Standardizing the Manufacturing Operation of a Multipurpose Cleaner in 32-Ounce Bottles in Order to Control the Process

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Abstract — *With the fast paste life we are currently living, manufacturers are always looking for innovative ways to simplify products, including cleaning and household products. With an all-purpose cleaner, there is no need to buy and store different bottles thus simplifying household chores. These products are designed to act as disinfectant, detergent, de-greaser, solvent or a combination to be used on different surfaces.*

In Puerto Rico, you can find many companies that are currently manufacturing these types of multi-purpose cleaners that are typically found in any household. This project is based on a multi-purpose cleaner manufactured in Puerto Rico which has been in the market since 1997. It is a multipurpose cleaner capable of cleaning any surface without damage, strong against dirt and grease, but not harmful to the skin. It is a non-corrosive, non-abrasive and eco-friendly product used in many households today.

Key Terms — *Manufacturing Process Control, Multipurpose Cleaner, Reducing Process Variation, Standardizing Manufacturing Operation.*

PROJECT STATEMENT

Currently, the manufacturing process for a multipurpose cleaner produced in Puerto Rico is not standardized, measured nor controlled. Manufacturing process starts with the mixing of raw materials in a 1,800-gallon stainless steel tank, where current manufacturing capacity has not yet been calculated. Product is later transferred to different filling stations, depending on the final packaging size of the product.

Project Description

This project is based on filling station #2, were product is filled in 32 oz bottles with atomizers. This filling station has 18 nozzles in order to fill 18 bottles at the same time. There are no samples currently taken to confirm 32 ounces are being dispatched to the bottles nor data for filling variation between the nozzles and filling time.

Since there are no standardized processes in place for the manufacture of this multipurpose cleaner, process may not be in control and final product may be affected. By not having current manufacturing capacity measured, the company won't be able to determine if they are capable of matching product demand or if they are having too much downtime or loss.

Project Objectives

The main objective for this project is to identify and focus on real issues involved in the multipurpose cleaner manufacturing process, measure data regarding capacity and filling variation effectively and analyze the real root causes for the problems identified. With this information, we can propose focused improvements and ensure control with the implementation of standardized solutions. With the help of the guidelines, operators will be able to reduce waste and improve productivity. At the end, the manufacturer will be able to improve competitiveness, guarantee in-specification final product, increase income and comply with customers' requirements.

SOAP AND DETERGENTS

The use of cleaning products has been around since the beginning of time, for obvious reasons: cleanliness and health. The history of soap dates from way back, from Ancient Babylon, when most cleaning products where created by mixing ashes, animal or plant fat and oil. The chemistry and manufacturing of soap essentially stayed untouched until World War I and World War II when animal and plant fats became scarce. This is when the history of cleaning products began to evolve in the mid 1900's with the use of other synthesized raw materials with similar properties to natural fat to create detergents [1].

Multipurpose Cleaners

Soaps were originally made from natural ingredients such as plant oils or acids derived from animal fat. Whilst now, detergents are made with synthetic, man-made derivatives such as surfactants. One of the most important differences between soap and detergent is how they behave in water. Soaps can form scum or residues with hard water, which can become a problem when cleaning or doing laundry [2]. Detergents are now being formulated as multipurpose cleaners in order to include ingredients that can help with all types of cleaning purposes and who do not react with minerals in water. Detergents are a great option to be able to use as: dishwasher detergent, laundry detergent, gels, laundry softener, mopping solutions, bathroom cleaners, etc. Most cleaning products today are detergents, since surfactants aid in cleaning by reducing surface tension and improving water's ability to spread evenly over it.

Surfactants

Surfactants, also known as surface-active agents, are compounds that reduce surface tension when added to a liquid, increasing its wetting and spreading properties [3]. Because of this property, surfactants may act as detergents, wetting agents, emulsifiers, foaming agents and dispersants. When acting as detergents, these surface-active agents concentrate at the areas of contact between water and oil/dirt. Surfactant molecules have either a positive or negative charge, this helps by attracting one end to water (hydrophilic) and the other end to the dirt or grease (hydrophobic). When sufficient amounts of surfactants are found in a solution, they combine together to form micelles as shown in Figure 1. When micelles form, the hydrophilic head position themselves to be exposed to water, while the hydrophobic side are grouped together in the center in order to be protected from water [4].

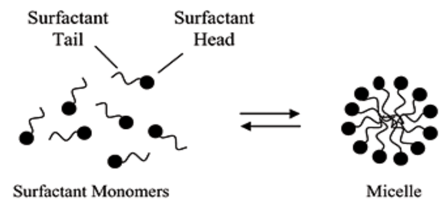

Figure 1
Surfactant Micelle

This attraction in the hydrophobic side aids to break up dirt/oil to and to mix it to the liquid, letting water loosen and "wash" dirt/oil away, making this compound act as a great detergent. At the hydrophilic side, air molecules are trapped and produce the foam seen in many detergents when cleaning.

Manufacturing Process

The first step in producing multipurpose cleaners is to select raw materials based on human and environmental safety, cost and specific properties based on the desired final product. The manufacturing process for multipurpose cleaners can be typically divided in two steps: mixing process either by batch or continuous and the filling process to its final package. Mixing in a batch process, all raw materials are loaded into a mixer together or in a defined sequence, they are mixed until a homogenous product is produced and discharged in a single lot [5].

In order to start with the mixing process in batch, raw materials are previously weight according to product formula. Raw materials used for detergent manufacturing consists of wet products and dry products. While this raw material prep goes on, the stainless-steel tank used for mixing is being filled with water. Wet materials include: surfactant, colorant, fragrance and other products, while the dry products typically act as enzymes and stabilizers. Once all materials are included in the batch mixing tank (Figure 2), they are continuously blended until fully mixed and the final lot is a homogenous multi-purpose cleaner.

Figure 2
Batch Mixing Tank

The now multipurpose cleaner manufactured goes through a filling process to the different types of packaging. When shopping around for multipurpose cleaners, you may find a variety of packaging from pails, to gallons to ounces. When filling material to 32-ounce bottles with atomizer, first thing is that empty bottles are placed at the beginning of the conveyor. Bottles slowly begin to move through the line, passing through the product filling station, where cleaner is now dispensed in the bottles. Atomizers are placed in each filled bottle and later passed through the "capping" station where atomizers are tightly closed. The bottle then goes through the labeling station in order to have product label included.

MEASUREMENTS

Capacity in manufacturing can be defined as the capability to produce a product or service, or total production quantity for a specific time period. Capacity can be measured in different ways: by input, output or the combination of the two depending on the nature of the manufacturing process [6]. Production capacity is a very important factor, since it has to match to your products demand. If we have a higher demand, we will not meet with customer's product requirements. On the other hand, if capacity is too high for demand, then companies can experience high equipment and employee down time.

Variability in a manufacturing process can be defined as the difference between the produced measure and its target. High variability in any process can lead to either waste or excess production cost and can also affect product quality and customer satisfaction [7]. This observed variability is an accumulation of many different variations that have occurred throughout the manufacturing process. All processes exhibit variation, this is a routine issue faced by most manufacturers. The right strategy would be to reduce the process variability by identifying and quantifying these various sources of variation so they can be minimized [8].

Single Batch Manufacture

Time taken to manufacture a single batch of the multipurpose cleaner was measured and presented in Table 1 in 3 different mixing batches in order to obtain an average time. This time will include the complete manufacturing process, from the beginning of raw material preparation to including all materials to the mixing tank.

Table 1
Measured Time for Single Batch Manufacture

Batch	Material Prep Time	Material Mix in Tank	Total Time
1 *	25 min	25 min	50 min
2 **	49 min	30 min	79 min
3 **	53 min	28 min	81 min

* Batch 1 already had water needed for prep in tank
** Batch 2 & 3 included water filling time in tank

The average time taken to produce a single batch of multi-purpose cleaner would be:

- With Water included in tank: 50 minutes
- Including Water Filling in tank: 80 minutes

When all materials are mixed in tank, product is left blending for 30 minutes.

Bottle Filling Process Data

In the bottle filling process, first 18 bottles from each nozzle was weight once filled and every 18 bottles every 20 minutes. Average Ounces by Nozzles variance and Average Ounces by Time variance were calculated in Tables 2 and 3 and graphed in Figures 3 and 4 from in process data measurements obtained prior to any improvements to the filling station.

- Empty bottle weight for tare: 1.9 Oz.

- Total Production: 19 Pallets (600 bottles/pallet) + 384 bottles = 11,784 bottles
- Average Weight: 34.3 Ounces
- Average Filled Difference: 2.3 Ounces

Table 2
Variation of Bottle Weight Average in Oz. Between Nozzles

Nozzle	Expected	Actual - Average	Variance	%
1	32	34.27	-2.27	-7.09%
2	32	34.32	-2.32	-7.25%
3	32	34.29	-2.29	-7.16%
4	32	34.32	-2.32	-7.25%
5	32	34.28	-2.28	-7.13%
6	32	34.83	-2.83	-8.84%
7	32	34.31	-2.31	-7.22%
8	32	34.36	-2.36	-7.38%
9	32	34.36	-2.36	-7.38%
10	32	34.32	-2.32	-7.25%
11	32	34.31	-2.31	-7.22%
12	32	34.29	-2.29	-7.16%
13	32	34.36	-2.36	-7.38%
14	32	34.29	-2.29	-7.16%
15	32	34.31	-2.31	-7.22%
16	32	33.87	-1.87	-5.84%
17	32	34.33	-2.33	-7.28%
18	32	34.23	-2.23	-6.97%

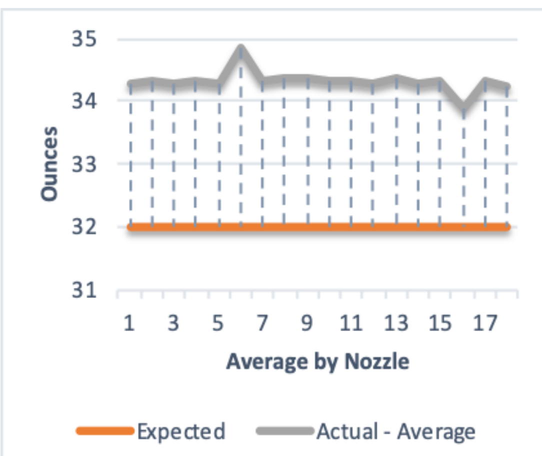

Figure 3
Average Ounces by Nozzle Variance

Table 3
Variation of Bottle Weight Average in Oz. With Time

Time	Expected	Actual - Average	Variance	%
8:50 AM	32	34.69	-2.69	-8.41%
9:10 AM	32	34.34	-2.34	-7.31%
9:30 AM	32	34.23	-2.23	-6.97%
9:50 AM	32	34.31	-2.31	-7.22%
10:10 AM	32	34.35	-2.35	-7.34%
10:30 AM	32	34.30	-2.30	-7.19%
10:50 AM	32	34.26	-2.26	-7.06%
11:10 AM	32	34.32	-2.32	-7.25%
11:30 AM	32	34.23	-2.23	-6.97%
12:30 PM	32	34.31	-2.31	-7.22%
12:50 PM	32	34.26	-2.26	-7.06%
1:10 PM	32	34.30	-2.30	-7.19%
1:30 PM	32	34.30	-2.30	-7.19%
1:50 PM	32	34.31	-2.31	-7.22%
2:10 PM	32	34.27	-2.27	-7.09%
2:30 PM	32	34.27	-2.27	-7.09%
2:50 PM	32	34.34	-2.34	-7.31%
3:10 PM	32	34.29	-2.29	-7.16%
3:30 PM	32	34.29	-2.29	-7.16%

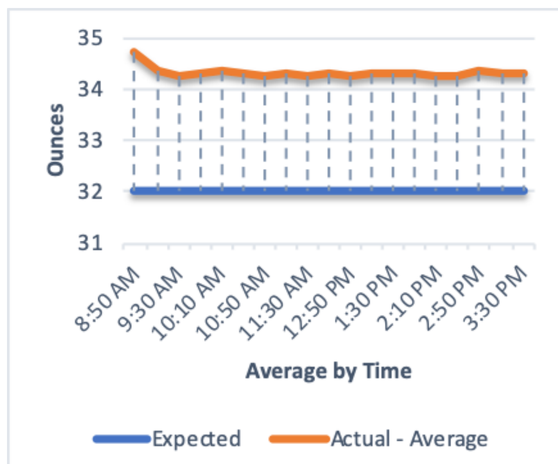

Figure 4
Average Ounces by Time Variance

Correct filling volume was established for the 32-ounce bottle of the multipurpose cleaner and PVC spacers for each nozzle were fabricated, installed and tested for each nozzle. Average Ounces by Nozzle variance and Average Ounces by Time variance were again calculated in Tables 4 and 5 and graphed in Figures 5 and 6 from in process data measurements obtained.

- Empty bottle weight for tare: 1.9 Oz.
- Total Production: 17 Pallets (600 bottles/pallet) + 480 bottles = 10,680 bottles
- Average Weight: 33.73 Ounces
- Average Filled Difference: 1.73 Ounces

Table 4
Variation of Bottle Weight Average in Oz. Between Nozzles

Nozzle	Expected	Actual - Average	Variance	%
1	32	33.67	-1.67	-5.22%
2	32	33.71	-1.71	-5.34%
3	32	33.73	-1.73	-5.41%
4	32	33.70	-1.70	-5.31%
5	32	33.69	-1.69	-5.28%
6	32	33.67	-1.67	-5.22%
7	32	33.74	-1.74	-5.44%
8	32	33.75	-1.75	-5.47%
9	32	33.83	-1.83	-5.72%
10	32	33.89	-1.89	-5.91%
11	32	33.80	-1.80	-5.62%
12	32	33.69	-1.69	-5.28%
13	32	33.74	-1.74	-5.44%
14	32	33.78	-1.78	-5.56%
15	32	33.76	-1.76	-5.50%
16	32	33.63	-1.63	-5.09%
17	32	33.81	-1.81	-5.66%
18	32	33.62	-1.62	-5.06%

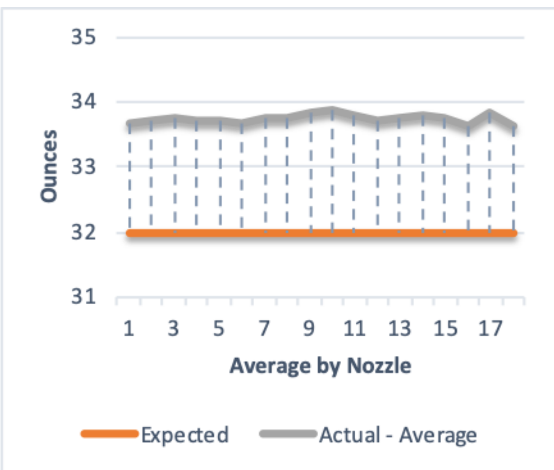

Figure 5
Average Ounces by Nozzle Variance

Table 5
Variation of Bottle Weight Average in Oz. With Time

Time	Expected	Actual – Average	Variance	%
8:50 AM	32	33.87	-1.87	-5.84%
9:10 AM	32	33.63	-1.63	-5.09%
9:30 AM	32	33.66	-1.66	-5.19%
9:50 AM	32	33.68	-1.68	-5.25%
10:10 AM	32	33.65	-1.65	-5.16%
10:30 AM	32	33.58	-1.58	-4.94%
10:50 AM	32	33.64	-1.64	-5.13%
11:10 AM	32	33.61	-1.61	-5.03%
11:30 AM	32	33.72	-1.72	-5.38%
12:30 PM	32	33.71	-1.71	-5.34%
12:50 PM	32	33.68	-1.68	-5.25%
1:10 PM	32	33.71	-1.71	-5.34%
1:30 PM	32	33.86	-1.86	-5.81%
1:50 PM	32	33.79	-1.79	-5.59%
2:10 PM	32	33.85	-1.85	-5.78%
2:30 PM	32	33.83	-1.83	-5.72%
2:50 PM	32	33.87	-1.87	-5.84%
3:10 PM	32	33.90	-1.90	-5.94%
3:30 PM	32	33.72	-1.72	-5.38%

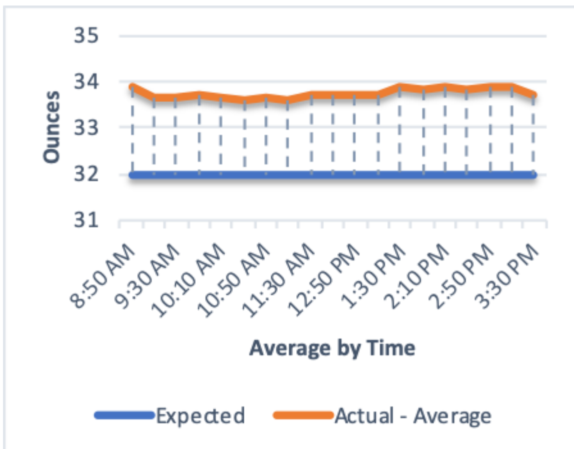

Figure 6
Average Ounces by Time Variance

CONCLUSION

Current manufacturing capacity of 80-minute average time per batch mixed is in accordance with current product demand and can increase if necessary. No changes or improvements were made during the scope of this project.

Production for the 32-ounce bottle is currently at 2 – 3 productions per week, one complete shift per production. With production capacity, filling station is currently running on an average speed and speed controls are currently locked in order to prevent that employees/operators change or manipulate filling capacity. If there is the need for more production capacity, machine can be operated at a quicker pace or have a second shift come in. Average Ounces by Time variance and Average Ounces by Nozzle variance were calculated and graphed prior to any improvements to the filling station. There was no significant variance in average ounces measured by time with a standard deviation of 0.0971, but an overall high variance with the expected 32-ounce fill volume can be seen. With the average ounces measured by nozzle, nozzles 6 and nozzle 16 demonstrated to have significant difference in filling average than the other nozzles and an overall standard deviation of 0.1684.

From the data obtained, an average of 2.3 ounces were being filled over the expected 32-ounce volume in each bottle, resulting in a total of 27,100 ounces (847 bottles) approximately of over filling in the production day data was taken. Reviewing data from the 2019 total production for the 32-ounce bottles produced, there were 727,500 bottles approximately filled. This sums up to 1,673,250 ounces of over filled product in 2019 resulting in a "loss" of 52,289 bottles.

Nozzle accessories and spacers for the filling station are "home-made", installed and "calibrated" based on a visual volume of what they assumed were the 32 ounces. There is no historical data of weight measurements being taken in order to ensure correct filling weight. Also, data from bottle supplier marking where the 32 fluid ounces should be is based on water and not current product (8 fluid ounces of product were weight and equals 8 ounces). It can be concluded that because of these reasons, there is a big variance between actual average fill weight and the expected 32 ounces of product per bottle.

Correct filling volume was established for the 32-ounce bottle and PVC spacers for each nozzle were fabricated, installed and tested for each nozzle. Average Ounces by Time variance and Average Ounces by Nozzle variance were again calculated and graphed from in process data measurements obtained. There were no significant differences in average ounces measured by time, but a slightly higher standard deviation was seen with a new value of 0.1013 compared to the value prior to improvements. There were no significant differences in average ounces measured by nozzle, improving variance between nozzles 6 and 16 and obtaining a lower standard deviation of 0.0705.

From the data obtained, an average of 1.73 ounces were being filled over the expected 32-ounce volume in each bottle, resulting in a total of 18,476 ounces (577 Bottles) approximately of over filling in the production day data was taken. Difference of what would have been over filled with the 2.3 ounces per bottle prior to improvements would be 24,560 ounces, resulting in an average of 6,084-ounce improvement for the production day data was obtained. Assuming a total production of 727,500 bottles for 2020 of 32-ounce bottles, sums up to 1,258,575 ounces of over filled product resulting in an approximate "loss" of 39,330 bottles. With the actual improvements made to the filling station, there has been an improvement of 12,959 bottles rather than the 52,289 bottles lost by over filling in 2019.

At the moment of implementing improvements with the fabricated spacers in each nozzle, it was noticed that the filling station is currently uneven. Also, the current springs and rubber joints found in the nozzles limit PVC spacer sizing in order to ensure fill is done correctly and efficiently without producing foam in bottles during filling. Due to both of these reasons, the new PVC spacers installed could not be designed to reach the expected 32-ounce volume fill, thus obtaining a slightly higher variance in filling volume with time. Once actual/average filling volumes are closer to the 32-ounce expected volume, there will be less material "lost" in each fill during production.

Manufacturing planning should be closer to production planning due to the lower filling variance expected once solutions for the problems in filling nozzles are put in place.

RECOMMENDATIONS

Current manufacturing process requires two employees and one forklift for the complete process. Where one of the employees has to load one by one of the previously weight materials to the top of the mixer tank using the forklift. It is recommended to purchase new mixing totes and pumps in order to load and mix materials in totes and have pumps load material mix directly into the 1,800-gallon mixing tank. Sensors can also be installed in the mixing tanks, so employees don't have to be on top of the tank to visually fill tank with water. These recommended changes will improve efficiency and employee safety since none of the employees will have to load material from the forklift one by one.

For the production process, filling station should be leveled in order to ensure that each nozzle is standardized, and nozzle accessory improvement design is made efficiently. Due to the problems encountered with the springs and rubber joints found in the nozzles, new accessories should be purchased and installed in order to standardize all leveled nozzles and help design effective new spacers that can achieve a closer 32-ounce fill per bottle. Once these PVC spacers have been tested and approved in production, custom and dedicated Stainless-Steel spacers should be ordered and installed.

Quality weight measurements for sample bottles during production intervals should be standardized in order to ensure filling station for the 32-ounce bottles continue with an effective production, with lower filling variances in order to ensure correct volume fill. New calibrated scales should be installed in order to ensure efficient weighing of materials and products. Quality Control for all products manufactured should also be established and put into place. Also, this project should be mimicked with other product packaging options in order to improve complete company process output and ensure all variances are lowered, resulting in less product lost by over fill and improvement in production costs.

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