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Utilization of Agricultural Residues in Improving Sludge Digester Efficiency

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Abstract: The disposal of Sewage sludge is one of the serious problems faces the world today. This Sewage sludge contains large concentration of organic substance, pathogens content and has high pollutant effects. This study is concerned with improving anaerobic sludge digester performance by co-digesting sewage sludge and other organic wastes. Molasses, Wheat straw, rice husk and rice straw checked and evaluated. A bench scale erected for this reason in El Berka wastewater treatment plant in El Sallam district, Cairo, Egypt. The experimented sludge was thickened sludge. The experiment consists of four stages. In the first stage molasses, rice husk and wheat straw were added to sewage-thickened sludge (TS) at mixing rates 5%, 10% and 15% by weight. In the second stage, the molasses was added to sewage-thickened sludge at 5%, 10%, 15%, 20% and 25% by weight. In the third stage mixture of agriculture residues Molasses + Rice husk and Molasses+ wheat straw added to sewage sludge at 15% mixing rate. In the fourth stage Molasses, wheat straw and mixture of Molasses+ wheat straw added to sewage sludge at 15% mixing rate by weight. Characteristics of thickened sludge such as Temperature, pH, COD, TS, VSS, total alkalinity, volume of methane and CBOD/NBOD ratio were monitored and evaluated. The most efficient material based on COD, BOD and VSS destruction percent evaluated and the results showed that co-digesting sludge with 15% mixing rate (7.5% molasses +7.5 % wheat straw) gives best results with respect to effluent BOD and COD.

Key words: Agriculture residues, anaerobic digestion, Molasses, Rice husk, wheat straw, Sludge treatment.

INTRODUCTION

Sewage sludge is an end product of the wastewater treatment process. This material can be used as a source of nutrients for the soil. Using this material as a fertilizer can benefit the environment by turning wastes into valuable resources. This sludge can be disposed by land filling, lagooning, incineration, or ocean dumping [1]. On the other hand, heavy metals which sometimes found in sewage sludge may present environmental problems. Ezzat *et al.,* [2] studied the affect of co-digesting sewage sludge and some agriculture residues (rice straw, grass clipping, sugar cane refuse and maize stalks) in anaerobic digester and found improving in COD destruction, VSS destruction and total alkalinity. He arranged the different residues according to the improvement in effluent sludge characteristics as follows 1) rice straw, 2) grass clipping, 3) sugar cane refuse 4)maize stalks. Essential elements & heavy metals were observed for effluent of the mixture of rice straw and sewage sludge to investigate it as fertilizer and the results indicated permissible concentration for agriculture use.

Danilovich [3] demonstrates the possibility of composting of municipal wastewaters sludge digested during 5-7 days, using traditional organic additives – sawdust, peat and thatch. Ribbed polyethylene spheres and Wood chips used to enhance the porosity of the composted mixture. Composting performed efficiently in both cases; however, the use of wood ships had technological and economical advantages.

Land application used as sludge disposal alternatives and there are many process can be used for sludge treatment to met EPA requirements for land applications [4].

- Pasteurization followed by mesophilic, anaerobic digestion.
- Batch-operated thermophilic anaerobic digestion/temperature phased anaerobic digestion (TPAD).
- Batch-operated thermophilic (two-stage) anaerobic digestion (TAD).
- Anaerobic, mesophilic digestion.

MATERIAL AND METHODS

The main objective of this study is to evaluate the effect of adding agriculture residue on wastewater, thickened sludge digestion process. The sludge was mixed with variable ratios of agriculture residue (as a source of organic carbon). The sludge used in these experiments was thickened sludge, obtained from the gravity thickener of El-berka wastewater treatment plant.

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To model the anaerobic conditions, the cells used were consisted of reactors connected to gas collectors with P.V.C. tube of diameter 1 cm. Each gas collector was attached to an open jar by a tube with valve to collect and measure the volume of water collected due to the pressure of the biogas. Every five cells were placed in a glass basin equipped with a heater and thermostat to maintain a constant temperature (37 ºC) during the experiments. (The cell used in this experiment consisted of one 5-L glass bottle used as a reactor and two 3-L glass bottles used as gas collector (water displacement) measurement. The reactors operated in EL Berka wastewater treatment plant laboratory. Figure (1) showed the model of a bench scale anaerobic digester.

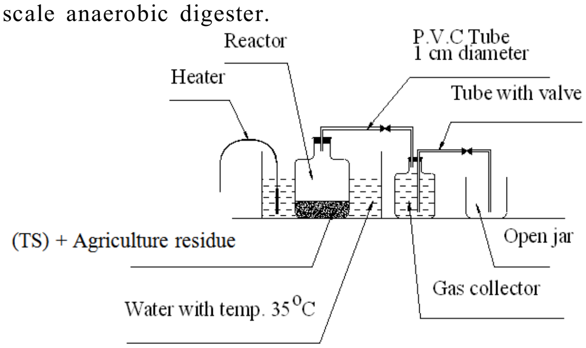

Fig. 1: A Schematic Diagram of Cell Used in Experiments

The study was consists of four stages:-

a) Stage 1: Molasses, Wheat straw and Rice husk was added to sludge at rates of 5%, 10% and 15% ((w/w) agriculture residue to thickened sludge).

b) Stage 2: Molasses added to sludge at rates of 5%, 10%, 15%, 20% and 25% w/w (agriculture residue to thickened sludge).

c) Stage 3: Mixture of (Molasses + Wheat straw), and (molasses + Rice husk) added to thickened sludge at 15% mixing ratio.

d) Stage 4: Molasses, wheat straw and (Molasses + wheat straw) added to thickened sludge at 15% mixing ratio.

Reactors performance monitored by measuring total solids (T.S.) and volatile suspended solids (V.S.S.), pH, total alkalinity and Chemical oxygen demand (COD). The ratio of carbonaceous BOD /nitrogenous BOD measured and considered as an approximation of C/N, (it expresses the amount of degradable carbon to nitrogen involved in the process). Alkalinity measured by titration of 0.00224u H_2SO_4 to methyl orange endpoint. COD was measured according to method 5220 of the American Standard Method[5] where as CBOD and NBOD measured according to methods 5210 of the American Standard Methods.(ASM 1995). The volume of gasses released measured by measuring the amount of water displacement.

RESULTS AND DISCUSSION

The physical and chemical properties of thickened wastewater sludge presented in Table (1).

The aim of adding agriculture residues is to increase C/N ratio for the digester substrate, which is needed for anaerobic digestion process.

These agriculture residues are available and have high C/N ratio which leads to increase C/N ratio for the mixture (of sludge and these residues) from 6 [8] to reach the optimum range for anaerobic digestion (C/N = 30) [9]. Table (2) illustrates the different C/N ratio for different agriculture residues.

Table 1: The physical and chemical properties of thickened wastewater sludge

Measuring parameters	Description
Total solids (mg/l)	23600
Total volatile solids (mg/l)	18280
Total suspended solids (mg/l)	17766
BOD_5 (mg/l)	17155
COD (mg/l)	31757
Temperature	28 °C
pH	6.3

Table 2: C/N ratio for the agricultural residues used (6), (7).

Residue	C/N ratio
molasses	27
Rice husk	74
Wheat straw	80

In stage 1 different mixing rate were tested. The mixing ratios were 5%, 10% and 15% (w/w) agriculture residue to thickened sludge. Table (3) represent the Characteristics of influent and effluent sludge for 5% mixing rate. Figure 2 shows COD values for the influent & effluents digested sludge (Thickened sludge (TS) + Molasses), (TS+ Wheat straw) and (TS + Rice husk) for 5% (w/w) mixing rate. The influent COD was 27020 mg/l and The effluent COD were 17500 mg/l for digested TS, 9500 mg/l, 13468 mg/l and 15262 mg/l for the above mentioned residues respectively.

The pH values were in optimum range, such values for the influent (TS) was 5.7, and for the effluents were 7.5 for digested TS, 7.7, 7.5 and 7.4 for the above mentioned residues respectively. The VSS for the influent TS was 11308 mg/l and for the effluents were as follows, 10360 mg/l for digested TS, 9920 mg/l, 9160 mg/l and 9478 mg/l for the above mentioned residues respectively. The volume of gasses released for the effluent were 200 cm^3 for digested TS, 275, 225 and 240 cm^3 for the above mentioned residues respectively. The quantities of gases released were less than the calculated quantities from COD balance, because the gas escaped with water in water displacement bottles. The influent BOD was 12936 mg/l and The effluents BOD were as follows, 10758 mg/l for digested TS, 5218 mg/l and 8275 mg/l 9046

Table 3: The Characteristics of influent and effluent sludge 5% mixing rate.

Date	Kind	Temp		T.S		S.S		BOD mg/l		COD	T.Alk		Rel.Gas	
		C	pH	Vol%	s.smg/l	Vol%	s.smg/l	CBOD	NBOD	mg/l	mg/l	C/N	ml	Dins
19/4/2006	Influent TS	23	5.7	2.2	22040	11308	14590	12936	3359	27020	1860	3.9		1.01
10/5/2006	ett.TS	37	7.5	3.5	35040	10360	26918	10758	2347	17500	3840	4.6	200	1.3
10/5/2006	ett.TS+molasses 5%	37	7.7	5.4	54420	9920	39378	5218	366	9500	4860	14.3	275	1.35
10/5/2006	ett.RS+wheat straw 5%	37	7.5	4	39580	9160	29160	8275	636	13468	3160	13	225	1.29
10/5/2006	ett.RS+rice husk 5%	37	7.4	3.1	39260	9478	35040	9046	965	15262	3380	13	240	1.32

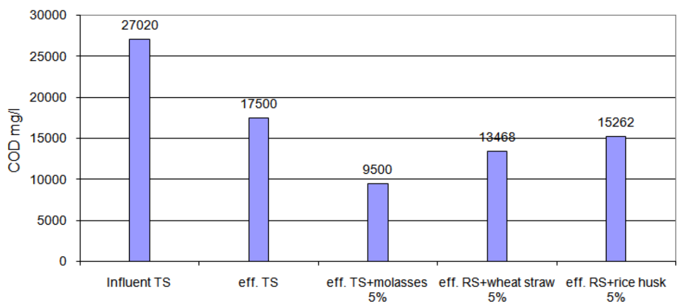

Fig. 2: COD for Different residues of 5 % mixing rate.

mg/l for the above mentioned residues respectively. The most suitable material based on effluent COD, BOD and VSS reduction was Molasses at 5% rate. Applying 10 % mixing rate, the results showed that, The influent COD was 26938 mg/l and The effluent COD values were 15273 mg/l for digested TS, 10386 mg/l, 12568 mg/l and 13846 mg/l for the above mentioned residues respectively. The pH values were in optimum range, such values for the influent was 5.94 and for the effluent were 7.31 for digested TS, 7.82, 7.64 and 7.68 for the above mentioned residues respectively. The influent VSS was 10120 mg/l, & the effluent VSS were 9582 mg/l for digested TS, 8076 mg/l, 9208 mg/l and 9315 mg/l for the above mentioned residues respectively. The volume of gasses released for the effluent were 597cm^3 for digested TS , 2041cm^3, 1540cm^3 and 1258cm^3 for the above mentioned residues respectively. The quantities of gases released were less than the calculated quantities from COD balance. Table 4 showed the results of 10% mixing rate, and figure 3 showed the effluent COD for the different agriculture residues.

The influent BOD was12754 mg/l and the effluent BOD were as follows 9847 mg/l for digested TS, 5267 mg/l, 7749 mg/l and 7024 mg/l for the above mentioned residues respectively. According to the previous results, the most suitable material based on effluent COD, BOD and VSS reduction was Molasses.

Table 5 showed the characteristics of influent and effluent parameters, and figure 4 showed COD values for the influent & effluent materials at 15% mixing rate. The influent COD was 32490 mg/l and the effluent COD were 13480 mg/l for digested TS, 8086 mg/l, 9872 mg/l and 10022 mg/l for the above mentioned residues respectively.

The pH values were in optimum range, such values for the influent (TS) was 6.13, and for the effluent were 7.28 for digested TS, 8.09, 7.75 and 7.63 for the above mentioned residues respectively. The VSS for the influent (TS) was 17530 mg/l and for the effluent were as follows 5931 mg/l for digested TS, 3850 mg/l, 4018 mg/l and 4828 mg/l for the above mentioned residues respectively. The volume of gasses released were 615 cm^3 for digested TS, 1509, 908 and 862 cm^3 the above mention material respectively. The influent BOD was19286 mg/l & effluent BOD were as follows 5062 mg/l for digested TS, 3136 mg/l, 3958 mg/l and 3994 mg/l for the above mentioned residues respectively.

The most suitable material based on effluent COD, BOD and VSS reduction was Molasses. This might be attributed to the fact that molasses is a great bacterial food source. It has lots of sugars, proteins, and amino acids. Bacterial activity seems to return to normal levels once the molasses is completely consumed [10]. According to the above results, the molasses was chosen to experiment the most suitable mixing rate.

In stage 2: different mixing rate were tested. The rates were 5%, 10%, 15%, 20% and 25% (w/w) molasses to (TS). The sewage sludge was taken from the effluent of the gravity thickener. Table 6 showed the characteristics of influent and effluent parameters, and figure 5 showed COD values for the influent & effluent different rates. The influent COD was 33249

Table 4: The Characteristics of influent and effluent sludge 10% mixing rate.

Date	Kind	Temp		T.S		S.S		BOD mg/l		COD	T.Alk		Rel.Gas
		C	pH	Volmg/l	s.smg/l	Volmg/l	s.smg/l	CBOD	NBOD	mg/l	mg/l	C/N	mlDins
22/5/2006	Influont TS	25	5.94	16400	20240	10102	15148	12754	3172	26938	1660	4	
17/6/2006	ett.TS	38	7.31	22580	37160	9582	30648	9847	1056	15273	3820	9.3	597
17/6/2006	ett.TS+molasses 10%	38	7.82	12000	153600	8076	137452	5267	341	10386	4760	15.4	2041
17/6/2006	ett.TS+wheat straw 10%	38	7.64	74900	90260	9203	78329	7749	591	12568	4220	13.1	1540
17/6/2006	ett.TS+rice husk 10%	38	7.68	80160	102460	9315	89417	7024	518	13847	4480	13.6	1258

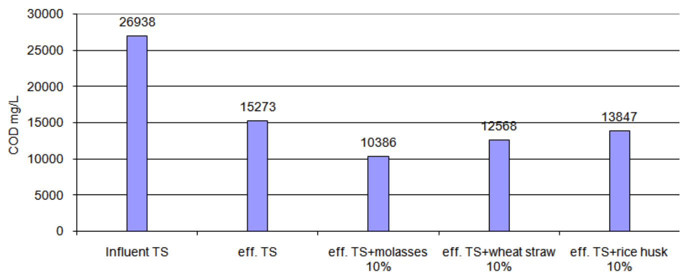

Fig. 3: COD For Different residues 10 % mixing rate.

Table 5: The Characteristics of influent and effluent sludge 15% mixing rate.

Date	Kind	Temp		T.S		S.S		BOD mg/l		COD	T.Alk		Rel.Gas
		C	pH	Volmg/l	s.smg/l	Volmg/l	s.smg/l	CBOD	NBOD	mg/l	mg/l	C/N	mlDins
28/6/2006	Influont TS	28	6.13	22580	37160	17530	28690	19286	4530	32490	1680	4.3	
29/6/2006	ett.TS	38	7.28	5720	67090	5931	52360	5062	340	13480	3440	14.9	615
29/6/2006	ett.TS+molasses 15%	38	8.09	4600	229800	3850	198475	3136	204	8086	5200	15.4	1509
29/6/2006	ett.TS+wheat straw 15%	38	7.75	6660	198600	4018	161430	3958	294	9872	4620	13.5	908
29/6/2006	ett.TS+rice husk 15%	38	7.63	5580	187860	4826	150040	3994	302	10022	4480	13.2	862

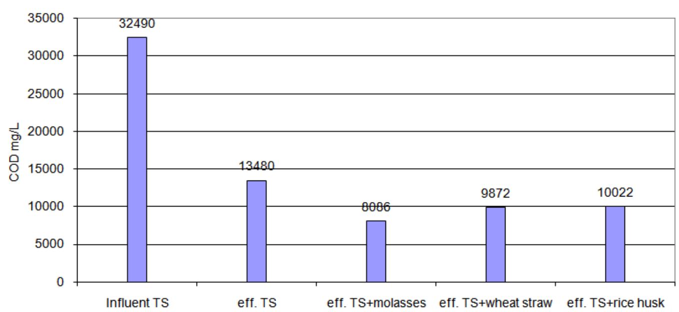

Fig. 4: COD For Different residues 15 % mixing rate.

mg/l and the effluent COD was 13300 mg/l for the digested thickened sludge. The effluent COD were 10340 mg/l for digested TS, 9930 mg/l, 8840 mg/l, 11732 mg/l and 11853 mg/l for the different mentioned mixing rate respectively. The pH values were in optimum range, such values were, 7.98 for influent TS, 8.14 for effluent digested TS, 8.2, 8.25 and 8.3 the different mixing rate respectively. The VSS were, 8631 mg/l for influent TS, 8240 mg/l for effluent digested TS, 8090 mg/l, 9280 mg/l and 10869 mg/l for the above mentioned rates respectively. The volume of gasses released were 510cm^3 for effluent digested TS, 995cm^3, 1270cm^3, 1485cm^3, 1175cm^3 and 1210 cm^3 for the above mentioned rates respectively. The influent TS was 19338 mg/l and effluents BOD were 10210 mg/l for digested TS, 10056 mg/l, 9630 mg/l, 9500 mg/l, 10368 mg/l and 10400 mg/l for the above mentioned rates respectively.

Table 6: The Characteristics of influent and effluent different mixing rate for stage 2.

Date	Kind	Temp		T.S		S.S		BOD mg/l		COD	T.Alk		Rel.Gas
		C	pH	Volmg/l	s.smg/l	Volmg/l	s.smg/l	CBOD	NBOD	mg/l	mg/l	C/N	mlDins
14/10/2006	Influont rS	27	6.69	18940	25086	14282	22075	19338	3690	33249	1360	5.2	
11/11/2006	ett.TS	38	7.3	10940	37528	9200	33674	10210	738	13300	2660	13.8	510
11/11/2006	ett.TS+5%molasses	38	7.98	10070	60846	8631	36253	10056	629	10340	3860	16	995
11/11/2006	ett.TS+10%molasses	38	8.14	9189	62572	8240	40338	9630	508	9930	4270	19	1270
11/11/2006	ett.TS+15%molasses	38	8.2	8940	64910	8090	53826	9500	477	8840	2570	19.9	1485
11/11/2006	ett.TS+20%molasses	38	8.25	10682	66428	9280	59652	10368	584	11732	4730	1708	1175
11/11/2006	ett.TS+25%molasses	38	8.3	10756	68820	10869	66388	10400	596	11853	4780	17.4	1210

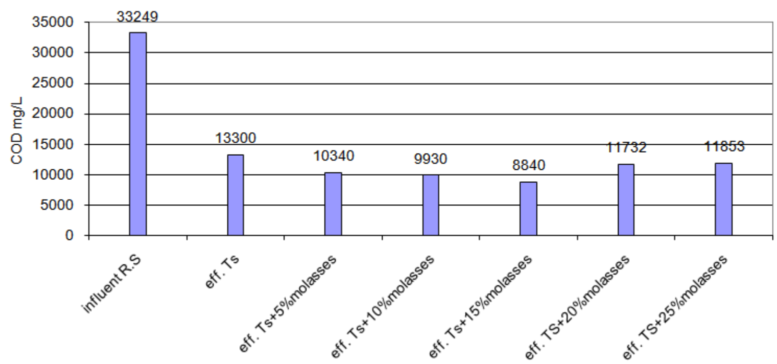

Fig. 5: COD for molasses Different mixing rates.

The most suitable rate based on effluents COD, BOD and VSS reduction was 15% mixing rate. It might be attributed to the increase of molasses mixing ratio increase the rate of bacterial reaction and the production of volatile acids, which decrease the pH value. The low pH is toxic to methane producing bacteria. Therefore, little gas will be produced [11].

In stage 3: The most suitable rate from the previous stage was 15% mixing rate. So checking mixture of molasses (at this rate) with different residues was the target of this stage. The different mixture of TS + molasses +wheat straw and TS + molasses + Rice husk respectively. The influent COD was 33805 mg/l and the effluents COD were 14200 mg/l for digested TS, 6287 mg/l and 10583 mg/l for the above mentioned different mixture respectively. The pH values were in optimum range, such values were 7.36 for digested TS, 7.91 and 7.8 for the above mentioned mixture respectively. The influent VSS was 14734mg/L, and the effluents VSS were 9608 mg/l for digested TS, 9937 mg/l and 11458 mg/l for the above mentioned mixture respectively. Table 7 and figure 6 represent the result of this stage.

The volume of gasses released were 978 cm^3 for digested TS, 1308 and 1125 cm^3 for the above mentioned material respectively. The BOD were 19580 mg/l for influent TS and 13522 mg/l for effluent digested TS, 5945 mg/l and 7686 mg/l for effluents digested mixed sludge for the above mentioned material respectively. The most suitable material at 15 % mixing rate based on effluent COD, VSS and BOD reduction was the mixture of molasses + wheat straw.

In stage 4: The most suitable mixture from the previous stage was the mixture of molasses + wheat straw .So checking the effect of mixing molasses + wheat straw compared with the results obtained from wheat straw and molasses alone was the target of this stage. The influent sludge was mixture of TS + molasses + wheat straw, TS + molasses and TS + wheat straw. The mixing rate was 15% ((w/w) agriculture residue to (TS). The sewage sludge was taken from the effluent of the gravity thickener. Table 8 and Figure7 represent the results of this stage for the influent. The influent COD was 36873 mg/l and the effluent COD were 15354 mg/l for digested TS, 7938 mg/l, 10262 mg/l, and 12953 mg/l for the above mentioned mixture respectively. The pH values were in optimum range such values were 6.63 for influent TS, 7.39 for effluent digested TS, 8.15, 8.24 and 8.11for effluent mentioned residues respectively. The VSS were as follows:- 15139 mg/l for influent TS, and 9952 mg/l for effluent digested TS, 8000 mg/l, 8217 mg/l and 9744 mg/l for effluent mentioned residues respectively. The volume of gasses released were 635 cm^3 for

Table 7: The Characteristics of influents and effluents different mixture of molasses and residues.

Date	Kind	Temp	pH	T.S		S.S		BOD mg/l			COD	T.Alk	Rel.Gas
		C		Volmg/l	s.smg/l	Volmg/l	s.smg/l	CBOD	NBOD	mg/l	mg/l	C/N	mlDins
15/5/2007	Influent TS	25	6.55	18147	23085	14731	20693	19580	3483	33805	1280	5.6	
4/6/2007	ett.TS	39	7.36	10109	36498	9608	32918	32522	820	14200	2340	16.5	978
4/6/2007	ett.TS+(wheat straw+mol)15%	39	7.91	10047	62254	9937	50897	5945	398	6287	4900	15	1308
4/6/2007	ett. TS+(rice husk+mol) 15%	39	7.8	13529	49083	11458	42038	7686	688	9583	3860	13.1	1125

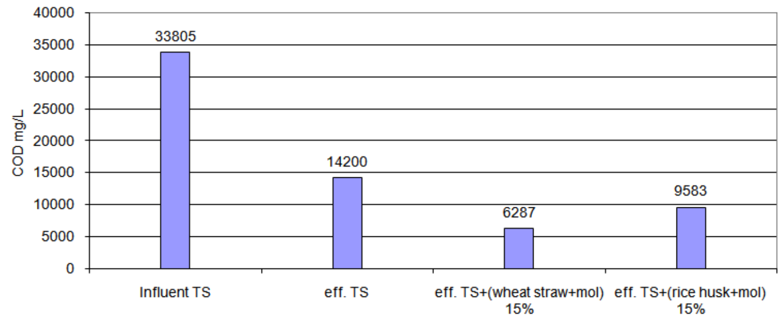

Fig. 6: COD For mixture of molasses and Different residue

Table 8: The Characteristics of influent and effluent different mixing rate for stage 4.

Date	Kind	Temp	pH	T.S		S.S		BOD mg/l			COD	T.Alk	Rel.Gas
		C		Volmg/l	s.smg/l	Volmg/l	s.smg/l	CBOD	NBOD	mg/l	mg/l	C/N	mlDins
24/3/2007	Influent TS	21	6.63	20688	28130	15139	23184	21527	3974	35873	1400	5.4	
11/4/2007	ett.TS	39	7.39	10317	38280	9952	34287	14806	889	15354	2820	16.64	635
11/4/2007	ett.TS+(wheat straw+mol)15%	39	8.15	9204	65364	8000	54706	54728	396	7938	5200	17	1285
11/4/2007	ett. TS+(rice husk+mol) 15%	39	8.11	11308	57691	9744	39245	10527	624	12953	4280	16.9	835

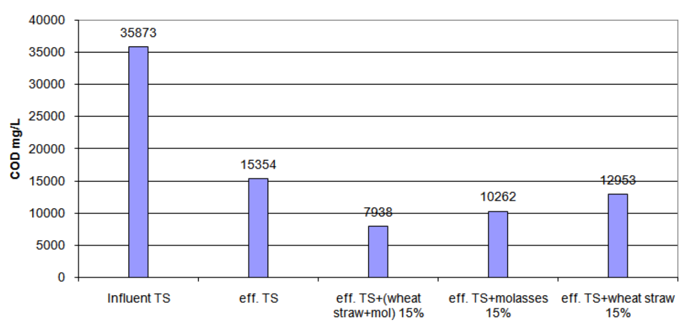

Fig. 7: COD For Different residues 15 % mixing rate.

effluent digested TS, $1285cm^3$, $835cm^3$ and $740cm^3$ for the above mentioned material respectively. The BOD was 21527 mg/l for influent TS and 14806 mg/l for effluent digested TS, 6728 mg/l 9628 mg/l and 10527 mg/l for the above mentioned material respectively. According to the previous results, the most suitable material was the mixture of molasses + wheat straw.

Conclusion:

- Co-digesting thickened sludge and agriculture residues improve the digestion process.
- The most suitable residues according to COD removal can be arranged as follows: (1) molasses 75%, wheat straw 69.6% and rice husk 69%.
- The optimum mixing ratio of molasses and thickened sludge is 15%(w/w).
- Mixing agriculture residues with thickened sludge increase the efficiency of anaerobic digestion process. The COD removal efficiency can be arranged as follows: molasses + wheat straw 81.4%, and molasses + rice husk 71.6%.
- The mixture of molasses and wheat straw give the

best results and the most suitable mixing rate for this mixture is 15% (w/w).

- Adding agriculture residue increases the C/N ratio and as a result improves the anaerobic digestion process.
- Despite of C/N ratio is a major parameter for anaerobic digestion, the result of molasses (with less C/N ratio) gives results better than wheat straw. This is might be due to the molasses is easily degradable than wheat straw and it is a great bacterial food source. Thus the mixture of molasses + wheat straw + TS had the best removal efficiency results.
- The mixing process increase the effluent solid concentration and as a result improving the dewater ability process.

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