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Engineering and innovation: a cleaner production proposal

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Abstract. - This paper presents an engineering design that promotes cleaner production in silicone cutlery design. The idea seeks to motivate the consumer to maintain a healthy life by eating food made at home. For this, they propose cutlery of easy transfer and comfortable use for different tastes. The idea is driven by the search for new food proposals contributing to environmental conservation in eating implements. The main results show that the proposal is feasible and that waste consumption is considerably reduced with an appropriate cleaner production plan.

Keywords: Ecology, environmental protection, healthy eating.

Ingeniería e innovación: una propuesta de producción más limpia

Resumen: En este trabajo se presenta un diseño de ingeniería que promueve la producción más limpia en el diseño de cubiertos de silicón. La idea busca motivar al consumidor a mantener una vida saludable comiendo alimentos realizados en casa, para ello se proponen cubiertos de fácil traslado y cómodo uso para diferentes gustos. La idea se impulsa a la búsqueda de nuevas propuestas alimenticias que además aporten a la conservación ambiental en el proceso de elaboración de los implementos para comer. Los principales resultados muestran que la propuesta es factible y que se reduce considerablemente el consumo de desperdicios con un apropiado plan de producción más limpia.

Palabras clave: Ecología, protección ambiental, alimentación saludable.

I. INTRODUCTION

In everyday life, as in working life, we have sometimes sought to manufacture parts or products that are relatively the same. However, in many cases, obtaining a component that is the same or very similar to the one required is impossible, and sometimes the product manufactured with the necessary material and shape is unknown or cannot be found. Therefore, cloning or replicating the product or part is the most feasible. Within the text Silicone Mold Making [1], the exact repetition of a piece we call replication or cloning. The materials used to make it are varied (plaster, resins, soft metals); however, the image is based on two primary objects:

1.- The model or piece to replicate 2.- The mold that will serve to clone the model.

Silicone molds are tools used to create shapes and repetitive and creative designs that are used for different areas since silicone molds can be used with other materials or products such as resin, clay, soaps, bricks, candles, plates, or cutlery holders to take them anywhere. This last one is beneficial for the environment because in the food industry or restaurants, much plastic cutlery is used when it is sent by delivery or the order is sent to take away, according to the newspaper El Español [2] the *North Sea Foundation*, in the last 30 years of cleaning beaches around the world, The Ocean Conservancy has recorded the collection of more than 14 million disposable plastic cutlery, it should be noted that these take about 400 years to decompose.

The problem that arises worldwide is huge since plastic cutlery is a product that pollutes the environment; Marine life is one of the most affected since many animals swallow this type of waste that, relatively the use we give them a few hours, and proceeds to discard them. However, the solution can be straightforward. In the newspaper El Español in the case of eating out, we can bring our metal cutlery. Some companies develop small pocket cases that make it easy to transport essential eating tools on an excursion or in the workplace [3].

Therefore, using silicone molds to transport cutlery generates positive impacts, first on the environment since everyone would carry their metal forks in their case, and the use of plastics would be eliminated. These molds are durable, meaning their useful life will be extended. Restaurants or food companies would save costs and improve their image since many people are concerned about the environment. In addition, using silicone brings notable advantages in molds since, according to the Delicista Blog, these molds have the particularity that they are flexible, versatile, easy to clean, non-stick, resist very high temperatures (240ºC), and very low (-40C), soft but firm and affordable [3].

Similarly, within Latin America, many people buy food instead of taking their food, which causes the more they believe in restaurants or ask for takeaway food, the use of this plastic cutlery will continue to increase, according to the Quito newspaper Últimas Noticias. However, most Latinos prefer homemade food; 41% eat out when they can prepare food at home. This is a large number since most of these places send food in plastics, just as the cutlery they use is made of this same type of material. Also, another of the suggestions proposed by this newspaper is that food is taken from home, which would help reduce costs for people, and silicone molds are perfect for carrying food or cutlery anywhere, work, school, universities, etc [4].

II. DEVELOPMENT

Wacker Chemie AG is a German company that is one of the leading manufacturers of silicones. Among the products they make are silicone fluids, silicone resin, sealants, etc. The company is committed to sustainability and is climate-friendly and efficient with the use of resources. Within its website, it can be seen that the company also cares about human rights and social responsibility and that it has undoubtedly applied cleaner production plans within its production and its logistics area. Within its production, you use the waste gas, water, solids, and heat to start the production of other products [5].

Lékué is a Spanish company that manufactures functional products for cooking and home, such as silicone molds for baking and cooking, silicone steamers, cases, and containers for conservation. The company carries out its production under ethics and responsibility aligning with the UN SDGs that all operations and decisions contribute to preserving the environment, customer satisfaction, and motivating a new lifestyle. Lékué promotes the reduction of waste in the home since it produces reusable and durable products. The material has a long useful life. In addition, its manufacturing processes use technologies and practices that minimize energy consumption and reduce carbon emissions. The company is ISO 14001 certified for environmental management [6].

Lunette is a Finnish company that manufactures soft, flexible medical-grade silicone menstrual cups. The silicone used is hypoallergenic, non-porous, and free of harmful chemicals. The company offers products that are tailored to individual customer needs. This company strongly focuses on sustainability, and its effect is made from a durable and reusable material, which means it avoids waste. Lunette has suppliers and manufacturers who share ethical values, so recyclable and biodegradable materials are used within its packaging to minimize the environmental impact. The idea of this company in creating this product is to significantly reduce the waste generated by disposable menstrual hygiene products [7].

Due to the background mentioned above, currently, single-use products represent a problem to be solved since they form a large part of the pollution of our planet because they have doubled their production in the last two decades. The production of plastic causes the accumulation of waste, pollution of the sea, impact on wildlife, etc. The cutlery holder seeks to reduce the use of plastic cutlery and provide more comfort to customers. The product is manufactured from silicones, so the activities within silicone products will be presented below [8].

Manufacturing food-grade silicone involves using a unique formulation that meets safety standards. Food-grade silicone is manufactured from high-quality, high-purity silicone polymers and other ingredients. Silicone products' general extraction and manufacturing process is detailed below (Fig. 1).

Polymer production (raw material)

1. Obtaining monomers, chemical precursors, additives, and other raw materials.
2. Polymerization.
3. The processing depends on the characteristics of the desired end product.
4. Add additives.
5. Finishing and post-treatment.

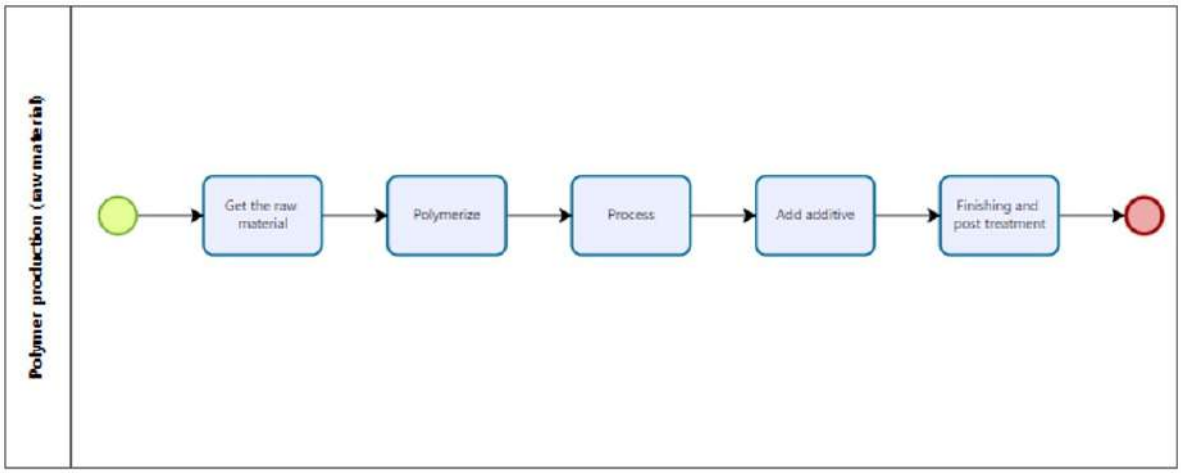

Fig. 1. Polymer production process.
Source: Own.

Within the extraction stage for the manufacture of the cutlery holder, some pollution can be generated, such as atmospheric emissions of volatile organic compounds (VOCs), wastewater containing chemical substances, solid waste, and the use of toxic chemicals.

Polymer-based silicone production

1. Selection of polymers based on quality standards.
2. Mix polymers with catalysts and additives based on the established formula.
3. Mixing and kneading to ensure components are evenly distributed.
4. The mixture undergoes a curing process, which may involve the use of heat or exposure to moisture.
5. Inspection and quality testing.

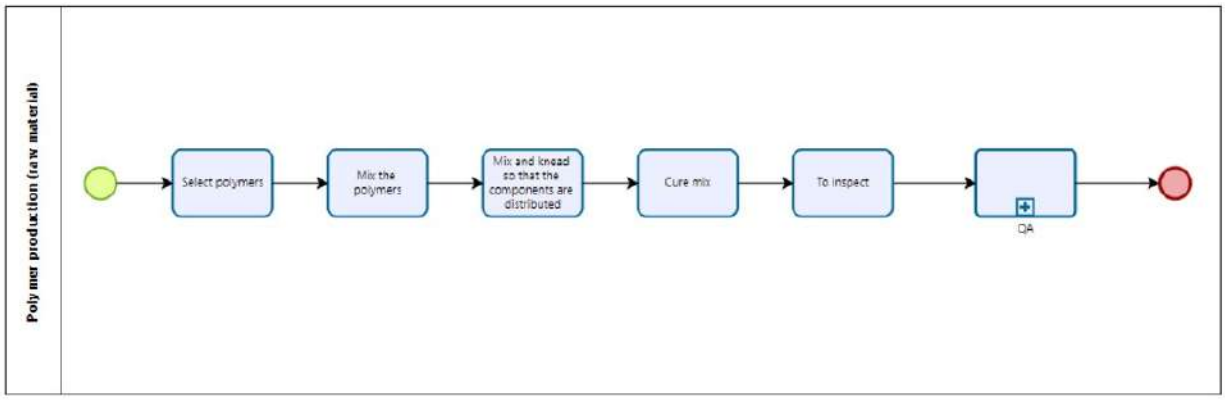

Fig. 2. Production of polymer-based silicones.
Source: Authors.

Within the production of silicones, there are potential pollution risks such as air emissions, chemical residues, and the use of hazardous chemicals.

B. Production of cutlery

Many people today decide to take food because it saves money, there is greater ease and control over the ingredients and portions consumed, and more options that eliminate the monotony when eating out. However, it is necessary to have all the elements such as napkins, cutlery, and condiments to be able food as if we were at home.

The proposal consists of a cutlery holder made of silicone that can adapt to any form of container, providing comfort, organization, and space-saving.

The elements that make up the product are the following:

1. Rectangular container with rounded edges made of silicone.
2. Adjustable snaps on the top, bottom, and sides.
3. Adjustable silicone strap.

Figures 3 and 4 show the proposed design, considering it is expected to be adaptable.

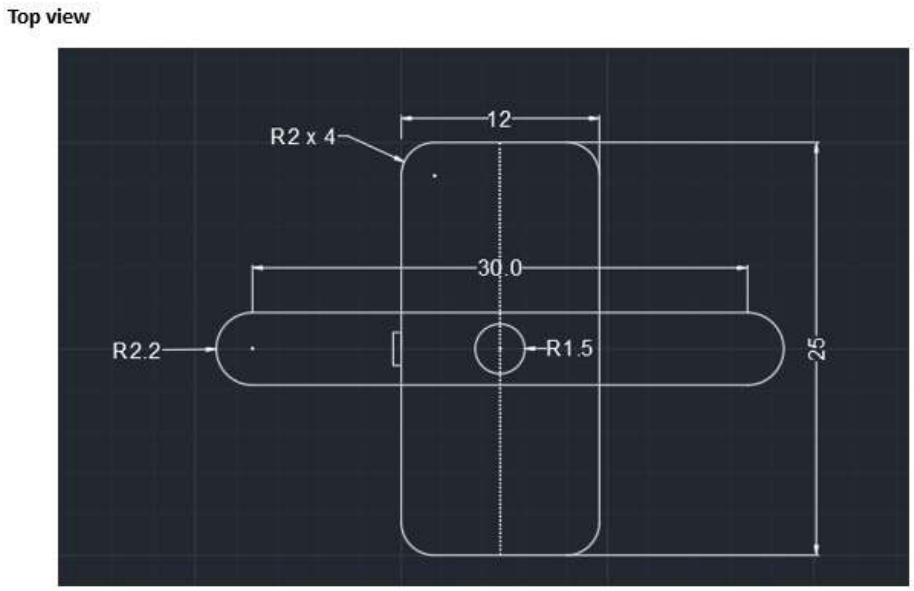

Fig. 3. Top view .
Source: Authors.

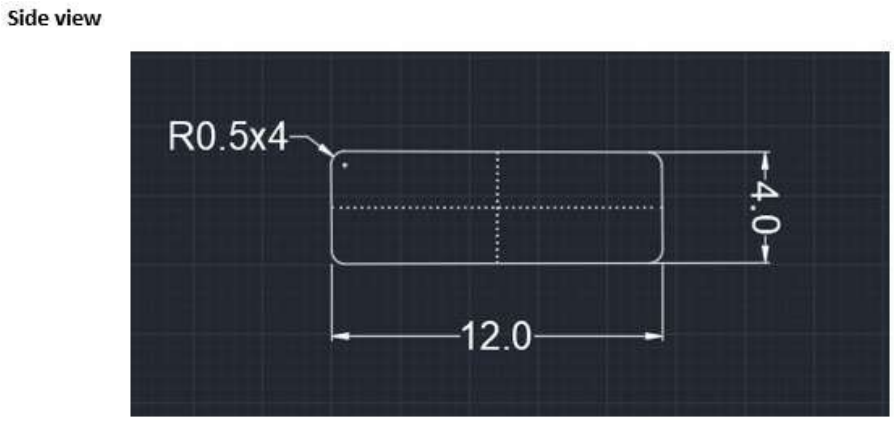

Fig. 4. Side view
Source: Authors.

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III. METHODOLOGY

Within the process of production of silicones from polymers, the stage that generates more pollution corresponds to the mixture of polymers with catalysts and additives based on the established formula; this is because the catalysts and additives that are added to the polymers contain chemical substances that impact the environment. To better understand what would be happening at this stage, we must know the functions of catalysts and additives. Catalysts are substances added in small quantities within the process, allowing silicones to harden and acquire properties; some catalysts can be platinum, tin, and titanium. Additives are substances such as plasticizers, thermal stabilizers, pigments, lubricants, and coupling agents that are added to silicones to improve or modify the characteristics of the final product.

Depending on the process, different catalysts and additives intervene. Unfortunately, some of these contain chemical substances that, when improperly treated, generate pollution, such as emissions of volatile compounds that contribute to smog formation, generate waste that does not degrade quickly in the environment, and, finally, can generate liquid effluents that can affect water and soil. This is why companies must implement sustainable and responsible production practices to minimize and control the environmental impact during this stage of the silicone production process.

Next, the flow of materials in this stage will be presented to make the corresponding P+L.

Material flow:

1. Enter polymers (granules, pellets, liquids).
2. Catalysts enter (liquid or powder).
3. Additives (liquid or powder) enter.
4. Enter water.
5. A mixing process occurs where the components are agitated to ensure even distribution.
6. A kneading process occurs where it is mixed more intensively and extensively to ensure the uniform distribution of the components.
7. A mixture of polymers, additives, and catalysts comes out.

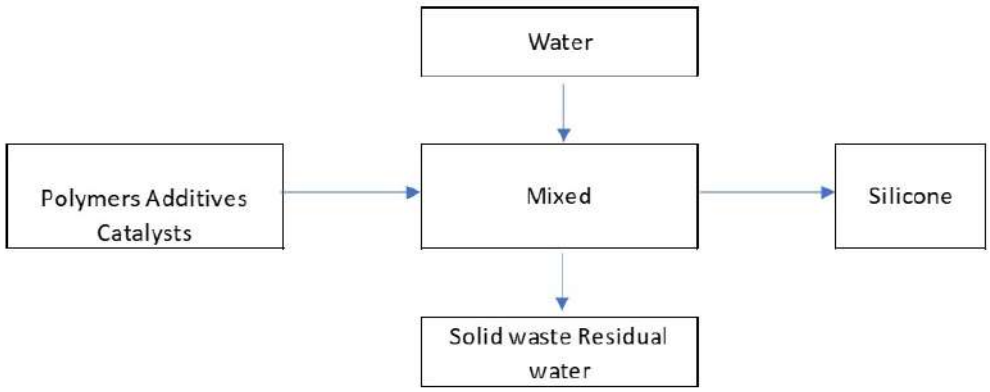

Fig. 5. Critical Process Material Flow Diagram
Source: Own.

Flow balance

To create the cleanest production plan, the flow balance was made based on the most critical operation corresponding to the polymer mixture (Table 1).

Table 1. Analysis of flow in critical operation.

Units	unit weight	unit	silicone to use	unit
500000	0,05	kg	25000	kg
use of raw materials for the production of 50,000 units				
polymer	60%	15000,0	kg	-
Water	30%	7500	7,5	m^3
additive to	3%	625,0	kg	-
additive B	3%	625,0	kg	-
catalyst A	3%	625,0	kg	-
Catalyst B	3%	625,0	kg	-

Table 2 shows the elements considered in the process input, considering the quantity and units of work.

Table 2. Process input materials.

Entrance

No.	Material	amount	Unit	C specific	full C	% Final product
1	polymer	15000	kg	$ 18,00	$270.00	59%
2	Water	8	m^3	$ 0.72	$ 5.4	17%
3	additive to	625	kg	$ 25,00	$390.63	1%
4	additive B	625	kg	$1.04	$26	1%
5	catalyst A	625	kg	$ 11,00	$6.88	1%
6	catalyst B	625	kg	$ 22,00	$13.75	1%

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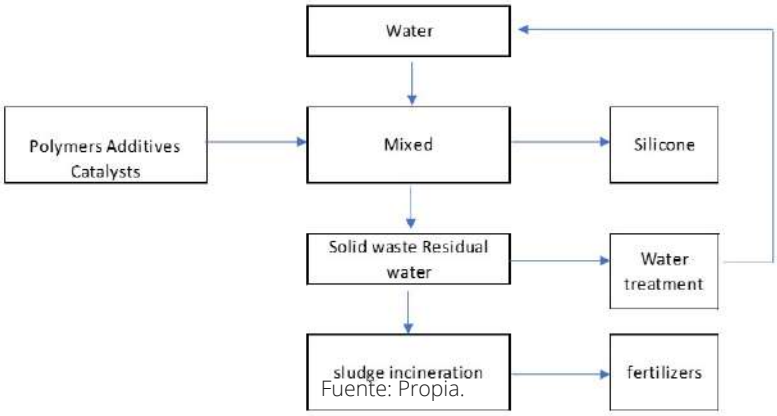

Fuente: Propia.

Fig. 6. Critical Process Material Flow Diagram
Source: Own.

With the addition of the water treatment plant and sludge incineration furnace, the following associated flow balance is obtained when the cleaner production plan has already been implemented.

IV. RESULTS

Table 3 shows the waste before the cleaner production plan. Again, it can be seen that there is significant waste in the water used in the process.

Table. 3. Problems and challenges for the development of technologies.

No.	Material	amount	Unit	C specific	full C	Total income (%)
2	Water	1	m^3	$ 0.72	$ 0.72	**13,3%**
3	polymer	200	kg	$ 18,00	$ 3,600	1,3%
4	additives	50	kg	$ 25,00	$ 12,50	4,0%
5	Catalyst	60	kg	$ 22,00	$4	4,8%

Table 4 shows the corresponding data once the cleaner production plan has been applied, and a significant change in water waste can be noted, which has been reduced by up to 6.7%. This value differs from the previous one by 51.53%, which indicates a considerable reduction with the cleaner production plan.

Table. 4. Waste after the cleaner production plan.

No.	Material	amount	Unit	C specific	full C	Total income (%)
2	Water	0,50	m^3	$ 0.72	$ 0.36	**6,7%**
3	polymer	200	kg	$ 18,00	$ 3,600	1,3%
4	additives	50	kg	$ 25,00	$ 12,50	4%
5	Catalyst	60	kg	$ 22,00	$4	5%

Additionally, the incineration of sludge with pollutants such as additives, catalysts, and polymers generates solid waste that acts as fertilizing agents suitable for agricultural use. In this way, the opportunity to generate income from selling these fertilizers to different companies is opened.

Figure 7 shows the relationship before and after applying the cleaner production plan, and the significant change in water waste can be noted.

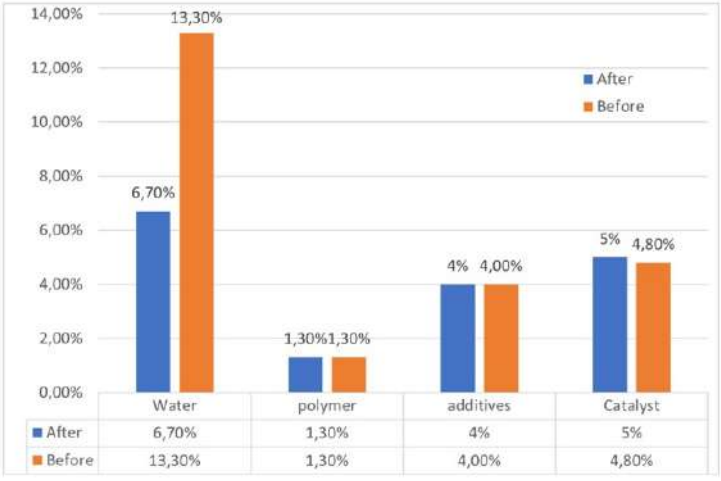

Fig. 7. Relationship before and after applying the cleanest production plan.
Source: Authors.

A. Economic analysis of investment

The equipment and implements necessary for implementing the cleaner production plan are presented below. Table 5 shows the most significant costs of the investment.

Table. 5. Investment of plant and furnace.

Investment in treatment plant and furnace	
investment	$ -500,000
interest	15%
Periods	5

When analyzing the net present value of the investment with a loan to the bank with an interest rate of 15% over a period of 5 years, a matter of one million two hundred and thirty-nine thousand one hundred and eighty-five dollars is obtained with an internal rate of return of 34% which infers that the investment means a viable project in which the company will get economic benefits in the reduction of the cost of production and sale of a new product obtained from waste and above all will reduce the environmental impact of its operations.

CONCLUSIONS

The analysis of the budget and the losses that occur during our production allows us to understand if there is viability to apply a cleaner production plan, so we can say that within our organization, a more pristine production plan can be used to reduce the waste of water and solid waste by implementing strategies that reflect the environmental commitment that is had in the production of our product.

Thanks to the detailed analysis that was carried out, it was possible to identify areas for improvement, which facilitates us to have better financial planning, greater control, informed decision-making, and effective communication, in addition to which it should be noted that the profitability and efficiency of our production process are improved.

The study carried out in this work gives us an understanding of the importance of understanding the processes and bonds of our company since, thanks to this. We can have comprehensive control concerning the risks that may arise in the company. It is essential to recognize that implementing a P + L allows us to grow the company, and that is maintained over time. It also positions us financially.

Being a sustainable company and applying a cleaner production plan opens the doors to new markets and customers. Furthermore, since it is currently valued that businesses are committed to sustainability, the realization of a project is innovative since it puts the company in a position to seek improvements and strategies.

By reducing water waste by 50% in our process, we contribute to the environment, which shows the concern that all companies must have for wanting to make a difference and support the fulfillment of objectives necessary to preserve our planet.

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