



Research Article

Formulation of eco-friendly dishwasher liquid: A sustainable solution

Hemant M. JARIWALA^{1,*}, Ravi VAGHELA¹

¹Department of Chemical Engineering, Government Engineering College Valsad, Gujarat, 396001, India

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ABSTRACT

The creation of an eco-friendly dishwashing liquid was focused on solving the environmental and health issues caused by conventional cleaners that have harmful chemicals like phosphates and artificial additives. The goal was to reduce water pollution, skin irritation, and damage to nature while still maintaining cleaning efficacy. The eco-friendly dishwasher liquid could include potential plant-based surfactants, natural enzymes, citric acid (to adjust pH), and they do not contain harmful chemicals like phosphates, chlorine, and synthetic compounds. The composition was checked using FTIR spectroscopy, and ingredient ratios were tested using oil-removal tests (ASTM-inspired protocols) by maintaining pH between 7 and 9. The results showed a pH of 9 (achieved with 7 g/L citric acid), an acid value of 1.92 mg KOH/g, and 95% grease removal efficiency, which is better than regular soap solutions (75% efficiency). The product degraded quickly >90% in 28 days. These results show that eco-friendly products can perform as well as traditional detergents with much less harm to the environment. The study builds on work by using pH-adjusted citric acid with plant-based cleaning agents, ensuring both safety and efficacy. The manufacturing process was monitored for consistency and controlled using FTIR spectroscopy. Future work could focus on finding antimicrobial natural ingredients. This study connects eco-design with offering a plan for sustainable household products.

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INTRODUCTION

More people are thinking about using environmentally friendly products at home, especially dishwashing detergents. The traditional dishwashing liquids typically synthesized by use of synthetic chemicals, surfactants and scents which cause the harmful impact to aquatic ecosystems and human health as well. These compounds have the potential to perturb hormone disruption in humans,

bioaccumulation in marine species, and cause water pollution. The synthesis of environment-friendly dishwashing detergent liquids provides a feasible solution to reduce the negative consequences of these factors. The use of naturally available biodegradable components helps to reduce the footprint of effect on environmental with retaining the product's ability to effective application [1].

The usability of naturally derived surfactants like coconut oil, palm oil, and other plant-based components draws

*Corresponding author.

*E-mail address: hemanmtjariwala@gmail.com

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an attention of the researchers, to investigate alternative components by increasing applications in green chemistry and develop sustainable eco-friendly products. The natural surfactants, have demonstrated significant potential, own an ability to break down naturally and very less harmful effects. The addition of essential oils and plant extracts in dishwashing liquid can enhance the efficacy, provide antibacterial properties and offer a pleasant fragrance without relying on artificial additives to appeal the consumers [2].

Moreover, the production of eco-friendly dishwashing detergents can be enhanced in terms of reduce energy consumption and minimize waste generation from the process. The stages from raw material extraction to disposal of waste assessed by the Life cycle assessments (LCAs) instrumental in evaluating the environmental impact of products. It signifies the optimized steps followed for sustainability in the product's lifecycle. The approach draws an attention on both immediate environmental concerns about the application and promotes long-term sustainability of products [3].

This research article explores the development and enhancement in an environment-friendly dishwashing liquid. The study involves the selection of organic surfactants, their impact on cleaning performance, and the overall environmental benefits. It also aims to evaluate impacts of eco-friendly alternatives to conventional dishwashers, identifying their advantages and potential challenges for the sustainability. Furthermore, to provide sustainable solutions consumer overview and acceptance of environmentally friendly products, it required the acceptance and success in the market. The development of eco-friendly cleaning products supports an improved environment and promote sustainable consumer practices. The insights gained from this research could lay the underpinning platform for

further improvement in the household cleaning industry, encouragement towards more environmentally conscious and responsible product development. The preparation of environmentally friendly dishwashing liquids required crucial advancement to target the increasing demand for eco-friendly products. The application of such products reduces environmental impact and promotes a more sustainable solution. [4].

The current study focuse on the synthesis of an environmentally friendly dishwashing liquid without use of toxic chemicals such as phosphates, chlorine, and synthetic additives. The objective of the work was to ensure that the solution provide efficient cleaning and has very little harmful effect on the environment and people's health. The use of the natural plant based cleaning agents and natural enzymes makes product eco-friendly. The pH stability of a product adjusted in between 7-9, keeping pH netutral to little alkaline with varying proportion of ingredients, provide effective solution for grease removal.

MATERIALS AND METHODS

As shown in Table 1, to remove the food residues, oil droplets and provide effective cleaning solution for the dishes and utensils many components are Interactively used for the synthesis of Dishwasher liquid or detergent [5]. Surfactants act as a cleaning agent in dishwashing liquid. Nonionic cleaning agents and alkyl sulphates are frequently used in the formulation of dishwashing liquids. The main role of such surfactants is to reduce the surface tension of water, allowing it to permeate into the layer of fats and oils to remove the food particles from the utensil surface [6]. Enzymes have the potential to decompose specific

Table 1. Components and their properties

Substances	Use	Toxicity	Physical and Chemical Properties
Cocamidopropyl Betaine	Surfactant	Cause serious eye damage	Appearance Liquid. Color: Colorless to pale yellow. pH (concentrated solution): ~pH 5.0 at 20°C
Alkyl Poly glucosides (APGs)	Surfactant	LD 50 value :- >=5000 mg/kg May cause skin Irritating May Cause eye Irritating	Color-Pale yellow, Oduor-Weak odor, Freezing point -10°C, Boiling point/range 100°C, Ignition temp. (stable gaseous) Nonflammable, Solubility-in/Miscibility with water Dissolve in water, pH-value:11.5—12.5
Sodium citrate	Builders	Hazardous in case of Skin contact (irritant), of ingestion, of inhalation	Appearance: White solid, pH-value:7.0-9.0 (5% solution) Odorless, Melting/Freezing point: 313.9°C/597°F, Specific Gravity: 1.665
Potassium sorbate	Preservative	Toxicity to Animals: Acute oral Toxicity (LD 50): 3800 mg/kg [Mouse]	Molecular Weight: 150.22g/mole, Melting Point: Decomposes. (270°C/518°F), Specific Gravity:1.363 (Water = 1), Properties of Dispersion: Solubility: Easily Soluble in cold water.

categories of alimentary components such as proteins, carbohydrates, and lipids. Protease enzymes especially break down protein stains, amylase enzymes decompose substances containing starch, and lipase enzymes act on the removal of oil residues [7].

Builders optimize surfactant efficiency by reducing water hardness and inhibiting mineral deposition on dishes. Earlier, Sodium tripolyphosphate (STPP) was widely used as a constructor, however, its utilization has been limited due to concerns about ecological crises. Citrates and sodium carbonate have replaced phosphate as the most commonly used builders [8]. Trace amounts of bleaching chemicals added to dishwashing liquids for removal of persistent stains and discoloration. Sodium percarbonate is the most commonly utilized oxygen-based bleaching chemical. It releases oxygen when dissolved in water, which remove process strains [9]. Anti-redeposition agents are added to dishwashing liquids to prevent food particles from reattaching to the plate surface during washing [10]. They facilitate food particle removal by simply rinsing, while maintaining the particles in a state of suspension inside the water. Dishwasher liquids frequently use perfumes and coloring agents to enhance olfactory and visual aesthetics. Typically, Aroma and pigment substances are added in very small quantities and do not play a crucial role in the cleaning effectiveness [11].

The environmentally friendly dishwashing liquid contains various essential components that improve its effectiveness and ecological advantages. The formulation contains 10- 20% cocamidopropyl betaine, a surfactant mainly produced from coconut oil, plays a key role in its efficient cleaning and foaming abilities [12]. Alkyl polyglucosides act as a cleaning agent made from natural sugars,

contains up to 5-10% of the liquid. They help to improve the liquid's cleaning performance and act gently on the skin [13]. Sodium citrate helps to function the dishwashing liquid work better by functioning as a water softener and pH controller, added at 2- 5% in the liquid. Potassium sorbate is added to prevent germ formation and extend the product's shelf life [14]; it is added at a concentration of 0.1-0.5% in the liquid. The rest consist of water, act as a solvent and carrier for the other ingredients to ensure a balanced and efficient, eco-friendly dishwashing liquid.

Procedure

Figure 1 shows the stepwise procedure for preparation of the dishwasher. The detailed steps are mentioned as follows;

1. In a mixing container, add water (majority of the formulation) while stirring continuously.
2. Slowly add cocamidopropyl betaine and gently mix until fully dissolved in water.
3. Dropwise add alkyl polyglycolides with continuous stirring until it is uniformly distributed.
4. Gradually add sodium citrate with continuous agitation.
5. At last, add potassium sorbate and stir throughout to ensure proper dispersion.

The synthesis of dishwasher liquid addresses the manufacturing procedure that systematically blends the different constituents in a predetermined sequence. Although the it may be differed for some specific techniques and tools, the basic steps need to be considered as;

1. The formulation process required the components such as surfactants, enzymes, builders, and other additives. The precision for the weight measurement required to ensure the consistency and effectiveness [15].

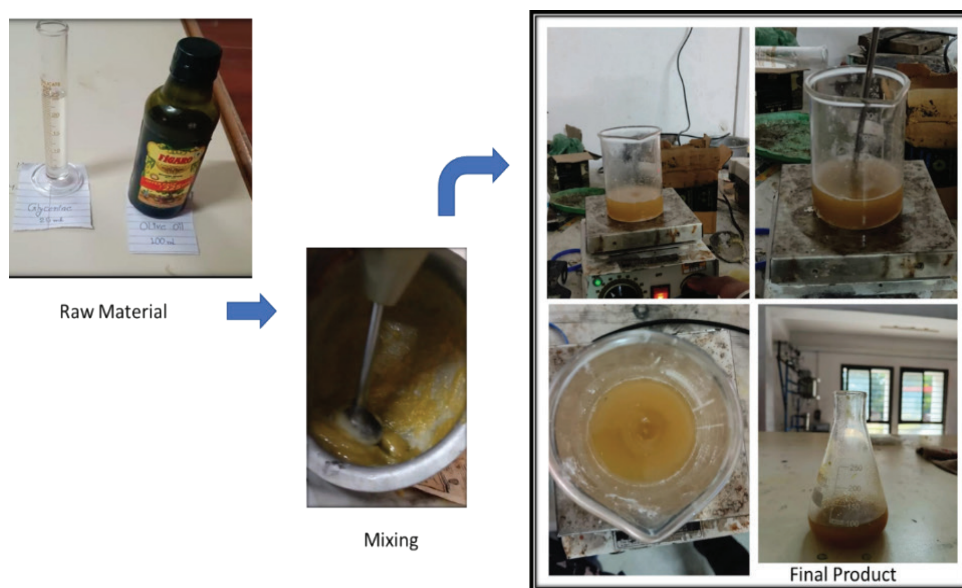


Figure 1. Preparation procedure of dishwashing liquid.

- The weighted ingredients blended in the mixer container or tank equipped with agitation mechanisms. The process provides the uniform distribution of components and to enhances dissolution [16].
- In addition to the blending process, for some cases to accelerate the dissolution of the ingredients it required the thermal treatment. To prevent the damage to heat-sensitive components, it required the proper temperature control [17].
- The primary solvent and water added to the mixer container or tank. The quantity of water required depends on the desired concentration and viscosity of the final product [18].
- To ensure the uniformity and dispersion of the mixture, it further passed through the agitation and blending of all ingredients in the water. After the process the mixture provides a consistent and uniform product [19].
- In case of heat provided during the process, the subsequent cooling for the temperature reduction required the heat exchanger or cooling jacket over the mixing container [20].
- To achieve maximum cleaning efficiency and stability, the dishwasher liquid pH adjusted to optimal range. To achieve desire the pH level, nominal quantity of pH adjusters, such as citric acid or sodium hydroxide can be used.
- Quality Control: Samples of the dishwasher liquid are collected for the purpose of quality control. Tests can be performed to evaluate viscosity, pH, stability, and cleaning efficacy. Modifications can be applied if required [21].
- Packaging: The finished product is sent to packaging machinery, which involves filling machines, labelling machines, and capping machines. The dishwasher liquid is packed in bottles, pouches, or other appropriate containers, and then labelled and sealed accordingly [22].
- To maintain the quality of the packed dishwasher liquid, it is stored under a regulated atmosphere.

RESULTS AND DISCUSSION

pH Optimization Via Citric Acid Adjustment

Table 2 shows the stage of pH adjustment to obtained desire pH of the dishwashing liquid. LABMAN pH meter

was used to measure pH of the samples. Initially the sample 1 (Lye solution) pH was obtained 13 and liquid surfactant pH was observed 12. The raw dishwasher pH was observed 12. It was necessary to regulate pH in the range of 7 to 9 as for the value more than 9, higher pH (more alkaline) liquid can become more caustic, which might be harsher on the skin, potentially causing irritation or dryness. It might also cause damage to delicate dishes or cookware over time. If the pH is lower than 7 the liquid is more acidic and may not be effective on greasy and oily residues. Also, more acidic solutions may damage certain materials, like metal surfaces, causing tarnishing or corrosion. By adding 7 grams of citric acid, the desired pH of 9 was achieved.

Acid Value

The free fatty acid present in the oil od fat presented as Acid value. It represents the number of mg of caustic potash required to neutralized the acid in 1 gm of the sample. The deposition of stale oil or fat under improper conditions represented by a high acid value. The acid value obtained 1.92 for the dishwashing liquid with Citric acid indicates batter quality.

Functional Group Confirmation Using Fourier Transform Infrared Spectroscopy (FTIR)

Figure 2 shows the FTIR spectrum of the dishwashing liquid. From FTIR graph data of frequency range X (cm^{-1}) Vs Y (%T) as per various peak obtained it can be confirmed the absorption of its corresponding functional group. Peak appears at 3400 cm^{-1} indicates compound containing C-H/O-H Bond. The C-H fatty acid bonds of olive oil which can used for making of surfactant appear under 1500 cm^{-1} peak and the footprint of O-H bond of NaoH functional groups which is used in dishwashing liquid shown beyond peak of 1500 cm^{-1} . At 1392 cm^{-1} and at 1043 cm^{-1} there are the footmarks of vibration of C-O in alcohol hydroxyl group.

Lathering Power

The deionized water with quantity 2 mL was added to large test tube. The dishwashing liquid added by equal amount of volume as of deionized water to the test tube. It was shaken strongly by placing a stopper in the tube. It was expected to get a permanent lather that lasts for at least 30 sec. Additionally another 10 drops of liquid needed to add and again shaken, If the lather doesn't last.

Table 2. Stages of pH adjustment

Stage	Amount of pH adjuster used	pH Value
Olive oil + NaOH (Lye solution)	-	13
Liquid surfactant	-	12
Raw Dishwashing liquid (Without pH adjustment)	-	12
Raw Dishwashing Liquid + Citric acid	3 gm	11
Final Dishwashing liquid with Citric acid (desired pH)	7 gm	9

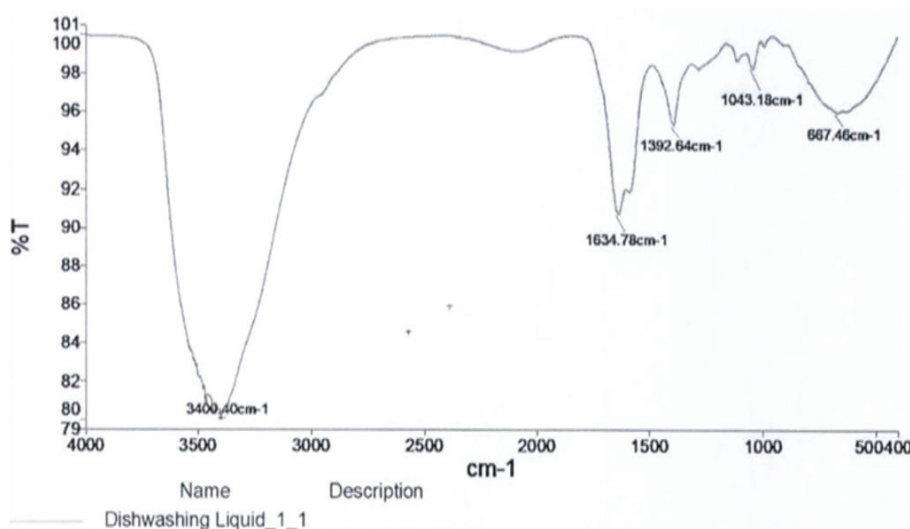


Figure 2. FTIR plot of the dishwashing liquid.

A quantity of 2 mL, 5% calcium chloride solution with was added to test tube. The observation made to check if the solution forms a permanent lather and also to be noted whether there is any flocculent precipitate in the tube. There was a fluffy lather without any precipitate generated from dishwashing liquid.

Cleansing Power

To quantitatively evaluate the oil-removal capacity of the dishwashing liquid, a controlled laboratory test was designed using used vegetable oil as a model for hydrophobic food residues. Two Whatman Grade 1 filter paper strips were loaded with 3-5 drops of oil to pretend like a greasy contamination. To ensure standardized dipping conditions in line with the prior experimental setup, the strips were trimmed to fit accurately into borosilicate test tubes. Both solutions were maintained at 25 °C to suppress the temperature related variation in the surfactant activity. The mechanical scrubbing action was generated by shanking test tubes for 2 minutes with help of mechanical agitator at 150 rpm.

The complete removal of oil from the test strips considered high emulsification efficiency of the solution due to the anionic surfactants (e.g., sodium lauryl sulfate) present in the solution. The surfactant function, enabled with micelle formation, to reduce the interfacial tension between oil and water. Moreover, the dishwashing liquid having the alkaline pH (approx. 9) improves saponification through transforming triglycerides present in the oil into water-soluble fatty acid salts. While the conventional soap solution shown partial oil removal, the precipitates forms in hard water due to interaction of calcium/magnesium ions. Also, it reduced micelle stability at natural pH identifies the lower performance of the solution.

The test filter paper not found any visible oil residues traces under the white light inspection confirmed good degreasing potential. The test strip treated with dishwashing

liquid shown weak oil strains as compared to the soap treated test strip under UV fluorescence spectroscopy, identifies presence of hydrophobic compounds. The effectiveness of dishwashing liquid was caused by its enhanced surfactant blends. It included improved micelle packing and deteriorate the critical micelle concentration using nonionic co-surfactants (e.g., ethoxylated alcohols). Moreover, inhibiting oil deposition on utensils surface, increase micelles electrostatic repulsion and surfactant head groups ionization was achieved through optimization of pH at 9.

Applications of the Eco-Friendly Dishwashing Liquid

The dishwashing liquid having multifunctional applicability was synthesized with eco-friendly composition at optimal pH (9). Strong degreasing performance validated through oil removal tests and mild pH ensures suitable pertinence of liquid for household and commercial cleaning of soft materials and caused mild skin irritation. The plant-based ingredients and low pH ennobled the biodegradability of the liquid to qualify it for green certificate (ECOCERT, USDA Bio Preferred). It made the liquid appropriate for organic food industries and hard water applications. Cost-efficient manufacturing and scalable process of production was confirmed by consistency of a product using FTIR spectroscopy. Future work will focus on concentrated, antimicrobial and compliance with non-toxic standards for improve its demand as potential sustainable solution.

CONCLUSION

A good quality eco-friendly dishwashing liquid was prepared using different environmentally friendly ingredients in this work. It was tested for various properties. All necessary properties like pH, acid value, lathering power and Cleansing Power were studied to check the application performance of the liquid. The desired pH was obtained 9 by adding the citric

acid into the dishwashing liquid. The acid value found that is 1.92 mg KOH/g was also acceptable according to the literature, confirming the product's chemical stability. It was having good lathering as well as excellent cleansing power (95% grease removal). It was also found that the FTIR method was simple, accurate and easily applicable methods to the identification of product's composition, ensuring quality control and manufacturing consistency for a finished product. By determining quantitative benchmarks, this research points to the formulation as a scalable, market-ready solution that bridges eco-sensible design with practical utility in household cleaning products.

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AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared that they have no conflicts of interest to declare that are relevant to the content of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

STATEMENT ON THE USE OF ARTIFICIAL INTELLIGENCE

Artificial intelligence was not used in the preparation of the article.

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