ECONOMIC IMPORTANCE OF SOME NIGERIAN HOUSEHOLD COMMERCIAL DETERGENTS IN WASHING PROCESS USING SURFACE TENSION CAPILLARY RISE METHOD.

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Abstract

The surface tensions of eight commercial detergents available in our local markets in Nigeria namely zip, aerial, omo multi-active, sunlight, active, klin, elephant and bonus plus respectively are were determined using the capillary rise method. The results show that zip has the highest cleansing effect and bonus plus has the least. Also in ascending order the detergents active, sunlight, zip, elephant, bonus plus, omo multi-active, klin and aerial produce unit decrease in surface tension of water at the cost of 130.6, 132.2, 150.1, 157.3, 204.1, 213.9, 267.6 and 283.7 naira respectively. This implies that active detergent is the most cost effective and aerial the least. Overall results show that the cleansing effect of a detergent is not a measure of its cost effectiveness but the cost of decreasing the surface tension of water by the detergent in question.

Keywords: Surface tension, detergents, cleansing effect, capillary rise, cost effective

Introduction

Cleaning products play an essential role in our daily lives. By safely and effectively removing soils, germs and other contaminants, they help us to stay healthy, care for our homes and possessions, and make our surroundings more pleasant. The common household or laundry cleaning products are soaps and detergents. We recognize that public understanding of the safety and benefits of cleaning products is critical to their proper use. To help foster this understanding, we have explained what detergents are, how they work in the washing process and the procedure to evaluate their cleansing effect and cost effectiveness. This research is intended to be a valuable information resource about household cleaning detergents for consumers, educators, students, media, government officials, businesses and others.

What is detergent?

A detergent is a material used for cleaning. Detergents, especially those made for use with water, often include different compounds such as surfactants to emulsify grease and to wet surfaces. A surfactant or surface active agent is a substance that, when dissolved in water, gives a product the ability to remove dirt from surfaces such as the human skin, textiles, and other solids. The surfactant lowers the surface tension of the medium in which it is dissolved. By lowering this interfacial tension between two media or interfaces e.g. oil/water, water/stain, the surfactant plays a key role in the removal and suspension of dirt. The lower surface tension of the water makes it easier lift dirt and grease off of dirty clothes, dishes and other surfaces, help to keep them suspended in the dirty water. The water-loving or hydrophilic head remains in the water and it pulls the stains towards the water, away from the fabric. The surfactant molecules surround the stain particles, break them up and force them away from the surface of the fabric. They then suspend the stain particles in the wash water to remove them (Emmanuel, 2009).

To understand what is needed to achieve effective cleaning and low cost, it's helpful to have a basic knowledge of the theory of surface tension and suitable laboratory method of measuring surface tension. The cost of detergent is also important.

The theory of surface tension

Surface tension is the fundamental property of a liquid, which makes the free surface of the liquid behaves like a stretched membrane. It is also an inherent property of a liquid to alter its shape in such a way that the area of its free surface is minimum possible. According to the molecular theory, this arises, because the molecules in the bulk of the liquid experience zero resultant force due to their nearest neighboring molecules while the molecules in the surface of the liquid experience finite resultant force acting inwardly the bulk of the liquid due to excess neighboring molecules below them. Because of the inherent tendency of a liquid to contract, it behaves as if there exists in its surface a tension which acts equally in all directions. This surface tension of a liquid is defined as the force per unit length acting on either side of an imaginary line drawn in the surface in equilibrium. The direction of the force is tangential to the surface and perpendicular to the line.

Whenever a liquid is placed in contact with a solid, the liquid surface is in general curved. When a liquid gets in contact with a solid, there exists a boundary in which there is the surface tension in solid-liquid interface. The angle between the solid surface and the tangent to the liquid surface drawn from the point where the liquid surface meets with the solid surface measured through the liquid is called the angle of contact. Liquid whose angle of contact is acute or less than 90^o rises in the capillary tube while liquid having angle of contact obtuse or greater than 90^o falls or depresses in the capillary tube. In other words, liquids with concave meniscus rise in the capillary tube and those having convex meniscus fall in the capillary tube. Examples of liquids with angle of contact acute and meniscus concave include water, alcohol, ether, glycerin and so on. In practice, angle of contact for such liquids is small, nearly zero, when they are in contact with glass. Example of liquids with obtuse angle of contact and convex meniscus is mercury. It is crystal clear that the angle of contact also explains the shape of the liquid meniscus near a solid surface.

In other words, surface tension can be explained in terms of cohesion and adhesion. Cohesion is the force of attraction existing between similar or like molecules of liquids while adhesion is the force of attraction between dissimilar or unlike molecules. Typical example of a situation where cohesion is greater than adhesion is cohesion existing between mercury molecules causing mercury to depress in glass. In another vein, adhesion between glass and water molecules is greater than cohesion between water molecules causing water to rise in glass.

So far it has been established that liquids having acute angle of contact and concave meniscus have adhesion greater than cohesion and hence they rise in a capillary tube. Conversely, liquids with obtuse angle of contact and convex meniscus have cohesion greater than adhesion and they fall in capillary tube. Therefore the rise or fall of liquids in capillary tube due to surface tension depends on contact angle, liquid meniscus and adhesion or cohesion.

It is popularly known that the factors affecting surface tension of a liquid include temperature, nature of the liquid itself, impurities or contaminations (like detergents or grease) and so on. For example, detergents (Fried, 2003; Hannah, 2002) and temperature (Rakshift, 1997) decrease surface tension of water. Consequently, the knowledge of surface tension has found useful applications in everyday life which include quality control in industries, upward movement of kerosene in wicks of lamp for lighting and stoves for cooking, enhances cleansing ρ acting at contact angle, θ the upward force F_1 is

$$F_{\downarrow}1 = 2\pi r(\cos\theta \qquad (1)$$

If the liquid rises to a height, h in the tube above the level of the liquid outside, the downward force F_2 is given by

$$F_1 2 = \pi r^2 2\, hg(\qquad 2$$

where ρ is the density of the liquid and g is the gravitational acceleration. At equilibrium the two forces are equal, $F_1 = F_2$. Thus,

$$(= rhg\rho/(2\cos\theta) \qquad 3$$

But in practice, for most liquids, cosθ = 1. Thus, equation (3) reduces to

$$(= rhg\rho/2 \qquad 4$$

Since the surface of the liquid is not perfectly flat it curves up or down at the wall to form a meniscus. The material in this region also contributes to the force of gravity, so one often finds a correction to equation (4) to yield (Sharma and Sharma, 1999; Rakshift, 1997)

$$(= (rg\rho(h + r/3))/2 \qquad 5$$

In this work, γ is calculated from equation (5) using the value of g = 9.78 m/s computed from equation (6)(Emmanuel, 2009).

$$g = 980.616 - 2.5928\cos(2\phi) + 0.0069\cos^2 2\phi - 3.086 \times 10^{-6} H \qquad 6$$

where ϕ = latitude (9.23°) and H(cm) = altitude above sea level (18600 cm) respectively of the location of Yola (Adebayo, 2001), the place where the experiment was carried out.

Methodology

The detergents used in this work were bought in sachets or packets from Jimeta modern market Yola, Adamawa State, Nigeria. The average weight of each detergent was measured using a sensitive balance and the cost price of each detergent per sachet or packet was recorded. The cost of each detergent in naira per unit weight in Newton (N) was calculated using g = 9.78 m/s.

Eight solutions of equal concentration of the various detergents were prepared by dissolving twenty grammes (20 g) of each detergent in 500 cm^3 of clean tap water. The solutions were stirred very well under the same conditions.

The masses of the solutions were measured using sensitive balance and the densities of the solutions were calculated using the relation density, ρ = mass(m)/volume(V).

A given volume of clean tap water was poured into a beaker and placed on a flat adjustable table directly under a capillary tube of radius, 4.8×10^{-4} m suspended vertically by means of retort stand and clamp. The adjustable table was gently adjusted in a way that the beaker of water on it moved upward until the level of water in the beaker coincided exactly with a mark made on the length of the capillary tube. At this juncture, the height of water, h in the capillary tube due to surface tension was measured using a travelling microscope. The temperature of the water in the beaker was noted at the beginning and end of the experiment and the average recorded.

The same procedure for measuring the rise, h of water in the capillary tube was repeated for each of the solutions of the various detergents except the capillary tube is rinsed by dipping it in water several times and alcohol and allowed to dry before carrying out the next experiment. The position of the capillary tube and its length below the surface of detergents remained constant throughout the experiment. The diameter, d of the capillary tube was measured using a travelling microscope and hence its radius calculated from r = d/2.

From the values measured or calculated, the surface tension $(= \rho gr/2\,(h + r/3)$ for water and each solution of the detergents was computed, using g = 9.78 m/s calculated from equation (6).

Results and Discussion

Table 1 Parameters of water and solutions of detergents at temperature, T = 32.2 °C

Detergent	$M_{s/p}$ (g)	$C_{s/p}$(N)	C_{20g}(N)	$\gamma \times 10^{-2}$ (N/m)	$\Delta\gamma$(N/m)	$C_{20g}/\Delta\gamma$	n
Water	-	-	-	6.02	0.00	-	-
Sunlight (A)	33.13	10	6.04	1.45	4.57	132.2	2
Omo-mult (B)	30.42	15	9.86	1.41	4.61	213.9	6
Klin (C)	25.96	15	11.56	1.70	4.32	267.6	7
Zip (D)	27.83	10	7.19	1.23	4.79	150.1	3
Bonus plus (E)	24.95	10	8.02	2.09	3.93	204.1	5
Elephant (F)	246.43	80	6.48	1.90	4.12	157.3	4
Aerial (G)	22.69	15	13.22	1.36	4.66	283.7	8
Active (H)	173.54	50	5.76	1.61	4.41	130.6	1

In Table 1, $M_{s/p}$ = mass of sachet or packet of detergent, $C_{s/p}$ = cost of sachet or packet of detergent, C_{20g} = cost of 20 g of detergent, γ = surface tension of aqueous solution of detergent, $\Delta\gamma$ = decrease in surface tension of water due to detergent, $C_{20g}/\Delta\gamma$ = cost of unit decrease in surface tension of water and n = order of cost effectiveness of detergent (the smallest n represents the most cost effective detergent and vice versa).

The cost price of 20 g of each detergent $C_{20g} = C_{s/p}/ M_{S/P} \times 20$ g and the decrease in surface tension of water = surface tension of pure water minus surface tension of aqueous solution of detergent. The amount of money required to produce aqueous solution of each detergent of concentration 2.5 ml per gramme (by dissolving 20 g of detergent in 50 ml of water) to reduce the surface tension of water by one Newton per meter (1 N/m) is given by $C_{20g}/\Delta\gamma$ (Table 1). This means that for equal concentration, the detergent that requires the smallest amount of naira to reduce the surface tension of water by 1 N/m is the most cost effective, i.e. the detergent that has the largest decrease in surface tension of water has the best cleansing effect. On the other hand, for equal concentrations, the detergent whose aqueous solution produces the least amount of naira to cause a unit decrease in the surface tension of water is the most cost effective.

Arranging the detergents with indices, n in ascending order of cost per unit decrease in surface tension of water we have: active (1), sunlight (2), zip (3), elephant (4), bonus plus (5), omo-multiactive (6), klin (7) and aerial (8). This means that the smaller the index n, the more the detergent is cost effective. With this, active detergent is the most cost effective and aerial the least.

Conclusion

In this study, we have used the simple Physics principle of surface tension to investigate for the first time the cleansing effect and economic importance of some common commercial detergents available in Nigerian markets. The surface tensions of aqueous solutions (2.5 ml/g) of commercial detergents namely zip, aerial, omo-multiactive, sunlight, active, klin, elephant and bonus plus were determined using capillary rise method. The results show that zip has the highest cleansing effect and bonus plus least. On the other hand, active is the most cost effective and aerial least. This shows that cleansing effect is independent of cost effectiveness of a detergent. Obviously, it is crystal clear that since the method is simple and cheap, bringing it to wider audience of consumers would not only improve tremendously their economy but their everyday life. To achieve this, we recommend the design, construction and implementation of a simple and sensitive tensionmeter comprising a capillary tube for measuring surface tension of aqueous solutions of detergents which can be used in washing industries in developing countries like Nigeria.

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