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Influence of Carboxymethyl Cellulose on the Preparation and Characterization of Liquid Detergent

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Abstract

The increasing pressure of reducing the cost of production, without adversely affecting the overall performance of the products to satisfaction of the consumers are some of the propelling factors for production improvement in the industry. In this research, the influence of carboxymethyl cellulose (CMC) on the properties of liquid detergent was investigated. *Chromolaena odorata* Carboxymethyl cellulose-detergent (CO-CMC-Det), *Penniseteum purpureum* Carboxymethyl cellulose (PP-CMC-Det), *Ananas comosus* Carboxymethyl cellulose (AC-CMC-Det), Detergent grade-CMC-Det (Detgrade-CMC-Det) and without CMC (Water–Det) were prepared after neutralization reaction between sodium hydroxide and linear alkylbenzene sulphonic acid. The viscosity analysis of the detergents revealed that Water–Det had 2.39, CO-CMC-Det had 4.77, PP-CMC-Det had 4.84, AC-CMC-Det had 4.25, while Detgrade-CMC-Det had 5.12. All the detergents had a specific gravity of 1.03 except Water-Det which had 1.01. All the detergents fortified with CMC had better cleaning performance of over 25% while Water-Det had 17.50%. The biodegradability test using biochemical oxygen demand (BOD) as the index indicated that degradation of the detergent recorded a drop in BOD which ranged from 1.18 to 2.29 in the first month and then ranged from 0.01 to 0.04 after seven months. The research revealed that addition of CMC could affect the performance of detergent positively

Keywords

Detergent, Carboxymethyl Cellulose, Cleaning-Ability, Biodegradable, Anti-redeposition

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1. Introduction

The use of soap for fabric washing is the most popular in the early time, but this has some drawback. This is because soap performance is affected by hard water due to the formation of an insoluble fatty acid salt of calcium and magnesium [Ameh et al., 2010]. Because of the drawback of soap, modern technology and consumer's desire for better product performance, changes caused by urbanization, information coverage, and dissemination, the rise in education and living standards. New products with cheaper price but high performance become necessary to meet the consumers' requirements. This gave birth to the development of liquid detergent.

Liquid detergents are becoming popular around the world, not because of their ease of dispersion and dissolution in the wash water, but also because they give a better performance than the available soap [Naganthran et al., 2017]. The liquid detergents are used among other things mainly to wash soiled dishes and fabrics, cooking utensils in the kitchen, car, hair, etc. Since soiled materials could have a mixture of oils, fats, grease, pectin, proteins, etc. A good cleaning and emulsifying performance are necessary to make the soiled materials free from soil streaks and stains [Sitaram, 2003; Azeez and Abegunde 2016].

The primary surfactant used in washing up liquid formulation includes linear alkyl benzene sulphonate (LABS), neutralised

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with sodium, ammonium, and magnesium hydroxide or sometimes with a triethanol amine. Liquid detergents are composed of a range of ingredients that give the final product its different characteristics. The most common ingredients apart from LABS and its neutralizing agent are builder, anti-redeposition agents, enzymes, bleaching agent, antimicrobial agents, fabric softeners, fragrances, optical brighteners, preservatives, hydrotropes, or solubilisers, processing aids, foam regulators, and corrosion inhibitors [Mohanty *et al*., 2003; Heydarzadeh *et al*., 2009; Diederik et al, 2007; Yangxin et al., 2008].

Although carboxymethyl cellulose is used in ice cream manufacture, paper sizing, textile finishing, food, paint, pharmaceuticals, cosmetics and mineral processing industries, drilling mud in oil industry, dye thickening, tissue engineering and polymer blends [Xiaojia *et a*l., 2009; Dolz *et a*l., 2007; Fijan *et al*., 2009; Barbucci *et al*., 2000; Benmouhoub *et al.,* 2008; Kulkarni and Sa 2008; Yi and Zhang, 2007; Jiang *et al*., 2008; Marci *et al*., 2006]. Although, carboxymethyl cellulose (CMC), carboxyethyl cellulose (CEC), starch-based compounds or other polymers [Biswal and Singh, 2004; Wei *et al*., 2009; Sitaram, 2003], have been named among anti-redeposition agent that could be added to liquid detergent. To the best of my knowledge, there is no research journal that has evaluated the performance characteristics of liquid detergent with CMC addition.

It is the desire of this study to present some new data on the influence of CMC on viscosity, specific gravity, cleaning ability, emulsional index and biodegradabity of detergents fortified with CMC.

2. Materials and Method

Analytical grade chemical reagents used were sodium hydroxide (BDH), linear alkylbenzene sulphonic acid, detergent grade-CMC (Detgrade-CMC-degree of substitution 0.42). All other carboxymethyl cellulose *Chromolaena odorata* Carboxymethyl cellulose (CO-CMC-degree of substitution 0.34), *Penniseteum purpureum* Carboxymethyl cellulose (PP-CMC- degree of substitution 0.33), and *Ananas comosus* Carboxymethyl cellulose (AC-CMC- degree of substitution 0.28) (Oluwasina et al., 2015)

2.1. Preparation of Liquid Detergent

The liquid detergent was prepared by the neutralization reaction between sodium hydroxide solution (2% w/v) and linear alkylbenzene sulphonic acid in ratio 1:2. The pH of the detergent was reduced to about 6.5 using few drop of equal molar sodium hydroxide and alkylbenzene sulphonic acid and the solution was then diluted with 200 mL of distilled water was then added. Exactly, 2% solution of carboxymethyl cellulose was then prepared and 20% of this solution (based on the total weight of detergent before addition of the 200 mL water) was then added to the detergent. The mixture was thoroughly mixed together to give a homogenous solution. The detergents were named according to the source of their CMC sources and then stored in different labelled plastic for further analysis.

2.2. Analysis of the Liquid Detergent

2.2.1. Cleaning Action

The cleaning action of detergent was based on a modification of methods of Aghel *et al*., [200]; Thompson *et al*., [1985]; Kharkate *et al*., [2005]; Kumar and Mali [2010].

2.2.2. Soil Medium

In a mortal, coconut oil (31.3 g), carbon black (23.7 g), red oil (15 g), liquid paraffin (15 g) and grease (15 g) were all mixed slowly together with a pestle to form a thick paste and thoroughly mixed for about 30 min to get a fine and smooth material.

2.2.3. Fabric Soiling

Ten percent solution (w/v) of the soil medium was prepared using hexane and 3 g of cotton fabric (previously dried to a constant weight) was dipped in 150 mL of the solution for 20 min under stirring condition. The cotton fabric was then removed and dried at room temperature for 2 days and the fabric weighed to determine the new weight, in order to calculate the soil load.

2.2.4. Preparation of Soap Solution and Washing Method

To determine the cleaning action of the detergent, exactly 0.1% detergent solution (v/v) was prepared using tap water and 150 mL of this detergent solution was measured into 250 mL beaker, to this was suspended the soiled fabric. This was then agitated for 5 min in a shaker and then allowed to stand for 15 min. The fabric was then removed and suspended in 100 mL of tap water for 10 min. The fabric was then removed and dried at room temperature for 2 days, further dried for 2 h at 40°C and the final weight determined. A control sample was prepared using 150 mL of tap water without detergent solution and all previous washing steps repeated. The cleaning action was calculated using the following equation;

$$\text{CA}\,(\%) = 100(1 - \tfrac{T}{B}) \quad (1)$$

Where:

CA is cleaning action

T is the weight of soil remaining in the test sample after washing

B is the weight of soil remaining in the control sample after washing

2.3. Emulsification Index

This was determined by adding 2 mL of a hydrocarbon (kerosene) to 2 mL of detergent in a graduated cylinder, mixing with a vortex for 2 min, and leaving to stand for 24 h. The index is given as a percentage of the height of emulsified layer (mm) divided by the total height of the liquid column (mm) [Cooper and Goldenberg 1987].

2.4. Viscosity Measurement

The standard method of determining viscosity was employed using the U-tube viscometer. A quantity of the detergent sample was poured into the U-tube viscometer and while the other side was corked. The cork was removed and the time taken for the content to run-up starting from the top mark to the middle mark was noted using a stopwatch. Viscosity was estimated (cP) at a constant temperature (25°C) [T230om-99]. The determination was done in triplicates.

2.5. Specific Gravity Measurement

The weight of washed, clean and dried empty 25 mL specific gravity bottle was determined. The same specific gravity bottle was fitted with the detergent sample and equal volume of distilled water separately and weighed. The difference in weight between the specific gravity of bottle filled with the detergent (or water) and empty specific gravity bottle was then calculated. The specific gravity was determined by dividing the weight obtained for the detergent by that obtained for the distilled water at 25°C. The determination was done in triplicates.

2.6. Biodegradability Test of Detergent

Five grams of various detergents was measured by biochemical oxygen demand (BOD) bottle. One millilitre of phosphate buffer, magnesium sulphate, calcium chloride, and iron (III) chloride was added to one litre of distilled water. This solution was added to top up the contents in the BOD bottle. This was left to stand for 2 h and the dissolved oxygen was measured. After incubation (the various detergents) in the dark at 20°C for five days the dissolved oxygen was also measured. The change in dissolved oxygen was then calculated.

3. Results and Discussion

There were significant differences between the properties detergents fortified with CMCs. Also, there was significance difference between fortified liquid detergent and the unfortified WaterDet as presented in Table 1.

3.1. Viscosity

During the preparation of the liquid detergent, 200 mL water was added to all CMC based detergent to reduce the viscosity but that was not done with water based detergent. Thus, going by this experienced 200 fold dilution, if this is taken into consideration that means that the viscosities of CMC based detergents are far higher than that of water. This mean that viscosity of Detgrade-CMC-Det which has the highest value of 5.12 would be in real sense by 1,024 (i.e. 200 x 5.12), while the second highest PP-CMC-Det would be 968 (200 x 4.84), followed by CO-CMC-Det with 954 (200 x 4.77) and AC-CMC-Det with 850 (200 x 4.25), and lastly WaterDet had 2.39. Smulders, 2002, has reported that CMC acts as a thickening agent and the reason for it's used in ice cream industry. Therefore, the increase in the viscosity of the CMC fortified liquid detergents could be attributed to the added CMC. The increase in the viscosity could afford producer more economy gain since the dilution of the detergent would increase the amount of it without reducing its performance efficiency as shown in other results obtained in this study. Also, Detgrade-CMC-Det had the highest viscosity could be linked to its degree of substitution, because swelling ability is a function of the degree of substitution (DS), [Latif et a., 2005 Oluwasina et al., 2015]. Also, according to Heinze and Koschella [2005] the higher the degree of substitution the more soluble and swelling the material

3.2. Specific Gravity

There was no significant difference in the specific gravity (1.03) recorded for all the detergent prepared with CMC, but there was significance difference between the specific gravity CMC fortified detergent and WaterDet. But taking into consideration the dilution of all the CMC fortified liquid detergent with 200 mL water, it would mean that the specific gravity of the CMC fortified liquid detergent is far higher than that without CMC. It could be inferred that addition of 20% of 2% CMC solution could increase the bulkiness of the liquid detergent, and that about 20 time equal volume of WaterDet could be obtained from the fortified liquid detergent. Just like the viscosity, this too would be of economy value to the producer, since the addition of little quantity of CMC could produce much volume of the detergent with improved properties and high income.

3.3. Emulsion Index

The Emulsification index which showed the ability of the detergent to act on hydrocarbon showed that all the CMC fortified detergent had better performance than the WatersDet, having recorded 50.00% for PP-CMC-Det and Detergent grade-CMC, 49.50%, AC-CMC-Det, and 47.00% for CO-CMC-Det against 26.65% of WaterDet. The emulsifying behaviour of the detergent could be explained based on the molecular structure. The detergent has both hydrophilic sides, Sodium carboxylated end and the hydrophobic, linear alkyl benzene sulphonate end. Since like attracts like, the Sodium carboxylated end would dissolve in the water and the linear alkyl benzene sulphonate end would dissolve in the kerosene to mop it up. The sodium ion of the liquid detergent could have probably precipitated the calcium and magnesium ions of the water, probably resulting into the better performance of the liquid detergent fortified with CMC, because according to Ameh, et al., [2010] surfactant ability could be affected by hard water cations.

3.4. Cleaning Action

The cleaning action of the detergent revealed that the CMC had a great effect since 0.1% detergent solution was able to record higher values that the WaterDet. The result showed that CO-CMC-Det has the highest value of 25.67%, followed by Detergent grade-CMC with 25.48%, AC-CMC-Det with 25.21%, PP-CMC-Det with 25.0% and lastly with WaterDet with 17.50%. The cleaning action could be as a result of anti-redeposition action [Smulders, 2002] of CMC, which would have prevented the dirt from been reabsorbed on the fabric. In their evaluation of cleaning action of prepared shampoo formulations and market shampoos, Kumar and Mali [2010], had reported 24.21%, 32.51%, 18.81%, 33.61% and 32.11% as cleaning action of different formulated shampoos containing CMC. The performance of the CMC detergent would probably be influenced by the added CMC. The result showed that CO-CMC-Det has the highest value of 25.67%, followed by Detergent grade-CMC with 25.48%, AC-CMC-Det with 25.21%, PP-CMC-Det with 25.0% and lastly with WaterDet with 17.50%. It might be that the added CMC sodium ion has assisted in the precipitation of the hard water ions (calcium and magnesium ions), thus promoting the surfactant ability of the linear alkyl benzene sulphonate in soil removal, because it has been reported by Abeliotis et al., [2015] that hard water affects the performance of detergent, this might have caused the low performance of WaterDet. Also, the linear alkyl benzene sulphonate would probably dissolve in the soil as it comes in contact with the soil and would later form form a layer around the soil. This formed layer might repel by another oil droplet because of their negative charges and thus drop down inside the water, this would be aided by agitation. The CMC on the other hand is the anionic carboxymethyl ether of cellulose (Basavaraja et al., 2013) which would have attached to the soiled fabric and might have ionized in the water to produce negatively charged fabric. The negatively charge fabric would repel negatively charge soil dirt of the hydrophobic end of the detergent causing it not to get re-attached. This might be the reason why liquid detergent fortified with CMC has higher soil removal.

3.5. Biochemical Oxygen Demand

The Biochemical Oxygen Demand (BOD) refers to the amount of oxygen utilized by micro-organisms within a 5-day period to convert organic matter in waste water (or substances) to carbon dioxide and water. The BOD can be used to establish the ease with which substances will biodegrade and could be an indication of the shelf life of a liquid detergent. All the CMC fortified detergents have higher BOD in the first month of the analysis PPSAECMC-Det and Detergent grade-CMC had the highest value (2.29), followed by 1.37 of AC-CMCDet, 1.18 CO-CMCDet and least value of 0.28 for WaterDet. The high BOD of the liquid detergent with CMC could be an indirect measure of their life span and it may suggest that they could be used for a longer period as compare with WaterDet. The BOD result after three months still, however, showed that all the detergents fortified with CMC had higher BOD than the water based detergent. After seven months of the experiment, the BOD of all the sample has reduced drastically, WaterDet has 0.02, while that of fortified detergent ranges from 0.1 (CO-CMCDet) to 0.04 (DetgradeCMC). The result suggests that addition of CMC to detergent will not only make such a detergent environment friendly, but will also prolong its shelf life, and preserve the viscosity and antiredeposition ability of the detergent.

Table 1. Physicochemical Properties of the Detergents.

Sample	viscosity (cP)	Specific gravity	Cleaning action (%)	Emulsional index (%)	BOD		
					1st month	After 3months	After 7months
WaterDet	$2.39^{a} \pm 0.11$	$1.01^{a} \pm 0.00$	$17.50^{a} \pm 0.70$	$26.65^{a} \pm 0.01$	$0.28^{a} \pm 0.01$	$0.03^{a} \pm 0.01$	$0.02^{a,b} \pm 0.00$
CO-CMC-Det	$4.77^{c} \pm 0.10$	$1.03^{b} \pm 0.01$	$25.67^{b} \pm 0.26$	$47.00^{b} \pm 0.30$	$1.18^{b} \pm 0.00$	$0.13^{b} \pm 0.02$	$0.01^{a} \pm 0.00$
PP-CMC-Det	$4.84^{c} \pm 0.16$	$1.03^{b} \pm 0.01$	$25.01^{b} \pm 0.98$	$50.00^{b} \pm 0.30$	$2.29^{d} \pm 0.01$	$0.25^{d} \pm 0.00$	$0.02^{a,b} \pm 0.00$
AC-CMC-Det	$4.25^{b} \pm 0.11$	$1.03^{b} \pm 0.00$	$25.21^{b} \pm 0.36$	$49.50^{b} \pm 0.35$	$1.37^{c} \pm 0.01$	$0.15^{c} \pm 0.01$	$0.03^{b,c} \pm 0.01$
Detgrade-CMC-Det	$5.12^{d} \pm 0.06$	$1.03^{b} \pm 0.01$	$25.48^{b} \pm 0.88$	$50.00^{b} \pm 0.32$	$2.29^{d} \pm 0.01$	$0.25^{d} \pm 0.00$	$0.04^{c} \pm 0.01$

Values are means of three replicate ± standard deviation. Column means followed by different letters are significantly different at P< 0.05.
WaterDet- Oridary water based detergent with no addition of CMC
CO-CMC-Det –*Chromoleana odorata*- carboxymethyl cellulose Deatergent,
PP-CMC-Det -*Peninisetum purpurem* - carboxymethyl cellulose Detergent
AC-CMC –Det-*Ananas comosus* - carboxymethyl cellulose Detergent
Detgrade-CMC-Det - Detergent grade carboxymethyl cellulose Detergent.

4. Conclusions

The fortified detergents have viscosity which almost double that of WaterDet, suggesting that addition of carboxymethylcellulose could assist in increasing the volume of detergent and this may have economy value for the producer. Also, detergent fortified with carboxymethyl cellulose have better performance in term of emulsional index and cleaning ability than the WaterDet. This research has shown that addition of carboxymethyl cellulose could be used to improve the performance of liquid detergent.

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