How Does Water Hardness Affect Soap's Dissolving Ability?

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Period 3

Problem

Have you ever noticed that sometimes you have to use more soap in order to make foam to clean?

Abstract

Soaps are used daily for various purposes of our daily lives. People need to wash their hands on a daily basis, and sometimes more soap is needed in order to make foam to clean. The purpose of this project is to test different water hardness and how they relate to soap's ability to dissolve. The lathering of the soap (dependent variable) is tested on these types of waters (independent variable): tap water, water treated with a water softener, and water obtained through reverse osmosis systems. The hypothesis was that if the water hardness is low, then less soap would be needed to lather. Since a very small amount of soap was used (1 drop), soap dissolving ability was tested by analyzing foamability and stability. Results showed that less hard water such as soft water, foams better when compared to hard water by producing thicker foam on the lather test (soft water average foam thickness 23.9 mm vs hard water foam thickness 17.8 mm vs reverse osmosis water 18.3 mm). Conversely, foam stability was the lowest with reverse osmosis water as evidenced by faster decline/flattening of the foam (20.7 % decrease) vs soft water (15.4%) and hard water (11.7 %). The hypothesis was partially supported. Additional studies are recommended to clarify contradictory results regarding water hardness and soap dissolving ability.

Project Overview

The purpose of this project is to test different water hardnesses and how they relate to soap's ability to dissolve. Water examples will include tap water, water treated with a water softener, and water obtained through reverse osmosis systems. The soaps utilized will be hand soap, dish soap, and laundry soap. The principle will test the soap’s dissolving ability using the lather test. Data collected will be subject to statistical analysis.

Research

“The simple definition of water hardness is the amount of dissolved calcium and magnesium in the water” (U.S. Geological Survey, n.d.-a). Water is soft if its concentration of calcium and magnesium ions is low (U.S. Geological Survey, n.d.-b). In contrast, water is hard if its concentration of calcium and magnesium ions is high (U.S. Geological Survey, n.d.-b). Water hardness is measured in mg/L (milligrams per liter). “General guidelines for classifications of waters are: 0 to 60 mg/L (milligrams per liter) as calcium carbonate is classified as soft; 61 to 120 mg/L is classified as moderately hard; 121 to 180 mg/L as hard; and more than 180 mg/L as very hard” (U.S. Geological Survey, n.d.-b).

According to HomeWater 101 (n.d.), the United States of America has roughly 85% of hard water. The cities with the hardest water include Indianapolis, Las Vegas, Minneapolis, Phoenix, San Antonio, and Tampa (HomeWater 101, n.d.). LeafHome states that the top five states with the hardest water include Utah, Wyoming, Colorado, Texas, and New Mexico (Homewater 101, n.d.). The top five states with the softest water consist of Hawaii, Maine, New Hampshire, Vermont, and Washington (LeafHome, n.d.)

The minerals in hard water often react with most soaps to create a “soap scum,” which is an insoluble substance that can temporarily adhere to your hands or the shower walls (U.S. Geological Survey, n.d.-b). Hard water makes it more difficult for soap to lather, and more water is often needed to rinse off the scum from your hands. On the other hand, using soft water with soap makes it lather more easily, requiring less soap, but also making hands feel slippery.

In a study conducted by the Centre of Industrial Rheology, the foaming ability of different laundry detergent brands were compared. Foamability is affected by water hardness and foam stability. Measuring this can provide valuable insights on product behavior. According to the study, there was hard water and soft water used. The soft water was deionized water and the hard water was local tap water.

Formability is the tendency for a substance to create foam (Centre for Industrial Rheology, n.d.-a). Foam stability is the ability for foam to be durable (Centre for Industrial Rheology, n.d.-b). Foamability and foam stability are well-known to be affected by the hardness of the water in which they are generated. Calcium and magnesium ions in hard water may prevent detergents from foaming, or can make the foam less stable. Although softeners in the detergent can mitigate against this to some degree, the water will still likely have an impact upon the foaming characteristics.

Hypothesis

If the water hardness is low, then less soap will be needed to lather.

Variables

Independent: The type of water

Dependent: The lathering of the soap

Controlled: the type of soap, amount of soap, amount of water, temperature

Materials

Soap: laundry, hand, dish
Water: tap, softened, reverse osmosis, distilled
Flasks
Pipette
Notebook
Camera

Procedures

1. Prepare a soapy solution by mixing soap and water for each type of soap
2. Fill the flasks with 10 mL of each type of water
3. Add 5 drops of soap solution to each flask
4. Seal the flasks and shake vigorously for 30 seconds
5. Observe the amount of bubbles and appearance of the mix
6. Document the results
7. Analyze data

Data/Observations

Table(s)

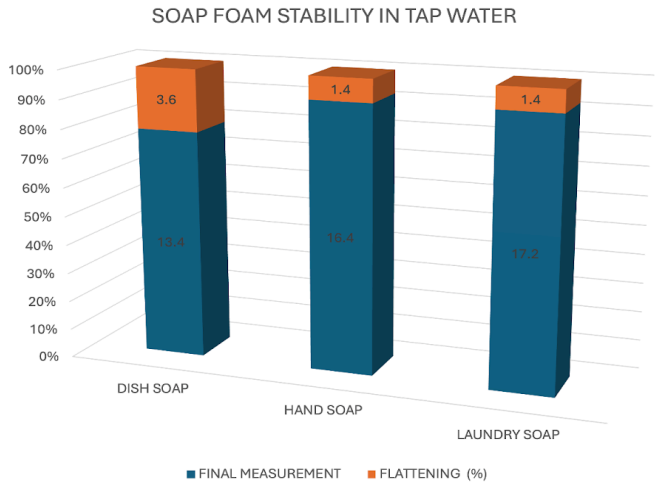
DISH SOAP TRIALS	TAP WATER		SOFT WATER		R/O WATER	
LATHER TEST	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL
1	19 mm	14 mm	22 mm	18 mm	20 mm	15 mm
2	18 mm	15 mm	23 mm	17 mm	21 mm	17 mm
3	17 mm	13 mm	60 mm	51 mm	19 mm	14 mm
4	15 mm	12 mm	21 mm	17 mm	18 mm	15 mm
5	16 mm	13 mm	20 mm	14 mm	16 mm	13 mm
AVERAGE	17 mm	13.4 mm	29.2 mm	23.4 mm	18.8 mm	14.8 mm

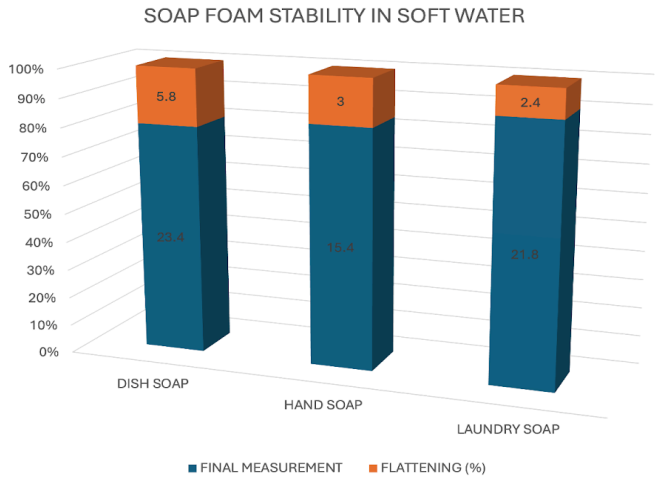
HAND SOAP TRIALS	TAP WATER		SOFT WATER		R/O WATER	
LATHER TEST	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL
1	18 mm	16 mm	20 mm	18 mm	14 mm	12 mm
2	20 mm	19 mm	19 mm	16 mm	20 mm	15 mm
3	15 mm	13 mm	20 mm	16 mm	19 mm	14 mm
4	17 mm	16 mm	16 mm	12 mm	13 mm	12 mm
5	19 mm	18 mm	17 mm	15 mm	18 mm	12 mm
AVERAGE	17.8 mm	16.4 mm	18.4 mm	15.4 mm	16.8 mm	13 mm

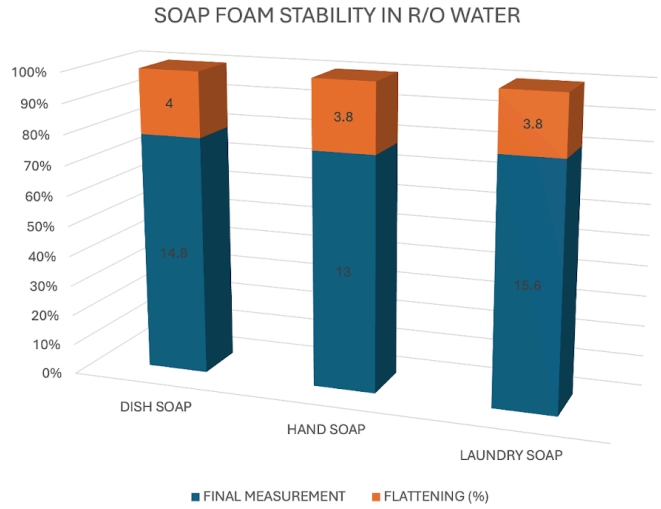
LAUNDRY SOAP TRIALS	TAP WATER		SOFT WATER		R/O WATER	
LATHER TEST	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL
1	20 mm	18 mm	22 mm	19 mm	20 mm	16 mm
2	19 mm	18 mm	21 mm	19 mm	20 mm	16 mm
3	20 mm	19 mm	25 mm	24 mm	18 mm	16 mm
4	18 mm	17 mm	25 mm	24 mm	23 mm	17 mm
5	16 mm	14 mm	28 mm	23 mm	16 mm	13 mm
AVERAGE	18.6 mm	17.2 mm	24.2 mm	21.8 mm	19.4 mm	15.6 mm

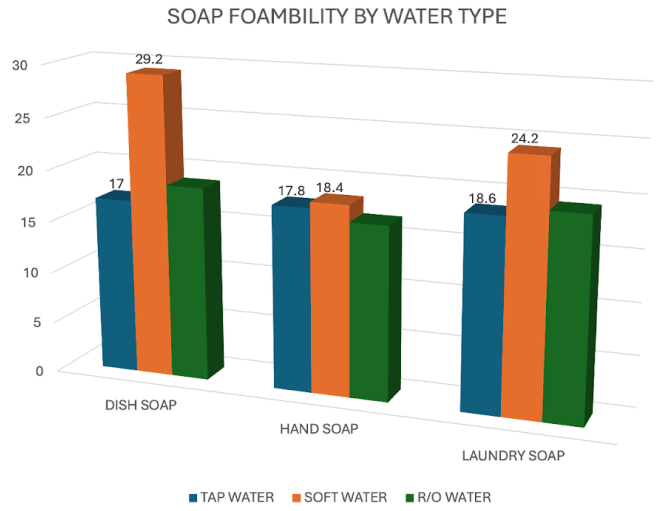
LATHER TEST BY SOAP TYPE (AVERAGE)	TAP WATER				SOFT WATER				R/O WATER			
	INITIAL	FINAL	DIFFERENCE	%	INITIAL	FINAL	DIFFERENCE	%	INITIAL	FINAL	DIFFERENCE	%
DISH SOAP	17 mm	13.4 mm	3.6 mm	21.1	29.2 mm	23.4 mm	5.8 mm	19.8	18.8 mm	14.8 mm	4 mm	21.2
HAND SOAP	17.8 mm	16.4 mm	1.4 mm	7.8	18.4 mm	15.4 mm	3 mm	16.3	16.8 mm	13 mm	3.8 mm	22.6
LAUNDRY SOAP	18.6 mm	17.2 mm	1.4 mm	7.5	24.2 mm	21.8 mm	2.4 mm	9.9	19.4 mm	15.6 mm	3.8 mm	19.5
TOTAL AVERAGE	17.8 mm	15.6 mm	2.1 mm	11.7	23.9 mm	20.2 mm	3.7 mm	15.4	18.3 mm	14.4 mm	3.8 mm	20.7

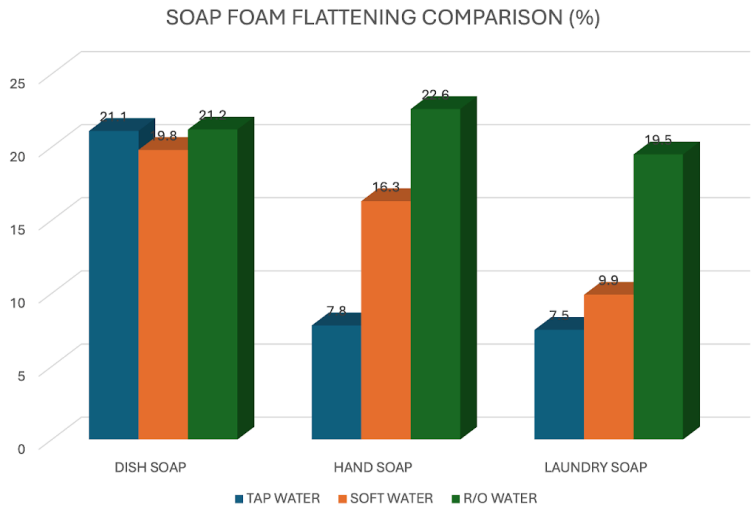
Graph(s)


SOAP FOAM STABILITY IN TAP WATER
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
3.6
1.4
1.4
13.4
16.4
17.2
DISH SOAP
HAND SOAP
LAUNDRY SOAP
FINAL MEASUREMENT
FLATTENING (%)


SOAP FOAM STABILITY IN SOFT WATER
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
5.8
3
2.4
23.4
15.4
21.8
DISH SOAP
HAND SOAP
LAUNDRY SOAP
FINAL MEASUREMENT
FLATTENING (%)


SOAP FOAM STABILITY IN R/O WATER
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
4
3.8
3.8
14.8
13
15.6
DISH SOAP
HAND SOAP
LAUNDRY SOAP
FINAL MEASUREMENT
FLATTENING (%)


SOAP FOAMBILITY BY WATER TYPE
30
25
20
15
10
5
0
29.2
17
17.8
18.4
18.6
24.2
DISH SOAP
HAND SOAP
LAUNDRY SOAP
TAP WATER
SOFT WATER
R/O WATER



Results

Soft water made the most foam regardless of the type of soap used as evidenced on average initial foam thickness of 23.9 mm on the lather test versus 17.8 mm and 18.3 mm on the hard water and reverse osmosis groups, respectively. Foam stability was noted to be the lowest with the reverse osmosis water group regardless of the type of soap used as evidenced by a faster decline in foam thickness of 20.7 % when compared to hard water and soft water groups of 11.7% and 15.4%, respectively.

Soft water higher foamability is likely due to decreased concentration of calcium and magnesium that are known to interfere with surfactants as opposed to hard water. However, the low foam stability noted in the reverse osmosis group contradicts the expected outcome as with a more pure water, foam solubility (foamability and stability) is expected to improve, which in this case suggests the presence or absence of specifics additives or contaminants that affected the expected outcome.

Since all groups were able to lather with the same amount of soap (1 drop), it was not possible to establish a relationship between ability to lather and soap concentration, however, foamability and foam stability were used instead to prove soap dissolving ability principle.

Conclusion

This study shows a higher foamability with soft water, which supports a better dissolving ability as water hardness improves. Nevertheless, foam stability was the lowest with the least hard water (reverse osmosis), which was unexpected. The hypothesis was partially supported given contradictory results, suggesting that presence or absence of an unaccounted substance may have played a major role in the results noted.

Recommendations

Based on the results obtained, procuring a different source of reverse osmosis water and possibly analyzing the effects of other surfactants on soup dissolving ability may provide additional information regarding this fascinating topic and its applicability.

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