Utilisation of Crop Residue and Manure Fermentation (CRAM) for Carbon Dioxide Enrichments in Chilli Kulai Production

Khairunisa Ab Aziz* and Nur Eastiharah Mohmad Hairin

Department of Agrotechnology and Bio Industry,
Politeknik Jeli Kelantan,
17600 Jeli, Kelantan, Malaysia.

*Corresponding Author's Email: khairunisa@pjk.edu.my

Article History: Received 8 April 2024; Revised 11 June 2024;
Accepted 25 June 2024

Abstract

Carbon dioxide (CO_2) dosing has become an integral part of greenhouse horticulture. Additional CO_2 promotes crop growth and increases production and/or improves quality. CO_2 supplementation is the process of adding more CO_2 in the greenhouse, which increases photosynthesis in a plant. Most commercial farmers invented various techniques to increase CO_2 concentration in the greenhouse, but those techniques were expensive and had some limitations. Therefore, this project is designed to produce CO_2 gases using crop residue and animal manure composting. The production of CO_2 by composting the crop residue and animal manure with selected microorganisms (*Aspergillus niger* and *Trichoderma*). Then, CO_2 gases were released inside the greenhouse from 8.00 to 11.00 am after one month of fermentation and fully monitored by the sensor to prevent any circumstances that can affect plants. Although releasing CO_2 in the greenhouse rise temperature inside greenhouse, the plants are not affected by heat. During the cultivation period, CRAM helps to increase CO_2 concentration which significantly increases plant height, total leaf area and total shoot of chilli. The application of a concentrated CO_2 system in greenhouse resulted early flowering and fruit ripening compared to control greenhouse. The yield also recorded 30% higher in concentrated CO_2 greenhouse compared to conventional practices. This project helps to recycle the into useful energy. Implementation of this project has the potential to sustain the environment as well as maintaining food security.

Keywords: Carbon Dioxide, Crop Residue, Manure, Chilli, *Aspergillus*

1.0 Introduction

Carbon dioxide (CO_2) dosing has become an integral part of greenhouse horticulture. Additional CO_2 promotes crop growth, increases production, and improves its quality [1]. In general, CO_2 supplementation is the process of adding more CO_2 to the greenhouse, which increases photosynthesis in a plant. In greenhouses, CO_2 concentrations are frequently below ideal levels for plant growth [3]. Greenhouses, with closed and controlled environments, have been used in agricultural production to meet the increasing demand for high-quality and healthy products. By keeping other growing conditions ideal such as the development of improved lighting systems, environmental controls and balanced nutrients, the amount of CO_2 is the only limiting factor for the maximum growth of plants. Thus, supplemental CO_2 can provide improved plant growth [4].

Chilli (*Capsicum annum* L.) is a type of vegetable fruit from the Solanaceae family which consist of various types of species and varieties. The plants can produce capsaicin element that gives a spicy taste and is an important component of spices in culinary cuisine. Chilli has been sold as fresh chillies, dried chillies, and powdered chillies in the market. In Malaysia, chilli crops are very popular among farmers because they are marketable and easily generate income and provide profit to the producer. Planting chilli under a greenhouse has many advantages over open field production including higher quality, enhanced yield and extended growing season for vegetable production.

Composting has become a popular method for handling agricultural waste [5]. The process involves a variety of microorganism species that break the organic waste components naturally. Fungal cellulase activity is responsible for the hydrolysis of cellulose. Cellulolytic fungi are those fungal groups that use cellulase enzymes to restructure cellulose [6]. One of the studies reports that some fungal genera containing cellulolytic abilities include genera Aspergillus, Penicillium, and Paecilomyces [7]. Besides that, the usage of effective microorganisms also can speed up the composting process.

There is an approach to raise CO_2 content throughout the day that was developed which is crop residues and animal manure composting (CRAM). Furthermore, the CRAM when added to soil, will enhance fertility, water retention, and soil structure. Through enhanced microbial activity and plant growth, it improves the soil's capacity to store carbon dioxide. More carbon dioxide is typically stored in healthy soils with higher organic matter contents than in degraded soils. Thus, this study intends to provide alternative methods for developing a CO_2 enrichment system using crop residue and manure composting (CRAM) in the greenhouse and to test the efficiency of CO_2 on the chilli growth.

2.0 Methods

This study was conducted in a greenhouse at Politeknik Jeli Kelantan. There were two types of greenhouses applied in this study: CO_2 Greenhouse and Control Greenhouse. The detailed specifications of both greenhouses are shown in Table 1. For the plant material, the seeds used was F1 Hybrid of red chilli Leckat Hot Sun (cili kulai) from Green World Genetic.

Table 1: Details specification of both CO_2 greenhouse (CO_2 GH) and control greenhouse (Control GH)

Specification	CO_2 Greenhouse	Control Greenhouse
Size	5m (width) x 15m (length) x 21m (height)	
Structure	Shape: gutter-connected straight sidewall	
Material	polyethylene plastic film	32 mesh Greenhouse netting
Ventilation	Exhaust Fan Brand: KDK Diameter: 24” Watt: 240	Roof ventilation

Specification	CO_2 Greenhouse	Control Greenhouse
	Unit: 4	
Sensor	Model: Arduino uno dan Arduino WeMos D1 R1 Function: Temperature, Relative Humidity and CO_2	

2.1 Crop Residue and Animal Manure Fermentation (CRAM) Preparation

The composting process was conducted in a blue tank with a size of 200L. The composting unit was set at a 4cm aeration bar to ensure sufficient aeration to Crop Residue and Animal Manure (CRAM). For this purpose, 40kg of crop residue, 16 kg of fresh manure (chicken dung) and approximately 12 L of water were added to the tank. Then, two kg of molasses and two litres of effective microorganisms (EM) were added to the mixture. After that, two fungal species namely (*Aspergillus niger* and *Trichoderma*) were inoculated into a CRAM mixture to enhance carbon dioxide production via fermentation. The CRAM mixture was incubated for one month with daily monitored of pH and the relative humidity. This composting process was repeated for three cycles to ensure sufficient CO_2 supply to the greenhouse.

2.2 Set Up of Composting Unit

Two blue tanks (200L) were set up for the composting process to facilitate CO_2 emission to the greenhouse (Figure 1). Each tank was installed with a ball valve female treaded 32mm and connected with a polypipe sized 16mm inside the greenhouse. The polypipe was equipped with a nozzle for CO_2 emission to the plants. A gas pressure meter was placed before the polypipe connection to monitor CO_2 production. Furthermore, the bottom of the tank was perforated to facilitate the cleaning management of unused compost waste.

Figure 1: Blue tank for waste fermentation

2.3 Carbon Dioxide Application

Carbon dioxide concentration was recorded by using the Arduino uno and Arduino WeMos D1 R1. The carbon dioxide was applied at 8.00 am and 11.00 am every day at the treated Greenhouse.

2.4 Data Collection

The experiment was carried out in a complete randomized design Complete Randomize Block Design (CRBD) with three replications. The whole plant was destructively sampled on every monthly basis to measure the growth performance after planting from each treatment plant growth parameters were examined by taking nine plants for each replicate. Parameters such as plant height, leaf area meter (using leaf area meter), number of flowers per plants, total fruits mass per plants and number of fruits per plants were recorded. The data was collected in three times which took 30, 60 and 90 days after transplanting. The yield was harvested eight times in one month.

2.5 Data Analysis

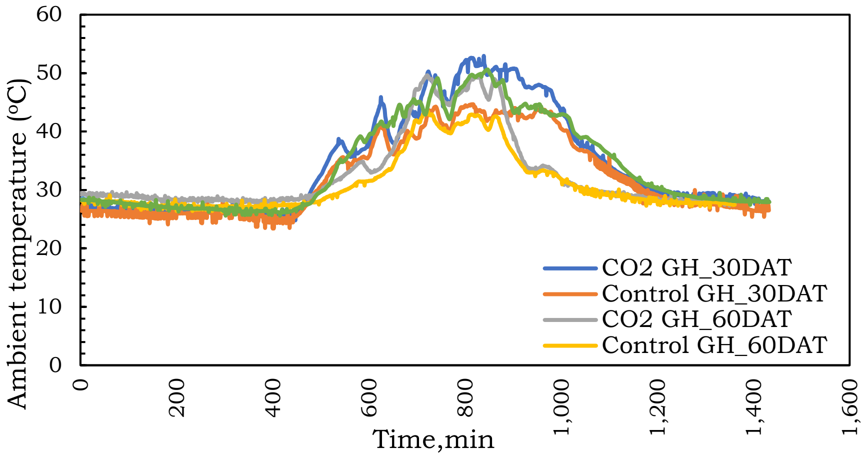
The data was analysed using a T-test to determine the significant difference between the treatment using Statistical Analysis Software (SAS). The mean differences were compared using the Least Significant Difference (LSD) at $p \leq 0.05$ level.

3.0 Results and Discussion

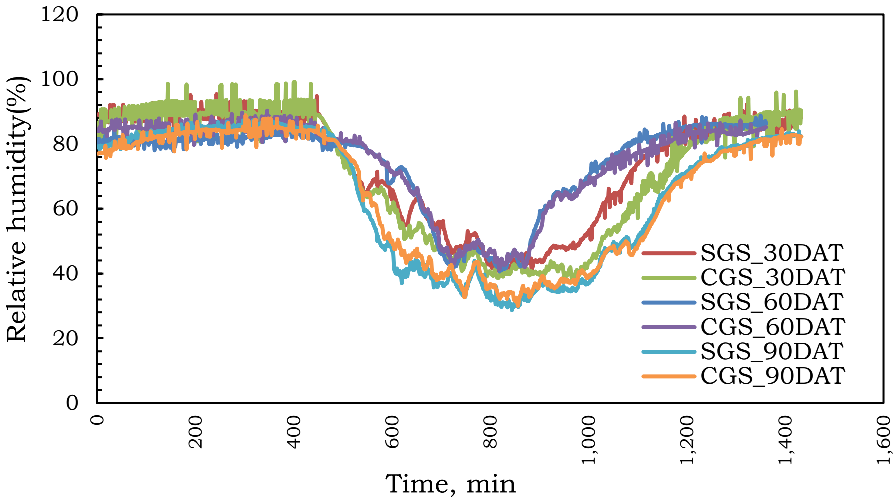
3.1 Temperature and Relative Humidity

Daily mean ambient temperature and relative humidity against time were plotted in Figure 2 (a) and (b), respectively. In 24 hours, the highest ambient temperature was recorded between 11.00 am to 3.00 pm in both greenhouses. However, CO_2 GH showed an increment in temperature of about 3-5°C. Furthermore, the relative humidity showed a lower percentage from 12.00 until 3.00 pm. Although CO_2 GH recorded high temperatures, the response of the plants towards heat was not significant.

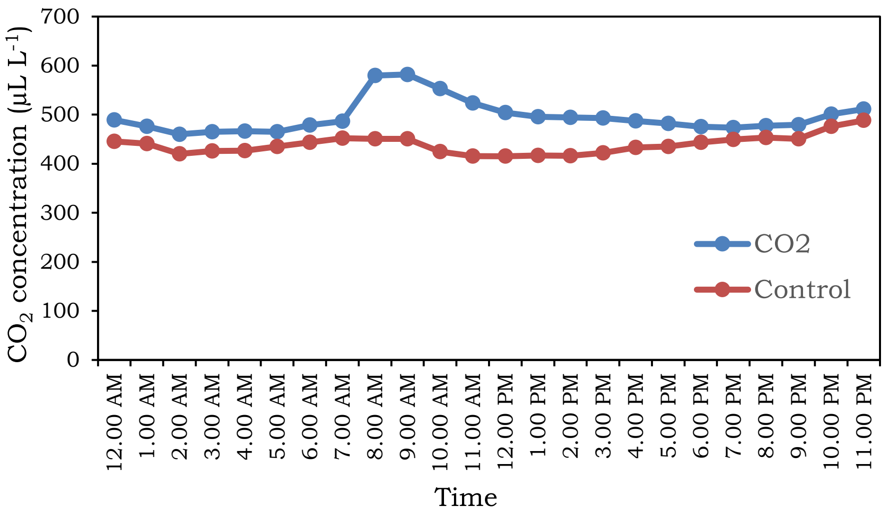
Figure 2 (c) shows the observation of daily mean CO_2 concentration in 24 hours throughout the planting period. The concentration of CO_2 was elevated in treated GH at 8.00 to 11.00 resulting in the increase of temperature of about 1-2^{o}C compared to control GH. It is due to carbon emission bouncing back to the greenhouse environment thereby heat the microclimate of greenhouse. The result indicated that CO_2 concentration in treated GH increased by 40% higher than control GH showing that fermentation of CRAM able to produce sufficient CO_2 in the greenhouse.



(a)



(b)



(c)

Figure 2: Time course of (a) ambient temperature (b) relative humidity, and (c) CO_2 concentration throughout the planting period

3.2 Plant Growth

Carbon dioxide enrichment using CRAM in the greenhouse had a significant impact on the chilli growth compared to the control treatment. The result showed that CO_2 enrichment initiated early flowering and fruit ripening one week before control treatment as shown in Table 2. The result of this study was in line with previous study where CO_2 enrichment in the greenhouse increased fruit set percentage of crop [2].

Table 2: Effect of CO_2 enrichment by fermentation of CRAM on growth of chilli

Treatment	Sowing	Transplant	CRAM application	First Flower	First Fruiting	Fruit Ripening
Year.Month.Day /	Day After Plant (DAT)					
CO_2	2021.12.01	2022.01.01	2022.01.06	25	39	59
Control	2021.12.01	2022.01.01	-	35	60	69

3.3 Plant Yield

Based on the result, the total yield was significantly different in both greenhouses. Yield in CO_2 GH showed a 40% increase from the 6th harvesting until the end of harvesting (Figure 3). Increased CO_2 will promote more carbohydrates in fruit during fruit development, leading to higher yield production. Moreover, previous study reported enormous yield has been produced in elevated CO_2 of vegetables and tomato [8].

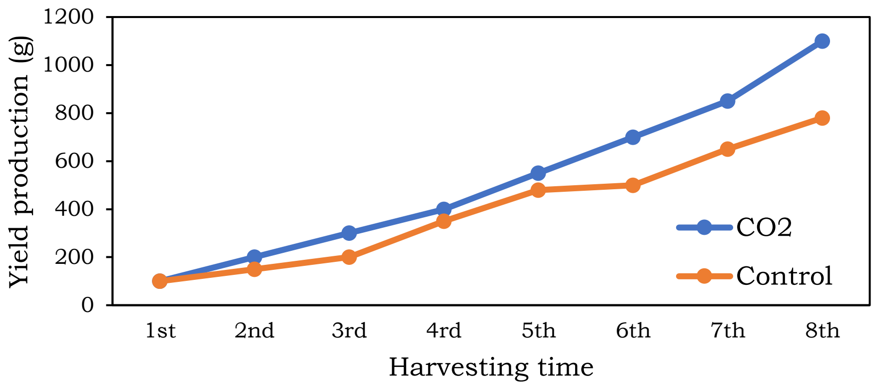


Figure 3: Cumulative yield production of chilli plant under different greenhouse conditions

4.0 Conclusion

From this study, there were improvements found in the growth and yield of the chilli production. The study showed that using CRAM application in the greenhouse system can increase plant yield and early harvesting. Other than that, this technique is also applicable and economical to the farmers. CRAM is also considered an important strategy for reducing agricultural waste. It can reduce the environmental pollution produced by the agriculture sector as well as the good management practices for agriculture by-products. Furthermore, the use of IoT technology in this project can easily and accurately monitored the environmental conditions in greenhouse.

Acknowledgement

The authors would like to thank the Ministry of Higher Education Malaysia, Jabatan Pendidikan Politeknik dan Kolej Komuniti and Politeknik Jeli Kelantan for the support provided for the completion of this project.

Author Contributions

K. A. Aziz: Conceptualization, Methodology (CRAM), Data Collection, Writing-Original Draft Preparation; **N. E. M. Hairin**: Conceptualization, Validation, Supervision, Writing-Reviewing and Editing.

Conflicts of Interest

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its submission, and declare no conflict of interest in the manuscript.

References

[1] A. R. Reddy, G. K. Rasineni, and A. S. Raghavendra. "The impact of global elevated CO_2 concentration on photosynthesis and plant productivity," *Current Science*, vol. 99, no. 1, pp. 46-57, 2010.

[2] H. Mamatha, N. S. Rao, R. H. Laxman, K. S. Shivashankara, R. M. Bhatt, and K. C. Pavithra. "Impact of elevated CO_2 on growth, physiology, yield, and quality of tomato (Lycopersicon esculentum Mill) cv. Arka Ashish," *Photosynthetica*, vol. 52, pp. 519-528, 2014.

[3] C. Jin, S. Du, Y. Wang, J. Condon, X. Lin, and Y. Zhang, "Carbon dioxide enrichment by composting in greenhouses and its effect on vegetable production," *Journal of Plant Nutrition and Soil Science*, vol. 172, no. 2, pp. 418-424, 2009.

[4] P. F. Hao, C. W. Qiu, D. Guohua, E. Vincze, G. Zhang, Y. Zhang, F. Wu, "Agriculture organic wastes fermentation carbon dioxide (CO_2) enrichment in greenhouse and the fermentation residues improve growth, yield and fruit quality in tomato," *Journal of Cleaner Production*, vol. 275, 123885, 2020.

[5] K. Azim, B. Soudi, S. Boukhari, C. Perissol, S. Roussos, and I. Thami Alami, "Composting parameters and compost quality: a literature review," *Organic agriculture*, vol. 8, pp. 141–158, 2018.

[6] K. M. H. Nevalainen, M. E. Penttilä, "Molecular biology of cellulolytic fungi," in *Genetics and Biotechnology*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 369–390, 2004.

[7] S. Sarsaiya, A. Jain, S. K. Awasthi, Y. Duan, M. K. Awasthi, and J. Shi,

"Microbial dynamics for lignocellulosic waste bioconversion and its importance with modern circular economy, challenges and future perspectives," *Bioresource Technology*, vol. 291, 121905, 2019.

[8] M. F. Karim, P. Hao, N. H. B. Nordin, C. Qiu, M. Zeeshan, A. A. Khan, F. Wu, and I. H. Shamsi. "CO_2 enrichment using CRAM fermentation improves growth, physiological traits and yield of cherry tomato (Solanum lycopersicum L.)," *Saudi Journal of Biological Sciences*, vol. 27, no. 4, pp. 1041-1048, 2020.