calculation results suggested that the BC_2N in the *Pmm2* phase gave the hardest material at 74.8 GPa, while it was just found at 32.2 GPa in the *C2/m* phase. These introduce us that the BC_2N in the *Pmm2* phase is one of the hardest materials; however, the usage of BC_2N for the robotic or mechanical devices has any question due to appearing the brittle-material property.

5. Conclusion

In summary, the present computational report with the first-principles calculations based on the DFT concepts has been performed to solve the Kohn-Sham equations by the self-consistent field method. The crystal structures of BC_2N in the *Pmm2* and *C2/m* phases were initially observed as shown in Figure 1. The energy-calculation result indicated that the *Pmm2* phase is a more stable phase due to the minimum free energy. However, we considered the physical properties in both phases due to the minimal energy difference of 0.51 eV. Then, the elastic constants were calculated so that the bulk modulus and hardness will be analyzed between the two phases. Both phases of BC_2N exhibited the condition of the brittle material. We also proposed the positive value of Vickers hardness that the BC_2N in the *Pmm2* phase gave the hardest material at 74.8 GPa, while it was just found at 32.2 GPa in the *C2/m* phase. Our calculation results introduce us that the BC_2N in the *Pmm2* phase is one of the hardest materials; however, the usage of BC_2N for the robotic or mechanical devices has any question due to appearing the brittle-material property.

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Interest of Junior High School Students towards STEM Careers

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Abstract

The birth of the Senior High School (SHS) curriculum here in the Philippines allows students to navigate different fields that are inclined into their future careers before tertiary education. One of the specializations under the academic track of the SHS is the STEM strand. The STEM strand offers multiple facets of career orientations for the advancement of human capital in the fields of science and mathematics. However, considering the great demand for STEM-skilled workers and the opportunity that the STEM field provides, the number of STEM professionals here and abroad is not enough to meet the future and current needs. With this, the paper reviews the varying reasons for the declining interest of students in STEM careers. STEM strands, STEM courses, STEM professions, and STEM in junior high school (JHS) were navigated to properly examine the current status of STEM.

Keywords : STEM education, student interest, STEM careers, STEM interest, interventions

1. Introduction

The outbreak of the COVID-19 pandemic resulted in a huge disturbance not only in the educational system, but even to the worldwide economy. The need for skilled individuals in the sciences and mathematics has become more prominent. To address the ongoing and subsequent economic problems, global concerns about enhancing Science, Technology, Engineering, and Mathematics (STEM) education have expanded exponentially (Fallis, 2015). The premise of STEM education is to empower the STEM workforce with skilled human capital that are capable of commercialization, innovation, and research (Kier et al., 2014). As emphasized by Uttal and Cohen (2012), the STEM principles focus on finding answers to global problems and on project-based education systems. With this, the demand for STEM graduates is extremely high yet, the interest of students towards STEM career is decreasing (Bottia et al., 2015). This problem is evident in the Philippines, indeed, the proportion of students interested in STEM careers is not enough to fill in the demands of the country in the future (Business World, 2021). Nonetheless, the Philippines is not the sole country to experience this problem. For example, America has stated that it is having difficulty filling the country's demand for STEM-skilled workers as a result of scarcity of participation in STEM fields (Wyss et al., 2012). Turkey is in a similar situation, with STEM-related jobs accounting for 18% of all national vacancies in the country (Bahar & Adiguzel, 2016).

The vast majority of innovations that improve people's lives are the result of contributions from STEM-related fields (Kuenzi, 2008). This is because STEM careers are among the most versatile and crucial in today's world. As stated by Peri et al. (2015), STEM jobs have a substantial influence on innovation and productivity growth in the majority of advanced economies. In fact, according to Zilberman and Ice (2021), STEM professions are expected to increase at a rate more than twice that of the total number of jobs over the next ten years. Yet, despite the high employment demand for STEM-skilled individuals, STEM workers are widely perceived to be in short supply (Cappelli, 2015). In addition, the number of proficient US citizens working in STEM fields is declining (Hurtado, 2010). According to Sanders (2004), as stated in Hossain and Robinson (2012), foreign-born scientists,

mathematicians, and engineers make up a significant share of the STEM workforce in the United States. This is one of the reasons why the Philippines does not have enough engineers and scientists to date. As stated by to Roan-Cristobal (2019), a country of 104 million people requires a minimum of 39,520 science and technology-skilled individuals in sectors to keep the economy running and promote the well-being of its citizens. However, the Philippine Statistics Authority (2020) reported that in 2019, there were about 2.2 million Filipinos working in foreign countries. Caulin (2018) reports that more than a quarter of Filipino workers working abroad devote their lives to caring for the sick. In the United States alone, 150,000 Filipino nurses are on the front lines of the current pandemic (Ladrido, 2020).

To address the scarcity of STEM students, universities and governments around the world prioritize attracting skilled students (Agamata & Alvin, 2018). As a result of the United States' willingness to devote more resources and time to STEM education, there is a dramatic growth in the amount of foreign students and employees in these fields (Planty et al., 2009). With the implementation of the Kinder to Grade 12 Program (K-12 Program) starting in the academic year 2016-2017, the Philippines has joined its neighboring countries in providing a more competitive educational system in the global context. This has created an opportunity to satisfy the country's continuous call for STEM experts since one of the aims of the program is to produce STEM experts in the light of the Senior High School (SHS) program. Also, to attract more students in the field, Republic Act No. 7687, also known as the "Science and Technology Scholarship Act of 1994," offers grants to gifted and worthy scholars whose families' socioeconomic status does not surpass the predetermined cut-off values. Qualifiers are obliged to concentrate on priority areas for basic sciences, other applied sciences, engineering, mathematics, and science teaching (Department of Science and Technology, 2018). The Department of Science and Technology – Science Education Institute (DOST-SEI) requires its scholars to serve in the country as a return service in their specialty areas for a period of time equal to proportion of years they acquire the scholarship (Department of Science and Technology, 2020).

A variety of factors influence students' STEM career choices, the majority of which are due to environmental, familial, and intrinsic factors (Kuechler et al., 2009). Song and Glick (2004) claimed that students' perceptions of potential careers and earnings could influence their enthusiasm for STEM careers. In addition, Archer et al. (2012) claimed that students' STEM career interests and aspirations are aroused by exposure to the environment and curriculum at school that actively promote participation in scientific activities or STEM. Thus, STEM courses, STEM interests, and STEM in junior high school in the Philippines will be thoroughly discussed to strengthen the need to address the issue.

2. A Walkthrough of STEM

2.1. STEM Courses

2.1.1. STEM as a Strand

According to Orbeta et al. (2018), the goal of proponents of K-12 law is for SHS graduates to have better job opportunities even if they do not plan to continue their education right away. In comparison to other strands, the STEM strand concentrates on advanced concepts and topics. Students in this strand are expected to become pilots, astrophysicists, architects, biologists, engineers, chemists, dentists, nutritionists, physicians, nurses, and other STEM professions (Bolds, 2017). According to Simpkins et al., as stated in Blotnicky et al. (2018), middle school years are the key stages that greatly influence students to strengthen their interest in STEM careers. Therefore, primary education indeed contributes well to developing STEM career aspirations. However, according to Albert (2016), the Philippines is

still problematic with the number of out-of-school children because of health, economic, and psychological factors, especially in public high schools. The study even reported that a significant number of children mentioned “lack of interest” as their primary reason for not attending school. In fact, about 36% and 44.1% of students highlight that their reason for not attending primary and secondary levels, respectively is lack of interest. In addition, 14.1% and 29.4%, respectively, pointed out that the “high cost of education” hinders them from attending primary and secondary schools. These reports clearly show that the Department of Education has to double their efforts to resolve the issue of the decreasing number of students' attendance to produce a more competent and sufficient number of graduates and skilled workers in the future.

A large majority of secondary school pupils experience abstract and theoretical mathematics and science with little application to their everyday lives (Freeman et al., 2014). Van Houte et al. as stated by Heleen and Vandamme (n.d.), due to the complexity of STEM-related disciplines, students have little or no experience in resolving multidisciplinary math and scientific problems. As a result, students fail to understand the importance of STEM classes. To aid the shortage of students going to the STEM strand, universities and governments around the world prioritize attracting skilled students (Agamata & Alvin, 2018). As the United States (US) invests more money and efforts to boost STEM education, a dramatically expanding number of international students and employees in these disciplines is evident (Planty et al., 2009).

Rask (2010) mentioned that in terms of the motivation of the person and future career potential, the STEM program is costly. However, because of insufficient scholarship programs, lack of family support, and many other factors, a huge amount of STEM students are not able to finish their chosen STEM careers (Rafanan et al., 2020). Another barrier that students face is the quota course policy that results in their not being able to enroll in their preferred course. Routinely, quota students in STEM courses fail their science and math core subjects in their first year of college and continue to experience difficulty as they matriculate (Ouano et al., 2019).

2.1.2. STEM as a Profession

In most advanced economies, STEM jobs contribute significantly to innovation and productivity growth (Peri et al., 2015). Despite the high employment pay for STEM students, STEM workers are generally perceived to be in short supply (Cappelli, 2015). A possible reason for this, as stated by Kennedy et al. (2018), is that about 52% of American adults claim that the subjects in STEM degrees are too hard, which is why young people do not pursue them.

STEM-related industries in the United States have also been relatively focused on increasing the number of students participating in STEM education (Baber, 2015). Consequently, according to Anito and Morales (2019), STEM graduates in the Philippines are low in numbers; therefore, the country has an insufficient number of scientists. Per million, the Philippines has only 189 scientists, which is far way beyond UNESCO’s recommendation of about 380 scientists per million (Anito & Morales, 2019). The insufficient number of scientists in the country is mainly due to STEM-related low graduation rates. In fact, the report from the Commission on Higher Education validated by EduTECH (2016), showed that, based on a 5-year data set, the completion rate for STEM areas was only about 21.10% until the academic year 2016-2017. In particular, science-related

According to Powers (2018), the advent of technological innovation transformed the world and changed STEM's career landscape, especially in academe. Over the last half a

century, STEM-skilled people have mostly worked for the same company for 40–50 years, yet because of the freelance opportunities today on the internet, employees switch jobs every 2-3 years. However, a lot of factors contribute to an employee's tenure. The National Science Foundation (2015), as stated by Korte et al. (2019), reports that more than 50% of the people in the United States earning STEM degrees do not actually work in STEM occupations.

2.2. Interest towards STEM Courses and Careers

In 2009, white and Asian American students tallied an average of 34% interest in taking STEM careers, as indicated by the 2009 Freshman Survey (Hurtado, 2010). A significant number of cases caught the attention of society when students graduating from the STEM strand started to choose a non-STEM course upon enrollment in college. Yet, a more serious problem is when most students who entered college pursuing STEM-related careers eventually shift to a non-STEM program or drop out of school (Chen, 2011). A claim by Hurtado (2010) specified a loss rate of about 20% to 50% happening in STEM disciplines. This downfall in the interest of students in taking STEM-related courses was supported by Drew (2011). He stated that about 40% of students who are initially planning to take science and engineering majors end up taking non-STEM courses. This is because of family support in science and math subjects, gender, and academic achievement (Hazari et al., 2017).

In the study of Cheng and Soldne (2014), in the years 2003–2004 in the US, only about 28 percent of college students and 20 percent of associate's degree students actually entered STEM fields. From among the college students, those interested in finishing biological or life science courses have the highest number. On the other hand, the physical sciences and mathematics are the two least populated fields. In the study of Chen (2011), it was revealed that students who were interested in STEM during high school actually took engineering and engineering technologies, natural and applied sciences, computer/information sciences, mathematics and statistics, and biological and agricultural sciences. Yet, the attrition rate in STEM fields is alarming; the attrition rate in STEM fields among college students is 28 percent, and 33 percent among associate's degree students (Cheng & Soldner, 2014).

A lot of factors influence students' STEM career choices; mostly this is because of environmental factors, background, and intrinsic factors (Kuechler et al., 2009). Song and Glick (2004) claimed that students' perception of their potential careers and potential earnings could influence their interest in STEM careers. In fact, according to Funk and Parker (2018), there has been a 79% improvement in STEM occupation employment since 1990; an increase from 9.7 million to 17.3 million has been recorded in the US. Additionally, STEM-related jobs have a median salary of $38.85 per day as compared to the $19.30 of non-STEM occupations (Education Commission of the States, 2017). A recent survey conducted by Emerson Electric Co. (2020), revealed that about 91% of Filipino students are interested in taking up STEM-related courses and 80% of them are encouraged to actually pursue them. Yet, as stated by The Manila Times (2019), the Department of Labor and Employment claims that 3 out of 10 young job applicants need further training and seminars to be fully employable. A possible reason for this is the technological change that happens constantly. This allows the birth of new jobs with skills that make the old ones obsolete (Deming et al., 2018).

In the year 2016, out of 645,973 university graduates in the Philippines, about 12% or 76,432 obtained their degrees in engineering, 1% or 6,828 obtained science degree, and only 2,736 or 0.4% are mathematics graduates (Oxford Business Group, n.d.). With the implementation of the K-12 curriculum, the Philippines is hoping to produce more STEM professionals who are globally competent (Franco-Velasco, 2012).

Archer et al. (2012) contended that exposure to a school curriculum and environment that actively promote participation in scientific activities, or STEM, arouses students' STEM career interests and aspirations. Effective teaching and learning strategies are therefore essential in the school environment when developing skills required for STEM-related jobs (Halim et al., 2018). As stated by Sahin et al. (2015), teaching and learning strategies that could enhance skills in the STEM areas include problem-solving, hands-on activities, daily applications of science content, cooperative learning, research activities, group work, and active learning. For instance, to increase students' STEM interests, informal science learning was identified as one of the most effective opportunities to begin with (National Research Council, 2011). After-school clubs, museums, zoos, and academic competitions such as Science Olympiad are examples of informal STEM learning opportunities Robelen (2011), as cited in Sahin et al. (2015). Informal STEM benefits include receiving informal coaching, learning in a fun way, applying science and mathematics simultaneously, increasing participants' confidence in essential STEM skills, and emphasizing camaraderie among students. These skills are essential for developing a competent workforce in the field of STEM in the future (Denson & Carolina, 2015).

Moreover, as stated by Halim et al. (2018), social influence contributes to students' STEM career interests for those individuals closest to the student, such as friends, teachers, role models, family members, and parents, who significantly influence them in choosing their career paths. Previous research has proven that in STEM-related job decision-making, the most influential people for students are their parents (Nugent et al., 2015). Parents play a huge role in their children's lives, including career choices in the early stages of life (Cridge & Cridge, 2015). Also, the attitude of the family members towards science or STEM careers influences the choices of students (Archer et al., 2012). Students' interest in STEM careers can be influenced by family members such as siblings and relatives. A reason for this is that students can learn from them and gain a better understanding of the lives of family members who are inclined towards STEM fields (Halim et al., 2018). Students' support acquired from formal education is likewise critical in attracting students' curiosity in STEM careers. Educators serve as mentors or role models, cultivating interest and self-efficacy in STEM (Cridge & Cridge, 2015; Sahin et al., 2015). Students' achievement, interest in science, and aspiration for STEM careers are all heavily influenced by the teaching methods and the quality of the teacher (Nugent et al., 2015). Friendship also influences one's thinking and it is essential in developing great expectations in STEM careers (Cridge & Cridge, 2015; Stake & Peterson, 2012). Peers who prefer science subjects are more motivated and intelligent than those who prefer humanities subjects (Taconis & Kessels, 2009). School counselors are similarly necessary in helping students think about their career options (Hall et al., 2011). In schools, students converse with their teachers and counselors about their career options. However, the number of counselors who have enough expertise or information about STEM careers is only about 10%. As a result, if school counselors do not have enough knowledge about career options, many students will not consider STEM careers (Halim et al., 2018).

Even media such as newspapers, the internet, scientific magazines, movies, books, and science-related television programs may influence students' interest in STEM careers (Cavas, 2011). In addition, video interviews featuring STEM-skilled individuals as a means of providing relevant job information in STEM, greatly contribute to students' engagement in STEM fields (Wyss et al., 2012). Media disseminates STEM information faster, in a way that allows students to explore STEM knowledge easily and have fun (Halim et al., 2018).

2.3. STEM in the Junior High School Curriculum

According to Sadler et al. (2012), students' interest in STEM careers at the beginning of high school significantly contributes to their interest at the end of high school. Despite this,

recent research has revealed that students in junior high school have a hazy understanding of science and engineering, despite the fact that these years are critical in developing a strong STEM interest (Compeau, 2019). Typically, junior high school years in the US range from 12 to 15 years old, yet the promising attitude of students sharply at the age of 10 drastically declines by the age of 14 (Tai et al., 2006).

As stated by Roberts (2012), embedding STEM curriculum is feasible at a junior high school. The embedded STEM curriculum is conducted without restructuring the curriculum; hence, engineering, technology, science, and mathematics are just integrated (A. Roberts & Cantu, 2012). Children at the age of 11 leave primary education and start their transition to secondary education. In this phase, these adolescents' transition to the thinking level (Piaget, 1965). Minderovic (2006) explains that the universal nature of humans is to follow inferences and to think logically, which is the foundation of the thinking level. Since STEM is problem-based learning, it needs logical thinking and in-depth analysis (Kelley & Knowles, 2016). Engaging students in their early junior high school to do experiments to solve problems in the learning phase can help them to think logically (King et al., 1998).

According to Penano-Ho (2004), the most effective teaching strategies for complex subjects such as science and mathematics are cooperative learning, hands-on experience, and self-discovery. These strategies help students to share even better understanding and knowledge, achieve their fullest learning capacity, and enhance their learning capability, respectively. In the study of a junior high school teacher in the Philippines, regarded that hands-on activities to introduce math topics and elicit discussion within and among students to activate meaningful learning help a lot. This is even better as compared to math classes that usually employ regular discussion that starts by giving rules and definitions of math concepts. Working in small groups, on the other hand, allows students to ask questions about math concepts for them to reason out logically, get some help, and communicate their knowledge well. As stated by Dr. Josette Biyo, DOST-SEI director, learning the basics of STEM prior to secondary level is essential as it serves as the foundation for processing more complex concepts in later years of education. To make sure that students will still receive the utmost learning alongside the current pandemic, DOST-SEI develops supplemental resources that enable students to enrich STEM learning for the purpose of encouraging students to consider STEM careers in the future. The DOST-SEI, in collaboration with the Department of Education (DepEd), enhances STEM learning in the light of "RadyoEskwela sa Siyensa" and "TuklaSiyensya sa Eskwela" programs for elementary and secondary students, respectively (Bulaon-Ducusin, 2020).

3. Conclusion

Synthesis

The demand for improving STEM skills in order to meet the worldwide economic challenges continues to increase in most countries (English, 2016). In most western countries, the need to improve their STEM-related programs has been evident with their immense educational reforms (Quinn et al., 2012). The Philippines, however, just started last year to implement the Enhanced Basic Education that aims to prepare its students to be globally competent even after high school. One of the curriculum tracks is the academic track, where the STEM strand is included.

According to Ouano et al. (2019), friends or the influence of peers affect students' decisions significantly in choosing their courses for the reason that they want to be accepted by the group. In addition, most students pursuing STEM careers are influenced by their family members (Lee et al., 2018). The major shift in the delivery of instruction in the

Philippines has affected students' engagement. Therefore, the possible effect of this on students' interest in going into STEM field careers is necessary to be determined. Another point to consider is that, with the continuous increase in technological advancements and demand for skilled personnel in the STEM field (Almerino et al., 2020), the interest of Filipino students in the STEM field should be revisited. STEM education is linked to scientific inquiry; students in the learning phase are exposed to investigation to answer formulated questions (T.J. Kennedy & Odell, 2014). In this sense, actual experience of students in math and science investigations is essential to strengthen their STEM aspirations, yet the pandemic is a burden..

Since the most recent survey of Filipino students' interest in STEM careers was conducted before the pandemic. The effects on the STEM interests of students of the sudden shift in the delivery of lessons to distance learning (such as modular learning, online learning, and blended learning) need to be evaluated. A substantial analysis of the factors that hinder junior high school students from pursuing STEM-related careers must be communicated for the implementation of necessary actions to alleviate the country's insufficient STEM professionals. If students have an extensive interest in STEM, math and science subject coordinators may intensify their programs to meet the needs and demands of these students. Parents may help their children in their career interests by providing sufficient moral and/or financial support. Guidance counselors may provide adequate lectures to students who have the same STEM-career aspirations to strengthen their interest in and support for each other. Curriculum developers and school administrators may come up with relevant programs and activities that could strengthen students' interest in STEM careers. Local and national officials may extend support such as scholarships and technology provisions to less fortunate and deserving students to convince them even more to pursue STEM education, especially in this time of crisis. Most public school students have no means or opportunities to nurture their interests and intensify their skills because of insufficient resources and support.

Recommendations for Further Studies

Future research studies may consider examining the different interests in STEM of students in public and private schools. Thus, STEM in public and private junior high schools may likewise be observed by doing an in-person interview with both teachers and students. This will provide an avenue for future researchers to clearly investigate the responses of the students to the questionnaires. Implementation of these interventions should be done to assess the effectiveness of the proposed interventions to strengthen STEM and STEM career interests. Thus, longitudinal research about STEM interests may be considered.

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