INTERNATIONAL JOURNAL OF AUTOMOTIVE AND MECHANICAL ENGINEERING (IJAME)
ISSN: 2229-8649 e-ISSN: 2180-1606
VOL. 19, ISSUE 4, 10094 – 10102
DOI: https://doi.org/10.15282/ijame.19.4.2022.06.0780

ORIGINAL ARTICLE

The Ability of Selected Plants to Absorbing CO_2, CO and HC from Gasoline Engine Exhaust

A. Syuhada, M.I. Maulana and R. Sary

Department of Mechanical and Industrial Engineering, Faculty of Engineering, Universitas Syiah Kuala, 23111 Banda Aceh, Indonesia

ABSTRACT – Global warming is the unusually rapid increase in the earth's average surface temperature, which has an impact on climate change. The cause of global warming is the inhibition of heat transfer from the earth's surface to space, which is analogous to the greenhouse effect. The occurrence of the greenhouse effect is due to the large amount of carbon dioxide (CO_2) produced by the complete combustion of fuel in vehicles and industrial processes. The rising use of fossil fuels and the ongoing reduction in forest plants' ability to absorb CO_2 is to blame for the rise in CO_2 levels in the atmosphere. To reduce the increase in CO_2 gas, one effort that can be made is to increase CO_2-absorbing plants. In this regard, plants are able to absorb CO_2 and convert it into oxygen and glucose by utilizing solar heat. The purpose of this study is to determine the ability to absorb CO_2 from several types of plants. The test was carried out using two closed test rooms with dimensions of 100×50×50 cm, where room 1 (first) was used to store 0.5% of CO_2 emissions, while room 2 (second) was used for the plants being tested. Gas is flowed into room 2 using a fan for 300 minutes, and data collection is carried out every 60 minutes. Based on results obtained in this line of research, the best plant ability to absorb CO_2 can be ordered as follows 0.25 mg/m^2.hour for squirrel tail, 0.243 mg/m^2.hour for trembesi, 0.2 mg/m^2.hour for mahogany, 0.177 mg/m^2.hour for kaffir lime, 0.166 mg/m^2.hour for mango, and 0.166 mg/m^2.hour for cape.

ARTICLE HISTORY
Received: 1st March 2022
Revised: 28th July 2022
Accepted: 4th Dec 2022
Published: 28th Dec. 2022

KEYWORDS
Plants;
Greenhouse effect;
CO_2;
Gasoline engine;
Global warming

INTRODUCTION

Global warming occurs when the increasing concentration of gas emissions in the earth's atmosphere forms naturally and from human activities. The types of gas emissions found in the earth's atmosphere, such as carbon dioxide (CO_2) play a vital role in increasing gas emissions in the atmosphere, and other gases, such as methane (CH_4), nitrous oxide (N_2O), and fluorine gases (HFC, PFC, SF6). This is also caused by a decrease in the amount of forest that absorbs CO_2 gas emissions from logging, burning, destruction, and land conversion, which results in an imbalance between the increase and absorption of gas emissions [1]-[3]. According to the IPCC (Intergovernmental Panel on Climate Change) in Muhi, basically, global warming is a phenomenon of increasing global temperature from year to year due to the greenhouse effect caused by increased emissions of gases such as CO_2, CH_4, N_2O and other gases such as chloro fluoro carbon (CFC) and Hydro fluoro carbon (HCFC), hence the sun's energy is trapped in the earth's atmosphere. Most of the increase in global average temperatures since the mid-20th century is most likely due to human activities. Climate models referenced by the IPCC project show global surface temperatures will increase by 1.1-6.4 °C between 1990 – 2100 [4],[5].

The increase in CO_2 and other gases can disrupt the balance of thermal energy in the universe, damage the ozone layer and inhibit heat transfer from the earth's surface to the atmosphere, thus causing the temperature on the earth to continue to increase (greenhouse effect). Biomass, such as trees, other green plants, and marine life that use CO_2, is a component of the biosphere that naturally recycles gaseous emissions, particularly CO_2 [6]. Efforts that can be figured out to reduce the increase in CO_2 include replacing or reducing the use of conventional fuels, switching to environmentally friendly renewable energy sources, and increasing the planting of CO_2-absorbing trees in city parks, land, and forests of the world that have been damaged or deforested. Increasing the number of CO_2-absorbing trees is the most efficient way to do this because plants are able to absorb CO_2 gas emissions and other gases through the process of photosynthesis to produce glucose and oxygen. Most significantly, plants have the capacity to absorb heat and lower the air temperature. The decline in air quality is due to the increasing use of diesel fuel and gasoline, which release a lot of hydrocarbons and CO_2 into the air. This should be balanced with the addition of sufficient green plants so that environmental balance occurs [7]-[10].

Much research has been carried out to study the effect of CO_2 in the air. Many of these studies link CO_2 emissions from power generation to many factors, including economic growth and fuel mix [11]-[15]. On the other hand, Kacar et al. linked the weight of vehicles to CO_2 emissions [16]. The link between CO_2 emissions to climate change, demographic change, and electricity utilization has also been studied [17]. To mitigate the impact of CO_2 emissions, the performance of carbon capture technologies has also been studied [18]-[22]. In terms of the ability to absorb CO_2 for each type of plant, especially different leaf areas and the number of leaves on each tree are very important and influential [23]. This makes research to examine the ability of plant species to absorb CO_2 emissions and other gases an interesting theme in offsetting the increase in CO_2 emissions and reducing the impact of global warming.

*CORRESPONDING AUTHOR | Syuhada | ✉ syuhada_mech @ yahoo.com

Naturally, greenhouse gases are formed from natural processes, such as the result of the eruption of Mount Merapi, respiration of living things, animal waste, decay of animals or plants and others whose gas concentrations are still within the limits that can be absorbed by nature. Meanwhile, greenhouse gases formed from human activities occur due to deforestation, massive use of fossil fuels that emit gas emissions, such as in industry and vehicles, and waste from industry and agriculture, which makes the concentration of greenhouse gases increase beyond the limit that can be absorbed by nature so that the average temperature on earth continues to increase. Greenhouse gases in the earth's atmosphere are CO_2, CO, CH_4, NOx, SOx and other gases [24] [25]. Data from the Bogor Agricultural Institute (IPB) released in 2019 showed that one mature trambesi tree with branches of more than 15 meters can absorb 28.5 tons of CO_2 equivalent gas per year or 78.000 gram CO_2/day [26]. In Aydin Shishegaran's research [27], aloe vera performs better than other plants based on decreasing CO_2 concentration and humidity. Tests were carried out to reduce CO_2 concentrations under various meteorological conditions, especially humidity and temperature. In addition, testing for combination of CO and CO_2 using a generator is proposed as a second suggestion because these gases are emitted together in several industries. Haffiz et al in 2018 conducted an analysis of variations in the absorption ability of atmospheric CO_2 for several types of trees that make up green open spaces in Banjarbaru City, South Kalimantan Province. The results showed that the highest CO_2 absorption was obtained by the Angsana tree, which was 720 kg/year, and the lowest was obtained from the guava tree at 61 kg/year [28].

To overcome this situation, an assessment of the ability of plants to absorb CO_2, CO, and HC emissions is urgently needed. The study was carried out on plant species that are abundant in Indonesia, so they have prospects for planting in parks in Indonesia, especially in toll road areas that are full of vehicles. The research was conducted by measuring the absorption rate of these gases by the plants by considering factors such as leaf area, number, and water content, as well as O_2 gas production by plants. Experimental results on selected plant subjects are presented in this paper.

LITERATURE REVIEW

Carbon Dioxide

CO_2 is colorless, tasteless and non-stimulating. From the first research conducted by a French chemist, Charles Thilorier, in 1825, at a temperature of -78.51°C, CO_2 immediately sublimes into a solid through a deposition process. The solid form of CO_2 is commonly referred to as "dry ice" [29]. CO_2 is the most abundant natural greenhouse gas in the atmosphere. CO_2 increases with increasing burning of fossil fuels, waste, and so on. The use of power tools, transportation, and industry are the biggest contributors to the increase in CO_2 [30]. With regard to this issue, Ismiyati et al., tried to examine that since the last ten years, there has been an increasing volume of vehicles which is a major contributor to air pollution in urban areas. Excess CO_2 content can disrupt the balance of thermal energy in the universe, damage the ozone layer and inhibit the transfer of heat from the earth's surface to the atmosphere, as a result, earth's surface temperature rises. [31]

The presence of excessive CO_2 in the air does not have a direct impact on humans. However, the excess CO_2 content causes the heat of solar radiation that reaches the earth's surface to be reflected back by the earth's surface in the form of infrared radiation to the ozone layer and the greenhouse gas CO_2; the heat from this infrared ray cannot return to the atmosphere because it is blocked by the existing CO_2 layer in the atmosphere. As a result, the temperature on the earth is getting hotter. This causes the temperature on earth, both day and night not much different or can even be said to be the same. The effect caused by excessive levels of CO_2 in the air is known as the greenhouse effect. [32]

Carbon Dioxide Cycle

CO_2 cycle dissolves in the surface waters of the ocean. Sea water provides a great opportunity to sink CO_2; this is because CO_2 has high solubility. Moreover, CO_2 also separates into ions and interacts with the constituent elements of seawater [33]. Plants, on the other hand, cycle CO_2 through photosynthesis as in Figure 1. Photosynthesis is the process of utilizing sunlight energy by plants that have chloroplasts in their leaves. The materials needed by plants to carry out the process of photosynthesis are water (H_2O) and CO_2 [34]. According to Taiz et al., basically a series of photosynthetic reactions can be carried out through two reactions, the light reaction (requires light) and the dark reaction (does not require light but requires CO_2). In the light reaction, light energy is converted into chemical energy and produces oxygen (O_2), while in the dark reaction, there is a series of reactions that form sugars from CO_2 and energy. [35]

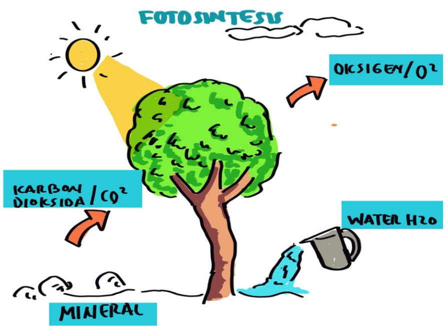


Figure 1. CO_2 absorption by plants through photosynthesis

Motor Vehicle Exhaust Emissions

Cities are the largest contributor to carbon emissions in the world. Most of the emissions emitted come from moving sources or motorized vehicles. As much as 60% of exhaust gas in urban areas is the result of combustion from motor vehicles, including CO [36]. According to Government Regulation No. 41/1999 on Air Pollution Control, emissions are substances, energy, and other components produced from an activity that enters and is introduced into the ambient air. Emissions may or may not contain potential pollutants. Exhaust gas emission is one of the emissions that have the potential for pollution, which is classified into two based on the source, namely moving and fixed. Movable sources are transportation facilities and immovable sources are industry, commercial activities, power plants, households, and others [37]. Exhaust gas emissions from incomplete combustion of motor vehicles have the potential to become air pollutants, including CO, NO_x, SO_x, hydrocarbons, particulate matter (PM), and Pb. Some exhaust gases can change because they react in the atmosphere and become more active or weak compounds. This reaction can be caused by sunlight, water vapor, or other compounds in the atmosphere. These compounds are very influential on public health if they are present in the air in large quantities and are also one of the causes of the greenhouse effect. The increase in CO_2 emissions will continue to occur if the use of energy from fossil fuels continues to increase, changes in the function of green land and increases anthropogenic activities. As much as 40% of the respiration process is CO_2 gas. Passenger cars are the largest contributor to carbon emissions into the air, amounting to 60%. CO in the atmosphere will turn into CO_2 naturally. CO_2 emissions produced by motorized vehicles differ from one another depending on the fuel used and the type of vehicle [38].

Leaf Moisture Content

Measurement of leaf moisture content was carried out to determine the effect of leaf moisture content on the plant's ability. To determine the tested leaf moisture content, a sample of five leaves per plant was taken. Then, the sample was weighed to determine the mass of the leaf sample. After recognizing the initial mass (wet moisture content), the sample is dried until its moisture content reached 0%. The dried sample is then weighed again; hence the final mass (dry moisture content) is known. The total leaf area of the plant species tested is different, where the total area (L_{tot}) is the product of the total number of leaves of each plant and the area per leaf. The number of leaves is calculated by the leaves' shape, which are approximately the same size from each plant. The leaf area is calculated by taking a sample of the leaves of each plant and calculated using the help of square millimeter paper. To determine the leaf water content, it can be expressed by the following formula:

$$KA = \frac{W_b - W_k}{W_b} \, x \, 100\,\% \tag{1}$$

where KA is the water content of the wet base leaf (%), W_b is the initial weight of the leaf sample (g) and W_k is the final weight of the leaf sample after the heating process (g).

Ability of Plants to Absorb CO_2

Before the plants were tested, the plants were first uniformed in area. The uniformity in question is in the form of the cross-sectional area of the entire leaf of the test plant so that all plants have the same cross-sectional area. To calculate the ability of plants, the following formulas were used:

i. Total leaf area, L_{tot}:

The total leaf area is received using Eq. (2)

$$L_{tot} = L_D \, x \, n_D \tag{2}$$

where L_{tot} is total leaf area (m^2), L_D is area per leaf (m^2), and n_D is total number of leaves. L_D is obtained by taking one leaf sample from a similar tree trunk as the entire leaf, then direct measurements are figured out with the help of a square field, while the n_D is counted directly from the total leaves on the tree trunk.

ii. Absorbed CO_2 (milligram/m^2.hour)

This process is actually the same as our process of determining the water content in the test sample, where the initial CO_2 absorption level is reduced by the final CO_2 absorption process. The process is calculated using an emission device to see the reduction in CO_2 levels in the environment or in the room. After understanding the total leaf area, then look for the CO_2 absorbed and the mass of CO_2 absorbed, C_t, which is obtained by using Eq. (3).

$$\text{Absorbed } CO_2 = \frac{CO_{2\,early} - CO_{2\,final}}{5\ hours} \tag{3}$$

where $CO_{2\,early}$ is CO_2 obtained in the 0th minute and $CO_{2\,final}$ is CO_2 obtained in the 300th minute (5 hours). After the CO_2 is absorbed, the resulting unit (%/hour), is converted into unit (milligrams/m^3.hour).

iii. Mass of CO_2 absorbed, C_t (milligram/hour)

Mass of CO_2 absorbed, C_t, is obtained using the following equation:

$$C_t = \text{absorbed } CO_2 \times \text{test chamber volume} \tag{4}$$

where the test chamber volume is 0.25 m^3.

iv. Plant ability, K_T (milligram/m^2.hour)

After getting to know regardless the total leaf area (A_t) and the absorbed CO_2 mass (C_t), a comparison was made to obtain the plant's ability using the following equation:

$$K_T = \frac{C_t}{A_t} \tag{5}$$

EXPERIMENTAL METHOD

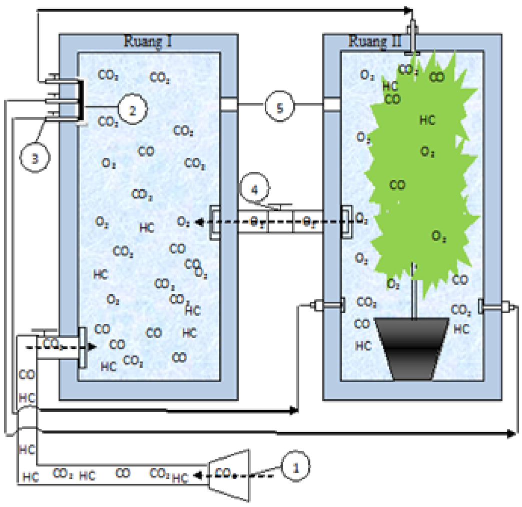
This experiment was carried out in closed system isolation, as shown in Figure 2. The main experimental test rig consisted of two isolated chambers separated by a channel with an adjustable valve. The test steps are described in stages as follows:

Preparation of the chamber

Six types of plants were prepared and placed into test chamber II. Chambers I and II were isolated by installing the connecting line between the two test chambers and closing any channel taps connected to chambers I and II. The emission analyzer measuring instrument was calibrated according to the procedure.

Testing chamber/chamber

The test chamber in Figure 2 consists of two chambers; the first chamber is used for vehicle exhaust gas storage, where the CO_2 gas concentration in chamber I is filled as much as 0.5%. The second chamber is used to store the plants to be tested and where exhaust gas emissions are channeled from chamber I. The testing chamber is made of wood and plywood and covered with glass. The dimensions of the two test chambers are 100×50×50 cm. Air circulation is particularly necessary to drain exhaust gases from chamber I to chamber II. The exhaust gas is distributed from chamber I to chamber II using a pipe/hose (with the help of a fan), while the distribution from chamber II to chamber I occurs due to an additional circulation channel from chamber II to the chamber I.



Description:
1. Exhaust emissions from the exhaust enter room I through the duct and faucet.
2. Fan.
3. Faucet and channel to chamber II.
4. Channel faucet for gas circulation from chamber II to chamber I.
5. Gas exhaust hole and for placing the emission analyzer tool.

Figure 2. Test chamber

Measuring equipment.

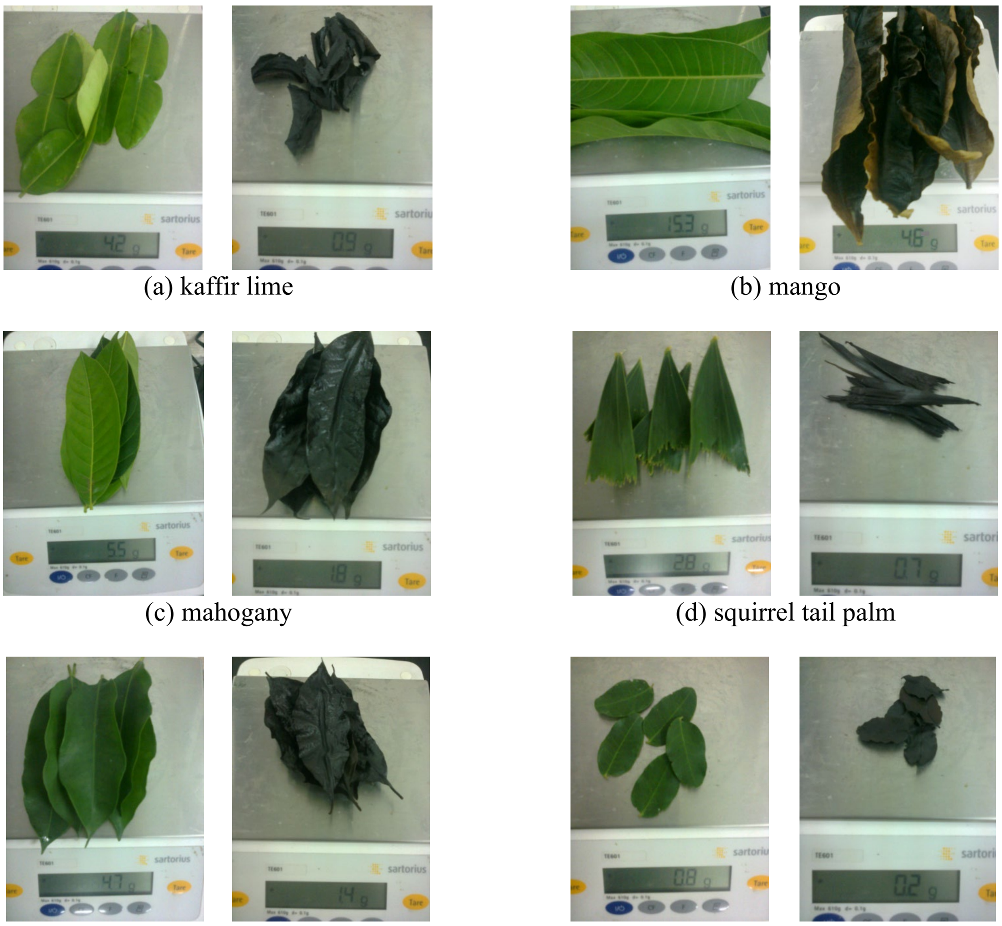
The measuring equipment used in this research is an Automotive Emission Analyzer type HG-520, time measuring device and mass measuring device. The automotive emission analyzer is used to measure the concentration of vehicle exhaust emissions, such as CO, CO_2, HC, NOx, AFR and O_2. Other supporting equipment are fans, faucets, pipes and insulation materials. The fan is used to channel exhaust emissions from chamber I to chamber II through 3 hoses with a size of an inch. The fan is only installed in chamber I. The fan is used with a power of 220 V. The faucet is used to open/close the test chamber/chamber, which is filled with vehicle exhaust emissions. Pipes, hoses and sockets are used to channel exhaust emissions from the vehicle to chamber I using a 3/4 inch diameter pipe, from chamber I to the chamber II using three pipes with a 1/4 inch diameter and gas circulation from the second chamber to the first chamber with using a 3/4 inch diameter channel. Other supporting measuring equipment is a stopwatch and digital scale.

Test materials and samples

The tested plants consisted of six species of kaffir lime, mango, mahogany, squirrel-tailed palm, cape and trembesi (in Figure 3). These types of plants are the most widely planted by the community and related government. The characteristics of the sample plants used are as follows:

i. Kaffir lime: The leaves are dark green, shiny, and the underside is light green or yellowish, opaque, when crushed, and smells good. Usually, the leaves grow in pairs and are like a figure eight. The leaf stalks are partially widened to resemble leaflets. The leaflets are round to oval in shape, the base is rounded or blunt, and the tip is blunt to tapered. It is 8-15 cm long and 2-6 cm wide and both surfaces are smooth with small, clear colored spots.
ii. Squirrel tail palm: It is a beautiful ornamental plant that is often planted as a roadblock. The leaves can reach up to 3 m (including the midrib), with leaflets narrow and growing around the mother petiole, giving it a "squirrel tail". Plant height can reach 10 m, with gray stems, segmented.
iii. Trembesi: Trembesi can reach a maximum height of 15-25 m. Diameter at chest height reaches 1-2 m. Trembesi has a canopy that can reach a diameter of 30 m. Trembesi forms an umbrella-shaped canopy, with a horizontal spread of the canopy that is greater than the tree height when planted in the open. In denser planting conditions, tree height trembesi can reach 40 m and smaller canopy diameter.
iv. Cape: Cape plants can grow to a height of 25 meters. It has a single leaf, scattered and long-stemmed, and is oval in shape. It has a flower that smells special. Cape wood is dense, hard and heavy, dark brown in color and smooth in texture, including mildew resistant but not durable.
v. Mango: The characteristics of the leaves on the mango tree are green and long wide with a pointed tip, depending on the variety. The leaves of this mango tree have pinnate leaves.
vi. Mahogany: Mahogany leaves are pinnate compound leaves with oval-shaped leaves, pointed tips and bases, and pinnate veins. Leaf length ranges from 35-50 cm. The young leaves of the mahogany plant are red and then turn green.

Meanwhile, gas emissions are taken from the exhaust gases of premium-fueled vehicles, which produce CO2, O2, CO, and HC emissions. Where CO_2 is a fixed variable, while O_2, CO, and HC are independent variables.



(a) kaffir lime (b) mango

(c) mahogany (d) squirrel tail palm

(e) cape (f) trambesi

Figure 3. Samples of plant leaves before and after drying to determine leaf moisture content.

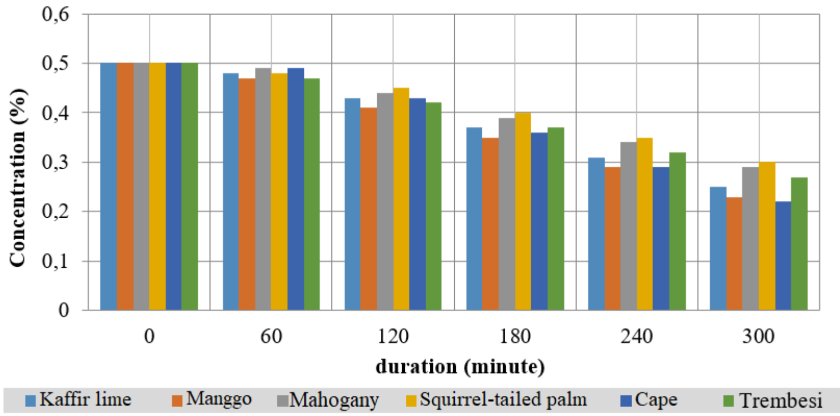
Preparation for testing

Prepare two test chambers by installing a connecting channel between the two test chambers and closing each channel valve connecting chambers I and II, positioning test chamber II in a place exposed to sunlight. Furthermore, six types of plants are prepared by entering one by one the plants to be tested into chamber II, then turning on and calibrating the automotive emission analyzer measuring instrument according to the procedure. The testing phase can be performed with the following stages, install the probe analyzer in test chambers I and II, then take the initial data from the test chambers. Then the motor is turned on, and the exhaust emissions of the motor are channeled from the exhaust to chamber I inlet. The exhaust hole of chamber I is opened to the environment, and therefore the initial gas exchange occurs in chamber I. Thus, the pressure inside test chamber I is the same as the pressure outside. The exhaust gas is channeled until a CO_2 concentration of 0.5% is reached in test chamber I. After reaching a CO_2 concentration of 0.5% in test chamber I, the motor is turned off. The exhaust duct entering chamber I is closed using a tap for the exhaust hole in chamber I closed. When the connecting tap between chambers I and II is opened, the fan is turned on, and the stopwatch is set. The gas from chamber I flows (with the help of a fan) to chamber II and circulates continuously from chamber I to chamber II and vice versa. Data was collected every 60 minutes for 300 minutes for each plant. The above steps were performed on six types of plants in sequence.

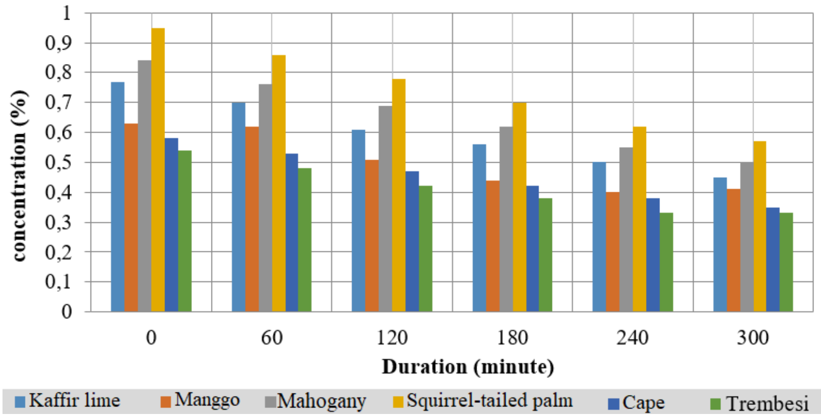
RESULTS AND DISCUSSION

A comparison of CO_2, CO and HC absorption from the plants tested is shown in Figure 4. In Figure 4(a), Absorptions of CO_2 gas for 300 minutes are presented with the highest CO_2 absorption ability at the beginning or at the 60th minute obtained in kaffir lime and mahogany plants. Over time up to 300 minutes (5 hours), the highest absorption was obtained in squirrel tail palm and mahogany at 0.3%/5hours and 0.29%/5hours, respectively. These results suggest that plants with large leaf surfaces do not necessarily absorb huge amounts of carbon dioxide. The leaf sample area impacts both divisors in the calculation method and the absorption of CO_2, according to studies by Shishegaran [27] and Syuhada [38]. The capacity of a leaf to absorb CO_2 decreases with its width. On the other hand, the ability to absorb CO_2 increases with leaf area.

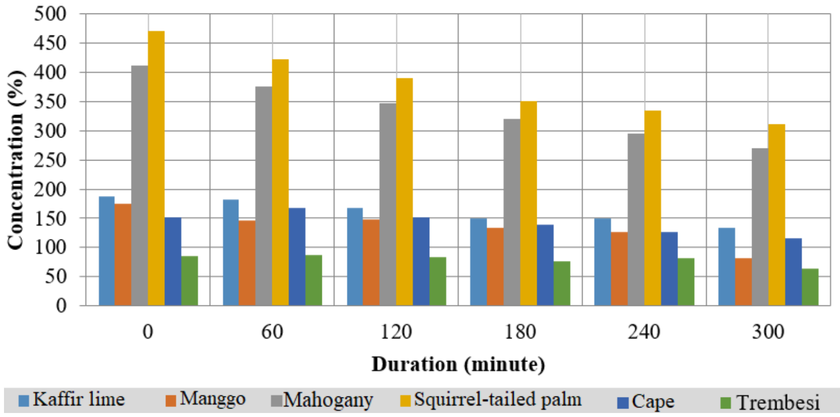
While Figure 4(b) shows a graph of the absorption of CO gas for 300 minutes when compared to the initial levels, the absorption ability can be sorted from the highest to the lowest; the squirrel tail palm tree is at 0.38%, 0.34% for mahogany, 0.32% for kaffir lime, 0.23% for cape, 0.22% for mango, and 0.21% for trembesi. Absorption of other gases also showed that the squirrel-tailed Palm plant obtained the highest absorption compared to other plants. In Figure 4(c), it can be seen that the absorption of HC obtained by each plant is sorted from the highest absorption capacity, namely the squirrel tail palm tree at 160 ppm/5 hours, mahogany: 142 ppm/5 hours, mango: 93 ppm/5 hours, kaffir lime: 54 ppm/5 hours, cape: 36 ppm/5 hours, and trembesi: 23 ppm/5 hours.



(a)



(b)



(c)

Figure 4. Comparative graph of (a) CO_2, (b) CO and (c) HC absorption by plants

Overall, as shown in Figure 5, the best absorption ability is in squirrel tail palm at 0.25 milligram/m^2.hour, then trembesi at 0.243 milligram/m^2.hour, mahogany at 0.2 milligram/m^2.hour, kaffir lime at 0.177 milligram /m^2.hour, mango at 0.166 milligram/m^2.hour and cape at 0.166 milligram/m^2.hour. According to Ahmad Syuhada et al., palm trees are not good at absorbing solar heat but have good resistance to high heat [39], while from the measurements in this study, palm trees are one of the best in CO_2 absorption. Research on squirrel tail palms is still very little. Needless to say, regarding this issue, one study conducted by Sengab et al. in 2015 discovered the presence of triterpenoids and phenolic compounds (secondary metabolites-MS). MS functions as a defence against other organisms, as an attractant for pollinators and seed dispersers, as protection against UV rays, and as an N-storage.

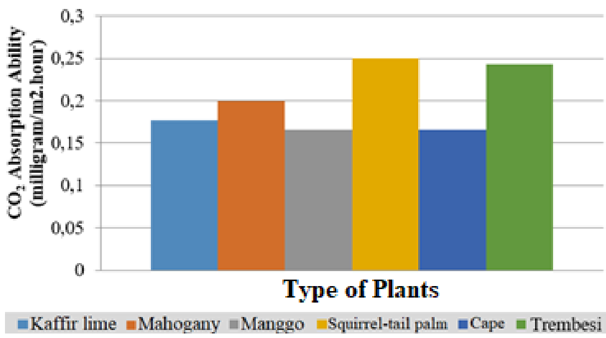


Figure 5. The ability of plants to absorb CO_2

From the calculation of Eq. (1), the moisture content of the leaves does not affect the ability to absorb CO_2 gas emissions, where the water content of kaffir lime leaves is 78.57%, mango is 69.93%, mahogany is 67.27%, and squirrel tail palm is 75%. The water content of each plant can be seen in the following Table 1. Data on the number of leaves and area per leaf can be seen in Table 2.

Table 1. Leaf moisture content

Types of plant	Initial mass of leaf sample (g)	Mass of dry leaf sample (g)	Leaf moisture content (%)
Kaffir lime	4.2	0.9	78.57
Squirrel tail palm	2.8	0.7	75.00
Trembesi	0.8	0.2	75.00
Cape	4.7	1.4	70.21
Mango	15.3	4.6	69.93
Mahogany	5.5	1.8	67.27

Table 2. Relation of leaf number/leaf area with leaf moisture content and CO_2 absorption

Types of plant	Leaf moisture content (%)	Amount of leaf	Total leaf area (m^2)	CO_2 absorb (%/hour)	Ability of plants (%/hour)
Kaffir lime	78.57	298	0.767	0.06	0.078
Mahogany	67.27	77	0.373	0.04	0.107
Mango	69.93	63	0.793	0.06	0.075
Squirrel tail palm	75.00	62	0.118	0.06	0.506
Trembesi	75.00	395	0.998	0.06	0.060
Cape	70.21	211	0.298	0.06	0.201

The squirrel tail palm (*wodyetia bifurcata*) anatomically has stomata that adapt to the environment. Visually the tree shows a good growth form but has a leaf quality that is not very fresh. The CO_2 absorption is carried out by the stomata, and this is related to the length and width of the stomatal pores. Stomata is the main door for the entry of CO_2 into the leaf. The process of absorption of CO_2 is lower in the leaves when the stomata opening gets smaller [14]. Squirrel tail palm has longitudinal leaves with stomata on both sides of the leaf surface, classified as potato type. The greater number of stomata on the lower surface is a mechanism of adaptation of trees to the terrestrial environment, thereby reducing transpiration. Thus, stomata and the surface area of the leaves are interrelated.

CONCLUSIONS

By way of conclusion, the results indicate the best plant ability to absorb CO_2 gas emissions from five other types of plants is squirrel tail palm with CO_2 absorption of 0.25 milligram/m2.hour. Squirrel tail palm also has the best absorption of gas emissions; 0.38%/5 hours of CO and 160 ppm/5 hours of HC. On the other hand, such a remarkable difference in leaf moisture content and total leaf area of the six types of plants did not significantly affect the ability to absorb CO_2, CO, HC, and O_2 gas emissions. Though palm trees are not good at absorbing solar heat, it has good resistance to high heat. This could also affect the plant's ability to absorb CO_2 gases from combustion. Since the results of the correlation test analysis showed no strong relationship between area parameters and carbon dioxide uptake per leaf and per tree, nor was it significant for CO and HC, it is necessary to conduct an in-depth study of the nature or characteristics of the squirrel tail palm plant.

ACKNOWLEDGEMENT

The authors are grateful for the contributions of all the students at the Graduate School of Mechanical Engineering, Universitas Syiah Kuala in this study. Our deepest appreciation and special gratitude go to Universitas Syiah Kuala for funding this research.

REFERENCES

[1] A. Boretti, "Continued fossil fuel emissions and cognition impairment," *Int. J. Glob. Warm.*, vol. 24, no. 1, pp. 86–90, 2021.

[2] O. F. Cansiz, K. Unsalan, and F. Unes, "Prediction of CO_2 emission in transportation sector by computational intelligence techniques," *Int. J. Glob. Warm.*, vol. 27, no. 3, pp. 213–236, 2022.

[3] M. Kayakus, "Forecasting carbon dioxide emissions in Turkey using machine learning methods," *Int. J. Glob. Warm.*, vol. 28, no. 3, pp. 199–210, 2022.

[4] Damayanti and D. Pentiana, "'Global warming' in the perspective of environmental management accounting (EMA)," *J. Ilm. ESAI*, vol. 7, no. 1, pp. 1–14, 2013.

[5] Z. Li, Y. Gao, S. Wu, and Y. Hao, "Numerical investigation of CO_2 And NO_x emission in a CFB combustor with flue gas recycle and oxy-fuel combustion redesign," *Int. J. Glob. Warm.*, vol. 25, no. 2, pp. 177–190, 2021.

[6] R. Cavicchioli *et al.*, "Scientists' warning to humanity: microorganisms and climate change," *Nat. Rev. Microbiol.*, vol. 17, no. September, pp. 569–586, 2019.

[7] Y. Chen, Y. Yang, L.S.Y. Shen, L. Wang, and X. Wang, "Analysis of carbon emission and its influencing factors of shanghai's textile and apparel industry," *Int. J. Glob. Warm.*, vol. 25, no. 2, pp. 123–134, 2021.

[8] K. Isinkaralar, G. Gullu, A. Turkyilmaz, M. Dogan, and O. Turhan, "Activated carbon production from horse chestnut shells for hydrogen storage," *Int. J. Glob. Warm.*, vol. 26, no. 4, pp. 361–373, 2022.

[9] W. Sun, Y. Han, F. Zhang, C. Hu, and Y. He, "Research on carbon productivity of the construction industry in Beijing-Tianjin-Hebei region using system dynamics model," *Int. J. Glob. Warm.*, vol. 25, no. 3, pp. 390–407, 2021.

[10] T.M. Yanar, and A.S. Demir, "How effective is carbon offset? Assessment of carbon dioxide reduction methods by using MCDM techniques: A case study of global automotive factory," *Int. J. Glob. Warm.*, vol. 24, no. 1, pp. 65–85, 2021.

[11] D. Diakoulaki, D. Giannakopoulos, and S. Karellas, "The driving factors of CO 2 emissions from electricity generation in Greece : an index decomposition analysis," *Int. J. Glob. Warm.*, vol. 13, no. 3, pp. 382–397, 2017.

[12] W. Sun, S. Liu, Y. Wang, and Y. He, "Research on the relationship between provincial economy and CO_2 emissions from the power industry in China: From static and dynamic aspects," *Int. J. Glob. Warm.*, vol. 26, no. 2, pp. 141–161, 2022.

[13] L. P. Fávero, R. D. F. Souza, P. Belfiore, M. R. Luppe, and M. Severo, "Global relationship between economic growth and CO_2 emissions across time: A multilevel approach," *Int. J. Glob. Warm.*, vol. 26, no. 1, pp. 38–63, 2022.

[14] H. E. Akbaş, H. A. Karaduman, and S. Canikli, "Impacts of carbon and energy aspects on financial performance," *Int. J. Glob. Warm.*, vol. 23, no. 2, pp. 118–128, 2021.

[15] J. Gyimah and X. Yao, "Globalisation and renewable energy impact on carbon emissions in Ghana," *Int. J. Glob. Warm.*, vol. 28, no. 2, p. 2022, 2022.

[16] I. Kacar, I. Durgun, F. Ozturk, and R. J. Simmons, "A review of light duty passenger car weight reduction impact on CO2 emission," *Int. J. Glob. Warm.*, vol. 15, no. 3, pp. 333–349, 2018.

[17] C. Coskun, "A time - varying carbon intensity approach for demand - side management strategies with respect to CO_2 emission reduction in the electricity grid," *Int. J. Glob. Warm.*, vol. 19, pp. 3–23, 2019.

[18] M. Bulut, "Change in energy demand and CO_2 emission in Turkey from the period 1981-1998 to the period 2007-2019," *Int. J. Glob. Warm.*, vol. 24, pp. 181–206, 2021.

[19] R. Moessner, "Evidence on climate policy, carbon dioxide emissions and inflation," *Int. J. Glob. Warm.*, vol. 28, no. 2, pp. 136–151, 2022.

[20] I.M. Ramatsa, E.T. Akinlabi, and R. Huberts, "Improving the stability and simultaneously capturing CO_2 during biogas production under controlled internal pressure using NaOH," *Int. J. Glob. Warm.*, vol. 21, no.1, pp. 62–71, 2020.

[21] A. Hasnain, U. Ali, and M. Imran, "Performance of rich solvent flashing for MEA-based post-combustion CO_2 capture," *Int. J. Glob. Warm.*, vol. 23, no. 3, pp. 331–354, 2021.
[22] N.K. Agarwal, N. Kundu, and S. Sarkar, "Novel molecular integrated process model for biomethane upgradation by CO2capture with monoethanolamine," *Int. J. Glob. Warm.*, vol. 27, no. 1, pp. 92–101, 2022.
[23] A. Syuhada and Hamdani, "Analisis tingkat kemampuan penyerapan panas radiasi matahari oleh tanaman taman untuk mengatasi panas lokal," In Proc. Seminar Nasional Tahunan Teknik Mesin XII (SNTTM XII), pp. 59–64, 2013.
[24] C. Coskun, M. Erturk, E. Arcaklioğlu, and K. B. and Z. Oktay, "The climate change impact projections on seasonal residential sector CO_2 emissions and energy demand forecasting for Turkish provinces," *Int. J. Glob. Warm.*, vol. 24, pp. 281–306, 2021.
[25] W. F. Lamb *et al.*, "A review of trends and drivers of greenhouse gas emissions by sector from 1990 to 2018," *Environ. Res. Lett.*, vol. 16, no. 7; p. 073005, 2021.
[26] E. N. Dahlan, "Trembesi vs lidah mertua: Mana lebih kuat menyerap polusi? Kelebihan dan kekurangan trembesi dan lidah mertua dalam menyerap polusi.," Aug. 2019 [Online]. Available: www.forestdigest.com, Edisi 5, [Accessed: May 10, 2022]..
[27] A. Shishegaran, A. Shishegaran, M. Najari, A. Ghotbi, and A. N. Boushehri, "Effect of plants on an environment with high carbon dioxide concentration," *Clean. Eng. Technol.*, vol. 1, no. August, p. 100002, 2020.
[28] H. Praseti, R. Riduan, and N. Annisa, "Variasi kemampuan beberapa jenis pohon dalam menyerap CO_2 pada Taman Kota Banjarbaru," *Tek. Lingkung.*, vol. 4, no. 2, pp. 72–76, 2018.
[29] K. Azuma, N. Kagi, U. Yanagi, and H. Osawa, "Effects of low-level inhalation exposure to carbon dioxide in indoor environments : A short review on human health and psychomotor performance," *Environ. Int.*, vol. 121, no. August, pp. 51–56, 2018.
[30] US Energy Information Administration, "Today in energy," 2021 [Online]. Available: https://www.eia.gov/todayinenergy/index.php?tg= biofuels [Accessed: May 10, 2022]
[31] Ismiyati, D. Marlita, and D. Saidah, "Pencemaran udara akibat emisi gas buang kendaraan bermotor," *J. Manaj. Transp. Logist.*, vol. 02, no. 03, pp. 241–248, 2014.
[32] R. Lindsey, and L. Dahlman, "Climate change : Ocean heat content," 2020 [Online]. Available: https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content [Accessed: 15 Mei 2022].
[33] Afdal, "Siklus karbon di atmosfer dan samudera," *Oseana*, vol. XXXII, no. 2, pp. 29–41, 2007.
[34] N. A. Campbell, J. B. Reece, L. G. Mitchell, and R. Lestari, *Biologi jilid 1*. Jakarta: Erlangga, 2002.
[35] L. Taiz and E. Zeiger, "Plant physiology, third edition," *Kew Bulletin*, vol. 15, no. 3. p. 410, 2002 [Online]. Available: https://www.jstor.org/stable/4115602?origin=crossref [Accessed: May 15, 2022]
[36] A. Saepudin and T. Admono, "Kajian pencemaran udara akibat emisi kendaraan bermotor di DKI Jakarta," *J. Teknol. Indones.*, vol. 28, no. 2, pp. 29–39, 2005.
[37] I. Samsoedin, I. W. Susidharmawan, Pratiwi, and D. Wahyono, *Peran pohon dalam menjaga kualitas udara di perkotaan*. [Online]. Available: http://puspijak.org/Portal/read/98, 2016.[Accessed: May 15, 2022].
[38] A. Syuhada and Hamdani, "Analisis tingkat kemampuan penyerapan panas radiasi matahari oleh tanaman taman untuk mengatasi panas lokal," In Proc. Seminar Nasional Tahunan Teknik Mesin XII (SNTTM XII), pp. 71–76, 2013.
[39] Y. U. Anggraito *et al.*, *Metabolit sekunder dari tanaman*. Semarang: Unnes, 2018.