University of San Carlos
Department of Chemical Engineering
Talamban, Cebu City, Philippines 6000

Laboratory Report

Laboratory Course	:	CHE3110L
Experiment Title	:	Laundry Detergent Production
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Assessed and Graded By: Dr. Camila Flor Y. Lobarbio

(Signature over printed name)

Date and Time ____

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CHE 3110L
Laboratory Simulation of Industrial Product Manufacture

Production of Laundry Detergent

A laboratory report submitted to

Dr. Camilla Flor Y. Lobarbio
CHE 3110L Instructor

by

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December 12, 2020

1. Introduction

Ever since 2800 BC, soap has been present and used to clean one's self in a bath (American Cleaning Institute, 2020). It wasn't until 7th century AD that it was an established art in Italy, Spain and France due to an abundance of ingredients, such as plant oils. Up until 1791, soap-making was quite taxing, and thus soap was regarded as a luxury, until Frenchman Nicholas Leblanc patented a soda ash production process derived from common salt, which combined with fat, can be cheaply made into soap. By the 20th century, shortages of fats and oils attributed to both World Wars led to the synthesis of other raw ingredients, which are considered as "detergents".

According to Wansbrough (n.d.), while soaps tend to be produced via certain proprietary methods, they all follow the same four basic steps:

1. Saponification – where a mixture of animal fat (tallow) and coconut oil is mixed with sodium hydroxide and heated, where the produced soap is a salt of a long chain carboxylic acid.
2. Glycerine removal – A byproduct of previous processes, it is removed with the addition of salt so as to separate it from the water-insoluble soap, though a small portion of it is retained in the soap for a soft and smooth finish.
3. Soap purification – Generally involves removes anything that is not the soap itself, such as the sodium hydroxide (removed via weak acid neutralization) and roughly 66% of the remaining water content.
4. Finishing – Entails adding preservatives, color, and odorants, and shaping for commercial distribution.

Detergents likewise follow the same general procedure, albeit with synthetic surfactants-the main ingredient that lifts dirt off of surfaces-instead of the metal fatty acid salts used in soaps, and come in various configurations, such as in a powder and liquid, and is commercially available as laundry powders or liquids, hard surface cleaners, dish washing liquids and the like, though the focus of this experiment is the laundry detergent.

According to Davidsohn (2020), in order for soaps and detergents to fulfill their function, their molecules must contain both a hydrophobic and a hydrophilic component.

The hydrophilic portion of the surfactant provides water solubility, allowing detergent to operate in a watery environment laundry calls for. Anatrace (n.d.) categorizes hydrophilic groups according to ionic activity, either as ionic, nonionic, or zwitterionic. The grease-loving hydrophobic tail is responsible for attaching itself to solids in the water or attached to the fiber.

The term “surfactant” is a combination of the words “surface-active-agent” (Rosen MJ, 2012). Surfactants are compounds that spontaneously bond with each surfactant molecule, thus producing a sealed bubble. In the case of detergents, surfactants lower the surface tension between two liquids or between a liquid and a solid. Surfactants are substances that also assemble independently to form molecular clusters called micelles in a solution, in this case water. They are amphiphilic molecules that are easily absorbed in the air-water interface.

LABSA or acid slurry, also known as Linear alkyl benzene sulphonic acid, is a synthetic surfactant formed via sulfonation of sulfuric acid, chlorosulfonic acid, sulfamic acid and diluted sulfurtrioxide. An anionic surfactant, LABSA can attack a broad range of soils, although they are unable to emulsify oily soils (Shapiro, 2018). Thus, it is added with soda ash, as its role as a builder enables it to emulsify oil stains, reduce dirt deposits, provide alkalinity, and to soften laundry water, allowing detergent to perform in most water conditions (Tata Chemicals Limited, n.d.). The reaction of the soda ash and acid slurry is considered as a displacement reaction wherein the hydrogen ion of the acid slurry is replaced by the sodium ion of the soda ash, which releases energy from the displacement action which is manifested as heat (*Replacement Reaction,* 2019)

LABSA has free acids which is converted to LAS salt on reaction with soda ash via neutralization with carbon dioxide and water as byproducts (Shina Dynamic Technology, Co., n.d.).

SLES is another surfactant produced industrially from palm kernel oil or coconut oil via ethoxylation of dodecyl alcohol where the resulting product, or ethoxylate is neutralized and converted to its salt form. It is used in soap-making to remove the primary surfactant from clothes; thus, it is anionic and tends to have excellent emulsifying properties. It is highly favorable to use thanks to its hard-water resistance and high-biodegradation.

Trisodium phosphate is a highly soluble, inorganic compound commonly sold in white, dry powder form and is typically used as a heavy-duty cleaning agent. According to Tucker (2011), TSP is a good rinsing agent as it rinses away soils and excess detergent from clothes without the damaging effects of bleach.

STPP is another builder used in powder soap production. It helps increase alkalinity and breaking soils from fabric, whilst not having the vulnerability of forming precipitates with mineral ions and instead forms "complexes" with them that are more readily washed away (JP Chemicals, n.d.)

According to SidleyChem (n.d.), CMC plays an active role as a soil suspending agent, preventing dirt reattachment during the washing process. The working principle is that charged sodium carboxymethyl cellulose is absorbed by the fabric, and with the negatively charged dirt granule, has a mutual electrostatic repulsion which, in turn, prevents it from reattaching to the clothes, and makes the dirt be readily absorbed by surfactants (Zhang, 2019).

Sodium Sulfate is a cheap pH-neutral substance used as filler in powder soap. It readily dissolves in water which simply passes through the system making the product less costly to produce per unit weight (Clegg, 2015). It also serves to adjust the concentration of the active surfactants in the soap and prevents clumping together forming a block rather than powder (The filler of detergent powder - Sodium sulphate/sodium sulfate, n.d.).

Color granules are materials added to detergent products with the sole purpose of enhancing the visual factor of the product in order to attract customers. It changes the appearance of the supposedly plain-white powder and makes it colorful. However, only a small amount of color granules, about 3% of the entire mass of detergent, is added so as to not affect product effectiveness.

Fragrances are added to detergents to not only increase the marketability of the product, but to also impart a pleasant scent onto washed clothing even after drying. Typically, oil-based fragrances or essential oils are added to the product for a longer lasting scent.

The maximum detergent action is attained at a pH of 10.7. At this pH, the detergent is in its optimum alkalinity which increases its detergent power which also depends on the nature of the present anions. (F.H. Rhodes, 1931). In addition, the expected pH of the soap is to be around the mild alkaline range which is between 9-10 (Jose Tarun, 2014)

As of present, only two methods of dry powder laundry detergent are in use by industries, namely the blender process and the agglomeration process. The blender process, as the name implies, blends the detergent's ingredients, until well-mixed via a tumbling blender or a ribbon blender. On the other hand, the agglomeration process agglomerates the dry ingredients to a fine consistency, whereupon the liquid ingredients are sprayed on via nozzles, producing a hot, viscous liquid. The liquid is then subjected to heating and drying, then undergoes pulverization and screening to produce granulated dry detergent.

2. Objectives of the Experiment

1. Prepare a process flowsheet for the manufacture of laundry detergent, complete with details in process conditions and stream specification;
2. Monitor overall and component mass and energy flows during the lab-scale implementation of the product manufacture;
3. Calculate component yields in every process step and for the entire process; and
4. Identify critical steps in the process based on laboratory data and the entire experience of generating the product.

3. Methodology

3.1. Methodological Framework

To meet the objectives, necessary steps were taken in the preparation of materials, execution of the procedures, data collection and processing, and analysis of the observations to ensure that these objectives are met.

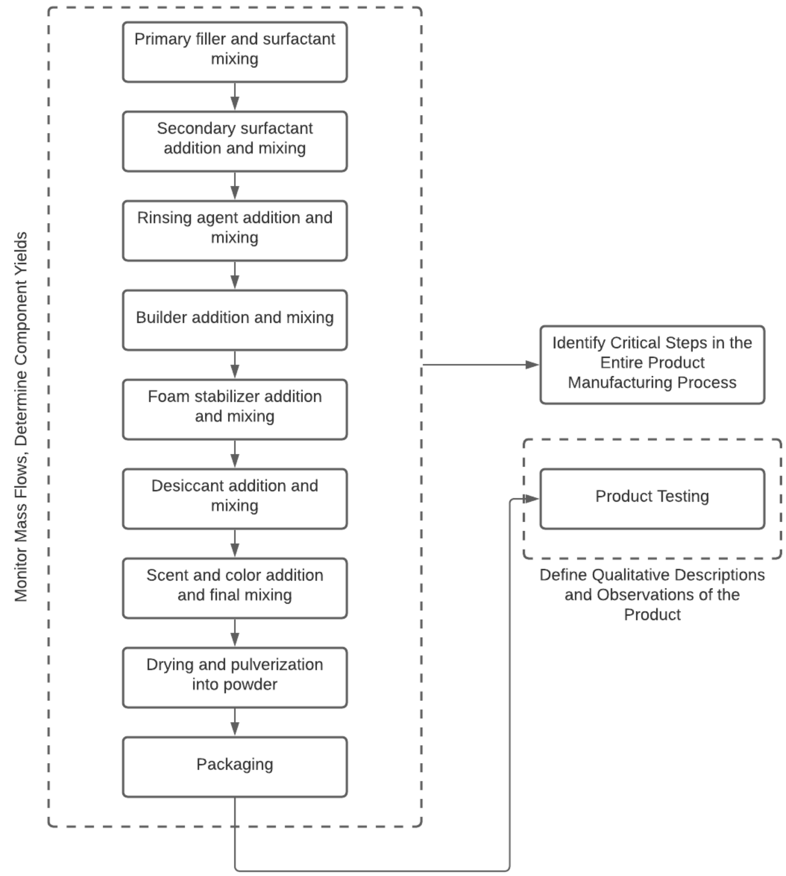
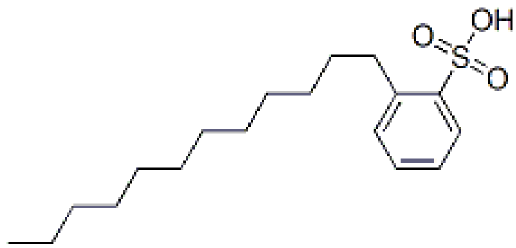


Figure 1. *Methodological Framework for the Production of Laundry Detergent*

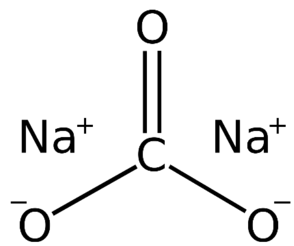
The framework presented in Figure 1 shows the flow of laundry detergent production, which shows the major steps needed to make the product. It is noted that the mass flows per each process are to be carefully monitored. Mass changes were monitored through weighing of the system per process.

3.2. Materials

LABSA or acid slurry, also known as Linear alkyl benzene sulphonic acid, is a synthetic surfactant formed via sulfonation of sulfuric acid, chlorosulfonic acid, sulfamic acid and diluted sulfurtrioxide. An anionic surfactant, LABSA can attack a broad range of soils, although they are unable to emulsify oily soils (Shapiro, 2018). Thus, it is added with soda ash, as its role as a builder enables it to emulsify oil stains, reduce dirt deposits, provide alkalinity, and to soften laundry water, allowing detergent to perform in most water conditions (Tata Chemicals Limited, n.d.). The reaction of the soda ash and acid slurry is considered as a displacement reaction wherein the hydrogen ion of the acid slurry is replaced by the sodium ion of the soda ash, which releases energy from the displacement action which is manifested as heat (*Replacement Reaction,* 2019).



*(**Figure 2.** Chemical Structure of Linear Alkyl Benzene Sulfonic Acid (LABSA*



*(**Figure 3.** Chemical Structure of Sodium Carbonate (*Na_2CO_3

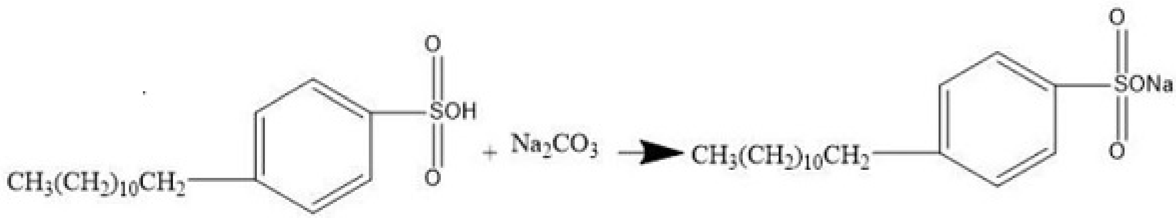


Figure 4. *Reaction of LABSA and Na_2CO_3*

LABSA has free acids which is converted to LAS salt on reaction with soda ash via neutralization with carbon dioxide and water as byproducts (Shina Dynamic Technology, Co., n.d.).

Figure 5. *Chemical Structure of Sodium Laureth Sulfate*

SLES is another surfactant produced industrially from palm kernel oil or coconut oil via ethoxylation of dodecyl alcohol where the resulting product, or ethoxylate is neutralized and converted to its salt form. It is used in soap-making to remove the primary surfactant from clothes; thus, it is anionic and tends to have excellent emulsifying properties. It is highly favorable to use thanks to its hard-water resistance and high-biodegradation.

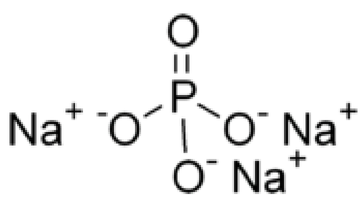


Figure 6. *Chemical Structure of Trisodium Phosphate (TSP)*

Trisodium phosphate is a highly soluble, inorganic compound commonly sold in white, dry powder form and is typically used as a heavy-duty cleaning agent. According to Tucker (2011), TSP is a good rinsing agent as it rinses away soils and excess detergent from clothes without the damaging effects of bleach.

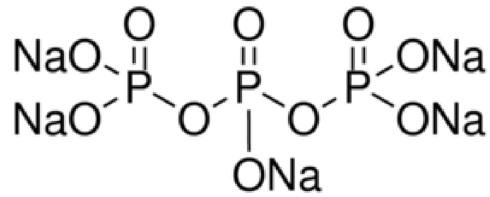


Figure 7. *Chemical Structure of Sodium Tripolyphosphate (STPP)*

STPP is another builder used in powder soap production. It helps increase alkalinity and breaking soils from fabric, whilst not having the vulnerability of forming precipitates with mineral ions and instead forms "complexes" with them that are more readily washed away (JP Chemicals, n.d.)

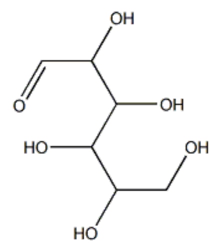


Figure 8. *Chemical Structure of Carboxymethyl Cellulose (CMC)*

According to SidleyChem (n.d.), CMC plays an active role as a soil suspending agent, preventing dirt reattachment during the washing process. The working principle is that charged sodium carboxymethyl cellulose is absorbed by the fabric, and with the negatively charged dirt granule, has a mutual electrostatic repulsion which, in turn, prevents it from reattaching to the clothes, and makes the dirt be readily absorbed by surfactants (Zhang, 2019).

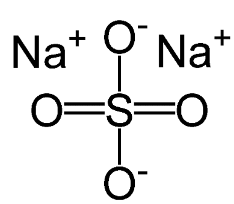


Figure 9. *Chemical Structure of Sodium Sulfate*

Sodium Sulfate is a cheap pH-neutral substance used as filler in powder soap. It readily dissolves in water which simply passes through the system making the product less costly to produce per unit weight (Clegg, 2015). It also serves to adjust the concentration of the active surfactants in the soap and prevents clumping together forming a block rather than powder (The filler of detergent powder - Sodium sulphate/sodium sulfate, n.d.).

Figure 10. *Color granules*

Color granules are materials added to detergent products with the sole purpose of enhancing the visual factor of the product in order to attract customers. It changes the appearance of the supposedly plain-white powder and makes it colorful. However, only a small amount of color granules, about 3% of the entire mass of detergent, is added so as to not affect product effectiveness. The color of the granules used here is blue.

Figure 11. *Lavender scent fragrance additive*

Fragrances are added to detergents to not only increase the marketability of the product, but to also impart a pleasant scent onto washed clothing even after drying. Typically, oil-based fragrances or essential oils are added to the product for a longer lasting scent. The specific ffragrance used in the procedure is lavender.

3.3. Equipment

In the actual conduct of the process, the key equipment are the following: Digital Weighing Scale, and pH papers. These equipment were purchased from the supplier.

Figure 12. *Digital Weighing Scale*
(Image Obtained From: https://shopee.com.my/)

The figure above shows a digital weighing scale. The digital weighing scale has a calibration bubble on its lower left. This bubble should be at the center to ensure accuracy and precision in weighing. This scale provides measurements in kilograms up to three decimal places.

Figure 13. *pH Paper with Color Indicators*
(Image Obtained From: https://www.aliexpress.com/item/4000523185088.html)

The pH paper used in the production process has different colors to indicate the pH of the said solution. It was used to determine the pH value of the final product. Other equipment used in the production of laundry detergent were a plastic basin, wooden ladle, and beakers. These equipment were used to contain the various additives as they are weighed, contain the mixture, and to stir it until it is homogeneous. These materials are readily available.

3.4. Procedures

Prior to the conduct of the manufacturing process, the process flow sheet below was prepared. This serves as a guide throughout the process since it depicts the parts where the temperature and pH should be measured.

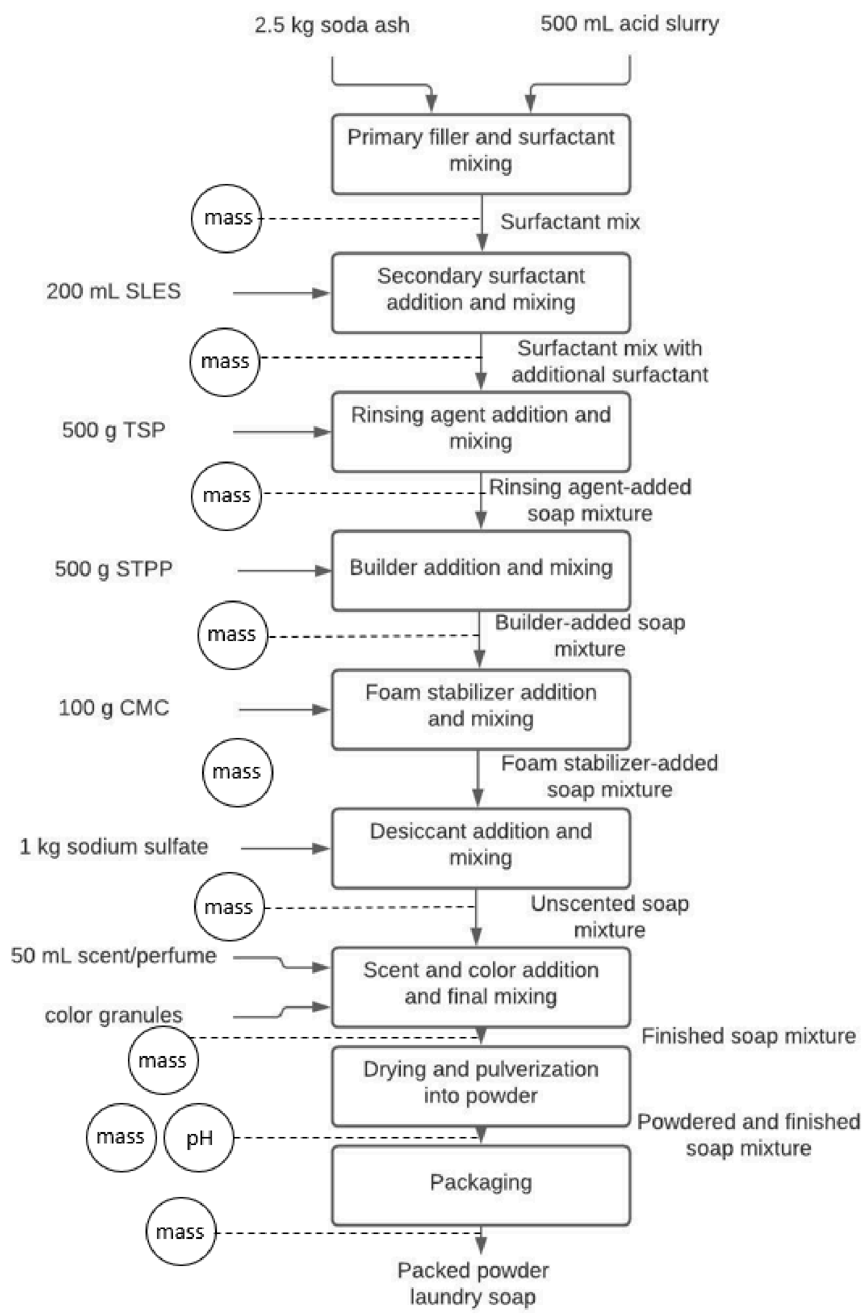


Figure 14. *Process Flow Sheet of the Production of Laundry Detergent*

All the materials and equipment were prepared before the conduct of the experiment. The equipment was washed with distilled water and was sterilized afterwards to prevent unfavorable reactions and an adverse change in quality for the product. 2.5 kilos of soda ash were placed onto the basin, where it was mixed thoroughly with 500 mL of LABSA. The planned process of obtaining 15 grams of mixture sample at each step-save for the last step-was abandoned due to a lack of distilled water, which was recommended for pH tests. The system was then weighed.

After the initial mixture, a secondary surfactant of 200 mL SLES was added and thoroughly mixed, and then weighed. All other additives that were added subsequently followed the same processes.

In calculating the component yield for the entire process, the following were done:

For the entire process yield,

$$Percent\ Yield,\ \% = \frac{Total\ mass\ of\ Packaged\ Final\ Product\ \ Detergent, kg}{Total\ mass\ of\ components\ added, kg} \times 100\% \quad \textbf{Eq. 1}$$

4. Results and Discussions

4.1 Process Flow, Process Conditions and Stream Specifications

The method used in the production of laundry detergent is the blender process. It involves mixing of the detergent's ingredients in a blender until it reaches a fine consistency. The key processes in this style of production are the addition of the surfactants, fillers, additives, builders, stabilizers, rinsing agents, cosmetic colorants, fragrances, and most importantly, mixing.

The first key process is the mixing of the primary surfactant and filler. In order to form a functional base for the detergent, it has to be mixed well, hence, the conditions required here and all subsequent steps require that the system always be constantly mixing to evenly distribute and mix the components, as well as to ensure a fine consistency.

The overall process conditions required for the whole procedure are not stringent and were done specifically in room temperature.

Due to the nature of the components and product, it is advised to wear protective gear for the eyes and respiratory masks, to prevent irritation and any potential long-term health effects.

4.2 Component Yields of Each Key Process

In this section, the streams of each key process would be described in terms of their respective component breakdown and yields (when applicable). Interpretations and inferences are also presented. Sample calculations for the component breakdown and yields are found in ANNEX V.

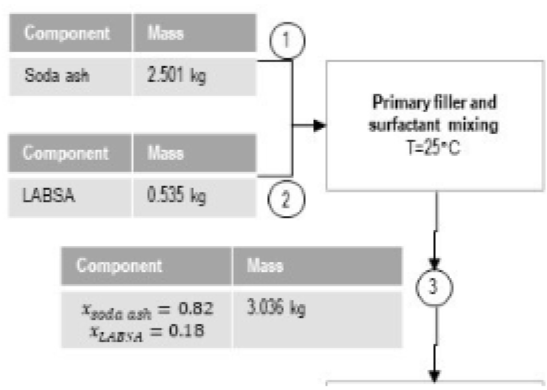


Figure 15. *Process flow diagram of primary filler and surfactant mixing step.*

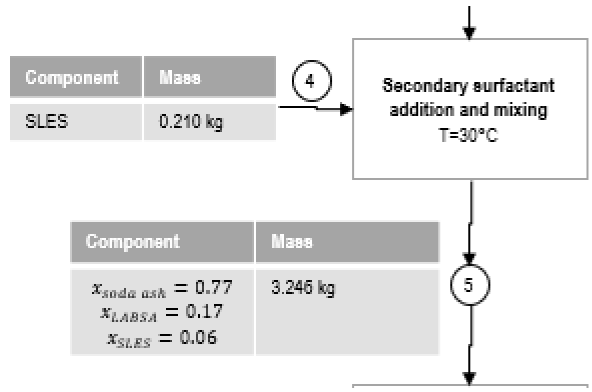


Figure 16. *Process flow diagram of secondary surfactant addition and mixing step.*

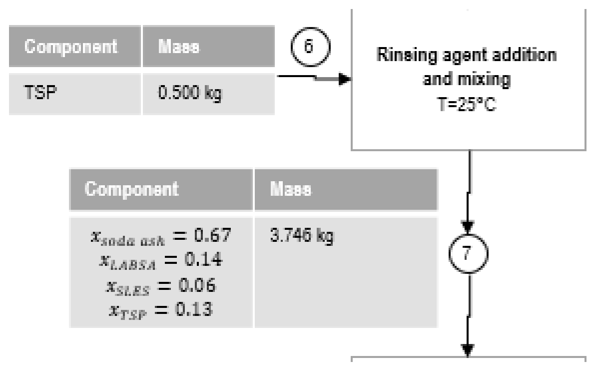


Figure 17. *Process flow diagram of rinsing agent addition and mixing.*

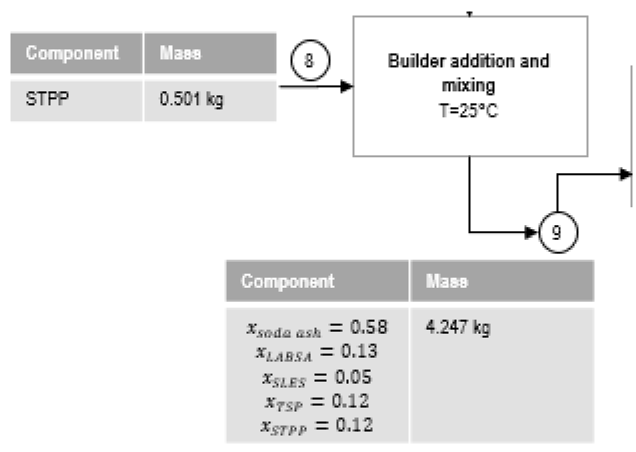


Figure 18. *Process flow diagram of builder addition and mixing step.*

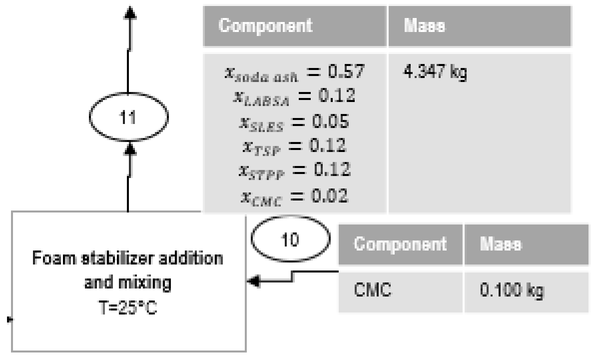


Figure 19. *Process flow diagram of foam stabilizer addition and mixing step.*

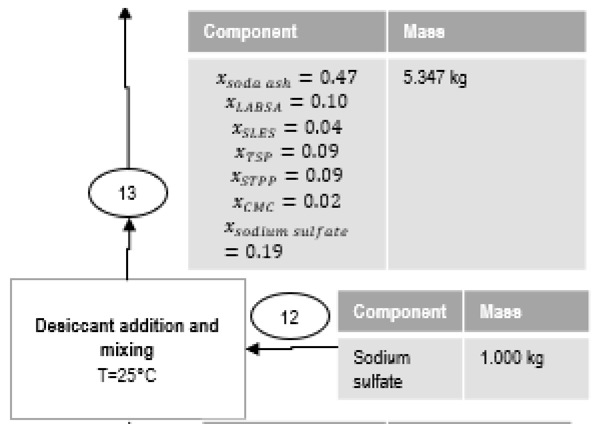


Figure 20. *Process flow diagram of desiccant addition and mixing.*

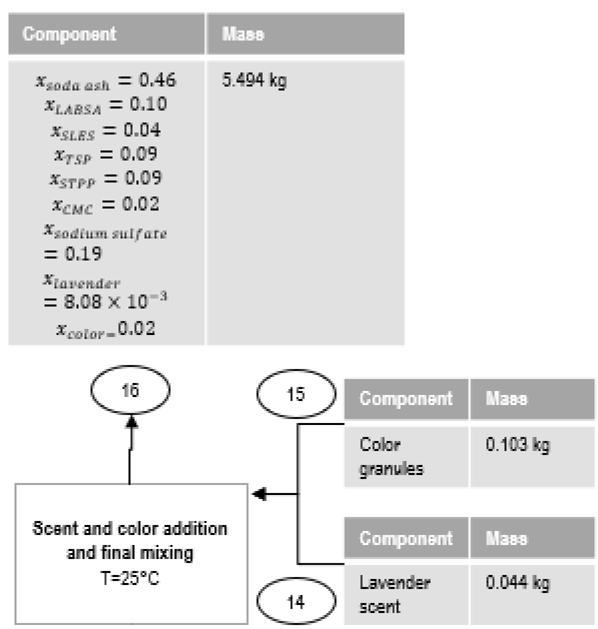


Figure 21. *Process flow diagram of scent and color addition and final mixing step.*

All the steps listed here incurred a 100% yield. This is due to the nature of the procedures not requiring an extraction step of any kind. also noted that as more components are added into the mixture, the mass fractions of the individual components decrease in value.

$$Percent\ losses = \frac{5.494\ kg - 5(0.980\ kg)}{5.494\ kg} \times 100\% = 10.8\%$$

However, the losses only occurred during packaging, as not all of the produced detergent is able to be placed into the five, 1-liter packaging containers which can only contain 0.980 kilograms of detergent each.

4.3 Critical Steps on the Production of Laundry Detergent

The production of laundry detergent was done within a house. As the procedure was done outside of the laboratory, steps were made to ensure proper sanitation.

The addition of both the soda ash and LABSA are critical as they are the main components of the detergent, along with the addition of all other components. It is also noted that for it to be effective, it has to be mixed well. To ensure the homogeneity of the mixture, consistent mixing must be done from start to finish of the production process. No special conditions were required, and the procedure was done under ambient conditions.

In terms of product storage, it is also important to store the product in a sealed container and in a dry place to prevent clumping due to exposure to moisture. Additionally, the product must be away from direct heat source to preserve product integrity.

5. Conclusions

The method adopted in the production of laundry detergent production is the batch method. 2,501 kilos of soda ash were added, mixed with 500 ml of LABSA, then subsequently mixed with 200 ml of SLES, 500 grams of TSP, 500 grams of STPP, 100 grams of CMC, 1 kilo of sodium sulfate, 50ml of lavender scent and 103 grams of coloring. The final mass produced was 5.494 kilos, while 4.900 kilos were successfully packaged in five 1-Liter containers, which led to a yield of 89.19%.

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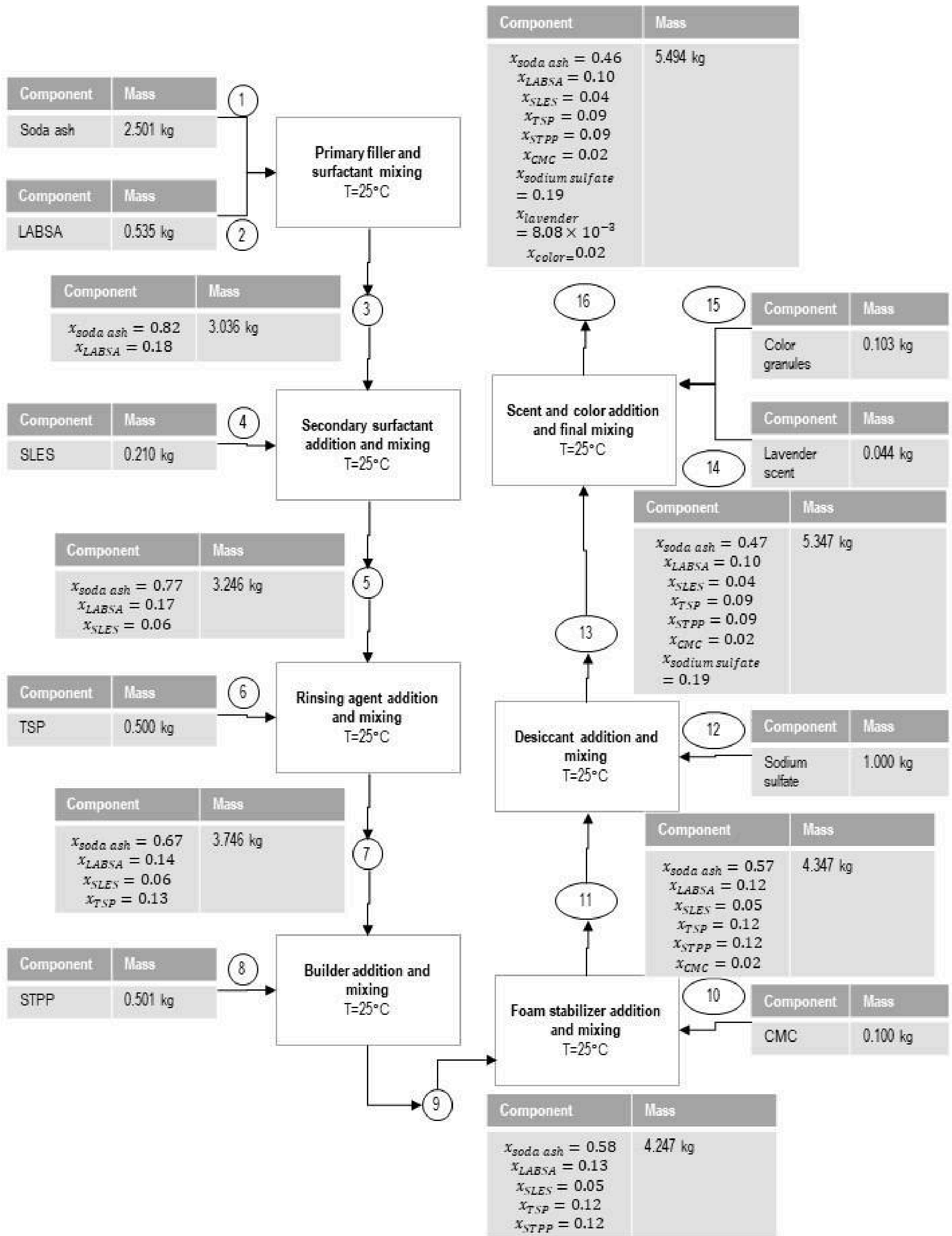
ANNEX I

Process Flow Sheet



ANNEX II

Financial Report

Table 1. *Proposed Budget for Materials*

Item Description	*Quantity*	*Cost/Unit*	*Subtotal*
Soda ash/Sodium Carbonate	3 kg	₱ 25.00/kg	₱ 75.00
Acid slurry	1 L	₱ 115.00/L	₱ 115.00
SLES (Sodium Lauryl ether Sulfate)	1 kg	₱ 85.00/kg	₱ 85.00
TSP (Tri Sodium Phosphate)	1 kg	₱ 50.00/kg	₱ 50.00
STPP (Sodium Tri Poly Phosphate)	1 kg	₱ 75.00/kg	₱ 75.00
CMC (Carboxy Methyl Cellulose)	1 kg	₱ 574.00/kg	₱ 574.00
Sodium Sulfate	1 kg	₱ 15.00/kg	₱ 15.00
Scent/perfume	60 mL	₱ 2.25/mL	₱ 135.00
Color granules	1 kg	₱ 45.00/kg	₱ 45.00
		Total	**₱ 1169.00**

Table 2. *Proposed Budget for Laboratory Equipment/Apparatus Use*

Item Description	*Quantity*	*Cost/Unit*	*Subtotal*
N95 Mask	1	₱ 94.00/unit	₱ 94.00
Nitrile gloves	1 pair	₱ 5.40/pair	₱ 5.40
Plastic basin, 18in.	1	₱ 139.00/unit	₱ 139.00
Wood spatula	1	₱ 99.00/unit	₱ 99.00
Digital weighing scale	1	₱ 999.00/unit	₱ 999.00 (borrowed unit, do not count in)
Beaker, 100 mL	1	₱ 85.00/unit	₱ 85.00
Beaker, 1L	2	₱ 220.00/unit	₱ 440.00
Plastic tub, 1L	5	₱ 15.00/unit	₱ 75.00
		Total	**₱907.4**

Table 3. *Room Rental Costs*

Room	*No. of days*	*Cost/day*	*Subtotal*
[1] ChE Unit Operation Laboratory	3	₱ 500/day	₱ 1,500.00
		Total	**₱ 1,500.00**

Table 4. *Overall Costs*

Grand total	**₱ 3576.40**
Grand total (with 20% contingency)	**₱ 4291.68**

ANNEX III

Raw Data Sheets

Table 1. Raw data from *Preparation*

	Quantity	Unit
Mass of dry basin	0.401	kg

Table 2. Raw data from *Primary filler and surfactant mixing*

	Quantity	Unit
Mass of soda ash	2.501	kg
Volume of LABSA acid slurry	500	mL
Temperature of acid slurry	25.0	°C
Mass of basin and mixture	3.432	kg

Table 3. Raw data from *Secondary surfactant addition and mixing*

	Quantity	Unit
Volume of SLES added into the basin	200.0	mL
Temperature of SLES	25.0	°C
Mass of basin and mixture	3.638	kg

Table 4. Raw data from *Rinsing agent addition and mixing*

	Quantity	Unit
Mass of TSP added into the basin	0.500	kg
Mass of basin and mixture	4.138	kg

Table 5. Raw data from *Builder addition and mixing*

	Quantity	Unit
Mass of STPP added into the basin	0.501	kg
Mass of basin and mixture	4.639	kg

Table 6. Raw data from *Foam stabilizer addition and mixing*

	Quantity	Unit
Mass of CMC added into the basin	0.100	kg
Mass of basin and mixture	4.739	kg

Table 7. Raw data from *Desiccant addition and mixing*

	Quantity	Unit
Mass of sodium sulfate added into the basin	1.000	kg
Mass of basin and mixture	5.735	kg

Table 8. Raw data from *Scent and color addition, and final mixing*

	Quantity	Unit
Volume of scent/perfume added into the basin	50.0	mL
Mass of color granules added into the basin	0.103	kg
Mass of basin and mixture	5.838	kg
Mass of overall product (final basin weight - dry basin weight)	5.437	kg

Table 9. Raw data from *Drying and Pulverizing to powder* **(step ignored, product didn't solidify)**

	Quantity	Unit
Mass of basin and powder	5.838	kg
pH of powder	10	

Table 10. Raw data from *Packaging*

	Quantity	Unit
Mass of cleaned and dried tub	0.051	kg
Mass of powder soap and tub	1.031	kg
Mass of powder soap	0.980	kg

Table 11. Raw data from *Post-Production Analysis*

Characteristics	**Observations**	
	Powder Soap Product	Brand X
Color	Mostly white with blue granules	Mostly white with sparse red and blue granules
Scent	Strong, lavender fragrance	Faint, rose fragrance
Powder Texture	Relatively fine, with some clumps present	Fine, with few to no clumps
Foam formed	Yes	Yes

ANNEX IV
Actual Conduct of Experiment

Figure 22. Materials and Equipment

Figure 23. Primary filler and surfactant mixing

Figure 24. Secondary surfactant addition and mixing

Figure 25. Builder addition and mixing

Figure 26. Foam stabilizer addition and mixing

Figure 27. Scent and color granule addition and mixing

Figure 28. Final product pH measurement (Brand X, left; Final Product; right)

Figure 29. Bubbling Test (Brand X, left; Final Product; right)

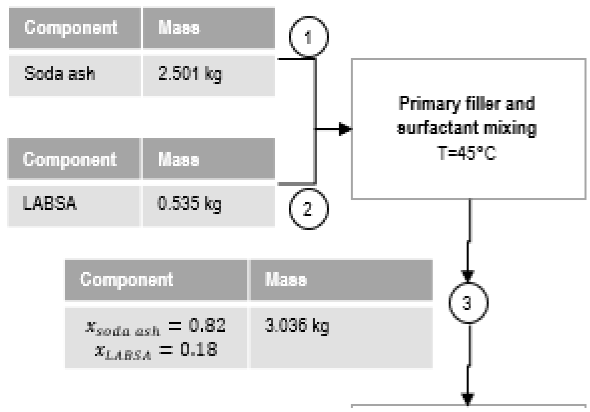
Figure 30. Final Product in Packaging

Link for the short clip of the actual conduct of experiment:

https://drive.google.com/file/d/1Hq6t0CRQqWpGYVhl7zolawFjsW9hjGAL/view?usp=sharing

ANNEX V
Sample Calculations

Key Process 1: Primary filler and surfactant mixing



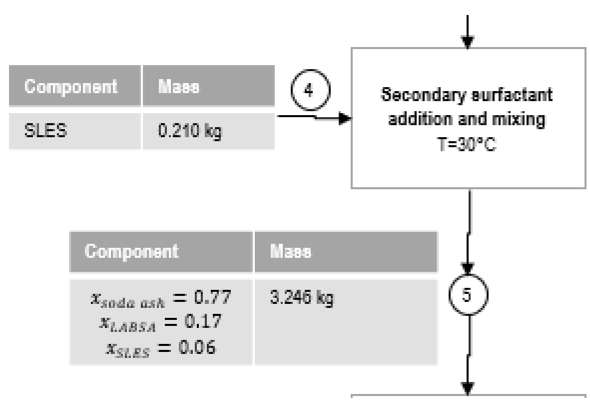
$$m_1 = 2.501\ kg$$
$$m_2 = 0.535\ kg$$
$$m_3 = 3.036\ kg$$

Calculating component yields:

$$\text{Soda Ash} = \frac{2.501\ kg}{3.036\ kg} = 0.8238\frac{w}{w} = 82.38\ \%\ Soda\ Ash$$

$$\text{LABSA} = \frac{0.535\ kg}{3.036\ kg} = 0.1762\frac{w}{w} = 17.62\ \%\ LABSA$$

Key Process 2: Acidification with Vinegar



$$m_4 = 0.210\ kg$$
$$m_5 = 3.246\ kg$$

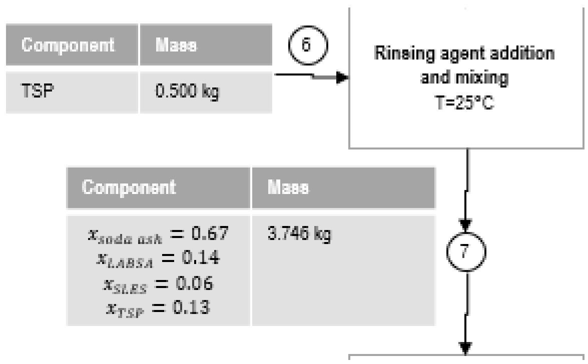
Calculating component yields:

$$\text{Soda Ash}=\frac{2.501\ kg}{3.246\ kg} = 0.7705\frac{w}{w} = 77.05\ \%\ Soda\ Ash$$

$$\text{LABSA} =\frac{0.535\ kg}{3.246\ kg} = 0.1648\frac{w}{w} = 16.48\ \%\ LABSA$$

$$\text{SLES} =\frac{0.210\ kg}{3.246\ kg} = 0.0647\frac{w}{w} = 6.47\ \%\ SLES$$

Key Process 3: Curd Separation



$m_6 = 0.500$ kg
$m_7 = 3.746$ kg

Calculating component yields:

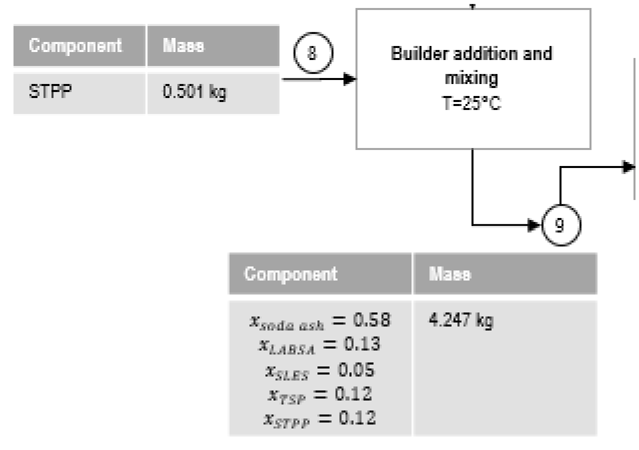
$$\text{Soda Ash}=\frac{2.501\ kg}{3.746\ kg} = 0.6676\frac{w}{w} = 66.76\ \%\ Soda\ Ash$$

$$\text{LABSA} =\frac{0.535\ kg}{3.746\ kg} = 0.1428\frac{w}{w} = 14.28\ \%\ LABSA$$

$$\text{SLES} =\frac{0.210\ kg}{3.746\ kg} = 0.0561\frac{w}{w} = 5.61\ \%\ SLES$$

$$\text{TSP} =\frac{0.500\ kg}{3.246\ kg} = 0.1335\frac{w}{w} = 13.35\ \%\ TSP$$

Key Process 4: Salting Process



$m_8 = 0.501$ kg
$m_9 = 4.247$ kg

Calculating component yields:

$$\text{Soda Ash} = \frac{2.501\ kg}{4.247\ kg} = 0.5889\frac{w}{w} = 58.89\ \%\ Soda\ Ash$$

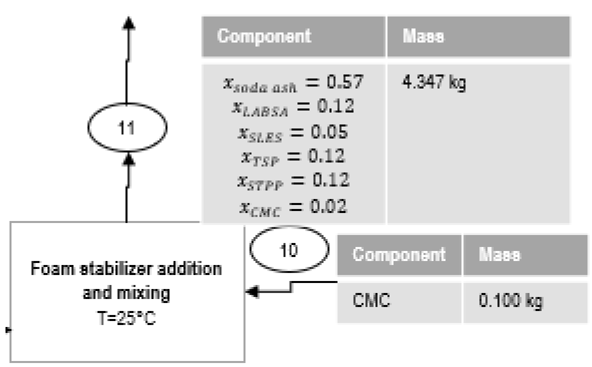
$$\text{LABSA} = \frac{0.535\ kg}{4.247\ kg} = 0.1260\frac{w}{w} = 12.60\ \%\ LABSA$$

$$\text{SLES} = \frac{0.210\ kg}{4.247\ kg} = 0.0494\frac{w}{w} = 4.94\ \%\ SLES$$

$$\text{TSP} = \frac{0.500\ kg}{4.247\ kg} = 0.1177\frac{w}{w} = 11.77\ \%\ TSP$$

$$\text{STPP} = \frac{0.501\ kg}{4.247\ kg} = 0.1180\frac{w}{w} = 11.80\ \%\ STPP$$

Key Process 5: Salting Process



$m_{10} = 0.100$ kg
$m_{11} = 4.347$ kg

Calculating component yields:

$$\text{Soda Ash}=\frac{2.501\ kg}{4.347\ kg} = 0.5753\frac{w}{w} = 57.53\ \%\ Soda\ Ash$$

$$\text{LABSA} = \frac{0.535\ kg}{4.347\ kg} = 0.1231\frac{w}{w} = 12.31\ \%\ LABSA$$

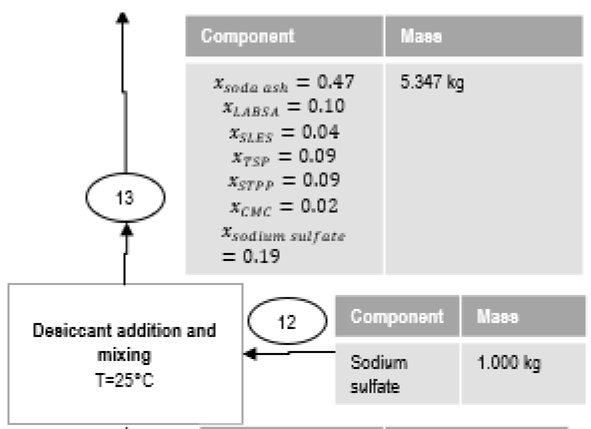
$$\text{SLES} = \frac{0.210\ kg}{4.347\ kg} = 0.0483\frac{w}{w} = 4.83\ \%\ SLES$$

$$\text{TSP} = \frac{0.500\ kg}{4.347\ kg} = 0.1150\frac{w}{w} = 11.50\ \%\ TSP$$

$$\text{STPP} = \frac{0.501\ kg}{4.347\ kg} = 0.1153\frac{w}{w} = 11.53\ \%\ STPP$$

$$\text{CMC} = \frac{0.100\ kg}{4.347\ kg} = 0.0230\frac{w}{w} = 2.30\ \%\ CMC$$

Key Process 6: Salting Process



m_{12} = 1.000 kg
m_{13} = 5.347 kg

Calculating component yields:

$$\text{Soda Ash}=\frac{2.501\ kg}{5.347\ kg} = 0.4677\frac{w}{w} = 46.77\ \%\ Soda\ Ash$$

$$\text{LABSA} = \frac{0.535\ kg}{5.347\ kg} = 0.1001\frac{w}{w} = 10.01\ \%\ LABSA$$

$$\text{SLES} = \frac{0.210\ kg}{5.347\ kg} = 0.0393\frac{w}{w} = 3.93\ \%\ SLES$$

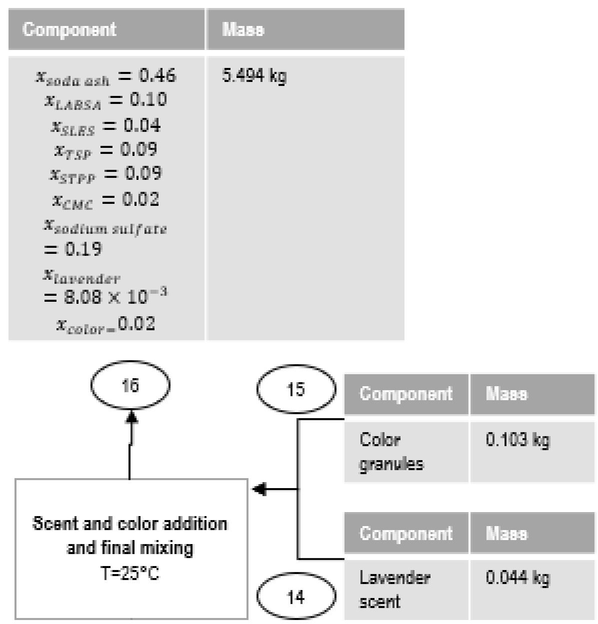
$$\text{TSP} = \frac{0.500\ kg}{5.347\ kg} = 0.0935\frac{w}{w} = 9.35\ \%\ TSP$$

$$\text{STPP} = \frac{0.501\ kg}{5.347\ kg} = 0.0937\frac{w}{w} = 9.37\ \%\ STPP$$

$$\text{CMC} = \frac{0.100\ kg}{5.347\ kg} = 0.0187\frac{w}{w} = 1.87\ \%\ CMC$$

$$\text{Sodium sulfate} = \frac{1.000\ kg}{5.347\ kg} = 0.1870\frac{w}{w} = 18.70\ \%\ sodium\ sulfate$$

Key Process 7: Salting Process



$m_{14} = 0.044$ kg
$m_{15} = 0.103$ kg
$m_{16} = 5.494$ kg

Calculating component yields:

$$\text{Soda Ash} = \frac{2.501\ kg}{5.494\ kg} = 0.4552\frac{w}{w} = 45.52\ \%\ Soda\ Ash$$

$$\text{LABSA} = \frac{0.535\ kg}{5.494\ kg} = 0.0974\frac{w}{w} = 9.74\ \%\ LABSA$$

$$\text{SLES} = \frac{0.210\ kg}{5.494\ kg} = 0.0382\frac{w}{w} = 3.82\ \%\ SLES$$

$$\text{TSP} = \frac{0.500\ kg}{5.494\ kg} = 0.0910\frac{w}{w} = 9.10\ \%\ TSP$$

$$\text{STPP} = \frac{0.501\ kg}{5.494\ kg} = 0.0912\frac{w}{w} = 9.12\ \%\ STPP$$

$$\text{CMC} = \frac{0.100\ kg}{5.494\ kg} = 0.0182\frac{w}{w} = 1.82\ \%\ CMC$$

$$\text{Sodium sulfate} = \frac{1.000\ kg}{5.494\ kg} = 0.1820\frac{w}{w} = 18.20\ \%\ sodium\ sulfate$$

$$\text{Lavender scent} = \frac{0.044\ kg}{5.494\ kg} = 8.009 \times 10^{-3}\ \frac{w}{w} = 0.8009\ \%\ lavender\ scent$$

$$\text{Color granules} = \frac{0.103\ kg}{5.494\ kg} = 0.0187\ \frac{w}{w} = 1.870\ \%\ color\ granules$$

Key Process 8: Packaging

$$m_{17}(\text{per packaging}) = 0.980\ \text{kg}$$

Calculating Overall Yield

$$\%\ \text{Yield} = \frac{5(0.980\ kg)}{5.494\ kg}\ x\ 100 = 89.19\ \%$$