IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Synthesis of Sugar Based Alkyl Polyglucosides a Mild Biodegradable Surfactant

Rahul P. Kedar*, Vishwajit Y. Valvi
Department of Chemistry
Arts, Commerce and Science College Dharangaon-425105

Abstract

Nowadays, there is increasing demand of biodegradable mild surfactants because of growing environmental issues and needs for sustainable alternatives. In cosmetic sector the surfactants are used for their emulsifying, foaming and cleansing properties, while being gentle on the skin biodegradable surfactants helps to minimize environmental pollutions as they break down easily without leaving harmful residue. The current study shows the preparation of alkyl polyglucoside, a sugar based mild surfactant prepared by using different alcohols and glucose by condensation reaction. The propertoes of the final prepared surfactant is characterized by chain of the alcohol used. Theses surfactant shows biodegradability and low toxicity. The structural characterization of surfactant was carried out using FTIR spectroscopy.

Keywords

Glucose, Alcohol, Condensation, Optimization, FTIR.

Introduction

The surfactants which are not biodegradable are hazardous for environment and human because they remain for long time, not easily breakdown [1], [2], [3]. Their contaminants are remains in water bodies and soil causing pollution and disturb natural ecosystem [4], [5]. These surfactants are reduce aquatic oxygen of living organism by forming foam on surface of water and pollute aquatic environment [6], [7]. Those surfactants are harmful for fish and other aquatic living organism. Few non-biodegradable surfactants are poisonous and they can affect human health [8].

The current study shows preparation of alkyl polyglucoside (APG) is mild and biodegradable surfactant, making it eco-friendly alternative to the hazardous non-degradable surfactants [9]. It is prepared from renewable feedstocks like alcohols and glucose which reduce environmental impact and enhance sustainability [10]. APG can easily breakdown by microorganism in to non poisonous materials because of it biodegradability so it reduce contaminate in water and soil [11], [12]. APG is suitable for uses in personal care, pharmaceutical and cosmetic formulations. APG is also known as skin friendly and non toxic nature surfactant. Irritation to an eye and skin are not occurring in APG [13], [14]. APG have good surfactant activities like wetting detergency and efficient foaming even at low concentration. APG are stable at different temperature and pH range also [15], [16].

In this study alcohol and glucose was reacted in round bottom flask in presence of 0.5% p-toluene sulphonic acid as a catalyst. The reaction mixture gradually heated under controlled temperature at 100^{o}C while continuous stirring improve condensation reaction for 5 hrs. The progress of reaction is monitored by checking reduction of free glucose. After completion of reaction, the product was cooled at room temperature and neutralized acid catalyst by sodium carbonate. The remaining product was washed by distilled water to remove unreacted glucose. The final product was characterized by FTIR spectroscopy.

Materials

All chemicals are purchased by sigma Aldrich stoinis USA.

Method

The alcohol and glucose was taken at appropriate molar ratio in round bottom flask. About 0.5% p-toluene sulphonic acid was added as catalyst. The reaction mixture attached to the reflux condensation and overhead stirrer for uniform mixing. The reaction mixture gradually heated under controlled temperature at 90-110^{o}C while continuous stirring improve condensation reaction. During the reaction water produced as byproduct and removed by azeotropic distillation. The reaction was allowed for 5 hr until the degree of conversion was achieved. The progress of reaction is monitored by checking reduction of free glucose. After completion of reaction, the product was cooled at room temperature and neutralized acid catalyst by sodium carbonate. The remaining product was washed by distilled water to remove unreacted glucose. The final product was characterized by FTIR spectroscopy.

Instrumentation

Fourier transforms Infrared Spectroscopy

The functional groups of the final synthesized surfactant were detected by Fourier Transforms Infrared Spectroscopy (FTIR). The spectra of FTIR were recorded from 4000 cm^{-1} to 450^{-1} with resolution of 64 scan.

Results

Azeotopic distillation

Table 1. Azeotropic distillation of water present in surfactant

Solvents	Ratio water: solvent (%)	Distillation temperature (^{o}C)
Hexane	15:85	63
Toluene	35:75	85
Butanol	48:52	92

The data present in table 1 shows capacity of various solvents in azeotrop removal of water from surfactant. The ratio shows the portion of water to solvent in azeotrope, which directly affects the capacity of water removal and process temperature. In hexane azeotropic percentage indicate more concentration of solvent and less water, with 63^{o}C distillation temperature. The result indicates that more solvent is required to remove less water. For toluene the azeotropic ratio shows more water concentration as compare to hexane with increase the distillation temperature. Indicate that improves the improve capacity of dehydration. In case of butanol, azeotropic composition reflects more water. The concentration of water from hexane to butanol, the capacity of water extraction improves but also increase the temperature of distillation.

Process optimization

Effect of temperature

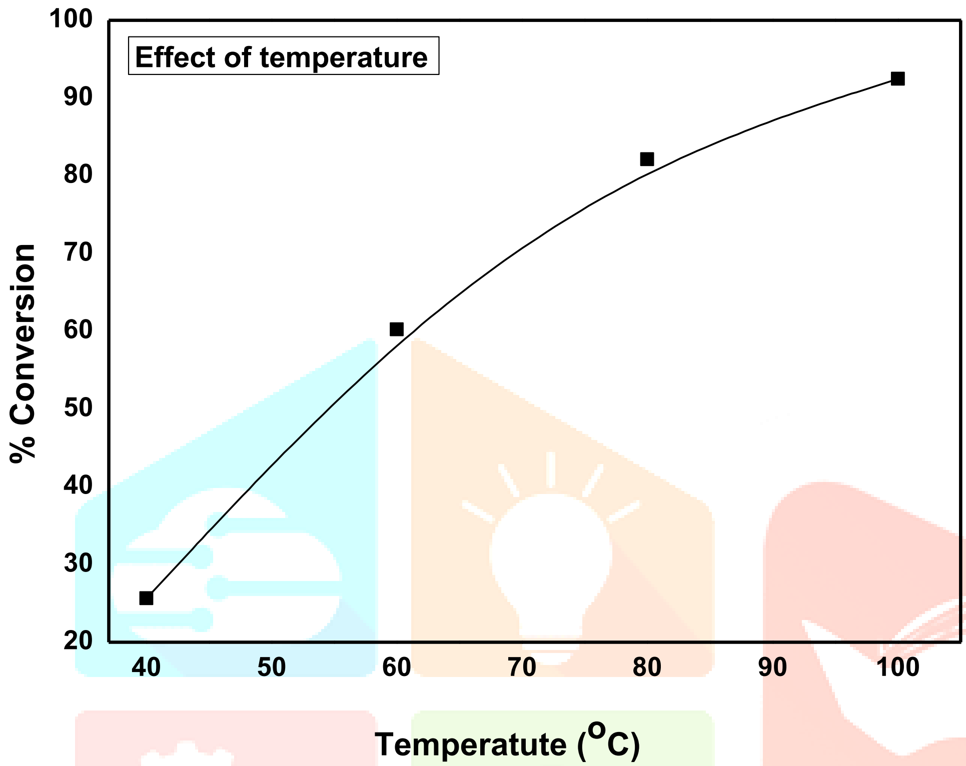

Fig. 1 Effect of temperature to conversion ratio

The graphical representation in temperature and conversion shows that the conversion rate increases with increase the temperature. The reaction process slowly at lower temperature due to limited energy and the product also converts fewer amounts. Rate of reaction is increase with increase the temperature also conversion of product is increases. It was found by graph the optimal temperature for the reaction is 100°C. At that temperature conversion achieved high percentage.

Table 2. Effect of temperature to conversion ratio

Temperature	Conversion
40	25.64
60	60.24
80	82.12
100	92.45

Effect of time

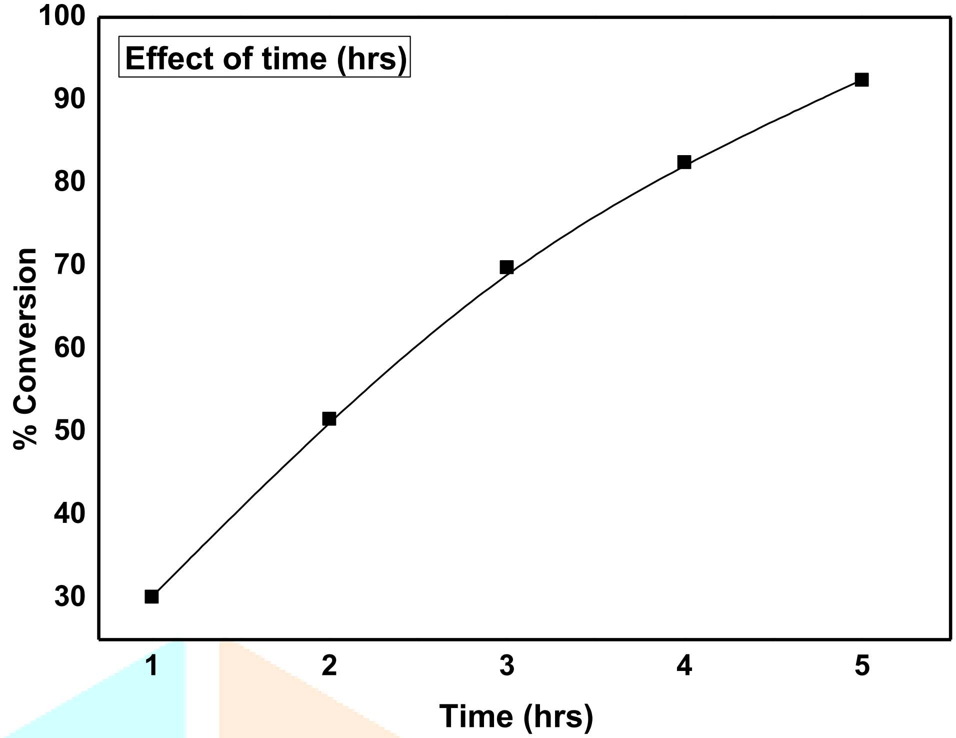

Fig. 2 Effect of time to ratio of conversion

The graphical relationship between time and % conversion shows in above figure. The time of reaction is increases conversion achieving high peak. Up to 4 hours the conversion is not completed. The reaction time at 5 hours the conversion achieved highest peak. It was found that the optimum time for the reaction is 5 hours.

Table 3. Effect of time to ratio of conversion

Time	% Conversion
1	30.15
2	51.61
3	69.88
4	82.54
5	92.45

Effect of catalyst concentration

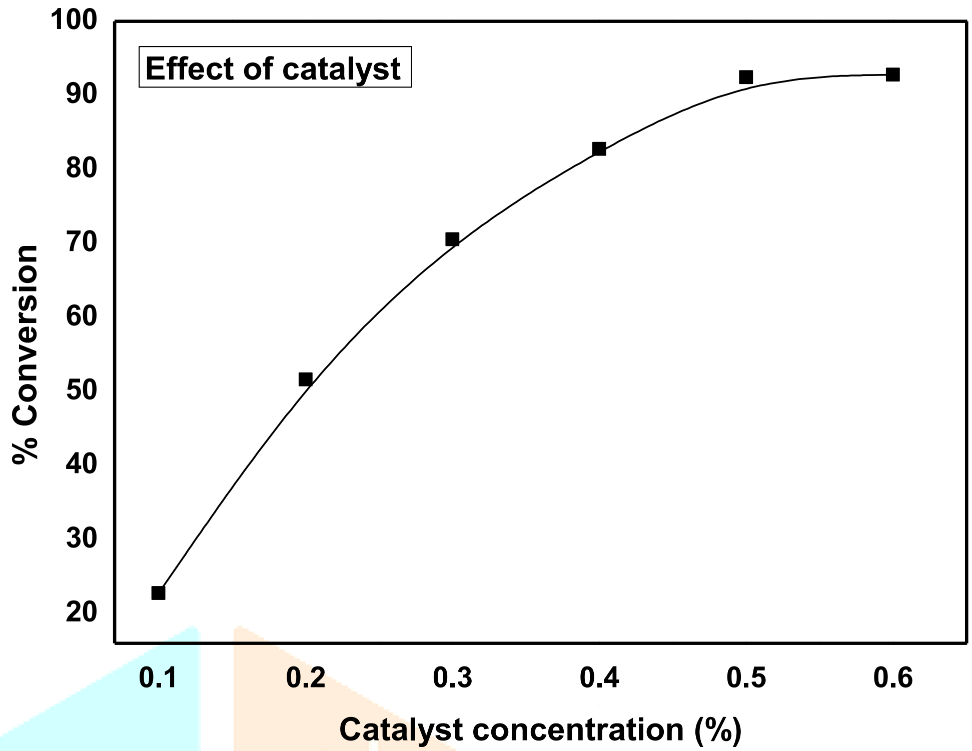

Fig. 3 Effect of catalyst concentration to ratio of conversion

Table 4. Effect of catalyst concentration to ratio of conversion

Catalyst (%)	Conversion (%)
0.1	22.78
0.2	51.64
0.3	70.56
0.4	82.77
0.5	92.45
0.6	92.79

The graphical representation in catalyst concentration and conversion shows that the conversion rate increases with increase the catalyst concentration. The reaction process slow at less catalyst concentration (0 to 0.4%). At 0.5 to 0.6% catalyst concentration no more changes is occurred. It was found by graph the optimum catalyst concentration is 0.5%.

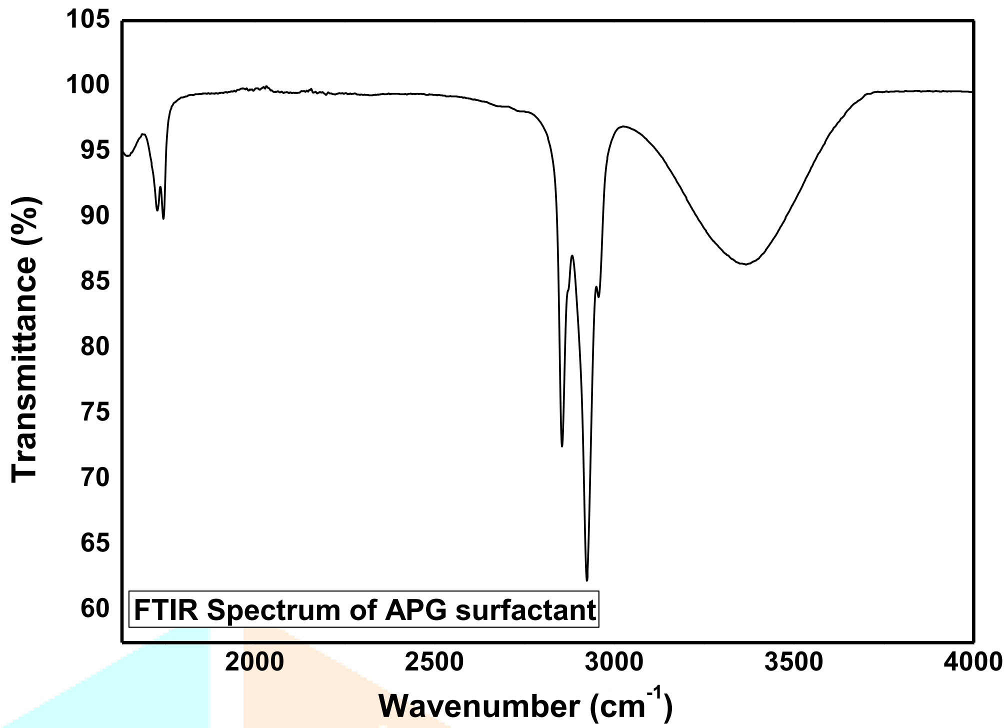

Fig. 4 FTIR Spectrum of alkyl polyglucoside

Above figure shows spectrum of APG mild surfactant a broad peak obtained at 3200-3500 cm^{-1} attributed to O-H stretching frequency, which formed from hydroxyl group present in glucoside structure. The peak obtained at 2850-2950cm^{-1} attributed to C-H stretching frequency of aliphatic methyl groups. The peak obtained at 1600-1650 cm^{-1} attributed to O-H bending frequency which commonly present in carbohydrate based compounds. From the FTIR spectrum it was confirmed that the pure alkyl polyglucoside a mild surfactant is prepared.

Conclusion

The study shows the successful synthesis of APG a mild and environmental friendly surfactant by applied renewable feedstock like alcohols and glucose. By formation of glucosidal linkage it is confirmed that the condensation reaction is completed. Its low toxicity and biodegradability make it suitable alternative to conventional surfactants. It is also good for applications in cosmetics, personal care formulation due to mild nature.

References

[1] N. A. T. Fernandes, L. A. Simões, and D. R. Dias, "Comparison of Biodegradability, and Toxicity Effect of Biosurfactants with Synthetic Surfactants," in *Advancements in Biosurfactants Research*, Springer International Publishing, 2023, pp. 117–136. doi: 10.1007/978-3-031-21682-4_6.

[2] U. Arora, H. K. Khuntia, H. N. Chanakya, and A. Kapley, "Surfactants: combating the fate, impact, and aftermath of their release in the environment," *Int. J. Environ. Sci. Technol.*, vol. 20, no. 10, pp. 11551–11574, 2023, doi: https://doi.org/10.1007/s13762-022-04549-2.

[3] R. P. Kedar, Y. N. Rajput, C. D. Girase, and R. D. Kulkarni, "Coconut oil refinery waste utilization in sustainable development of biodegradable betaine surfactant," *Tenside Surfactants Deterg.*, vol. 62, no. 2, pp. 200–210, 2025.

[4] J. Arora *et al.*, "Surfactant pollution, an emerging threat to ecosystem: Approaches for effective bacterial degradation," *J. Appl. Microbiol.*, vol. 133, no. 3, pp. 1229–1244, 2022, doi: https://doi.org/10.1111/jam.15631.

[5] M. Tiwari and D. B. Tripathy, "Soil contaminants and their removal through surfactant-enhanced soil remediation: a comprehensive review," *Sustainability*, vol. 15, no. 17, p. 13161, 2023, doi: https://doi.org/10.3390/su151713161.

[6] K. Jardak, P. Drogui, and R. Daghrir, "Surfactants in aquatic and terrestrial environment: occurrence, behavior, and treatment processes," *Environ. Sci. Pollut. Res.*, vol. 23, no. 4, pp. 3195–3216, 2016, doi: https://doi.org/10.1007/s11356-015-5803-x.

[7] K. A. Vu and C. N. Mulligan, "An overview on the treatment of oil pollutants in soil using synthetic and biological surfactant foam and nanoparticles," *Int. J. Mol. Sci.*, vol. 24, no. 3, p. 1916, 2023, doi: https://doi.org/10.3390/ijms24031916.

[8] B. K. A. Bellanthudawa *et al.*, "A perspective on biodegradable and non-biodegradable nanoparticles in industrial sectors: applications, challenges, and future prospects," *Nanotechnol. Environ. Eng.*, vol. 8, no. 4, pp. 975–1013, 2023, doi: https://doi.org/10.1007/s41204-023-00344-7.

[9] N. A. Negm and S. M. Tawfik, "8 Environmentally Friendly Surface Active Agents," *Surfactants Tribol. Vol. 3*, vol. 3, p. 147, 2013.

[10] S. Stubbs, S. Yousaf, and I. Khan, "A review on the synthesis of bio-based surfactants using green chemistry principles," *DARU J. Pharm. Sci.*, vol. 30, no. 2, pp. 407–426, 2022, doi: https://doi.org/10.1007/s40199-022-00450-y.

[11] F. Zhang *et al.*, "Effects of alkyl polyglycoside (APG) on composting of agricultural wastes," *Waste Manag.*, vol. 31, no. 6, pp. 1333–1338, 2011, doi: https://doi.org/10.1016/j.wasman.2011.02.002.

[12] F. Liu, C. Wang, X. Liu, X. Liang, and Q. Wang, "Effects of alkyl polyglucoside (APG) on phytoremediation of PAH-contaminated soil by an aquatic plant in the Yangtze estuarine wetland," *Water, Air, \& Soil Pollut.*, vol. 224, no. 7, p. 1633, 2013, doi: https://doi.org/10.1007/s11270-013-1633-y.

[13] S. Balamurugan, P. Lakshmanan, L. Piramuthu, and D. Geetha, "Novelty of glycoside surfactant derivatives for sustainable development: A new perspective," *Vietnam J. Chem.*, vol. 61, no. 2, pp.

135–146, 2023, doi: https://doi.org/10.1002/vjch.202200091.

[14] M. Tasic-Kostov, S. Vesic, and S. Savic, "Objective skin performance evaluation: How mild are APGs to the skin?," in *Alkyl Polyglucosides*, Elsevier, 2014, pp. 135–161.

[15] Q. Wang, D. Wang, H. Wang, and C. Xu, "Influence of alkyl polyglucoside and fatty alcohol ether sulfate on the foaming and wetting properties of sodium dodecyl benzene sulfonate for mine dust control," *Powder Technol.*, vol. 345, no. 3, pp. 91–98, 2019, doi: https://doi.org/10.1016/j.powtec.2018.12.084.

[16] B. Zhang *et al.*, "Progress on the synthesis and applications of the green non-ionic surfactant alkyl polyglycosides," *RSC Adv.*, vol. 15, no. 55, pp. 47333–47359, 2025, doi: 10.1039/D5RA06961K.