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An Empirical Testing of a New Biogas Digester Obtained from Engineering Combination of Chinese and Indian Digester Models

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ABSTRACT

This paper proceeds to the analysis, design, construction and operation of a new household biogas digester for rural applications. This new digester is a combination of Chinese and Indian models. Typical biogas digesters generally have low production efficiency which one of its reason is lack of existence of an outlet tank resulting in biogas leakage. In the design and construction of new digester and in order to increase the efficiency, a mechanical mixer is used for feed homogenization and a gas cap is used to collect the biogas from the outlet tank. All calculations are carried out by EES V9.430 in this paper. In the problem analysis, the mixer and the gas cap are investigated in details. To detect the performance improvement, three digesters are constructed and tested empirically including 1) simple, 2) equipped with a mixer, and 3) equipped with mixer and gas cap. In this digester, the feed residence time is selected to be 117 days with total volume of 9,600 liters receiving the food including cow garbage and water mixed with a ratio of 1:1. This new digester has the ability of producing more than one cubic meters of biogas averagely per day. The digester is constructed with reinforced concrete in Firuraq village, Khoy city in the northwestern boundary of country. The outlet tank has a volume of 2 cubic meters and the gas cap has a volume of 350 liters in the optimized state. The initial capacity of the digester is 12 tons of foods and then 80 Kgs of livestock waste daily. Based on the experiments and experimental measurements carried out, the typical and unequipped value of the output gas is 1,014 liters per day which increases 6.5%, 21% and 27.5% using the mixer, gas cap and combination of mixer and gas cap respectively. With respect to the number of the experiment days, the experimental results are presented for 1 to 117 days and the software simulation is carried out during the year.
KEYWORDS: Anaerobic digester, Design of biogas system, Clean energy, Environmental protection, Biogas.

1. INTRODUCTION

The organic materials, livestock wastes, human wastes and plant wastes are all recoverable and under particular conditions, methane gas may be produced from them [1-4]. Biogas is one of the simple methods of supplying energy in non-enjoyed and far regions. In general, the collection of the gases produced from decomposing and fermentation of livestock, human and plant waste which is generated as a result of lack of oxygen and anaerobic bacterial activities in a chamber called digester, is so-called biogas [5-8]. Biogas may also be produced from livestock and human wastes, remainders of plants such as bagasse, straw, beet, Damask rose and even urban garbage [9-13]. The importance and development of biogas is considered in the world during the recent years, so that the number of these devices has reached to several millions in some countries, e.g. China, India and USA [14]. The beginning of using the biogas in China was since the early 1930's, and currently, in this country, the biogas consumption has reached to urban regions from the rural regions and different consumptions of it are carried out except household consumptions [15]. The importance of using this technology is mainly because of energy production, stable development and pollution reduction reasons. Lack of application of biogas may also has many reasons including lack of sufficient recognition and universal propagation [16-25]. A biogas device generally consists of both inlet and outlet tanks, a fermentation reservoir and a gas chamber which is constructed and operated in different shapes based on particular climatic conditions and technical and financial facilities. In order to carry out the process of formation of biogas well in the fermentation reservoir, the temperature should be about 20°C to 35°C, and the initial materials should be mixed with the water with the same volume [26-28]. In figure 1, a sample of Indian digester is illustrated and in figure 2, a sample of Chinese digester is illustrated.

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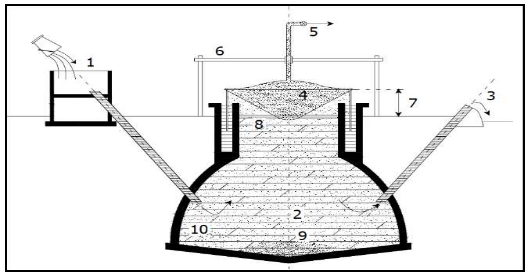

Fig.1. Indian digester of biogas system

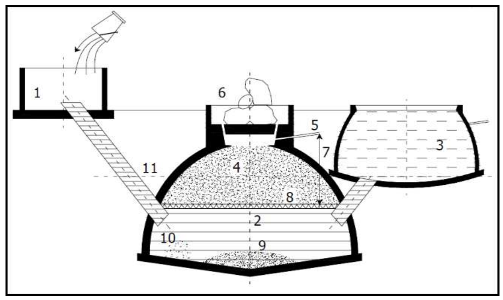

Fig.2. Chinese digester of biogas system

In the present research, a reactor combining of Chinese one and Indian one is used to prevent the gas wastage and also gas cap is used to maintain the temperature of the digester. In order to produce biogas, the most important agent is temperature in anaerobic digesters, and because of the point that the cap is floating on the wastages, a biogas layer is always placed on the wastages which acts as an isolator preventing from cooling the outlet reservoir. In order to increase the production of the digester gas, the mixer is used which results in homogenization of the wastages and distribution of bacteria generating methane inside of the digester and it increases the gas production [29]. According to the structure of the Chinese digester which has a great outlet reservoir, the top of this reservoir is open and in addition to this point that the biogas is smelt around the digester, also the gas existing in the food of this part enters the atmosphere. The gas cap which is among the innovations of the present research prevents from this wastage and it prevents from scattering of the smell in the environment by authorizing that obstacle. Among the other innovations of the present research is the usage of mixer and the cap at the same time which causes raising of the level of biogas production. Low production causes destruction in most of the digesters not responding to the constructor's demand after construction [7].

2- Design of combinatory anaerobic reactor

In this paper, the stages of design and experiment of a biogas unit is described for a residential house in Firuraq village located in western Azarbaijan province, Khoy city, according to figure 3.

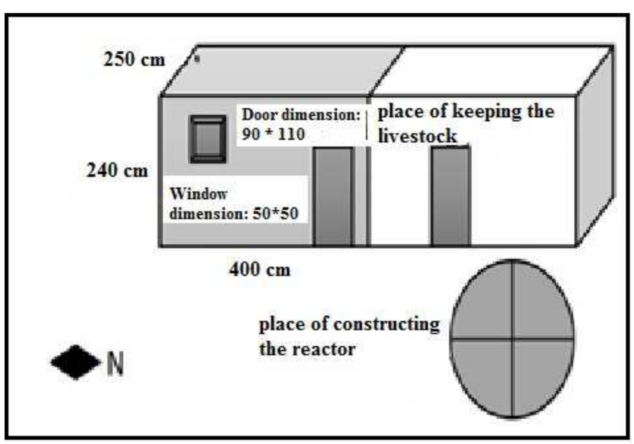

Fig.3. Dimensions and position of plan

In the designed digester, both Indian and Chinese models are adopted and it is why the term "combinatory" is used in this paper. This reactor is illustrated in figure 3.
After application of a Chinese model, the outlet reservoir is covered on the Indian model by a cap and the gas is collected in this part. The method used to design is completely new and it is obtained using logical accommodation and relation between the conduction heat transfer equations, displacement and design of biogas systems.
The calculation is in this way that at first the daily load of building is obtained using the conventional methods. Then the value of the biogas which may generate this heat value is calculated [30-32]. The combinatory reactor is designed for supplying the family's demand for energy of cooking and energy of heating. The heat load of the building includes wall loads, infiltration loads, and cooking loads and it is calculated through the calculation methods of the building installations [30].

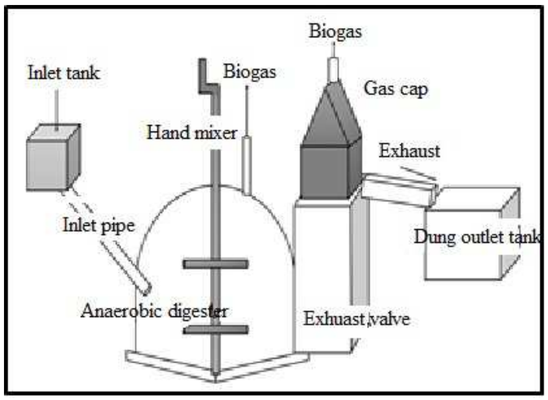

Fig.4. Combinatory Chinese and Indian anaerobic reactor

The temperature of the environment is considered using table. 1, the temperature of the inside is considered to be 16° C and the temperature of the place of keeping the livestock where there is no heating is considered to be 10° C.

Table 1. Climatic characteristics of Khoy city [33]

Row	Months	Maximum	Minimum	Ground temperature
1	March	18/2	5/6	18
2	April	23/2	9/4	19
3	May	28/5	12/7	21
4	June	34	16/2	23
5	July	32/1	15/2	24
6	August	28/2	10/5	21
7	September	20/4	5/6	19
8	October	12/4	1	17
9	November	5/4	3/4	15
10	December	2/2	-7	11
11	January	4/9	-4/7	14
12	February	12/5	0/1	16

The rural house is uninhabited daily and the residence exists only in the nights. Hence, to estimate the monthly consumptions, all day long is not considered. Using the required biogas value, the food value and the digester dimensions and also the coil and cap dimensions are calculated [34]. The food is provided from 4 dairy cattle and 2 calves. The value of the initial materials is 40 Kgs of wastes which are mixed with water in an equal ratio. Having the residence time based on chart 5, the value of daily production is extracted. For digester and cap calculations, the equations governing on the biogas devices are used [9], [30] and for the mixer calculations, equations of paddle mixers are used [29]. The mixer causes homogenization and equal distribution of heat temperature and the anaerobic bacteria in the digester through breaking down the floating floors layer on the food. This action increases the value of biogas production 40%. For usage and accommodation, the paddle mixer equations may be referred [29].

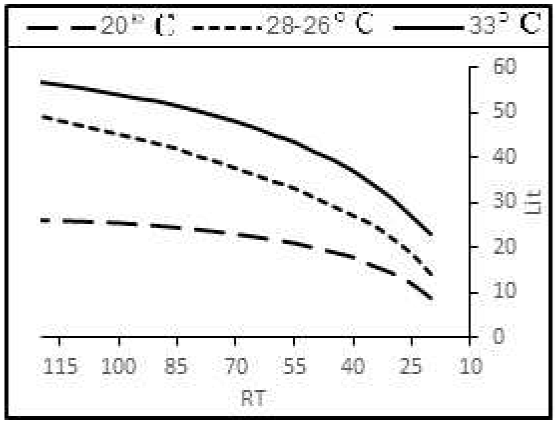

Fig.5. Producing biogas from new cow dung [3]

2-1- Characteristics of the designed reactor

The characteristics of the designed reactor is illustrated in three tables including Chinese digester in table 2, Indian digester or cap in table 3 and mechanical mixer in table 4.

Table 2. Characteristics of Chinese digester

Row	Sign	Characteristic	Unit	Value
1	RT	Residue level	day	117
2	G	Daily production level	lit	1014
3	G_d	Net production level	lit	25/41
4	ODM	Food value	kg	40/02
5	Vd	Digester volume	lit	9365
6	V_g	Outlet tank	lit	2035
7	Rd	Digester diameter	m	1/65
8	R	Outlet radius	m	0/99
9	l_{mkhrt}	Floor height	m	0/41

Table 3. Characteristics of Indian digester

Row	Sign	Characteristic	Unit	Value
1	RT	Residue level	day	117
2	Gsrp	Daily production	lit	220
3	G_d	Net production	lit	25/41
4	Msrp	Food value	kg	8/682
5	$V_{g.srp}$	Gas tank	lit	269
6	$V_{d.srp}$	Outlet tank	lit	2032
7	R_{srp}	Cap dimension	m	0/901

Table 4. Characteristics of hand mechanical mixer of combinatory reactor

Characteristics	Unit	Sign	Value
Power	Watts	P	62
Power number	Without unit	P	0/3
Momentum	N.m	M_{pt}	98

Maximum load	N	F_s	210
Number of rotations	Cycle/s	N	0/25
Bending moment	N.m	M_b	820
Shaft length	m	L_{sh}	3/9
Shaft dimension	mm	D_{sh}	35
Yield stress of steel	MN/m²	σ_y	235
Allowable yield stress of steel in loading	MN/m²	τ_y	136
Shear stress of acceleration of mixer	MN/m²	τ_{pk}	196
Wing load from the liquid side	N	F	6/25
Value of liquid load momentum	N.m	M	2/93
Thickness of wing	mm		2

2-2- Costs of implementation and payback period of the designed anaerobic reactor

The incomes obtained from the combinatory reactor is investigated in two cases. The first case is the costs which annihilate with the production of biogas and the second case is incomes which help the owner financially through producing the biogas.

The first case is the income obtained from removing the oil cost, the income obtained from removing the cost of supplying the natural gas of the consumed liquid and the income obtained from removing the transportation cost for supplying the energy. The relations of this part are simple daily relations and they are not adopted from any references and they are all written by the author.

0.6 USD is imposed on the family per each liter of oil. To calculate the income obtained from removing the oil cost, at first the value of oil consumption is calculated hourly according to the total heat load and it is multiplied in the price value of each liter. Of course, it should be noted that because of this point that the capsule is used in cooking, the cooking load should be deducted from the total load.

A 5% coefficient is also considered for oil costs, capsule and the number of oil loading for unpredictable costs. According to this point that all of the cooking was carried out by the capsule, the income obtained from removing the cost of supplying the capsule is carried out using the value of cooking heat load.

Having the value of coefficient of converting the biogas to capsule gas, the capsule price is calculated. The price of each capsule is considered to be 2 USD which assigning each 10.5 Kgs for each capsule, the price of each Kg of liquid gas of natural liquid gas capsule is calculated 0.19 USD.

To calculate the income obtained from removing the transportation cost for supplying the energy, the number of times for oil discharge and also the number of times for supplying the capsule should be determined. The cost of each time of oil loading is 5.71 USD and the cost of each time of supplying the capsule is 1.14 USD. The sum of transportation costs for supplying the gas capsule and the costs of oil transportation accounts for the total value of transportation costs.

The total income obtained from saving the costs, the sum of removing the cost of transportation, gas and oil capsules are daily. The second case is the incomes obtained from dung sales and biogas production. The value of the produced dung is the same value of the food which is converted to dung with a little change in the weight. The value of the food is the criterion for the dung level and it has 8.57 USD price for each ton. The dung income is calculated by multiplying the value of produced dung in its price. Using the table 5, the heat value of the biogas is 0.64 times the natural gas.

Table.5. The amounts of heating value of the fuels

Fuel	Amount of heating value
Oil	10000 KCal/hr
Natural gas	10500 Kcal/hr
Biogas	5000 Kcal/hr

If the amount of the produced biogas with the available coefficient converts to natural gas, the same natural gas rate may be applied and the amount of the produced biogas price may be obtained. The price for each cubic meter of the natural gas raises up to 0.03 tomans taking the costs of toll, insurance, subscription and added value into account.

The income obtained from the biogas is calculated having the coefficient of converting the biogas to the natural gas and the price of the natural gas and the amount of production.

The only considerable point is that because of applying the price of the natural gas in cubic meters, the value of biogas production should also be in cubic meters. The total income is obtained from the sum of total income obtained from removing the costs and production of biogas and annual dung. The results of all of these calculations is presented in table 6 throughout the year.
The costs of the combinatory reactor are given in table 7. The total cost of construction is calculated 350 USD. If the total annual income is divided to the value of the project costs, the amount of payback period is calculated in months. Comparing these costs with the level of incomes, it can be concluded that the payback period will be 25 months.

Table.6. Table of saved costs and incomes of combinatory Chinese and Indian anaerobic reactor (USD)

Months	Capsule cost	Oil cost	Transportation	Dung income	Biogas income	Total income
1	0/7	1	0/43	10/63	0/8	13/57
2	1/09	1/09	0/65	10/63	0/86	14/33
3	1/09	0/73	0/63	10/63	0/96	14/04
4	1/27	0/45	0/73	10/63	1/09	14/17
5	1/27	0/6	0/72	10/63	1/36	14/59
6	1/09	0/98	0/64	10/63	0/9	14/25
7	0/73	1/04	0/45	10/29	0/38	12/9
8	0/47	0/84	0/29	10/29	0/42	12/32
9	0/29	0/45	0/16	10/29	0/35	11/67
10	0/19	0/49	0/14	10/29	0/26	11/46
11	0/19	0/44	0/14	10/29	0/33	11/48
12	0/24	0/45	0/16	10/29	0/4	11/3
Sum	8/65	8/55	5/12	90/9	8/16	156/12

Table.7. Costs of combinatory reactor

	Materials	Rate
1	Concrete	98/28
2	Mixer	34/27
3	Rebar and wire	105/42
4	Pipes and fittings and valves	37/14
5	Cap and welding and etc.	31/42
6	Stipend	42/85
	Total amount	350

3- Stages of constructing laboratory reactor

The total time of constructing the combinatory reactor took 1.5 months. The place of the reactor was a pit with the dimensions of 3m in 5m and height of 3m and the place of reactor was excavated manually because of impassability of the way and lack of facilities.
Then stonework and concrete work of cone floor and reinforcement, shuttering, piling and concreting of reactor were carried out. In figure 6, the initial stages of reactor concreting and in figure 7, the final stages of the work are observed.
The cap and the mixer are painted after construction and the cap is gas-tightened by bituminous waterproofing. The appropriate food was laded from the supplying region and the reactor after landscaping around the reactor and the place of keeping the livestock.
The next stage is carrying out the experiments which took 117 days.
After loading the reactor, the water leakage experiment was carried out by the water contour line for 48 hours and no tangible reduction was observed in the height. The experiment of gas leakage was carried out by handmade pump and with a pressure of about 50 cm of water for 2 hours and no reduction was observed in the pressure according to the contour line. The reactor was recognized to have no leakage.
To measure the temperature inside the digester, mercury-in-glass thermometer was used. To measure the pressure, U-shaped pipe is used, and to measure the discharge of the outlet gas, a gas meter tested by national Iranian gas company was used. The equipment of pressure measurement, temperature measurement and discharge measurement are observed in figures 8, 9 and 10 respectively.


Fig.6. Initial stages of reactor concreting


Fig.7. Final stages of reactor concreting


Fig.8. U-shaped pipe for pressure measurement

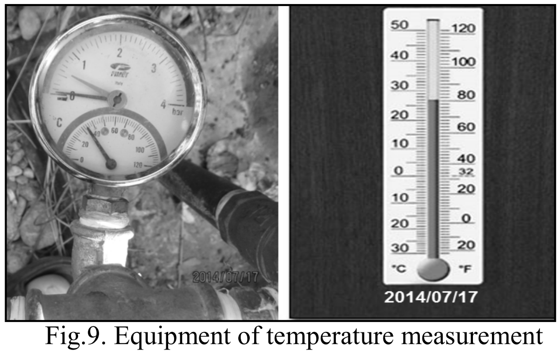

Fig.9. Equipment of temperature measurement

Fig.10. Equipment of discharge measurement

4- RESULTS

4-1- Results obtained from software calculations

According to table 1, the ground temperature is different during the seasons of the year, so the value of the produced gas will also be different during different days of the year. According to the ground temperature, the production of biogas is illustrated daily and in monthly average in chart 11 in simple form, state of having mixer, state of having cap and combinatory form for Khoy city during different month of the year. The average of low temperature of the ground in Khoy city is considered in the calculations for the year. In chart 12, the value of monthly production is calculated for the year.

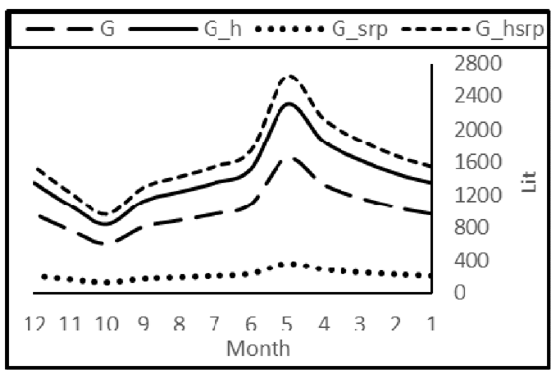

Chart 11. Value of biogas produced in simple digester, mixer digester, cap, combinatory reactor for monthly average during the year

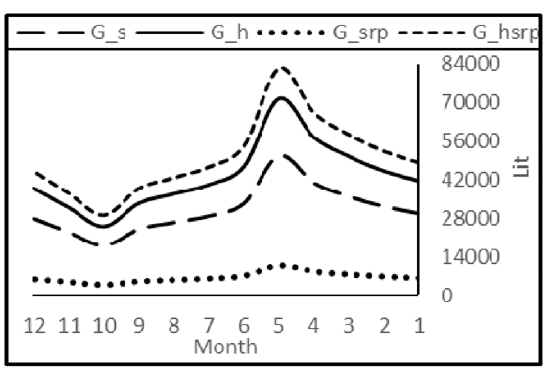

Chart 12. Value of biogas produced in simple digester, mixer digester, cap, combinatory reactor for monthly average during the year

The values of the biogas produced in the simple digester, equipped with mixer, equipped with cap and equipped with both mixer and cap are calculated and presented in table 8.
It should be noted that this calculation is carried out for the date 3 April. Comparing the four models of table 8, if model 1 is selected, it is inappropriate and not responding the demands of the building.
Model 3 will not probably respond to the demand during the year, but it is acceptable. Model 2 will respond to the demand and it is acceptable. But the best system will be model 4 which may meet the demand of the building with further reliance. Model 4 is used in this paper to design the combinatory Chinese and Indian anaerobic reactor.

Table.8. Analysis of production of digester types

	Type	G_m	G_t	G_e	G_{de}	G_{kh}
1	Simple	1033	1014	0	0	0
2	Having mixer	1033	1419	386	40	37
3	Having cap	1033	1234	201	21	19
4	Combinatory	1033	1639	606	62	58

According to chart 13 which represents the monthly heating loads, the value of biogas required for supplying these heating loads is calculated and presented in chart 14.

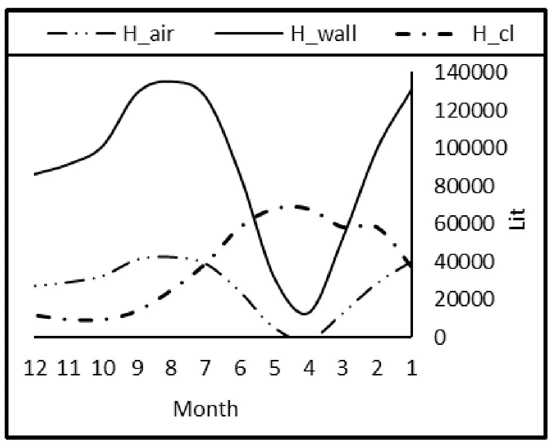

Chart 13. Value of monthly heating loads

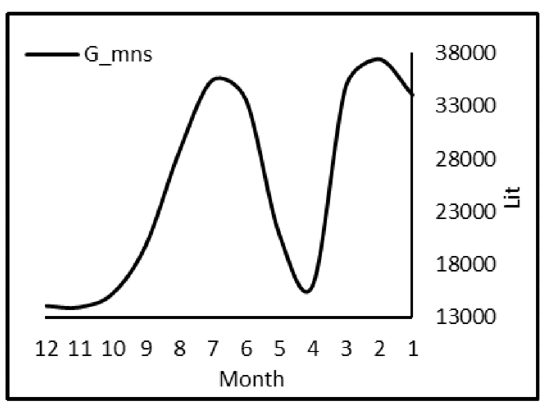

Chart 14. Value of monthly required biogas

4-2- Experimental results

The temperature and pressure levels are measured experimentally during the test and they are according to chart 15.

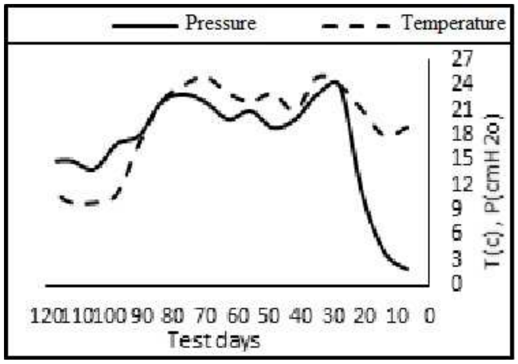

Chart 15. Experimental temperature and pressure measured in the reactor

In table 9, the details of test conditions and the numbers and figures related to the time period of the test are illustrated. The level of biogas production in table 9 is presented for all of the food in chart 16 and the value of net production for unit food is presented in chart 17.

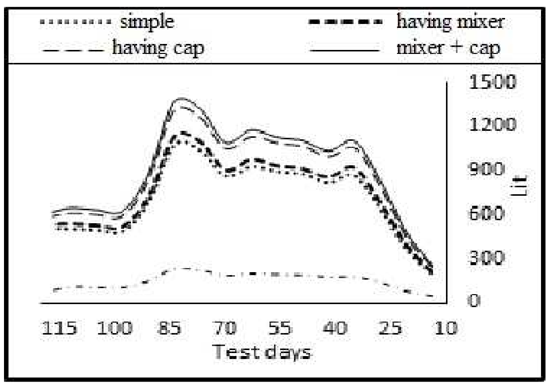

Chart 16. Level of producing biogas from experimental results for all wastes

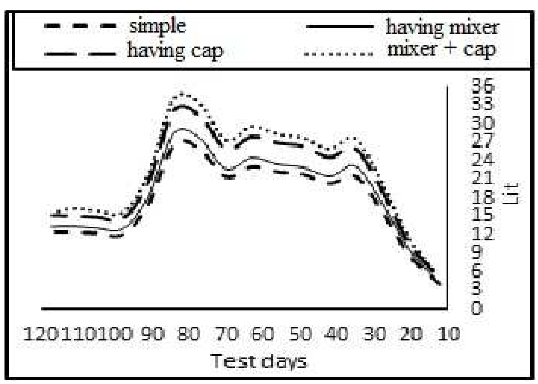

Chart 17. Level of producing biogas from experimental results for 1 kg of wastes

It should be described that the reactor is not gas-tightened for about 10 days after loading in order for the produced oxygen to exit, and these experiments and the results are recorded after the first ten days.

4-3- Comparison and analysis of results

According to this point that the calculations were carried out using the temperatures of table 1 and the obtained experimental temperatures of chart 10 are different with those in table 1, the values of biogas production are calculated based on chart 10 for correct comparison, and then they should be compared with the obtained experimental results. We may have an accurate estimation of the production level based on the average temperature, like charts 6 and 7 for the experiment period and the residence time of wastes. For example, in 14th day, the temperature is 17° C, and in the 70th day, the temperature of 25° C is available.

Table.9. The level of produced biogas in test conditions

Week	Residence	period	Since date	Until date	Considerations	Previous gas meter	Current gas meter	Production level	Daily production	Unit production
1	7	7	June 21, 2014	June 27, 2014	Simple	-	9897	-	-	-
2	14	7	June 28, 2014	July 4, 2014	With mixer	9897	11386	1489	212	5/31
3	21	7	July 5, 2014	July 11, 2014	With cap	11386	14532	3146	449	11/16
4	28	7	July 12, 2014	July 18, 2014	Combinatory	14532	20335	5803	829	20/71
5	35	7	July 19, 2014	July 25, 2014	Simple	20335	26388	6053	864	21/61
6	42	7	July 26, 2014	August 1, 2014	With mixer	26388	32400	6012	858	21/46
7	49	7	August 7, 2014	August 8, 2014	With cap	32400	39848	7448	1064	26/48
8	56	7	August 9, 2014	August 15, 2014	Combinatory	39848	47751	7903	1129	28/21
9	63	7	August 9, 2014	August 22, 2014	Simple	47751	54233	6482	926	23/14
10	70	7	August 23, 2014	August 29, 2014	With mixer	54233	60575	6342	906	22/65
11	77	7	August 30, 2014	September 5, 2014	With cap	60575	69411	8836	1262	31/36
12	84	7	September 6, 2014	September 12, 2014	Combinatory	69411	78994	9583	1369	34/2
13	91	7	18 September 2014	September 19, 2014	Simple	78994	83784	4790	684	17/1
14	98	7	20 September 2014	September 26, 2014	With mixer	83784	87421	3637	519	12/98
15	105	7	27 September 2014	October 3, 2014	With cap	87421	91614	4193	599	14/88
16	112	7	October 4, 2014	October 10, 2014	Combinatory	91614	96150	4536	648	16/19
17	117	5	October 11, 2014	October 15, 2014	Simple	96150	98661	2511	502/2	12/55

For 70 days of residence and an environment temperature of 25° C, the value of gas production is 25 liters per each Kg of food in the day and this is while if it could reach to 70 days since the beginning of loading with constant temperature of 25° C, it could produce this value of gas and if it has temperature fluctuations during the 70-days period, the production will also be in fluctuations. Therefore, for accurate and correct estimation of production, a constant temperature should be selected which is common during the period. In the next stage, the value of production in fluctuation is calculated in the experimental measurement temperature. The production range is between these two curves. The constant value which is common in all days is 10° C. Therefore, 10° C has been always existing since the beginning of lading and the production will be higher than this curve.

Using chart 15 and the mentioned method, the level of produced gas is presented in chart 18 using experimental temperature and scientific calculation.

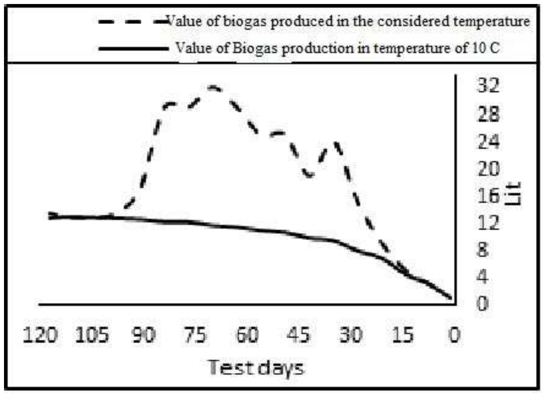

Chart 18. Accurate estimation of production of combinatory reactor of Khoy city

Comparison between charts 17 and 18 is presented in chart 19. Through comparison, it is obtained that the value of the biogas which is produced is nearly inside the considered range.

With analyzing the charts 16 and 17, the value of increase by the gaseous cap is the constant number 21. The percentage of increase in numerical mixer is calculated to be between 4 and 8 and the accurate average value is 6.42%, and the value of increase in the produced biogas in the combinatory reactor of biogas (having both mixer and cap) is 27.76%. These results are presented in chart 20.

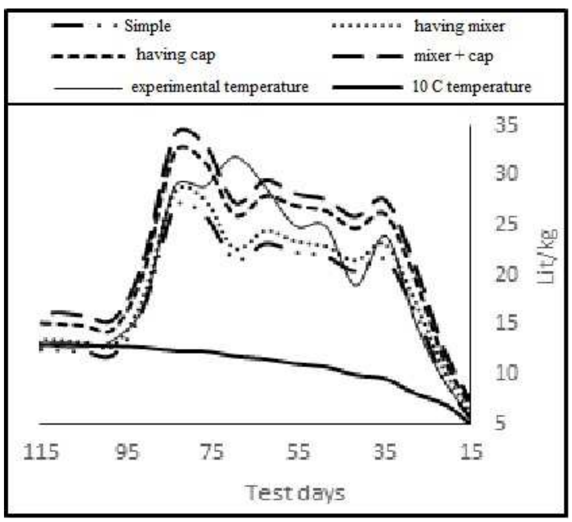

Chart 19. Comparison between the level of biogas production in experimental and estimated results

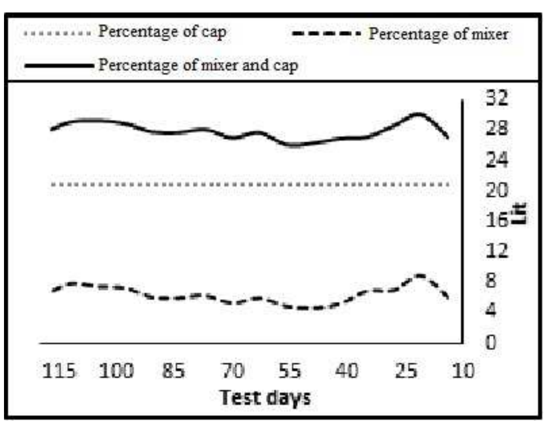

Chart 20. The level of increase in biogas production in combinatory reactor of biogas

The correct value obtained from the calculations has coordination with the experimental value. The Only part which is not coordinated with the calculations is the value of production with the mixer which is considered 40% in calculations and it is obtained 6.42 experimentally. The experimental work of the present research is close to work [29] and in the table 10, the value of production of simple digester and mixer-digester is presented [29].

Table 10. biogas production [29]

Week	Volume of produced biogas at the end of the week (liters)	Level of daily food (Kg)
1st week without mixer	102	49
2nd week with mixer	147	49
3rd week without mixer	150	49
4th week with mixer	210	49

Using drawing of the points in table 10, the results are presented as the chart 21.

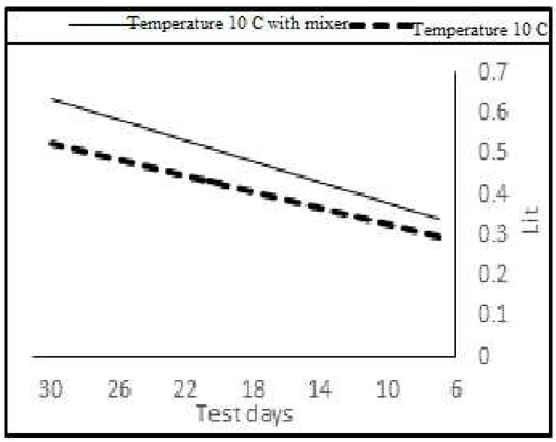

Chart 21. Results of value of simple and with-mixer productions [29]

The result of table 10 increases 40% with utilizing the mixer [29]. Regarding this result, with a strong probability and certainly, the nearly 11% difference is because of 10 reasons which are described in below:

1- According to this point that this result is obtained through dividing the numbers of 1st and 2nd week and also dividing the numbers of 3rd and 4th week, and according to the plotted chart, it can be concluded that with this method, the obtained number 40% is not correct and the value of simple production in the first week should be compared with the equivalent of production by the mixer in the first week, and also in the second week, the equivalent of the simple production should be compared with the value obtained with the mixer in the second week, and for the third and the fourth week, this rate should be calculated. In the present research, the experimental results are entered in Excel software in a completely accurate way, and using the ratio of simple production to with-mixer and with-cap or both of them, they are obtained by the software through estimating the intervals. For instance, the 1st, 5th, 9th week and etc. are related to the simple digester and the 2nd, 6th, 10th week and etc. are related to the state of having mixer and in this way, it is available for the state of having cap and both of them. The value of producing the simple digester is given in the first week. But the next three cases are not given. In order to obtain the percentage of increase in the production, the result of the simple digester in the first week cannot be compared to the result of the digester having mixer in the second week, but it should be compared to its equivalent for the 1st week, and this analysis exists for all weeks and in this research, it is acted in this method.

2- The correct calculated value is a number between 13 and 21 which is 17.77 for the average of all experimented days. In the present research, this number is 6.5%.

3- Having the value of 17.77% of increase, the percentage of increase in production in the state of having mixer should also be the same value for the present research, while it is 6.5% for the present research and the modified value is 17.77%. A nearly 11% difference is observed between both researches.
4- The volume of loading is 49 Kgs of food for the 4900-liters digester [29], while the volume of loading is 40 Kgs for the 12000-liters digester in the present research.
5- In the digester of the present research, pure cow dung is used, but in the digester of Tehran Science and Research branch [29], herbal excrement is also used in the food combination which this problem is surely influencing on the level of production.
6- the most important factor of production is the days of residence. The number of residence days is 117 days in the present research and since the beginning of lading, continuous experiments are carried out without pause, and new cow wastes are used, while the residence time for the comparison case is considered 50 days [29] and it is not pointed to the newness of the used wastes, i.e. the used wastes might have more retention time and the results of the research might be due to a particular interval of residence time.
7- The building of the digester in the present research is of reinforced concrete type and the type of the mixer is manual while the digester [29] is brick-made and the type of the mixer is electrical in this state.
8- The results are not carried out by logical calculations and there is no scientific analysis carried out on the closeness of the experimental results of the simple digester to the calculations [29]. In a simpler explanation, there is no coordination between the design calculations and the results. In the present research, the experimental results are analyzed scientifically and they are proved.
9- The concept of correct design is manifested when the results of the research may achieve to what is predicted before, or at least when the results may be closer to it. In the present research, the carried out scientific designs matches to the obtained experimental results, but taking a look to the results [22], there is no logical relation between the experimental results and the scientific design. If there is any logical relations, it is not mentioned.
10- The value of production is 1.8 m^3 at the end of the 50^{th} day [29]. But what is observed in the results is the value of 0.03 m^3 which this very great difference has no scientific analysis. In the present research, the value of production is calculated 1014 liters at the end of the 117^{th} day and this production is also available at the end of the 117^{th} day with a little approximation, and this confirms the validity of the calculations.

5- DISCUSSION AND CONCLUSION

The biogas produced in the simple digester is nearly 433 m^3 annually which the combinatory reactor represents 27.76% of increase in comparison to it. The approximate value of this increase is 166 m^3 per year which is really not negligible. If the equipment inserted on the digester are removed, the digester may not meet the family's demand at all. Therefore, the equipment of the mixer and the cap and the tools increasing efficiency are introduced for new digesters.

The value of the dung produced in the reactor is nearly 15 tons which 4 tons out of it is transferred directly to the garden earth in the owner's garden by pouring in the water streams and it is consumed and the remainder is sold. This valuable dung causes increase in productivity of soil and it has positive influences on the quality and quantity of the fruits significantly. The type of this family's demand is in terms of consumption is heating energy in winter and cooking energy during the year which is easily possible through the carried out analysis. This reactor has a very well psychological influence on the residents for stable development and it has made the people more obliged to use the biogas energy. According to the obtained results, the constructed digester is a secure and reliable source for the current and the prospective generation due to producing clean energy and supplying a rural family's demand.

If the equipment inserted on the digester are removed, the digester may not meet the family's demand at all. Therefore, equipment of mixer and cap and tools increasing the efficiency are introduced for new digesters. The results obtained from this research may be generalized for other cities and villages of country. In this case, there is a model which estimates the capacity of biogas production with a very less error.

6- Symbols

Ht	**Total heating capacity** (kcal/hr)
G_d	**Value of biogas production** (lit. kg/day)
G ، G_s	Value of biogas production in simple digester (lit)

G_h	Value of biogas production with mixer (lit)
G_srp	Value of biogas production with cap (lit)
G_hsrp	Value of biogas production in combinatory reactor (lit)
G_m	Value of required biogas (lit)
G_t	Total value of biogas production (lit)
G_e	The value added to the system(lit)
G_{de}	Value of added gas (%)
G_{kh}	Ratio of added gas to the required gas (%)
Lit	Liter
Test Time	Time period of experiment
Month	Months of year

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