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Dairy Wastewater and Its Potential Waste Management

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Abstract: *Rapid urbanization, increase in population, industrialization generates a large amount of waste. Presently, waste management requires more attention as it is in critical situation. In recent days one of the most polluting industries is dairy industry. Due to increased milk demand, dairy industry has grown swiftly. An initiative has been taken to characterize the dairy wastewater. Study found the presence of high concentrations of chemical oxygen demand (COD), biochemical oxygen demand (BOD), fatty acids and inorganic pollutants in dairy wastewater. The FTIR spectra analysis showed presence of C=O bond of protein (1625.96cm^{-1}), C-O polymer of carbohydrate (1547.60cm^{-1}–1242.61cm^{-1}) or C-O stretch of fatty acid (1092cm^{-1}), C-N stretch of amino acid in protein (1547.60cm^{-1}–1242.61cm^{-1}). Dairy wastewater contains fatty acids group which can be used for further production of biodiesel. Also, it contains many nutrients such as nitrogen and phosphorus compounds which can be reused in application of agricultural purposes. This study discusses on characterization of dairy wastewater and their impact on environment and the management of dairy waste.*

Keywords: *dairy, extraction, management, reuse, waste*

1. Introduction

The dairy processing industry is mainly associated with large volume of wastewater generated from industry containing high levels of organics. Wastewater that contains high organic waste requires treatment before discharge, as they causes problem for environment. Production of dairy wastewater is increasing day by day because dairy industry demands huge amount of water for its processing, which is about 8 times the total amount of milk [1], [2]. Dairy effluent contains both inorganic and organic pollutants, which affect the surrounding environment, human and aquatic life [3], [4]. Organic pollutants include oil, fat, grease, protein, lactose, etc. whereas inorganic pollutants include hydrogen peroxide, chlorine, quaternary ammonia compounds etc.

In spite of its polluting species that can cause adverse effect on environment, these can be utilized as resource for various valuable products such as lipid, carbohydrate, protein. For example, extraction of lipid from dairy effluent can be used for production of biodiesel. In this regards, many studies [5], [6], [7] have been centered on lipid extraction from wastewater sludge for biodiesel production. Few studies utilized some

biological agents and fresh dairy wastewater for extraction of lipids, while few others utilized activated sludge obtained from effluent treatment plant to extract lipid from solvent extraction.

Due to pollution caused by petroleum-based diesel and limited fossil fuel, the interest for sustainable bio-resources has been expanding around the world. Various other sources for biodiesel have been started and used in different parts of country [8], [9]. Advantages of using biodiesel production over petroleum based diesel such as reduction in emission, non-toxic, bio-degradability and superior lubrication [10]. Absence of sulphur, aromatic compounds of hydrocarbon, metals which enhance the property of non-toxic in biodiesel. Biodiesel is also called as fatty acid methyl ester (FAME) because it is an esterified fatty acid. This fatty acid esterification is done with the help of alcohol in presence of a base/acid/enzyme catalyst. Mainly lipids from animal fats and vegetable oil are the basic materials for biodiesel production [11].

2. Experimental Section

2.1 Source of Dairy Effluent

The raw effluents of dairy industry were obtained from OMFED, Bhubaneswar, Odisha, India. Samples were collected in bottles for characterization of various physical and chemical parameters and stored at 4^0C for further analysis. Different physicochemical parameters were analyzed such as pH, BOD, COD, TDS, TSS, TP, and phosphate.

2.2 Preparation of Sample And Extraction

Dairy effluent and hexane were homogenized in the ratio 1:1 for 15 min in separating funnel. For complete separation and clarification immiscible liquid was allowed to settle for 20 min. Layers which contain organics were removed and same process was repeated for 5 times to extract maximum amount of lipids from dairy effluent. Further, organics were separated and then dried by using sodium sulphate. By the use of rotary evaporator, hexane was allowed to evaporate. Final sample was kept on vacuum desiccator for 3 days for complete dry.

2.3 Detail Instrumentation

To analyze various compounds and their functional group, FTIR technique was used. For detection of functional group present in raw effluent of dairy industry, Fourier Transform Infrared spectrum was used (Shimadzu IR Prestige 21). Spectral data were observed in the range 4000 to 500 cm^{-1}. Nearly 4-5 mg of extracted sample was used for analysis. Also, to confirm the compounds, NMR (Bruker, Avance III) was used. In this analysis extracted lipids with $CDCL_3$ was taken.

3. Result and Discussion

3.1 Characterization of wastewater

The samples were characterized 6 times for different physicochemical properties. The standard [12] was followed for the analyses of different parameter. Dairy effluent pH is found to be acidic in nature i.e., 5.83 (±0.57). It may be due to decomposition of lactose to lactic acid under anaerobic condition. BOD and COD of dairy wastewater is also very high i.e. 730(±66.62) mg/l, 900(±76.94) mg/l. The presence of TSS, TDS in effluent is summarized in table 1. Dairy wastewater also contains protein, amino acid, nutrients; all these also may increase the concentration of BOD, COD levels in wastewater. Table1 shows the presence of acids in dairy effluent. High COD and BOD alongwith acidic pH confirm acid presence in wastewater. Total nitrogen is an essential compound which helps in the recovery process of protein as it is a polymer of amino acid containing nitrogen. Presence of phosphorus in wastewater increases the risk of eutrophication in water bodies.

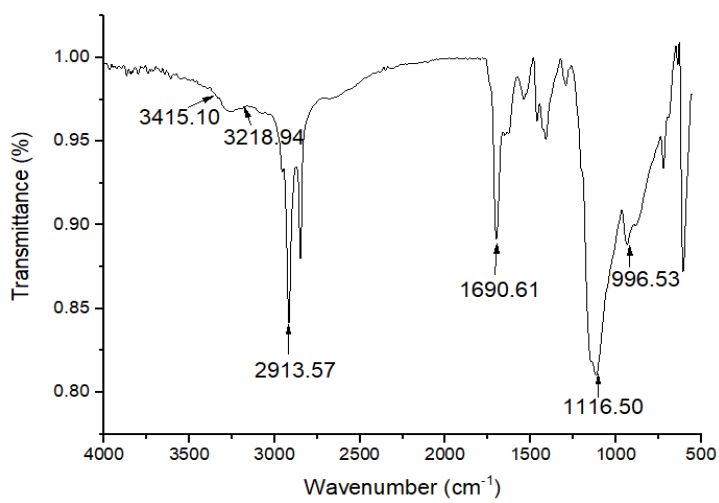
TABLE I: Characterization of dairy effluent

Sl.no.	Parameter	Average concentration	Tolerance limit IS:2490 Inland surface water
1	pH	5.83(±0.57)	5.5-9
2	TSS(mg/l)	1344(±20.93)	100
3	TDS(mg/l)	984(±43.20)	2100
4	BOD(mg/l)	730(±66.62)	30
5	COD(mg/l)	900(±76.94)	250
6	Turbidity (NTU)	97(±8.68)	-
7	TP(mg/l)	30(±1.41)	-
8	TN(mg/l)	83(±1.44)	100
9	Phosphate(mg/l)	37(±1.32)	-
10	Protein (mg/l)	1562(±65.85)	-

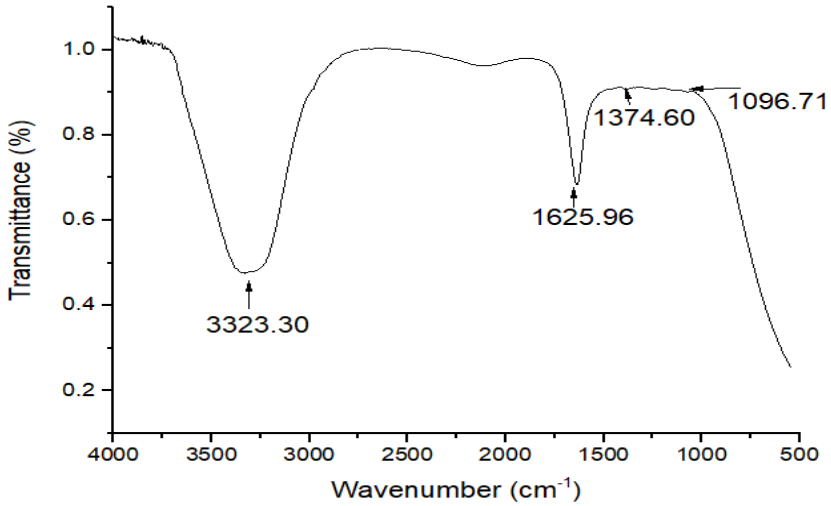
3.2 Spectral Analysis

3.2.1 FTIR Analysis

The dairy effluent contains dissolved solid and suspended solid, organic and inorganic components, lactose, fats, nutrients, etc. It can be used as raw material in manufacturing different materials such as such as feed for animal, biomedicine, bioplastic, biofuel. Presence of lipids, proteins, fatty acids, carbohydrate have been identified by FTIR technique as summarized in figure 1.



(a)



(b)

Fig. 1: (a) FT IR spectra of extracted solid sample and (b) raw liquid sample of dairy wastewater

The broad peak found between 3415.10-3218.94cm^{-1} which signifies the presence of lipid, protein, carbohydrate in wastewater. Also, peak signifies the presence of stretching vibration of –OH, -NH, -NH_2. The stretching of –OH is may be due to water or presence of carbohydrate in dairy effluent. The stretching vibration of –NH may be due to peptide bond of protein [13]. Strong peak of 2913.57cm^{-1} is due to C-H group in wastewater as carbon chain of fats, carbohydrate and protein. Peak of 1690.61cm^{-1} -1625.96cm^{-1} attribute the bond of protein (-CO-NH) i.e. peptide (C=O). Band at 1116.50cm^{-1} represents either C-O bond in fatty acid [14] or C-N of protein as amino acid 1547.60cm^{-1}–1242.61cm^{-1} [15]or 1547.60cm^{-1}–1242.61cm^{-1} C-O bond in carbohydrate as polymer linkage [16]. Peak of 1092 cm^{-}1-996.53 cm^{-1} signifies the stretching vibration of C-O bond in glycerol. This provides confirmation about the presence of fats and fatty acid in dairy wastewater [17].

3.2.2 NMR Analysis

The ^{1}H NMR spectra does not provide confirmation of presence of compound in wastewater, but it gives the skeleton structure of carbon in organic compound present in dairy effluent. Lipophilic compounds were analyzed in NMR using $CDCL_3$ as shown in figure 2.

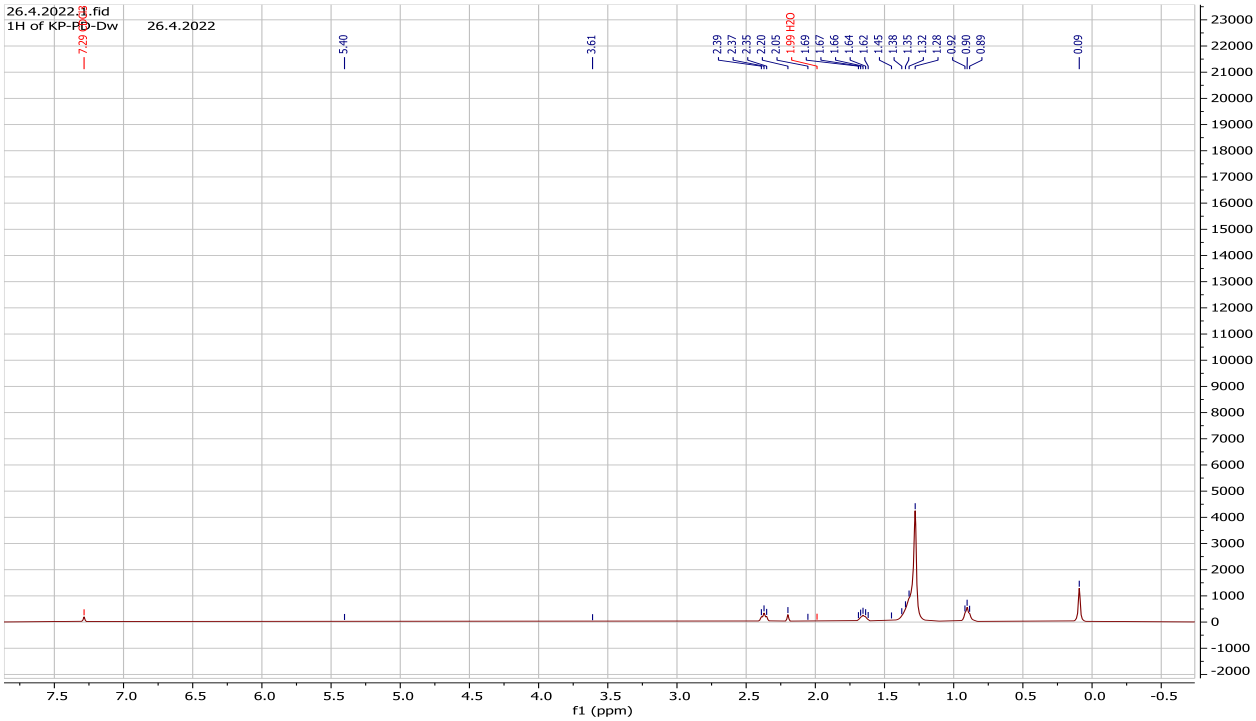


Fig. 2 : ^{1}H NMR of extracted sample with $CDCL_3$

The extracted lipid from dairy wastewater using hexane was analyzed on NMR spectra. It contain compounds such as aromatic (7.285ppm), it may be due to presence of some detergent e.g. n-alkyl dimethyl benzyl ammonium chloride, which is a surface active element in dairy wastewater [18], [19]. Also oxidized fats are confirmed in the range (5.402-5.291ppm).

4. Conclusion

Dairy wastewater is found to be an innovative material for its sustainable management. Its high content of organic waste can be useful in extraction of fatty acids for further uses, especially in biofuel and agricultural purposes. Biodiesel has many merits over petroleum-based diesel such as toxicity, biodegradability, chemical emission, etc. The conversion of lipid to biodiesel is viable commercially. However, the lipid cost specially from vegetable or animal source does not allow the conversion process to biodiesel. One of the best and economic methods to extract fatty acids is from dairy wastewater. Analysis by NMR and FTIR confirms the presence of protein, lipid, different organic acid and carbohydrate. Therefore, dairy wastewater can be one of the low cost raw materials for the conversion of lipid to biodiesel. Hence, further research should be done on the quantification of fatty acid for production of biodiesel.

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6. References

[1] M. Custodio, R. Peñaloza, C. Espinoza, W. Espinoza, J. Mezarina, Treatment of dairy industry wastewater using bacterial biomass isolated from eutrophic lake sediments for the production of agricultural water, Bioresour. Technol. Reports. 17 (2022) 100891. https://doi.org/10.1016/J.BITEB.2021.100891.

[2] W. Shi, M.G. Healy, S.M. Ashekuzzaman, K. Daly, J.J. Leahy, O. Fenton, Dairy processing sludge and co-

products: A review of present and future re-use pathways in agriculture, J. Clean. Prod. 314 (2021) 128035. https://doi.org/10.1016/J.JCLEPRO.2021.128035.

[3] E. Ercin, T.I.E. Veldkamp, J. Hunink, Cross-border climate vulnerabilities of the European Union to drought, Nat. Commun. 12 (2021) 1–10. https://doi.org/10.1038/s41467-021-23584-0.

[4] L. Flach, S. Kühl, C. Lambertz, M. Gauly, Environmental impact and food production of small-scale mountain dairy farms at different supplementation levels, J. Clean. Prod. 310 (2021) 127429. https://doi.org/10.1016/J.JCLEPRO.2021.127429.

[5] E. Daneshvar, M.J. Zarrinmehr, A.M. Hashtjin, O. Farhadian, A. Bhatnagar, Versatile applications of freshwater and marine water microalgae in dairy wastewater treatment, lipid extraction and tetracycline biosorption, Bioresour. Technol. 268 (2018) 523–530. https://doi.org/10.1016/J.BIORTECH.2018.08.032.

[6] M. Khalaji, S.A. Hosseini, R. Ghorbani, N. Agh, H. Rezaei, M. Kornaros, E. Koutra, Treatment of dairy wastewater by microalgae Chlorella vulgaris for biofuels production, Biomass Convers. Biorefinery. (2021). https://doi.org/10.1007/s13399-021-01287-2.

[7] R. Balasubramanian, A. Sircar, P. Sivakumar, K. Anbarasu, Production of biodiesel from dairy wastewater sludge: A laboratory and pilot scale study, Egypt. J. Pet. 27 (2018) 939–943. https://doi.org/10.1016/J.EJPE.2018.02.002.

[8] A.R. Behera, K. Dutta, P. Verma, A. Daverey, D.K. Sahoo, High lipid accumulating bacteria isolated from dairy effluent scum grown on dairy wastewater as potential biodiesel feedstock, J. Environ. Manage. 252 (2019) 109686. https://doi.org/10.1016/J.JENVMAN.2019.109686.

[9] M.N. Siddiquee, S. Rohani, Experimental analysis of lipid extraction and biodiesel production from wastewater sludge, Fuel Process. Technol. 92 (2011) 2241–2251. https://doi.org/10.1016/J.FUPROC.2011.07.018.

[10] M. Tabatabaei, M. Aghbashlo, B. Najafi, H. Hosseinzadeh-Bandbafha, S. Faizollahzadeh Ardabili, E. Akbarian, E. Khalife, P. Mohammadi, H. Rastegari, H.S. Ghaziaskar, Environmental impact assessment of the mechanical shaft work produced in a diesel engine running on diesel/biodiesel blends containing glycerol-derived triacetin, J. Clean. Prod. 223 (2019) 466–486. https://doi.org/10.1016/J.JCLEPRO.2019.03.106.

[11] W. Xie, F. Wan, Immobilization of polyoxometalate-based sulfonated ionic liquids on UiO-66-2COOH metal-organic frameworks for biodiesel production via one-pot transesterification-esterification of acidic vegetable oils, Chem. Eng. J. 365 (2019) 40–50. https://doi.org/10.1016/J.CEJ.2019.02.016.

[12] APHA, Standard Methods for the Examination of Water and Wastewater, (2012) 1496.

[13] J. Tang, J. He, T. Liu, X. Xin, Removal of heavy metals with sequential sludge washing techniques using saponin: Optimization conditions, kinetics, removal effectiveness, binding intensity, mobility and mechanism, RSC Adv. 7 (2017) 33385–33401. https://doi.org/10.1039/c7ra04284a.

[14] T. Xu, J. Lin, Y. Luo, W. Fu, Z. Jia, D. Jia, Z. Peng, Quantitative analysis of the higher fatty acids in acetone solutes (AS) from raw natural rubber and their impacts on the structure and properties of NR/silica composites, Ind. Crops Prod. 121 (2018) 80–89. https://doi.org/10.1016/J.INDCROP.2018.05.010.

[15] E. Lazzari, T. Schena, M.C.A. Marcelo, C.T. Primaz, A.N. Silva, M.F. Ferrão, T. Bjerk, E.B. Caramão, Classification of biomass through their pyrolytic bio-oil composition using FTIR and PCA analysis, Ind. Crops Prod. 111 (2018) 856–864. https://doi.org/10.1016/J.INDCROP.2017.11.005.

[16] X. Ke, H. Xiaobing, W. Zhao, R. Hongqiang, D. Lili, Advanced Treatment of Vitamin C Wastewater by Coupling Electrochemical Oxidation and an Integrated Bioreactor, J. Environ. Eng. 139 (2013) 873–880. https://doi.org/10.1061/(asce)ee.1943-7870.0000675.

[17] M. Kowalski, K. Kowalska, J. Wiszniowski, J. Turek-Szytow, Qualitative analysis of activated sludge using FT-IR technique, Chem. Pap. 72 (2018) 2699–2706. https://doi.org/10.1007/s11696-018-0514-7.

[18] M. Valladao, W.E. Sandine, Quaternary Ammonium Compounds in Milk: Detection by Reverse-Phase High Performance Liquid Chromatography and Their Effect on Starter Growth, J. Dairy Sci. 77 (1994) 1509–1514. https://doi.org/10.3168/JDS.S0022-0302(94)77090-9.

[19] K. Slimani, A. Féret, Y. Pirotais, P. Maris, J.P. Abjean, D. Hurtaud-Pessel, Liquid chromatography-tandem mass spectrometry multiresidue method for the analysis of quaternary ammonium compounds in cheese and milk products: Development and validation using the total error approach, J. Chromatogr. A. 1517 (2017) 86–96. https://doi.org/10.1016/J.CHROMA.2017.08.034.