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# Synthesis and Utilization of a Biodegradable, Novel Carbohydrate-based Polymer

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**Abstract -** *Over the past few decades the use of petroleum-based surfactants has increased in large number, most of which are non-biodegradable in nature, causing harm to the environment mainly in the form of foaming. To overcome this issue, a polymer based on a renewable source i.e. liquid glucose has been synthesized. The polymer is based on liquid glucose with small quantities of citric acid, borax and sodium bisulphate. This synthesized polymer was analyzed for its various physiochemical properties like viscosity (340 sec), surface tension (43.3 dyne/cm$^2$), Hydrophile to lipophile balance (14.9). Biodegradation study of polymer was carried out by BOD/COD test and it was found to be biodegradable based on the BOD/COD ratio of 0.6944. The polymer was utilized to formulate liquid laundry detergent, which on its analysis was found to be on par with commercially available petroleum based liquid laundry detergents.*

***Key Words***: Biodegradable, polymer, surfactant, liquid laundry detergent, BOD/COD ratio, eco-friendly

## 1. INTRODUCTION

Most of the main active matters added into commodities such as detergent, soap, shampoo, and facial cleanser come from petroleum-derived products, such as linear alkyl benzene sulfonate (LABS), alpha olefin sulfonate (AOS), primary alcohol sulphate (PAS), alcohol ethoxy sulphate (AES), etc. These products may soon face the problem of shortage of the raw materials as the increasing consumption and decreasing natural reserves of crude material. Hence to overcome such issue, surfactants from renewable sources must be synthesized. During the last few decades, the demand of synthetic polymeric materials has been fairly increasing. This success is mainly related to their properties namely, low cost and aesthetic qualities. In the present research work, an innovative form of polymer has been synthesized from a natural renewable carbohydrate-based source i.e. liquid glucose [1,2]. The polymer is based mainly on liquid glucose along with citric acid, borax, sodium bisulphate, sodium hydroxide and Sodium lauryl ether sulphate (SLES). Various compositions of polymer were prepared and then they were analyzed for their properties like surface tension, viscosity, Hydrophile to lipophile balance (HLB) ratio. Based on these results, the composition, order of addition of ingredients, reaction temperature was standardized to get desired properties. The polymer was then tested for its various other physiochemical properties like % solids, density, pH, biodegradability. Its HLB ratio indicates that the polymer is well suited for detergency, hence a liquid laundry detergent [3] was formulated using the polymer. The prepared liquid laundry detergent was tested for its basic characteristics and stain removing properties. The result has been compared with standard commercial liquid laundry detergent to know the practical viability of formulation.

## 2. MATERIALS AND METHODOLOGY

### 2.1 Synthesis of carbohydrate polymer

The synthesis was carried out in a 4-neck glass reactor of two-liter capacity. One neck was fitted with a thermometer, central neck was reserved for stirrer and another neck for addition of ingredients. Weighed quantity of all the ingredients were introduced from this neck. Heating was started. The temperature was raised slowly and steadily. The temperature of 80 – 90 C was maintained for the entire process. The heating and agitation were continued for 3 hours. The prepared polymer was then allowed to cool down and the batch was withdrawn and stored in tightly closed bottles.

**Table – 1:** Composition of carbohydrate polymer

| Sr. No | Polymer ingredients | Composition (%) |
|---|---|---|
| 1 | Liquid glucose | 85 |
| 2 | Citric acid | 2.5 |
| 3 | Borax | 7.5 |
| 4 | Sodium hydroxide | 2.5 |
| 5 | Sodium Bisulphate | 0.5 |
| 6 | SLES | 2 |

### 2.2 Preparation of liquid laundry detergent

Liquid laundry detergent was prepared in batch process. An assembly of Heating mantle, mechanical stirrer and one-liter glass reactor with four necks were utilized. One neck was fitted with a thermometer, central neck was reserved for stirrer and another neck for addition of ingredients. Water was added into glass reactor and heating was started along with constant stirring. The rest of the weighed components were consecutively added. Temperature is slowly raised to 70 C and process was continued until the entire mass became homogeneous. Fragrance and colour are added at

room temperature. Then the prepared liquid detergent is filled in bottles.

**Table – 2**: Composition of liquid laundry detergent

| Sr. no. | Component | Composition (%) |
|---|---|---|
| 1 | Acid slurry | 5 |
| 2 | Polymer | 10 |
| 3 | SLES | 20 |
| 4 | Sodium hydroxide | 1.5 |
| 5 | Borax | 1.5 |
| 6 | Sodium bisulphate | 0.5 |
| 7 | Salt | 0.5 |
| 8 | Water | 61 |

## 3. CHARACTERIZATION

### 3.1 Analysis of polymer

The prepared novel polymer sample was analyzed for its physiochemical characteristics by standard laboratory methods [4,5,6,7].

**Table – 3**: Physiochemical analysis of polymer

| Sr. no. | Polymer characteristic | Observation |
|---|---|---|
| 1 | Foam height (1% solution) ($cm^3$) | 170 |
| 2 | pH (1% solution) | 8 |
| 3 | Viscosity (sec) using ford cup no. 4 | 340 |
| 4 | % solids | 57.2 |
| 5 | Density ($gm/cm^3$) | 1.392 |
| 6 | Surface tension ($dyne/cm^2$) (by stalagmometer) | 43.3 |
| 7 | HLB ratio | 14.9 |

### 3.2 Biodegradability of polymer

Biodegradation is defined as the decomposition of substances by biological systems. There is a world-wide research effort to develop biodegradable polymers to reduce pollution in the environment [8]. Biodegradability is determined by the chemical structure of a polymer, on the other hand physical properties of the polymer are responsible for affecting the rate of biodegradation. Straight chain compounds are more readily biodegradable than branched compounds but only a few high molecular weight carbon chain polymers are biodegradable, hence it is necessary to check the biodegradability of polymers. In this context the biodegradability of polymer was experimentally analyzed using waste water treatment method [9]. For this, ratio of biochemical oxygen demand [10,11] (BOD) and chemical oxygen demand [12] (COD) was analyzed.

**Table – 4**: Biodegradability analysis of polymer

| Sr. no. | Day | BOD (mg/L) | COD (mg/L) | BOD/COD |
|---|---|---|---|---|
| 1 | 2nd Day | 100 | 288 | 0.3472 |
| 2 | 4th Day | 150 | | 0.5208 |
| 3 | 6th Day | 175 | | 0.6076 |
| 4 | 8th Day | 200 | | 0.6944 |
| 5 | 10th Day | 200 | | 0.6944 |

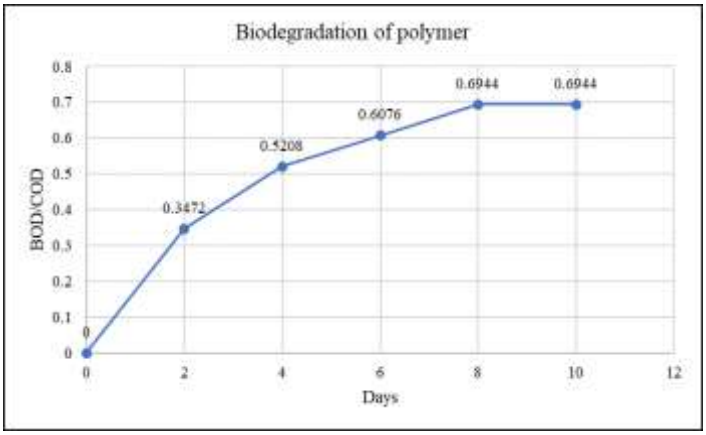


**Chart -1**: Rate of biodegradability analysis of polymer

The experimental data of biodegradability of polymer is subjected to regression analysis, which yields the following equation [2].

$$\mathbf{BOD/COD = 0.26603(day)^{0.44624}}$$

### 3.3 Analysis of liquid detergent [7,13,14,15,16]

After preparing the liquid detergent, it was stored in tightly closed bottle, cooled and left overnight. After a day it was filtered and a transparent solution was obtained. It was then analyzed for its various physiochemical properties and characteristics. Different stain samples of soil, tea and coffee were prepared to analyze the detergency [17,18]. Similarly, a commercially available liquid laundry detergent was also analyzed to compare it with the prepared laundry detergent.

**Table – 5**: Physiochemical properties of liquid laundry detergent

| Sr. no. | Characteristic | Observation for LS | Observation for CS |
|---|---|---|---|
| 1 | pH (1% solution) | 10 | 6 |
| 2 | Viscosity (sec) using ford cup no. 4 | 620 | 294 |
| 3 | Appearance | Transparent | Transparent |

Note: CS - Commercially available liquid laundry detergent
LS - Prepared liquid laundry detergent sample

**Table – 6**: Physiochemical analysis of liquid laundry detergent

| Concentration | Sample | Foam Volume ($cm^3$) | | Surface Tension ($dyne/cm^2$) |
|---|---|---|---|---|
| | | 0 min | 20min | |
| 1% | LS | 950 | 200 | 21.71 |
| | CS | 700 | 200 | 26.14 |
| 0.5% | LS | 400 | 350 | 22.42 |
| | CS | 550 | 100 | 27.64 |
| 0.25% | LS | 370 | 330 | 21.43 |
| | CS | 300 | 100 | 28.91 |

**Table – 7**: Cleaning analysis for 1% solution

| Sample | Staining medium for cotton cloth | | | Total points |
|---|---|---|---|---|
| | Soil | Tea | Coffee | |
| LS | 4 | 4 | 3 | 11 |
| CS | 3 | 4 | 3 | 10 |

Cleaning Points: - 0- no cleaning, 1- 25% Cleaning, 2- 50 % Cleaning, 3- 75 % Cleaning, 4 -100% Cleaning.

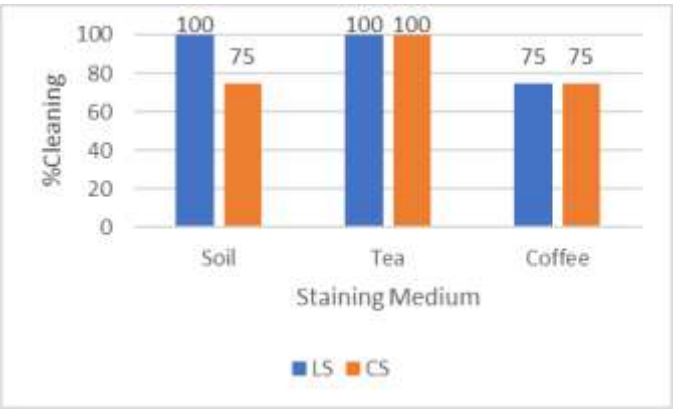


**Chart -2**: Cleaning analysis for 1% solution

## 4. RESULTS

1) Table – 1 gives the composition of novel polymer. Liquid glucose, borax, citric acid, Sodium hydroxide, SLES were reacted for about 3 hours to form the polymer.
2) The physiochemical analysis of polymer is given in table – 3. The polymer has an excellent viscosity of 340 seconds, HLB ratio of 14.9, surface tension of 43.4 $dyne/cm^2$, 57.2% solids are present in the polymer. It has a foam height of 170 $cm^3$, its density is 1.392 $gm/cm^3$ and has a pH of 8.
3) Chemical oxygen demand of diluted polymer was found to be 288 mg/L
4) Biochemical oxygen demands and ratio of BOD/COD are given in Table – 4. The rate of biodegradability analysis of polymer is given in chart – 1.
5) Laundry detergent based on the composition of polymer, acid slurry, SLES has been prepared. Its composition is given in table-2.
6) Laundry detergent has an alkaline pH and gives excellent result of foaming, surface tension and stain removing properties for stains of soil, tea and coffee as given in Tables – 5, 6, 7 and chart – 2.

## 5. CONCLUSIONS

1) The polymer after selection of proper mole ratio, heating period give final product which can be used as partial replacement of acid slurry in laundry detergent compositions.
2) It exhibits many advantages of being non-toxic, being low excitant to humans, and demonstrating exceptional performance of environmental compatibility.
3) The measure of biodegradability is the ratio of BOD/COD. If Ratio is 0.6 and above the polymer is considered to be biodegradable. The biodegradation study indicates that Polymer has a ratio of 0.6944. Therefore, the polymer can be considered as biodegradable.
4) Liquid detergent based on the polymer can be prepared. Only using 10% of the polymer can give results on par with commercially available liquid laundry detergents.

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