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Biogas Yield Potential Research of *Tithonia diversifolia* in Mesophilic Anaerobic Fermentation in China

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***Abstract*—**BioEnergy is an archetypal appropriate technology and alternate source of energy in rural areas of China, and can meet the basic need for cooking fuel in rural areas. The paper introduces with an alternate mean of research that can accelerate the biogas energy production. *Tithonia diversifolia* or the Tree marigold can be hailed as mesophillic anaerobic digestion to increase the production of more Bioenergy. *Tithonia diversifolia* is very native to Mexico and Central America, which can be served as ornamental plants- green manure and can prevent soil erosion. *Tithonia diversifolia* is widely grown and known to Asia, Africa, America and Australia as well. Nowadays, Considering China's geographical condition it is found that *Tithonia diversifolia* is widely growing plant in the many tropical and subtropical regions of southern Yunnan- which can have great usage in accelerating and increasing the Bioenergy production technology. The paper discussed aiming at proving possibility that *Tithonia diversifolia* can be applied in biogas fermentation and its biogas production potential, the research carried experiment on *Tithonia diversifolia* biogas fermentation under the mesophilic condition (35 Celsius Degree). The result revealed that *Tithonia diversifolia* can be used as biogas fermentative material, and 6% concentration can get the best biogas production, with the TS biogas production rate 656mL/g and VS biogas production rate 801mL/g. It is well addressed that *Tithonia diversifolia* grows wildly in 53 Counties and 9 cities of Yunnan Province, which mainly grows in form of the road side plants, the edge of the field, countryside, forest edge, open space; of which demersum-natures can form dense monospecific beds -causing serious harm to agricultural production landforms threatening the ecological system as a potentially harmful exotic plant. There are also found the three types of invasive daisy alien plants -*Eupatorium adenophorum*, *Eupatorium odorata* and *Tithonia diversifolia* in Yunnan Province of China-among them the *Tithonia diversifolia* is responsible for causing serious harm to agricultural production. In this paper we have designed the experimental explanation of Biogas energy production that requires anaerobic environment and some microbes; *Tithonia diversifolia* plant has been taken into consideration while carrying experiments and with successful resulting of generating more BioEnergy emphasizing on the practical applications of *Tithonia diversifolia*. This paper aims at- to find a new mechanism to provide a more scientific basis for the development of this plant herbicides in Biogas energy and to improve the utilization throughout the world as well.

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***Keywords*—**Biogas Energy Production, *Tithonia diversifolia,* Energy Development, Ecological Agriculture, *Eupatorium adenophorum, Eupatorium odorata,* Anaerobic Fermentation, Biogas Production Potential, Mesophilic Fermentation.

I. Introduction

TITHONIA DIVERSIFOLIA, with alias: sunflowers, *Rudbeckia laciniata*, smelly daisy, tree daisy. *Tithonia diversifolia*, an annual herb, which belongs to *Asteraceae* Tithonia and that, can grow in various types of soil for its well-developed root system and strong reproductive efficiency

1. *Tithonia diversifolia* origins from Mexico and Central America, which is widely introduced in many parts of Asia, Africa, the Americas, Australia as ornamental plants, green manure and helps in preventing soil erosion [3].
2. Currently, *Tithonia diversifolia* has become a kind of grassland, riparian, roadside invasion weeds.
3. The seeds of Tiithonia *diversifolia* have a strong reproductive potential, once the seed dispersal and after a period of nutritional growth and settling, *Tithonia diversifolia* can produce the roots of cloning plants having relied on the base of the plant and adventitious bud formation [1]. Besides, since *Tithonia diversifolia*'s own canopy density the understory plant gets difficult to grow, thus the cloning plants can grow rapidly to become monospecific communities [7].
4. In recent years, as a large potentially harmful exotic plant, *Tithonia diversifolia* has grown in 53 Counties in 9 prefectures in Yunnan Province, mainly grown in the road, the edge of the field, countryside, forest edge, open space to form dense monospecific groups, which has been brought serious harmful impacts on the agricultural production [8].
5. The enlarge growth of *Tithonia diversifolia* found concentrated in the tropical and subtropical regions with the richest biodiversity of Yunnan Province [6] will undoubtedly force threat to the local biodiversity prefaces.
6. Facing the increasingly serious harm to the ecological environment and agricultural production by *Tithonia diversifolia*, human beings are constantly looking for new approaches to control the growth of *Tithonia diversifolia* and to improve its utilization [4]. Additionally, the most economical method to control its population growth through the economical ways using *Tithonia diversifolia* are also being researched [2].

7. At present, there are a great numbers of reports on research works of *Tithonia diversifolia* have been found, which are researched mainly in drug usage, pesticides and herbicides, fertilizers and feed utilization research
8. However, the certain research on *Tithonia diversifolia*'s anaerobic fermentation biogas potential has not been reported [5], though the study on its' anaerobic fermentation biogas production is of great significance in agricultural production
9. In the research, *Tithonia diversifolia* in Yuxi region of Yunnan Province has been selected to study as the potential for biogas production in the mesophilic anaerobic fermentation, so that to explore the possible grogram of *Tithonia diversifolia* in furtherance, and to provide a theoretical basis for the effective utilization of *Tithonia diversifolia*.

II. Materials and Methods

A. Fermentation -Raw Materials and Inoculum

Tithonia diversifolia from Mosha Town, Xinping County of Yuxi Region has been adopted as fermentation raw material in the study, which will be cut into pieces for experiment. And the inoculum used in the experiment is from the anaerobic activated sludge that cultivated by Biogas Energy Laboratory, Solar Energy Institute of Yunnan Normal University. The Total Solid (TS) value and Volatile Solid (VS) value are shown in Table I.

TABLE I
Properties of Raw Materials

Raw Material	TS	VS	pH
Tithonia diversifolia	17.25%	81.84%	7.8
Inoculum	8.849%	51.44%	7.0

1. Experimental Excogitation and Experimental Device

Experimental Excogitation

The experiment was carried under a condition of mesophilic condition (35°C), with the inoculum amount of 30%. Experiment groups have been set as 3%, 6%, and 9% of concentration, each provided with three parallel placements. Addition of a control group which is being repeated by distilled water. The total volume of the experimental and control groups fermentation liquid is 400mL. The specific material ratios are shown in Table II.

TABLE II
Proportioning of the Fermentation Feed Liquid

Groups	Raw material	Ratios
Group A	*Tithonia diversifolia*	Raw material: 40.99g, inoculum:120mL
Group B	*Tithonia diversifolia*	Raw material:77.70g, inoculum:120mL
Group C	*Tithonia diversifolia*	Raw material:147.27g, inoculum:120mL
Control Group	Distilled water	Raw material:280mL, inoculum:120mL

Experimental Device

The experiment adopted the well - controllable constant temperature fermentative apparatus with the capacity of 500mL, which is shown in Fig. 1.

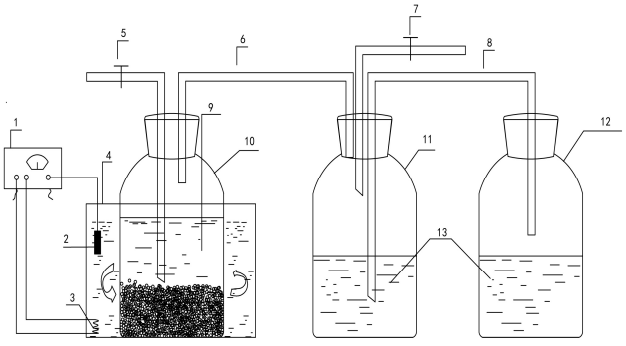

Fig. 1 Schematic Diagram of Constant Temperature Anaerobic Fermentation System 1.Temperature Controller; 2. Sensor; 3. Heating Wire; 4. Thermostatic Water Bath; 5. Sample Connection; 6. Gas Pipe; 7.Gas Outlet; 8. Aqueduct Pipe; 9.Fermentative Feed Liquid; 10.Fermentative Flask; 11.Gas Collector; 12. Water Collector; 13. Saturated $NaHCO_3$

B. Analysis and Testing

(1) TS, VS value can be found by "conventional analysis method".
(2) pH value: pHS-3C precision acidity meter, which are produced by Shanghai Hongyi Instrument co., LTD.
(3) Biogas production: drainage gas-collecting method. After the experiment has been successfully started, daily biogas yield should be recorded for each group, and the average biogas yield is needed to be calculated --as the intent to characterize the gas production.

1. Data Processing

The research adopted the way of daily recording and gas production ratings, calculation methods for data processing. Besides, the software "Origin" is applied for data processing, and "Word table" is used as imaging signs.

III. Results and Analysis

A. Affect Produced by Different Fermentative Concentration on Biogas

The comparison of biogas yield under different fermentative concentration

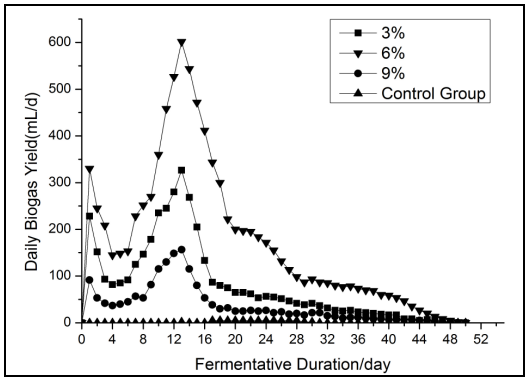

Fig. 2 Influence of Different Fermentation Concentration Exert on Biogas Yield per Day

As shown in Fig. 2, the fermentative period takes 50 days to complete. In the Group A (with the concentration of 3%), the fermentative system reaches the maximum biogas yield on the day fourteenth with the value of 325m --as like the average daily biogas yield. In the Group B (with the concentration of 6%), the digestion system goes to the biogas production peak on the day fifteenth in the value of 600mL – which accounts for the average daily biogas production. In the Group C (with the concentration of 9%), the biogas production appears on the day sixteenth-- in which the daily average biogas yield is 155mL. Thus, it is drawn a conclusion that in the fermentative system, the most efficient biogas digestion states is in Group B; where the Group A is in the second place, and the fermentative concentration of Group C: 9% is not suitable for the biogas digestion system of *Tithonia diversifolia*.

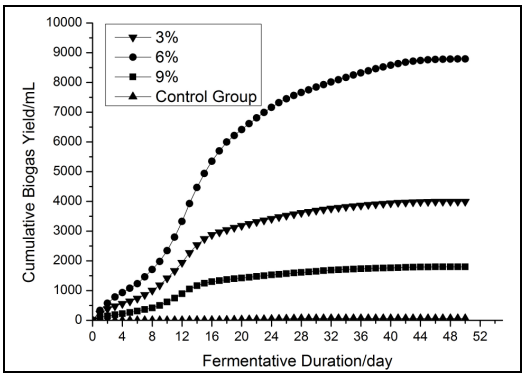

Fig. 3 Influence of Different Fermentation Concentration Exert on Cumulative Biogas Yield

It is shown in Fig. 3 that biogas yield condition is not ideal mostly at the very beginning –when the biogas digestion system gets started. And during sixteenth to the thirty-eighth days it is found that the biogas production remains in a relevant steady level. Additionally, it is shown that the biogas digestion process of *Tithonia diversifolia* generally gets completed by the early 36-44days --since when the fermentative system gets ready.

B. Analysis on Biogas Yield Potential of Tithonia diversifolia

At the beginning and the end of the experiment, the Total Solid (TS) value and Volatile Solid (VS) value of the fermentative feed liquid are measured; the values are shown in Table III.

TABLE III
TS AND VS VALUE OF FEED LIQUID BEFORE AND AFTER THE FERMENTATION

Groups	Beginning		End	
	TS%	VS%	TS%	VS%
3% Concentration	5.18	54.79	2.85	51.30
6% Concentration	6.43	71.55	4.42	56.52
9% Concentration	7.28	81.22	5.13	64.75
Control group	3.30	56.83	2.31	49.95

Table III shows that, the TS & VS value has changed before and after the biogas fermentative process, which reveals that *Tithonia diversifolia* has been digested into biogas in the process of anaerobic fermentation.

TABLE IV
BIOGAS YIELD POTENTIAL COMPARISON OF *TITHONIA DIVERSIFOLIA* AND OTHER STRAW BIOMASS

Raw Fermentative Material	TS Biogas Yield Rate (mL/g·TS)—35°C
Grass	440
Cornstalk	500
Rice Straw	400
Wheat Straw	450
Tree Leaf	210~294
Tithonia diversifolia	656

Table IV [10] shows the biogas yield potential of different straw biomass, when the biogas fermentative temperature is 35°C. It is well expressed that the TS biogas yield rate of *Tithonia diversifolia* is relatively higher than the other five raw fermentative materials which are wildly used in biogas fermentative process in rural areas of China.

IV. CONCLUSION

The conclusions through the complete data analysis and comparisons for each index of *Tithonia diversifolia*'s biogas fermentation under different raw materials concentration can be drawn as the followings:

1. *Tithonia diversifolia* can be considered as one of the good biogas fermentative raw materials. The proper fermentative concentration of *Tithonia diversifolia* as the raw materials will have an important effect and usage in increasing the biogas production level.
2. *Tithonia diversifolia* helps in easing the fermentation digestion. The biogas can yield potential in low concentration of *Tithonia diversifolia* where as 565mL/ g·TS, 119mL/ g·VS, which can be raised by improving the fermentative concentration, when the concentration goes to 6%, it will reach the biogas yield peak: 656mL/ g·TS, 801mL/ g·VS. In a word, when *Tithonia diversifolia* is used in biogas fermentation process, the concentration of 6% is easier to be digested, where as it is hard to be digested both in 3% (relevant lower concentration) and 9% (relevant higher concentration).
3. The anaerobic fermentation process of *Tithonia diversifolia* can be applied in daily life agriculatural production while balancing ecological environment protection as well in the invasion regions of *Tithonia diversifolia* [9]. Meanwhile, *Tithonia diversifolia* can be used as one of the diversified biogas fermentative raw materials providing a safe and sound locality to residents both in agricultural production and daily life livelihoods.

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REFERENCES

[1] Callaway R M, Maron J L What have exotic plant invasions taught us over the past 20 years [J]. Trends in Ecology and Evolution, 2006, 21:369-374.
[2] Holm L, Doll J, Holm E, et al. World Weeds natural histories and distribution [J]. New York John Wiley& Sons Inc, 1997: 1-37.
[3] Sonke D.Tithonia weed—a potential green manure crop [J]. Echo Development Notes, 1997, 57:5-6.
[4] Williamson J, Harrison S. Biotic and abiotic limits to the spread of exotic revegetation species [J]. Ecological Applications, 2002, 12: 40-51.
[5] Hobbs R J, Huenneke L F. Disturbance diversity and invasion: implications for conservation [J]. Conservation Biology, 1992, 6: 324-337.
[6] Wang S H, Sun W B, Cheng X. Attributes of plant proliferation, geographic spread and the natural communities invaded by the naturalized alien plant species *Tithonia diversifolia* in Yunnan [J]. China Acta Ecological Sinica, 2004, 24: 444-449.
[7] Yang Haiyan, Luo Zhongze, Li Guihua et al. Research on the Allelopathy of Tithonia diversifolia on the Phaseolus radiate and Oryza sativa Seed [J].Journal of Anhui Agri. Sci, 2011,39(13):7576-7578.
[8] Xu Chengdong, Lu Shugang. Invasive Plants in Yunnan Province [J]. Guangxi Plant, 2006, 26(3):227-234
[9] Cui Qingguo, Peng Hua, Li Renqiang et al. Effects of habitat types on population- and individual-level performance of an invasive plant species Tithonia diversifolia[J]. ACTA Ecologica Since, 2007, 27(11):4671-4678.
[10] Zhang Wudi, Song Hongchuan, Yin Fang et al. The Comprehensive Utilization of Biogas Fermentation [M]. Practical Biogas Technology, 2004, 12(1):101-106.