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Study of cologne production process and improvement proposals to increase the production capacity.

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There are three classes of people: those who see, those who see when they are shown and those who do not see.

Leonardo da Vinci

Primero de todo, agradecer a la Dra. Esther Chamarro y Xènia Costa, tutoras del trabajo de fin de grado, por ayudarme a realizar el proyecto con toda la dedicación que ha supuesto. Agradecer también al Dr. Manuel Vicente todo el tiempo y la ayuda proporcionada, aún sin ser mi tutor. Por último, agradecer a todas las personas cercanas por el apoyo recibido en todo momento.

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SUMMARY

Air-Val International is a familiar enterprise which is dedicate to the design and production of care-products such as hand-creams, cosmetics, colognes and perfumes. In this project the cologne production of Air-Val International both in the field of organization and production process has been studied.

The enterprise works a total of 230 days (2530 h) and the studied products are divided in two main families:

- EDT (Eau de Toilette) child: 165 references
- EDT adult: 81 references

The difference between the two families resides in the maceration process. This activity in the production process is only required in EDT adult due to its higher quantity of essence and the importance of having the cologne stabilized.

The timing of each production activity in a 2000 L batch size cologne has been experimentally measured. With the results, the batch time obtained is 240 minutes for an EDT child (the same as occupation time) and an occupation time of 180 min for an EDT adult (without the 6600 minutes of maceration). The equipment that limits the time in the cologne production process are the mixer vessel for an EDT child and the maceration vessels in the case of an EDT adult.

As the enterprise works with more than 70 different batch sizes, depending on the orders, a classification of sixteen subgroups has been proposed, in order to find a series of functions that allow to calculate the batch time for each of those.

Once obtained the functions and calculated the batch time for each batch size, it has been theoretically calculated the total time required to cover de demand. Once performed this study, it can be seen that with the current situation in which the enterprise works by campaigns, there are delays in the production planification.

- Summer season: June (88 batches, 110 000 L of cologne), July (88 batches, 140 000 L of cologne).
- Autumn season: February (50 batches, 74 000 L of cologne), April (50 batches, 68 000 L of cologne).

To solve the problem an improvement in the organization and the methodology of work, which consists in the overlap of some stages in the production process, has been proposed. This offers a decrease in the total production time of 10 %.

Moreover, the current production process, which consists of a single mixer vessel, has been studied. As the interval of the batch sizes is between 100 – 3300 L, there are some situations in which the stirring mechanism of the actual mixer vessel (DEM 3000) does not work properly. For this reason, an investment proposal for a new mixer vessel with enough capacities to complement the former vessel has been made. The main improvement will be found in the production of batch sizes smaller than 1000 L, in which the current vessel has stirring issues. The new vessel will have a total volume of 1170 L (1.36 m height and 1.15 m of diameter), build with stainless steel AISI 304 and covered with stainless steel AISI 316L for the areas exposed directly to contact with the product. The stirring mechanism is formed by a double blade mixer (semi-anchor and TRIVAK) with a mixing power of 0.75 kW and two deflectors to improve the mixing of the product.

Additionally, the pumps needed for the transfer of the colognes and raw materials have been selected.

Finally, a PID (Pipes and instrumentation diagram) has been design in order to represent in a visual form the production process with the improvement proposals both for EDT child and EDT adult production.

Keywords: **Eau de Toleitte, maceration, production capacity, production by seasons, mixer vessel.**

RESUMEN

Air-Val International es una empresa familiar dedicada al diseño y producción de productos para el cuidado personal tales como crema de manos, cosméticos, colonias, perfumes, etc. En este trabajo se ha estudiado la producción de colonias de Air- Val International tanto en el ámbito organizativo como en el proceso de producción.

La empresa trabaja un total de 230 días (2530 h) y en referencia a los productos estudiados se encuentran dos familias:

- EDT (Eau de Toilette) infantil:165 referencias
- EDT Adulto: 81 referencias

La diferencia entre las dos familias reside en la maceración. Esta actividad del proceso de producción solo se da en las EDT Adulto debido a su mayor cantidad de esencia y la importancia de tener una colonia estabilizada.

Se han medido experimentalmente los tiempos de cada actividad de la producción de un lote de 2000 L. Con ellos, se ha obtenido un tiempo de lote de 240 minutos para una EDT infantil (que concuerda con el tiempo de ocupación del mezclador) y un tiempo de ocupación del depósito mezclador de 180 min para una EDT adulto (en este último caso no se incluyen los 6600 minutos de la maceración). Los equipos que limitan el tiempo del proceso de producción de colonia son el depósito mezclador para el caso de las EDT infantil y los depósitos de maceración para el caso de las EDT adulto.

Como la empresa trabaja con más de 70 volúmenes de lote diferentes, dependiendo de los pedidos a realizar, se ha propuesto una clasificación en 16 subgrupos con tal de encontrar una serie de funciones que permitan calcular el tiempo de producción para cada uno de ellos.

Una vez obtenidas las funciones y calculado el tiempo de producción de cada volumen de lote, se ha calculado teóricamente el tiempo total requerido para cubrir la demanda. Una vez realizado el estudio, se puede ver que con la situación actual en la que la empresa trabaja por campañas, hay demoras en los plazos de producción:

- Temporada de verano: junio (88 lotes, 110 000 L de colonia), julio (88 lotes, 140 000 L de colonia)
- Temporada de otoño: febrero (50 lotes, 74 000 L de colonia), abril (50 lotes, 68 000 L de colonia).

Para solventar el problema se ha propuesto una mejora organizativa y de la metodología de trabajo, que consiste en el solapamiento de algunas etapas del proceso de producción, que ofrece una disminución del tiempo total de producción de un 10 %.

A parte, se ha estudiado el método de producción actual, el cual consiste en un solo depósito mezclador. Como el rango de tamaños de lote es entre 100 – 3300 L en ocasiones el sistema de agitación del depósito DEM 3000 no funciona adecuadamente. Por esta razón, se ha realizado una propuesta de inversión en un equipo nuevo (depósito mezclador) con capacidades para complementar el primer depósito. La principal mejora es en la producción de volúmenes de lote más pequeños de 1000 L, en los cuales el depósito actual tiene problemas de agitación. El nuevo depósito contará con un volumen total de 1170 L (altura de 1.36 m y diámetro de 1.15 m), construido en acero inoxidable AISI 304 y recubierto con acero inoxidable AISI 316L para las zonas expuestas al contacto con el producto. El sistema de agitación contará con un agitador de doble pala (semi-áncora y TRIVAK) con una potencia de 0.75 kW junto a 2 placas deflectoras para mejorar la mezcla del producto.

Asimismo, se han seleccionado las bombas necesarias para realizar el trasvase de las colonias, materias primas, etc.

Por último, se ha diseñado un diagrama de implementación y tuberías (PID) para representar de forma visual el proceso con las propuestas planteadas diferenciando entre producción de EDT infantil y EDT adulto.

Palabras clave: Eau de Toleitte, maceración, capacidad de producción, producción por campañas, depósito de mezcla.

1. INTRODUCTION

1.1 COMPANY OUTLINE

Air-Val International is a family business founded in Barcelona, in 1979. Its main potential is the manufacturing of colognes, perfumes, hand creams and body lotions among other care products.

It was in 1980 when Air-Val International received Disney license for manufacturing its colognes and perfumes.

This situation eased the way to obtain more licenses at the same time that Air-Val International kept growing. Accompanied by the creation of Tailored Perfumes, allowing the business to expand the production and to obtain more licenses like “Fútbol Club Barcelona”, “Real Madrid”, “Mango”, “Pedro del Hierro”, “Corte Fiel”, and “Women’s Secret”, among others.

Nowadays, it exports about 65% of its total production to more than 75 countries around the world, especially to Europe (France, Italy, Estonia, Holland, Sweden…) but also to the United States, Latin America, etc.

Air-Val International has offices in Dubai, Miami and Florence but the headquarter, where all the products are produced and distributed, is settled in Gavà, a city of Catalunya.

Figure 1: Air-Val International, Gavá (photo: www.air-val.com, April 2020)

The factory is divided in 3 areas, the fabrication area, the production area and the warehouse. The fabrication area is where this project is focused because it is where colognes and perfumes are manufactured.

The main manufactured and commercialised products by Air-Val International are:

- Gel
- After-Shaves
- Colognes
- Perfumes
- Body lotions
- Hand creams

However, this project is focused on colognes and perfumes, so the main types manufactured in the plant are:

- EDT (“Eau de toilette”) (for men and women)
- EDT for children
- EDP (“Eau de perfume”) (For men and women)

Production process inside each group could be affected because of essence requirements.

Figure 2: Example of one EDT: Child (photo: www.air-val.com, April 2020)

1.2 PRODUCTION OF "EAU DE TOILETTE" AND "EAU DE PERFUME"

The main difference between cologne and perfume is the quantity of essence it contains. Usually, cologne is around 5-8% whereas perfume contains 30% of its volume.

Therefore, a noticeable difference between intense perfume scent and soft cologne odour exists. Furthermore, perfume scent duration last longer than colognes.

1.2.1 Raw materials

The main raw materials used while manufacturing the aforementioned products are:

- Distillate water
- Alcohol
- Essence (one different for each cologne and perfume)

Complementary products[1]:

- Antifoaming agents: To reduce and hinder the formation of foam in liquids.
- Solubilizing agents: To help in the dissolution of a solute increasing its solubility constant. (Some raw materials are not very soluble).
- Emollients: To soften the texture of the products.
- Absorbents: To take up water or some remaining dispersed substances
- UV radiation filters: To provide protection against UV radiation.
- Moistening agents: To enhance hydrating ability.
- Disinfectants: To inactivate or destroy possible residual microorganisms or inert substances that could remain somewhere.
- Antioxidants: To help stabilize essences which are likely to be oxidised. Oxidation in essence can cause colour and smell changing.
- Preserving agents (stabilizers): Like antioxidants, they help stabilizing essences to prevent changes in its composition.

[1] Not all complementary raw materials are used in every cologne or perfume.

Altogether, Air-Val International has 20 types of products (12 EDT's for adults and 8 EDT for children) in which each one has its own formula based on combining the required substances.

This depends of the essence used because some are very unstable substances and require specific products to remain steady.

Table 1. Example of raw materials requirements for an EDT: Adult

Example of EDT: Adult	
Raw Materials	Quantity [%]
Alcohol	80
Water	11
Essence	8,5
Antioxidant	0,002
Preserving agents	0,008
UV readiaton filters	0,49

Table 2. Example of raw materials requirements for an EDT: Child

Example of EDT: Children	
Raw Materials	Quantity [%]
Alcohol	73
Water	18
Essence	8,5
Solubilizing agents	0,002

1.2.2 **Manufacturing process**

The production process is summarized in the following diagram:

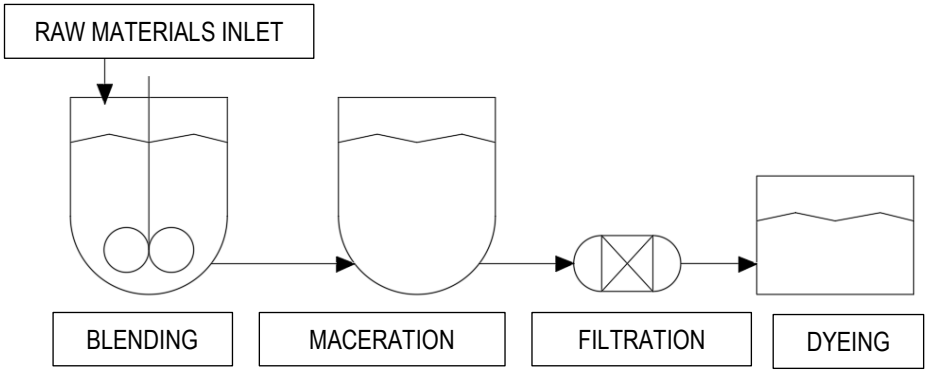


Figure 3: Basic diagram of the process.

Perfume and cologne production method is quite harder than it seems. Basically, it consists on blending alcohol, water and essences. But essences are complex substances.

First, alcohol is charged in vessels with stirring mechanisms. It usually is the main component of the blend (around 60-80% volume). Straightaway, essence is added. Stability of this substance can be affected many times by an oxidation. As mentioned before, this can cause changes in its properties such as colour changing or smell loss.

In order to solve this problem and to keep the initial properties steady preservative, sun block and antioxidants products among other ones must be added. Once homogenized, water must be charged. After stirring for a few minutes, when cologne has been done, it is the turn of maceration.

Maceration is a liquid-solid extraction process which acquires this name when foodstuff and plants among other human consumption products take part of it. In this case, after the blend has been produced, it is sent to maceration vessels where the product acquires all the organoleptic properties which finally define and differentiate it from all the other products.

Maceration lasts two weeks and it is only necessary in the case of producing an EDT/EDP for adult because of the major quantity of essence in the cologne. Also, in the first settlement days, the cologne can be oxidized altering its colour towards a yellow tone. This avoids that once the dye is applied the cologne changes its original colour over time. After maceration, it is the turn of filtration.

This separating process allows to clear possible contaminants carried by essences. Finally, the cologne is dyed on IBCs (Intermediate Bulk Container). Usually there are no reference values for dyeing, so it is up to the operator the quality of the colour. The manufacturing process its different depending of the type, EDT child or EDT adult. The difference lies on the maceration process, because in only carried out in EDT adults and it lasts two weeks. At the end of the process, before dyeing is applied both in EDT adult and EDT child, they have to go through a filtering process in order to eliminate possible solid rests from the essence, among other foreign bodies.

The fabrication area has mixer, maceration and storing vessels and the filtering equipment listed:

Mixing vessels:

- DEM 3000: 3300 L
- Movable mixing vessel: 700 L

Maceration vessels:

- 6 vessels of 800 L
- 15 vessels of 1000 L
- 11 vessels of 2500 L
- 5 vessels of 5500 L

Storing vessels:

- IBCs. These vessels are used in the cologne dyeing process to transfer it to the packaging area after.

Filtering equipment:

- Adsorption filter compounded by cellulose and resins (it contains also a secondary inorganic filter.

1.3 JUSTIFICATION OF THE PROJECT

Over the evolution of an enterprise, there are some situations which oblige to conduct changes related to the initial project. These changes could be:

- Renewing equipment in bad conditions
- Implementing equipment due to new projects requirements
- Renew/implementing new equipment or redistributing some processes due to the enterprise's path (new products, new characteristics, changes in the demand, etc.)

Due to the demand, which is organized in seasons, the timing of the delivery cannot be accomplished and there might be delays. The aim of this project is to solve the current situation. In order to do so, it is necessary to propose a group of measures for an improvement in the organization of the production process and methodology of work, aside from investment proposals to get new equipment.

2. OBJECTIVES

As mentioned before, the aim of the project is to propose and establish a group of measures to increase the production capacity of the enterprise with organization improvements in production, methodology of work and productivity of cologne. To achieve this aim, the project is divided into different subobjectives:

- To conduct an analysis of the production process
- Determine experimentally the activities' timing, occupation time (OT) and batch time (BT) for a 2000 L batch size.
- Establish variation batch time functions according to its batch size in order to calculate the total production time required.
- Implement the methodological improvements in production and planification needed during the production process to avoid delays in the delivery of the orders.
- Propose an implementation of a new mixer vessel to improve the quality of the blend and the productivity of the plant on the one side, and the security of the operators' work on the other side.

3. CURRENT SITUATION

5.1 ANNUAL PRODUCTION OF 2019

In order to study the 2019 colognes and perfumes production all the necessary information related to the monthly litres produced along with monthly number of batches achieved has been compiled. It could happen that not all the batches are made with maximum vessel capacity. As a result, there are some months with less production than others, but with more batches.

This factor depends on the variety of the manufactured references (different colognes and perfumes) and quantity produced of each one. There is a total of 165 references for EDT (children) and 81 references for EDT/EDP (adult). Figure 4 shows monthly batch and cologne production.

In order to get an annual view:

For EDT/EDP Adult

- Batch production: 225
- Cologne production: 392 300 L

For EDT Children:

- Batch production: 540
- Cologne production: 720 500 L

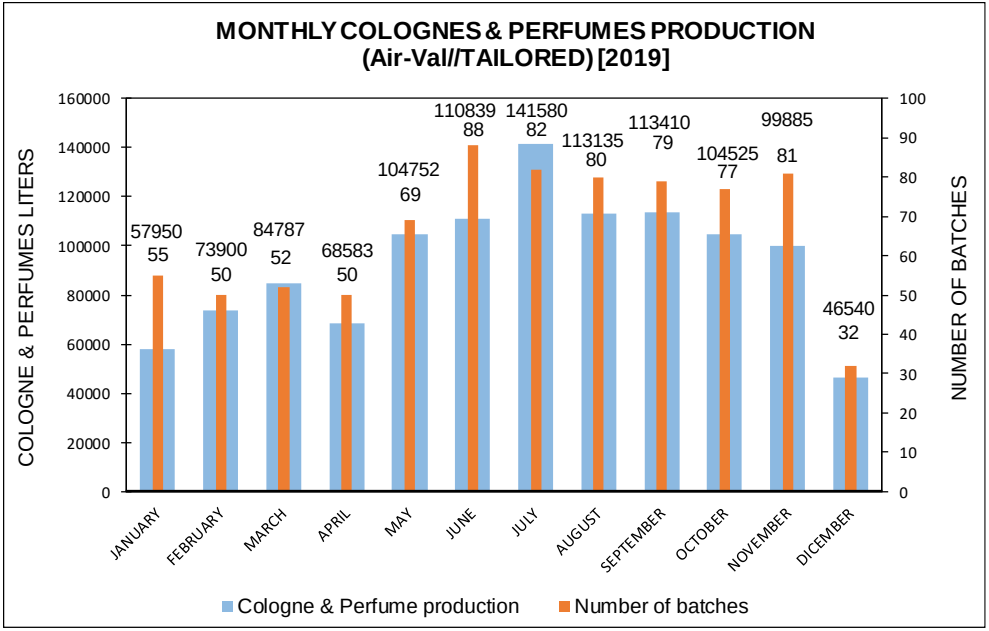


Figure 4: Monthly cologne production and quantity of batches in 2019

As it can be seen in Figure 4 (Table 15 and 16 in APPENDIX 1) maximum batches are made in November, but the major quantity of litres is gathered in July. Regarding data exposed, it can be confirmed that a close and difficult relation between batches and total volume manufactured exists because the demand depends on seasons.

Some seasons require a large quantity of a few different colognes, so the maximum capacity of DEM 3000 is needed while the total batches done are less than other months. On the other hand, there are some months where the enterprise needs to produce a large variety of products with a lower quantity demand.

Therefore, in order to success at completing the season and covering maximum necessity production there are two elements to keep in mind through the year.

- Cologne production capacity
- Batch time capacity

5.2 FORECAST PRODUCTION

Analysing annual production data in 2019 and according to the marketing department, there will be an evolution of around 7 % due to the enterprise growth. This production increment will be considering there are no changes in the product mix of 2019.

For 2020:

EDT/EDP Adult:

- Batch production: 270
- Cologne production: 420 000 L

EDT Children:

- Batch production: 580
- Cologne production: 770 000 L

For 2021:

EDT/EDP Adult:

- Batch production: 290
- Cologne production: 450 000 L

EDT Children:

- Batch production: 620
- Cologne production: 820 000 L

4. BATCH TIME STUDY

One of the most important parameters in the production process is the time needed to complete one batch. Depending on the maximum batches attainable per working day, monthly production will be affected.

In order to conduct the study, this following enterprise information is required:

- Working days per year: 230
- Working days per week: 5
- Working day journey: 11 hours

There are two journeys: the first one from 7:00h to 15:00h, and the second one from 8:00h to 18:00h with a break between 13:00h and 15:00h.

- Annual production time: 2530 hours

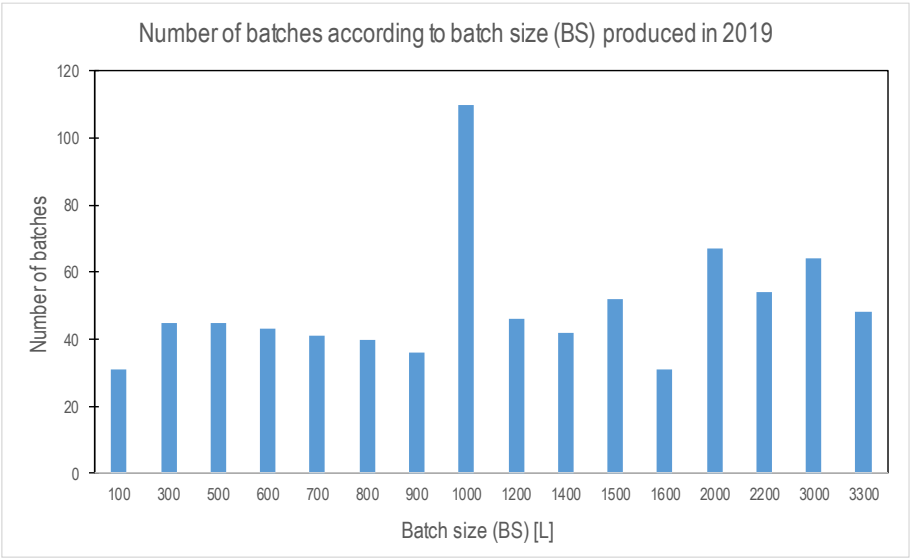


Figure 5: Classification of batch sizes by frequency

Throughout the year, many different batch sizes are produced. According to production department data, around 70 different BS are produced every year due to different demand of products, annual trade shows, etc.

Conduct a study with 70 different BS registered is so elaborated. But focusing in data recorded it can be seen some of the different BS are produced less than 10 times per year. This allow gather some different ones together. Owing to this surmise only 16 groups remain, easing so the study.

Evidently every surmise done accumulate an error. In order to prove the surmise used, the margin of error taken has to be less than 3% of reality deviation (Table 17 in APPENDIX 1).

In order to conduct an analysis of the batch time required to produce each one of the different batch sizes, the fabrication of an EDT child of 2000 L has been analysed in Table 3 and Figure 6. Once analysed all the activities developed in the production of a batch, they can be classified into two types.

For an EDT child:

Constant time activities: Are those activities that, independently of the batch size, batch time does not vary in a significant way:

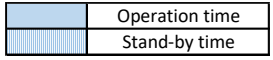
- Raw materials preparation
- Raw materials charge (60%)
- Stirring time
- Quality affairs
- Vessel cleaning
- Dyeing

Variable time activities: Are those activities that, depending of the batch size, they will have different duration.

- First filling of alcohol
- Raw materials charge (40%)
- Water inlet
- Second filling of alcohol
- Filling the IBC

Table 3: List of activities for producing a 2000 L EDT Child cologne

EDT CHILD: BS = 2000 L				
EQUIPMENT	**Activity**	**Start**	**End**	**Time [min]**
DEM 3000	**1. Production of the cologne**	**0**	**120**	**120**
	1. 1. Raw materiales preparation	0	15	15
	1. 2. First filling of alcohol	15	35	20
	1. 3. Raw materials inlet	35	80	45
	1. 4. Stirring time	35	120	85
	1. 5. Second filling of alcohol	80	90	10
	1. 6. Water inlet	100	110	10
	2. Quality affairs	**120**	**135**	**15**
	2. 1. Laboratory verification	120	130	10
	2. 2. Realization of report	130	135	5
	3. Vessel discharge	**135**	**195**	**60**
	4. Cleaning the vessel	**225**	**240**	**15**
FILTER	**5. Filtering**	**135**	**195**	**60**
IBC 01	**6.**	**135**	**210**	**75**
	6. 1. Filling the "IBC"	**135**	**165**	**30**
	6. 2. Dyeing the IBC	**195**	**210**	**15**
IBC 02	**7.**	**165**	**225**	**60**
	7. 1. Filling the IBC	**165**	**195**	**30**
	7. 2. Dyeing the IBC	**210**	**225**	**15**



Time [min]	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225
Equipment 1: VESSEL "DEM 3000"	195														15
Equipment 2: Filter									60						
Equipment 3: IBC 1000									30				15		
Equipment 4: IBC 1000											30			15	

Figure 6: Production time of the whole process

For an EDT adult:

Constant time activities:

- Raw materials preparation
- Raw materials charge (60%)
- Stirring time
- Quality affairs
- Vessel cleaning
- Maceration
- Dyeing

Variable time activities:

- First filling of alcohol
- Raw materials charge (40%)
- Water inlet
- Second filling of alcohol
- Transfer of the cologne to the maceration vessels
- Filling the IBC

The only variable not considered in the previous classification is the number of 1000 L IBCs used in each case. The production rank comprehends a quantity between 100 – 3300 L.

According to the data aforementioned the study has been divided in four options:

- Batch of 1000 L (For volumes between 0 – 1000 L, 1 IBC)
- Batch of 2000 L (For volumes between 1001 – 2000 L, 2 IBC)
- Batch of 3000 L (For volumes between 2001 – 3000 L, 3 IBC)
- Batch of 4000 L (For volumes between 3001 – 4000 L, 4 IBC)

The resulting functions[2] for the batch time calculation depending on the batch size (EDT child):

Table 4. Resulting functions for the calculation of the batch time of an EDT child

Application range	Functions
Entre 0 – 1000 L, 1 IBC	BT = 107 + 0.0590 · BS
Entre 1001 – 2000 L, 2 IBC	BT = 122 + 0.0590 · BS
Entre 2001 – 3000 L, 3 IBC	BT = 137 + 0.0590 · BS
Entre 3001 – 4000 L, 4 IBC	BT = 152 + 0.0590 · BS

The resulting functions for the batch time calculation depending on the batch size (EDT adult):

Table 5. Resulting functions for the calculation of the batch time of an EDT adult

Application range	Functions
Entre 0 – 1000 L	BT = (92 + 0.0440 · BS) + (15 + 0.0300 · BS)
Entre 1001 – 2000 L	BT = (92 + 0.0440 · BS) + (30 + 0.0300 · BS)
Entre 2001 – 3000 L	BT = (92 + 0.0440 · BS) + (45 + 0.0300 · BS)
Entre 3001 – 4000 L	BT = (92 + 0.0440 · BS) + (60 + 0.0300 · BS)

[2] The variation of variable time activities has been considered lineal.

The batch time functions for an EDT adult are not the total batch time as it does not consider the maceration time. In them, it is only represented the occupation time of the vessel (OT) and the filtering + dyeing time (DT).

With the batch time functions for each batch size, the production time needed to cover the 2019 requirements can be theoretically calculated (see Table 6).

- Total production time: 2445 h

The production time needed is very close to the available annual production time (2530 h). As it can be seen in Figure 4, in the months of June and July, 88 and 82 batches are produced respectively. However, in the first months of the year, the number of batches produced is around 50. This is because, as aforementioned, the demand is seasonal.

In the months where the number of batches produced is higher, is difficult to cover all the demand.

If the same study is conducted for years 2020 and 2021:

- Total production time (2020): 2560 h
- Total production time (2021): 2715 h

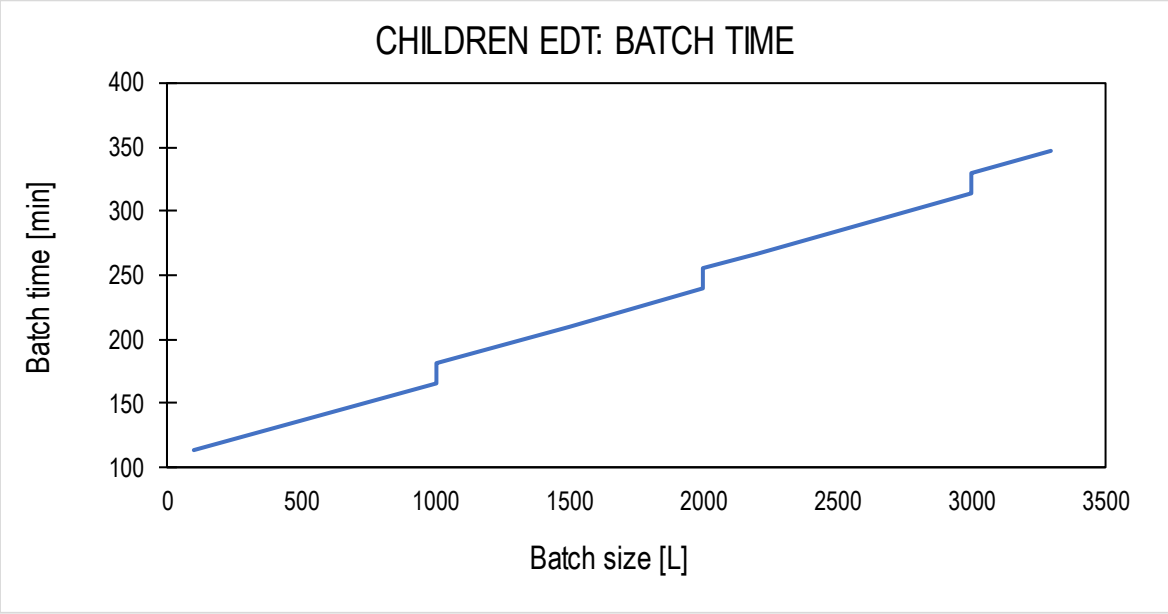


Figure 7: Batch time required for each batch size

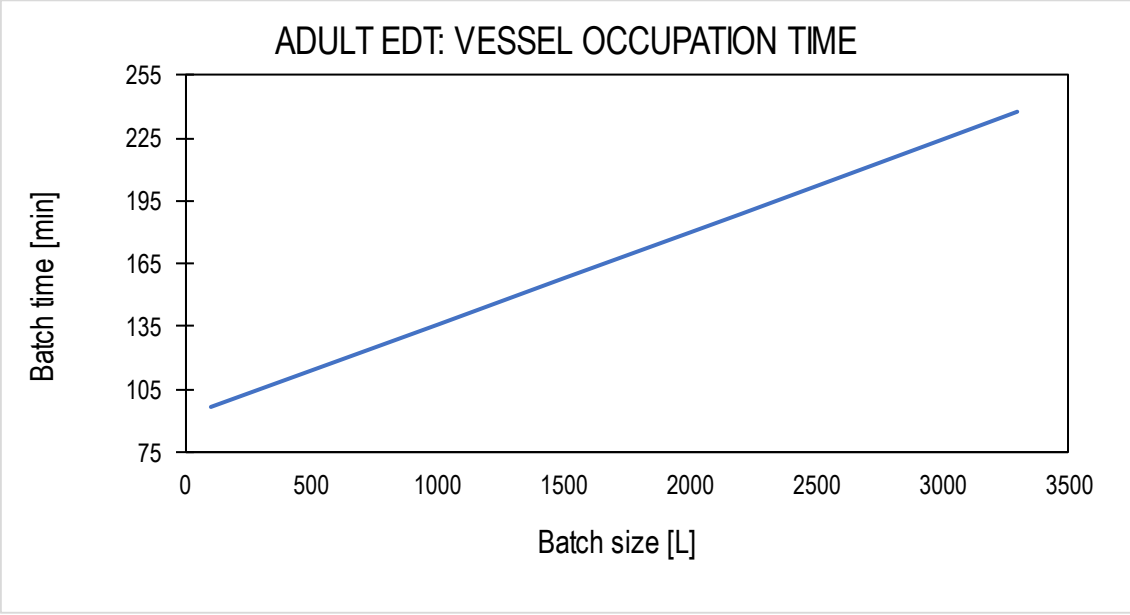


Figure 8: Vessel occupation time required for each batch size

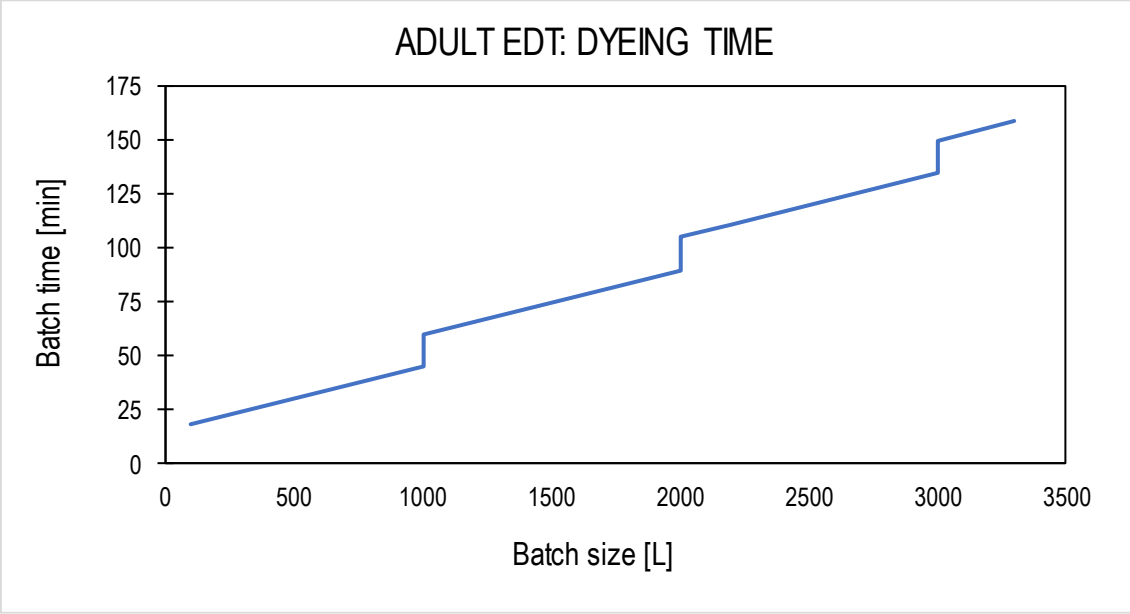


Figure 9: Dyeing time required for each batch size

Table 6: Batch time required for each batch size (EDT Child and EDT Adult)

CHILDREN EDT					ADULT EDT/EDP				
BS [L]	**n. Batch/year**	**Prod. [L]**	**BT [min]**	**BT [h]**	**n. Batch/year**	**Prod. [L]**	**OT [min]**	**DT [min]**	**BT [h]**
100	20	2000	112,9	37,6	11	1100	96,4	18	17,7
300	31	9300	124,7	64,4	14	4200	105,2	24	24,5
500	34	17 000	136,5	77,4	11	5500	114,0	30	20,9
600	30	18 000	142,4	71,2	13	7800	118,4	33	25,7
700	31	21 700	148,3	76,6	10	7000	122,8	36	20,5
800	30	24 000	154,2	77,1	10	8000	127,2	39	21,2
900	31	27 900	160,1	82,7	5	4500	131,6	42	11,0
1000	74	74 000	166,0	204,7	36	36 000	136,0	45	81,6
1200	28	33 600	192,8	90,0	18	21 600	144,8	66	43,4
1400	31	43 400	204,6	105,7	11	15 400	153,6	72	28,2
1500	36	54 000	210,5	126,3	16	24 000	158,0	75	42,1
1600	27	43 200	216,4	97,4	4	6400	162,4	78	10,8
2000	38	76 000	240,0	152,0	29	58 000	180,0	90	87,0
2200	34	74 800	266,8	151,2	20	44 000	188,8	111	62,9
3000	43	129 000	314,0	225,0	21	63 000	224,0	135	78,4
3300	22	72 600	346,7	127,1	26	85 800	237,2	159	102,8
Total	**540**	**720 500**		**1766,5**	**255**	**392 300**			**678,7**

The study conducted previously, is based on the surmise that maceration is not a limiting process in batch time. If at any point, all maceration vessels were full and there was not the option to transfer an EDT adult to maceration, even though the DEM 3000 was free, there could not be the possibility to produce more batches.

To prove that maceration is not a limiting activity, a monthly study of all batch sizes compared to the total maceration vessels available has been conducted (see equipment list in section 1.2.2.).

In a working month a same vessel can produce 2 macerations, that is to say, the number of batches that it can macerate are:

- 12 batches of 800 L
- 30 batches of 1000 L
- 22 batches of 2500 L
- 10 batches of 5500 L

In Figures 11, 12 and 13, global annual occupation of the maceration vessels gathered in 4 groups (800 L, 1000 L, 2500 L and 5500 L) is represented.

In any of them, it can be seen that the maceration capacity is over the required. Therefore, there would not be any issue when considering maceration as not a limiting activity.

Even so, as seen in Figure 10, the quantity of 800 L batch size produced in 2019 (also applicable to 2020 and 2021), is equal to the maximum number of batches that can be macerated. If at any point, all the 800 L maceration vessels were full, the 1000 L maceration vessels should be used instead (knowing that a 200 L dead volume would be left).

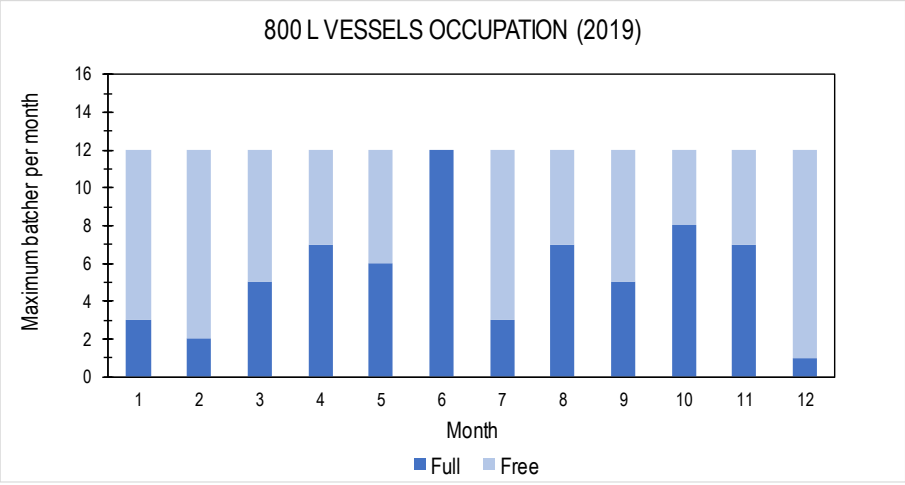


Figure 10: Vessel occupation on maceration process in 2019

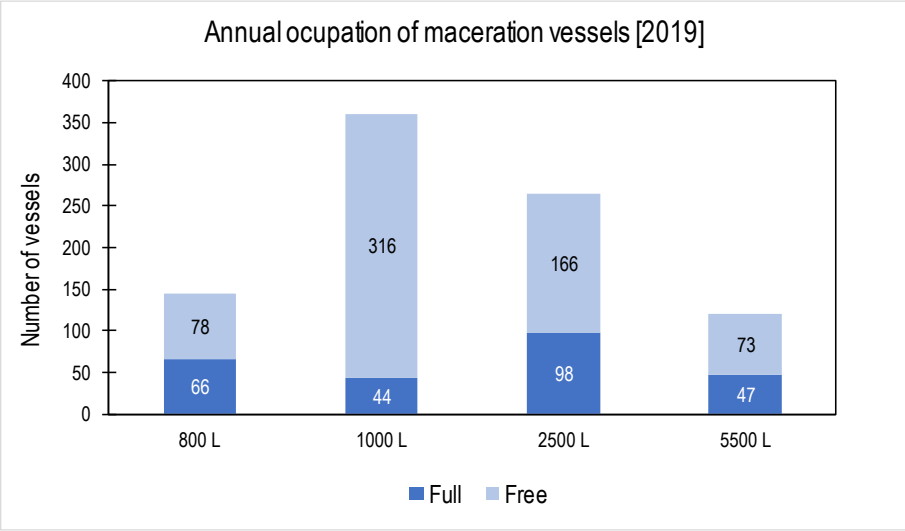


Figure 11: Annual occupation of vessels on maceration process in 2019

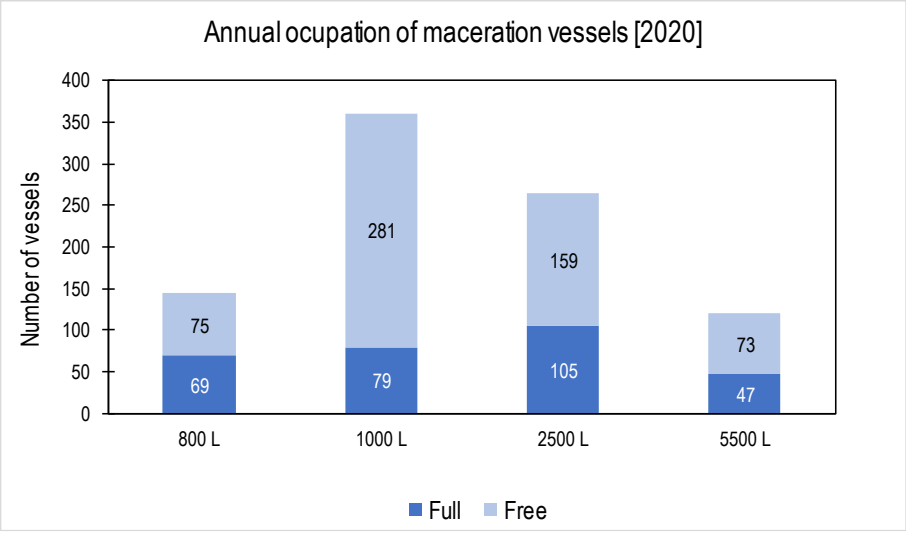


Figure 12: Forecast annual occupation of vessels on maceration in 2020

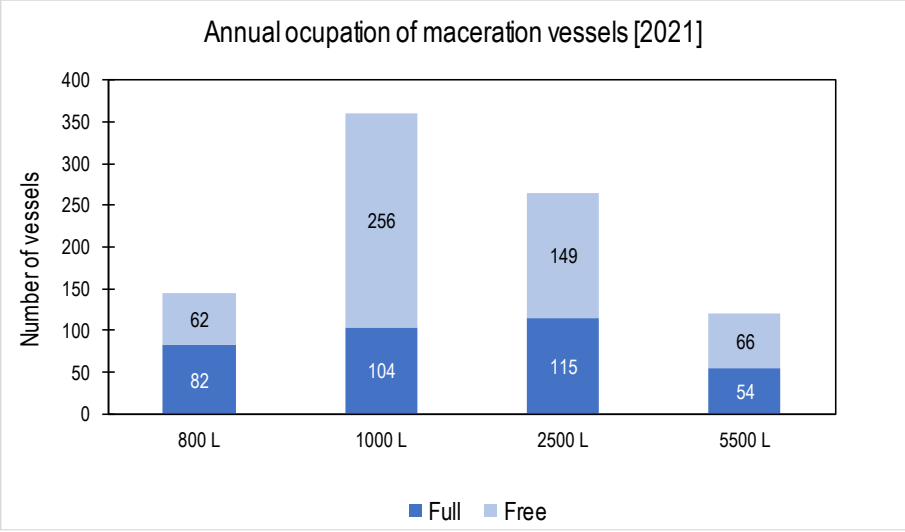


Figure 13: Forecast annual occupation vessels on maceration in 2021

5. IMPROVEMENT PROPOSALS

5.1 BATCH TIME IMPROVEMENTS

As it is seen on data aforementioned, annual production capacity is very similar to that required in 2019 so it's hardly attainable.

Focusing on every production activity in order to manufacture cologne or perfume, from the preparation of raw materials to dyeing, some weaknesses come out.

The main weakness is the organization when cologne is produced. A viable form to improve the batch time production is a better organization of the operators in order to overlap different activities which can be done at the same time.

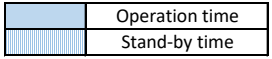
First of all, the first charge of alcohol can be done from the beginning of the process while raw materials are being prepared (15 min time saving).

Provided that there is more than 1 IBC of 1000 L, dyeing can be done during the next cologne charge (15 min time saving per IBC).

With both of these overlaps an improvement of batch time between 6% - 15.5 % (depending of batch size) for an EDT child is achieved. For an EDT adult, the improvement is between 5 % - 12 % of batch time.

Table 7: List of activities for producing a 2000 L EDT Child cologne

EDT CHILD: BS=2000 L				
EQUIPMENT	**Activity**	**Start**	**End**	**Time [min]**
DEM 3000	**1. Production of the cologne**	**0**	**105**	**105**
	1. 1. Raw materiales preparation	0	15	15
	1. 2. First filling of alcohol	0	20	20
	1. 3. Pour raw materials	20	65	45
	1. 4. Stirring time	20	105	20
	1. 5. Second filling of alcohol	65	75	10
	1. 6. Pour water	85	95	10
	2. Quality affairs	**105**	**120**	**15**
	2. 1. Laboratory verification	105	115	10
	2. 2. Realization of report	115	120	5
	3. Vessel discharge	**120**	**180**	**60**
	4. Cleaning the vessel	**195**	**210**	**15**
FILTER	**5. Filtering**	**120**	**180**	**60**
IBC 01	**6.**	**120**	**165**	**45**
	6. 1. Filling the "IBC"	120	150	30
	6. 2. Dyeing the IBC	150	165	15
IBC 02	**7.**	**150**	**195**	**60**
	7. 1. Filling the IBC	150	180	30
	7. 2. Dyeing the IBC	180	195	15



Time [min]	15	30	45	60	75	90	105	120	135	150	165	180	195
Equipment 1: VESSEL "DEM 3000"	180												15
Equipment 2: Filter								60					
Equipment 3: IBC 1000								30		15			
Equipment 4: IBC 1000										30		15	

Figure 14: Production time of the whole process

Contrary to the previous study, in this case batch sizes are divided into 5 groups:

- BS of 1000 L (for sizes in between 0 – 1000 L, 1 IBC)
- BS of 1500 L (for sizes in between 1001 – 1500 L, 2 IBC)
- BS of 2000 L (for sizes in between 1501 – 2000 L, 2 IBC)
- BS of 3000 L (for sizes in between 2001 – 3000 L, 3 IBC)
- BS of 4000 L (for sizes in between 3001 – 4000 L, 4 IBC)

This difference is because, due to overlapping, the first alcohol charge is not the limiting activity for batch sizes smaller than 1500 L, but it is for batch sizes bigger than 1500 L.

Alcohol charge for 1001 – 1500 L batch sizes have a duration equal or shorter than 15 min, while the raw materials preparation has a constant duration of 15 min.

From batch sizes bigger than 1500 L alcohol charge becomes the limiting activity.

The resulting functions of the different batch sizes for EDT child are (see on Table 8):

Table 8. Resulting functions for the calculation of the batch time of an EDT child

Application range	Functions
Between 0 – 1000 L, 1 IBC	$BT = 107 + 0.0490 \cdot BS$
Between 1001 – 1500 L, 2 IBC	$BT = 122 + 0.0390 \cdot BS$
Between 1501 – 2000 L, 2 IBC	$BT = 92 + 0.0590 \cdot BS$
Between 2001 – 3000 L, 3IBC	$BT = 92 + 0.0590 \cdot BS$
Between 3001 – 4000 L, 4 IBC	$BT = 92 + 0.0590 \cdot BS$

The resulting functions of the different batch sizes for EDT adult are (see on Table 9):

Table 9. Resulting functions for the calculation of the batch time of an EDT adult

Application range	Functions
Between 0 – 1000 L	BT = (92 + 0.0340 · BS) + (15 + 0.0300 · BS)
Between 1001 – 1500 L	BT = (92 + 0.0340 · BS) + (15 + 0.0300 · BS)
Between 1501 – 2000 L	BT = (77 + 0.0440 · BS) + (15 + 0.0300 · BS)
Between 2001 – 3000 L	BT = (77 + 0.0440 · BS) + (15 + 0.0300 · BS)
Between 3001 – 4000 L	BT = (77 + 0.0440 · BS) + (15 + 0.0300 · BS)

With the new batch time functions for each batch size, the total production time used for 2019 can be estimated (see table 10):

- Annual production time: 2209 h

This reduction of time compared to the first one, leads to an improvement of 9.65 % of the annual invested production time, required to support the demand in the upcoming years. With the reduction of BT, it is more likely to finish the batch within the journey (As a general rule, it is not allowed to produce the same batch in two different journeys. This can only be done in specific activities of the global process and exceptional cases).

If the same study is conducted for years 2020 and 2021:

- Annual production time (2020): 2350 h
- Annual production time (2021): 2500 h

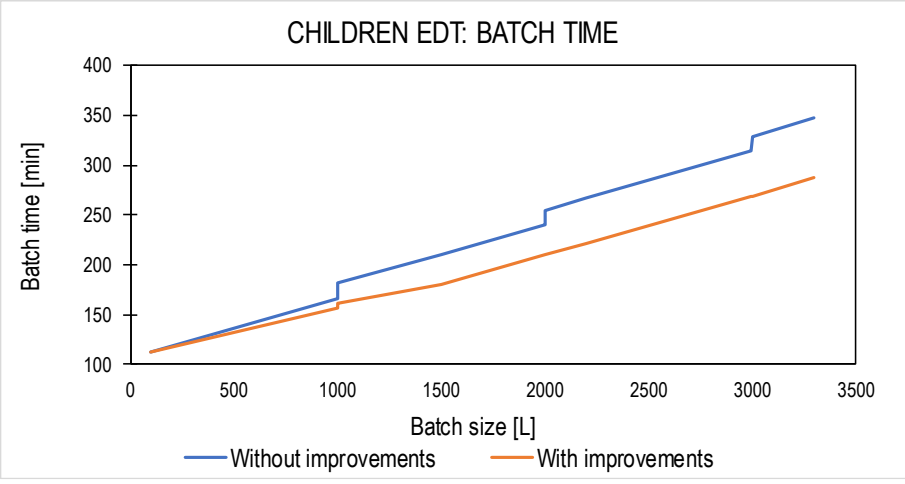


Figure 15: Comparative analysis between improved planification and normal planification

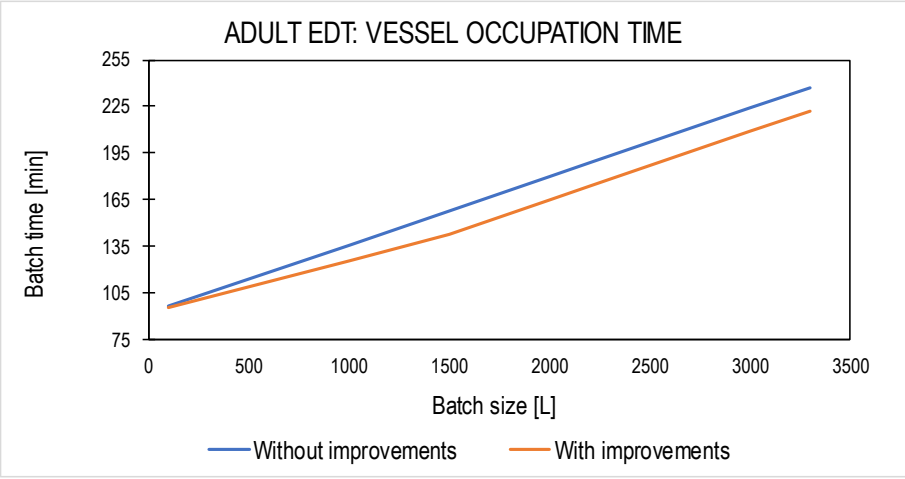


Figure 16: Comparative analysis between improved planification and normal planification

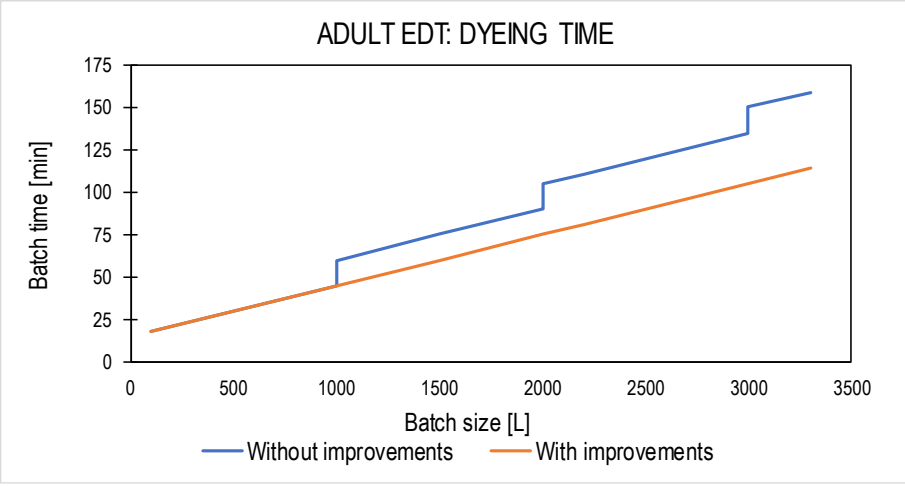


Figure 17: Comparative analysis between improved planification and normal planification

Table 10: Batch time required for each batch size (EDT Child and EDT Adult)

CHILDREN EDT					ADULT EDT/EDP				
BS [L]	**n. Batch/year**	**Prod. [L]**	**BT [min]**	**BT [h]**	**n. Batch/year**	**Prod. [L]**	**OT [min]**	**DT [min]**	**BT [h]**
100	20	2000	111,9	37,3	11	1100	95,4	18	17,5
300	31	9300	121,7	62,9	14	4200	102,2	24	23,8
500	34	17000	131,5	74,5	11	5500	109,0	30	20,0
600	30	18000	136,4	68,2	13	7800	112,4	33	24,4
700	31	21700	141,3	73,0	10	7000	115,8	36	19,3
800	30	24000	146,2	73,1	10	8000	119,2	39	19,9
900	31	27900	151,1	78,1	5	4500	122,6	42	10,2
1000	74	74000	156,0	192,4	36	36000	126,0	45	75,6
1200	28	33600	168,8	78,8	18	21600	132,8	51	39,8
1400	31	43400	176,6	91,2	11	15400	139,6	57	25,6
1500	36	54000	180,5	108,3	16	24000	143,0	60	38,1
1600	27	43200	186,4	83,9	4	6400	147,4	63	9,8
2000	38	76000	210,0	133,0	29	58000	165,0	75	79,8
2200	34	74800	221,8	125,7	20	44000	173,8	81	57,9
3000	43	129000	269,0	192,8	21	63000	209,0	105	73,2
3300	22	72600	286,7	105,1	26	85800	222,2	114	96,3
Total	**540**	**720500**		**1578,3**	**255**	**392300**			**631,2**

Improving annual production capacity allows the enterprise to be prepared for upcoming requirements of cologne produced following the growth tendency of the business.

However, other measures could be taken. In case of charging alcohol into the vessel, pumping time draws out manufacturing global process. Pumping 1000 L of alcohol requires more than 20 minutes. This supposes that pumps, pipes, valves, etc. offers a flow of 3 m^3/h (small for industrial processes).

With a fast filling of IBCs, batch time production could be considerably reduced. This would allow increasing the number of batches produced and an improved production planning. But this problem has a high complicity solution.

The problem is that can't be filled faster because of the ATEX security installations (pipes, pumps…). The faster cologne goes through the pipe the more risk of static electricity it has. If this occurs, the equipment doesn't have enough protection to avoid an accident. Due to this, the flow must be low.

One solution for this problem would be change all the pumps, pipes and other instrumentation involved in the process by new equipment with an upper grade ATEX protection. Unfortunately, the cost is high. So, the first solution related to improve the organization while doing the process is the best at this moment.

5.2 EQUIPMENT IMPROVEMENTS

Besides batch time, another important actual problem is some batch sizes needed to produce. Around 40% of total batches are less than 1000 L. This entails a major problem related with the DEP 3000 stirring mechanism because blades can't reach the bottom of the vessel so it's impossible to mix the blend effectively.

As usual, a stirring mechanism works correctly when the vessel is 20-30% full (Koh, C. G., & Perry, M. J., 2009). DEP 3000 has a total usable volume of 3300 L meaning batch sizes of 700 L or less (21% of capacity) can't be blended.

Currently, these cases are covered with another vessel of polyethylene with a total usable volume of 700 L and a movable stirring mechanism. Due to its material and for the operators' comfort, this vessel must be renewed. The new one has to be compatible with all the raw materials used in manufacturing process (it could be the same material as DEP 3000, stainless steel AISI 316L), it should have a major usable volume (1000 L) and must have a better stirring mechanism (not movable) that assures a high quality blending.

Batch sizes of 100 L will stop being produced in the following years as it represents a big loss of production time. Usually these batch sizes are ordered in small quantities and with a better organization they could be gathered in 300-500 L batch sizes, which could be produced easily in the new 1000 L vessel.

5.2.1 **Vessel basic design**

One of the main objectives of this new vessel is to solve the bad functioning of the DEM 3000 vessel stirring mechanism for batch sizes inferior than 1000 L. Therefore, the useful vessel volume has to be, at least, of 1000 L.

The vessel must not be completely full because, due to the vortex generated by the mixer, the liquid in the vessel walls increases (Coulson, J. M., Richardson, J. F., B., J. R., & H, J. H. ,1954). For this reason, the vessel must have a security margin. There is not one single security margin for all the situations, it will always depend on the vessel and the mixer used. After discussing the different options with the provider, the selected security margin for this vessel will be of 15%.

$$V_{vessel} = \frac{V_{useful}}{(1-0.15)} \quad (1)$$

Therefore, for a usable volume of 1000 L, the vessel should have a total volume of around 1170 L. According to the API 650 regulation, there is no [diameter / height] strict value, it depends on the designer's election. Still, for potentially dangerous areas because of strong winds or seisms the relation must be higher than 1.3. In the case of Air-Val International, as the production area is closed and does not present any potential risks, the vessel can be design according to the space availability. In this case, the relation of [diameter/height] selected is 1.

The proposed provider's offer, after the requests made, was a vessel with the following characteristics (https://vakkimsa.com/, April 2020): (see data sheet in Table 11 and Figure 18):

- Height: 1000 mm
- Diameter: 1150 mm
- Top head: conical with a 15º angle
- Low bottom: conical with a 20º angle

Currently, the deposit used is made of polyethylene. This is an inadequate material when alcohol is involved in the process.

According to the Alcohol 96º safety sheet (MARCA, S., & Carrilet, S. A. 2006), in section "safe storing conditions", the best material to storage or work with this compound complying with the current APQ normative are:

- Stainless steel, titanium, cast bronze and carbon steel, among others.

Stainless steel is a versatile material and it is also the used material or vessel DEM 3000, existing in production already. The part of the vessel which is in contact with the product is stainless steel 316 L, and for the rest of the vessel, stainless steel 304. These steels offer for resistance to corrosion.

The stirring mechanism used in this vessel consist of one double-blade mixer and has the presented characteristics (see data sheet in Table 11 and Figure 19):

- Spear length: 1154 mm
- Blade diameter: 350 mm
- Mixer power and speed: 0.75 kW / 218 rpm
- Semi-anchor mixer
- TRIVAK mixer (provider's company ownership)
- Material: Stainless steel 304 and stainless steel 316 L

The vessel has to deflectors intended to avoid vortexes and provide a better mixer. These deflectors will not be directly attached to the vessel's wall and will have a length of 10 cm.

As it is a batch process (due to the different type of cologne to produce by the enterprise), every time a batch is completed the vessel must be cleaned. Currently, the cleaning system of the existing vessel is manual and has to be done by the operator. For a better cleaning of the vessel and a better ergonomic cleaning process for the operators when they perform this task, the vessel has a cleaning system attached to the top head which allows to clean the vessel in a shorter time.

- Cleaning product: Alcohol 96º

5.2.2 **Pipes and discharge hoses**

The pipes in which raw materials like water, alcohol and essences are transferred, will be of the same material as the other vessel's actual pipes, stainless steel AISI 316 L. The d_{nom} will also be the same in order to respect the same flow velocities and pumping powers, d_{nom} = 60 mm.

The pipes in which cologne is transferred of the vessel to the maceration process will be of stainless steel AISI 316 L, d_{nom} = 40 mm.

The hoses in which cologne is transferred to the IBC are currently of reinforced PVC with an interior coil. The issue with this material is that, over time, it loses its flexibility hindering the handling of the hose by the operator forcing the enterprise to renew them periodically.

To solve this issue and following the recommendations specified in the alcohol's security sheet and ATEX protection normative, the new material will be UPE (polyethylene of a high molecular weight) with a coil to reinforce the hose. Polyethylene is resistant to corrosive chemical products such as: strong acids, chloride solutions, aromatic hydrocarbons, etc. and has a good resistance to ageing.

The process involves inflammable products manipulation and the flow velocity has been set to be lower than the regular average (1 m/s). Therefore, among the options offered by the hose's provider, the d_{nom} = 40 mm.

5.2.3 **Pumps**

To transfer the different raw materials needed to produce colognes (alcohol, water, essences…), it is necessary to own the adequate pumps. Two different pumps are required in the process. Both of them will be diaphragm pumps.

- Discharge cologne pump from the mixer vessel to the maceration vessels (in the case of an EDT adult). The flow does not have to go through the filter and, therefore, the resistance to be surpassed by the flow is minor.
- Discharge cologne pump from the maceration vessels or from the mixer vessel to IBC. In this case the flow must go through the filter, which determines the maximum admissible flow rate at which the discharge can be done. Thus, as the resistance to the cologne is higher, another pump with more capacity is required.

To select the pumps a provider enterprise has been contacted, which together some characteristics exposed in Table 12, Figure 20, Table 13 and Figure 21, an agreement has been reached to use the following pumps (https://www.psgdover.com/almatec, May 2020):

- ALMATEC-CMX 50 pump: For the cologne discharge from the mixer vessel to the maceration vessels.
- ALMATEC-CMX 130 pump: For the discharge of the cologne from the maceration vessels or mixer vessel to the IBC.

5.2.4 **Filter**

Once the cologne has been manufactured, as explained in the process aforementioned, foreign bodies can remain in the blend from the essence, among other problematics raw materials. For the process, it has been decided to use the same adsorption filter currently used by the enterprise for its good efficiency (see Table 14 and Figure 22 and 23).

5.2.5 **Data sheets**

Table 11. Vessel data sheet

HOJA DE ESPECIFICACIÓN DE TANQUE MEZCLADOR	
FUNCIÓN	Homogenización de los diferentes componentes de la colonia
CONDICIONES DE OPERACIÓN	
Fluido	Colonia (Agua, Alcohol, Aceites)
Temperatura de oepración (°C)	20
Presión de operación (atm)	1
Densidad (kg/m^3)	980
Viscosidad (cPs)	≈1
Volumen útil (%)	85
DATOS DE DISEÑO	
Volumen (L)	1170
Diámetro (mm)	1150
Altura (mm)	1360
Grueso cilindro (mm)	2.5
Grueso fondo (mm)	2.5
Material de construcción	AISI 316L // AISI 304
Densidad del material (kg/m3)	7940
Norma de diseño	Código ASME
Tipo de cabezal	Cónico (15°)
Tipo de fondo	Cónico (20°)
AGITACIÓN	
Tipo	Semi-áncora // TRIVAK
Material de construcción	AISI 316L
Velocidad agitador (rpm)	218
Longitud de lanza, L (mm)	1154
Diámetro de lanza, d (mm)	42.2
Diámetro de pala, D (mm)	350
Potencia (kW)	0.75
Certificaciones	ATEX
CONNEXIONES	
A	Entrada líquidos: DN50
B	Boca de hombre: DN400
C	Bolas de limpieza
E	Deflectores
F	Salida para vaciado: DN50

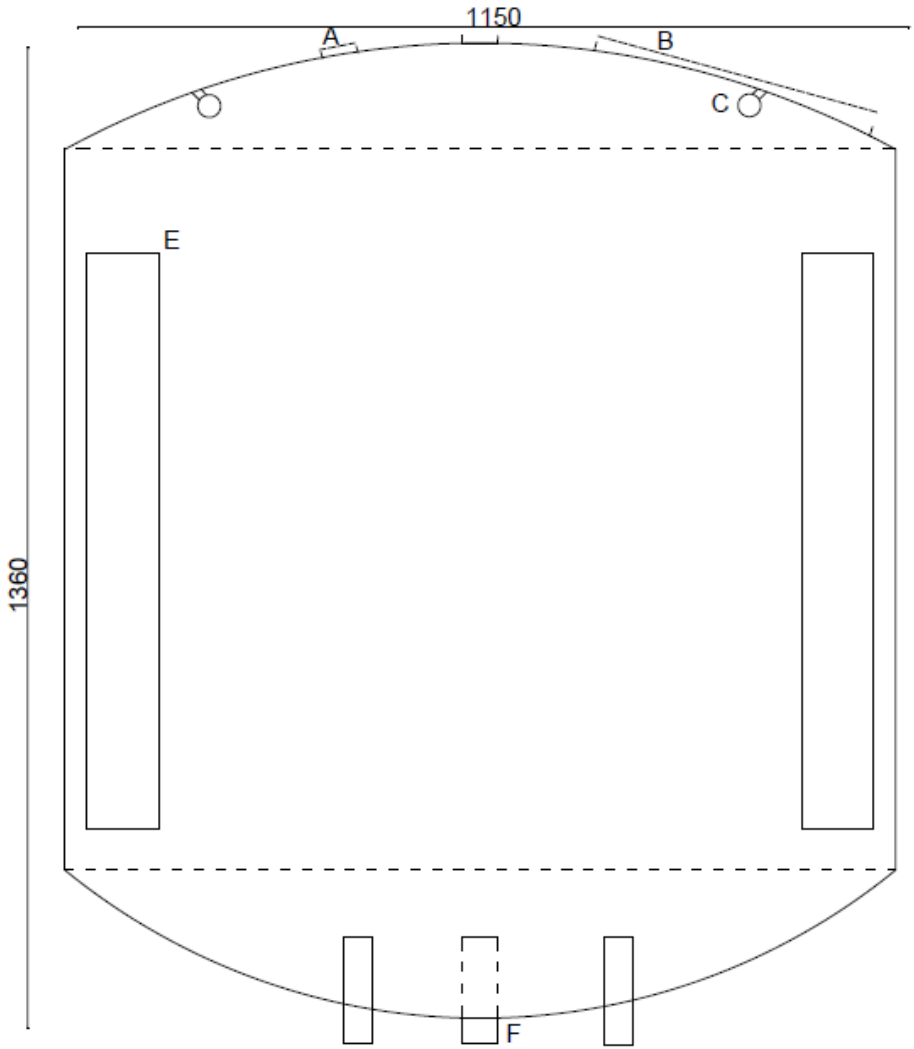


Figure 18. Vessel diagram

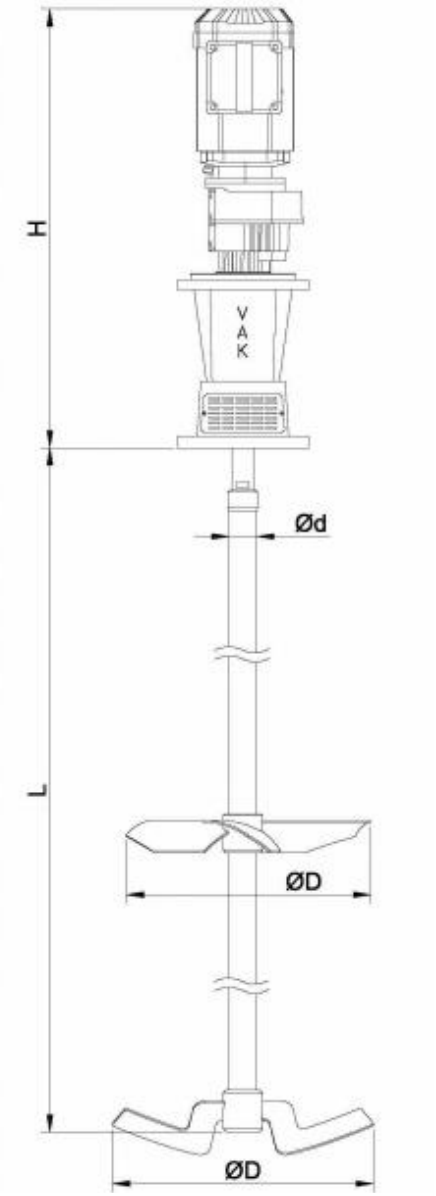


Figure 19. Agitator diagram

Table 12. Discharging pump data sheet

HOJA DE ESPECIFICACIÓN DE BOMBA DESCARGA	
Descripción	Bomba de descarga
CONDICIONES DE OPERACIÓN	
Fluido	Colonia (Agua, Alcohol, Aceites)
Temperatura de oepración (°C)	20
Presión de operación (atm)	1
Densidad (kg/m^3)	980
Viscosidad (cPs)	≈1
Caudal (m^3/h)	3
NPSH requerida	3
NPSH disponible	9
DATOS DE DISEÑO	
Tipo	Diafragma (pneumàtica)
Norma	ISO 9906
Longitud (mm)	240
Altura (mm)	217
Ancho (mm)	265
Conexión de aire	1 1/4" NPT
Caudal máximo (m^3/h)	7.8
Temperatura de diseño (°C)	70
Lubricante	No
Certificaciones	ATEX

Performance range of the pump

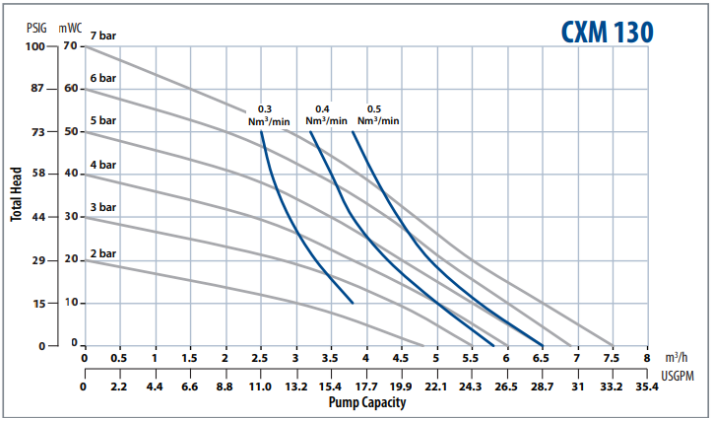


Figure 20. Discharging pump diagram

Table 13. Maceration pump data sheet

HOJA DE ESPECIFICACIÓN DE BOMBA MACERACIÓN	
Descripción	Bomba de maceración
CONDICIONES DE OPERACIÓN	
Fluido	Colonia (Agua, Alcohol, Aceites)
Temperatura de oepración (°C)	20
Presión de operación (atm)	1
Densidad (kg/m^3)	980
Viscosidad (cPs)	≈1
Caudal (m^3/h)	2
NPSH requerida	2
NPSH disponible	8
DATOS DE DISEÑO	
Tipo	Diafragma (pneumàtica)
Norma	ISO 9906
Longitud (mm)	175
Altura (mm)	167
Ancho (mm)	201
Conexión de aire	3/4" NPT
Caudal máximo (m^3/h)	3
Temperatura de diseño (°C)	70
Lubricante	No
Certificaciones	ATEX

Performance range of the pump

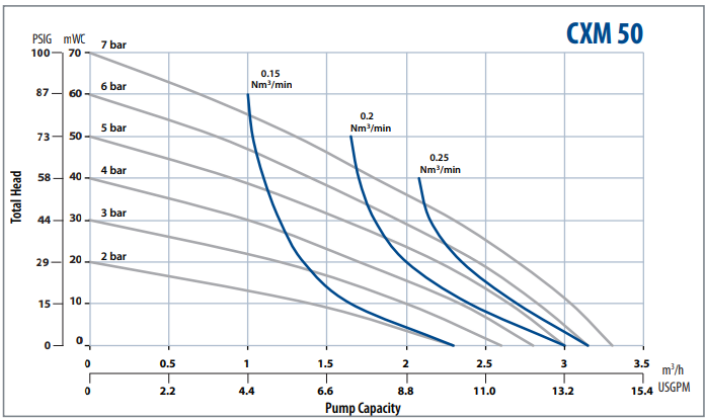


Figure 21. Maceration pump diagram

Table 14. Filter data sheet

HOJA DE ESPECIFICACIÓN DEL FILTRO	
Descripción	Filtro para EDT/EDP
CONDICIONES DE OPERACIÓN	
Fluido	Colonia (Agua, Alcohol, Aceites)
Temperatura de oepración (°C)	20
Presión de operación (atm)	1
Densidad (kg/m^3)	980
Viscosidad (cPs)	≈1
Caudal (m^3/h)	2
DATOS DE DISEÑO	
Tipo	Adsorción (Ion-exchange)
Norma	FDA (eeuu Food/drug administration)
Longitud (mm)	400
Altura (mm)	1112
Ancho (mm)	400
Àrea de filtrado (m^2)	1.5
Caudal máximo (m^3/h)	7
Temperatura de diseño (°C)	82

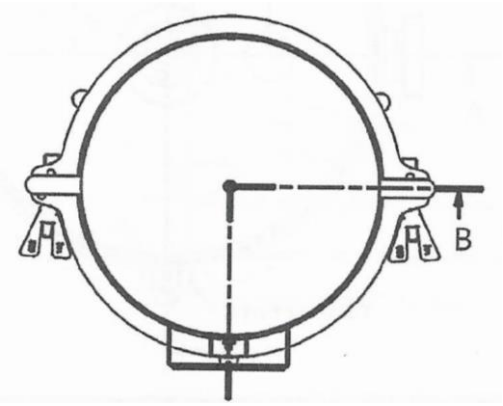


Figure 22. Filter diagram 1/2

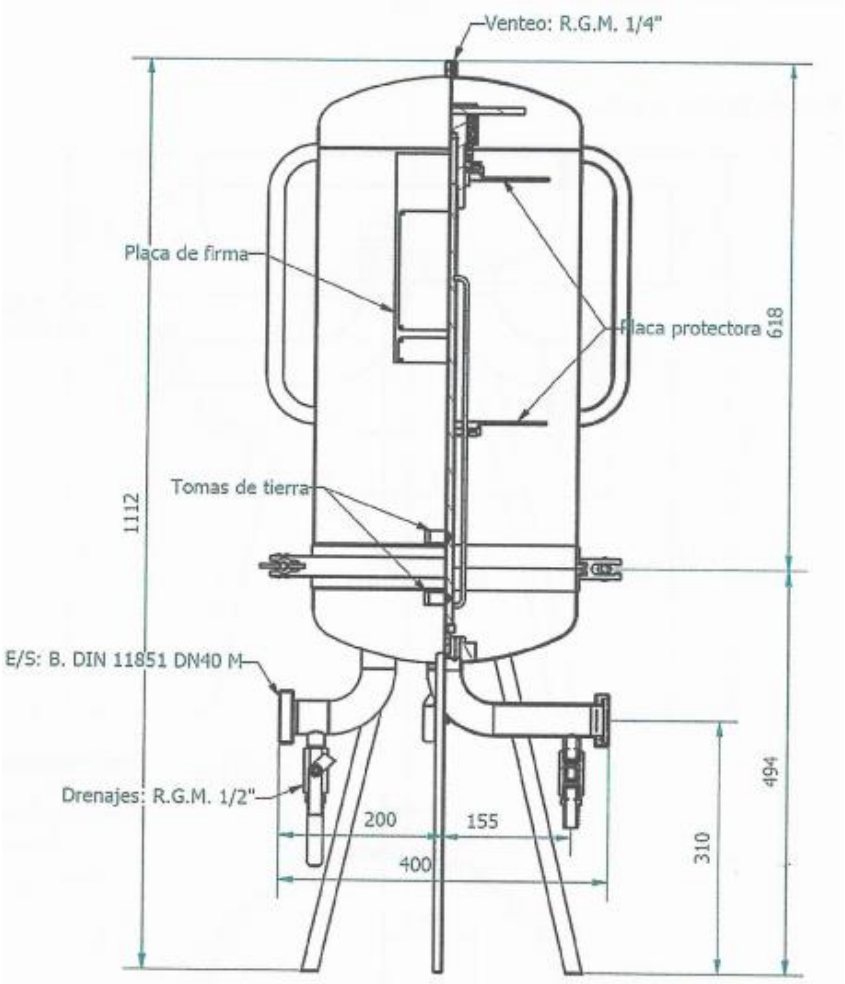


Figure 23. Filter diagram 2/2

5.2.6 Piping & instrumentation diagram (PID)

In Figures 24 and 25 it is represented the PID (Piping & instrumentation diagram) of EDT child production and EDT adult production.

In Figure 24 (EDT child production), it can be seen that when the cologne is discharged into the mixer vessel CMV 1000 and it cooled in E01, it is transferred directly to the filter FILTER01.

In Figure 25 (EDT adult production), after cooling the cologne, it is transferred to the maceration vessels ML1-ML6 (there is a line used depending on batch sizes). Afterwards, it is transferred to the filter FILTER01 as in the EDT child.

Chosen nomenclature for the pipes: nominal diameter – flow type – enumeration, where the flow type can be:

- Alcohol: OH
- Water: W
- Raw Materials: RM
- Product: P

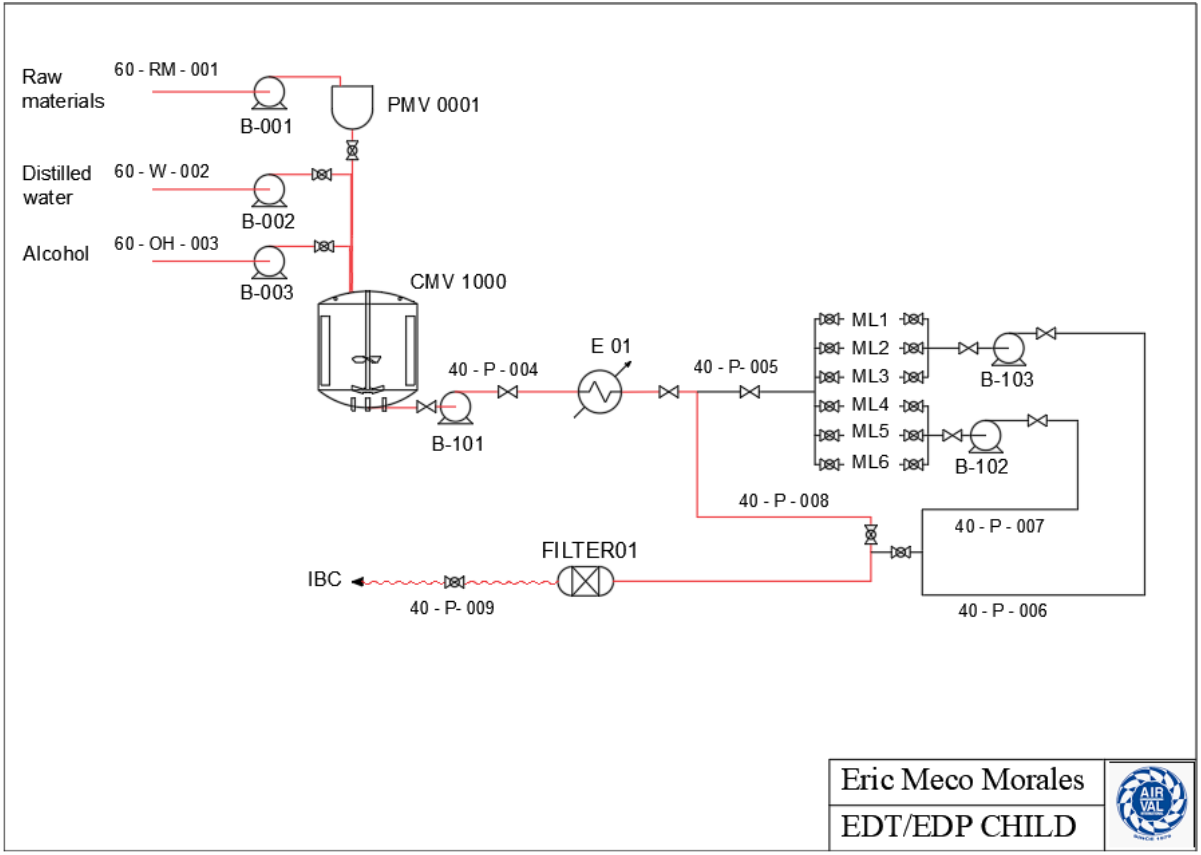


Figure 24. Piping and instrumentation diagram for an EDT: Child

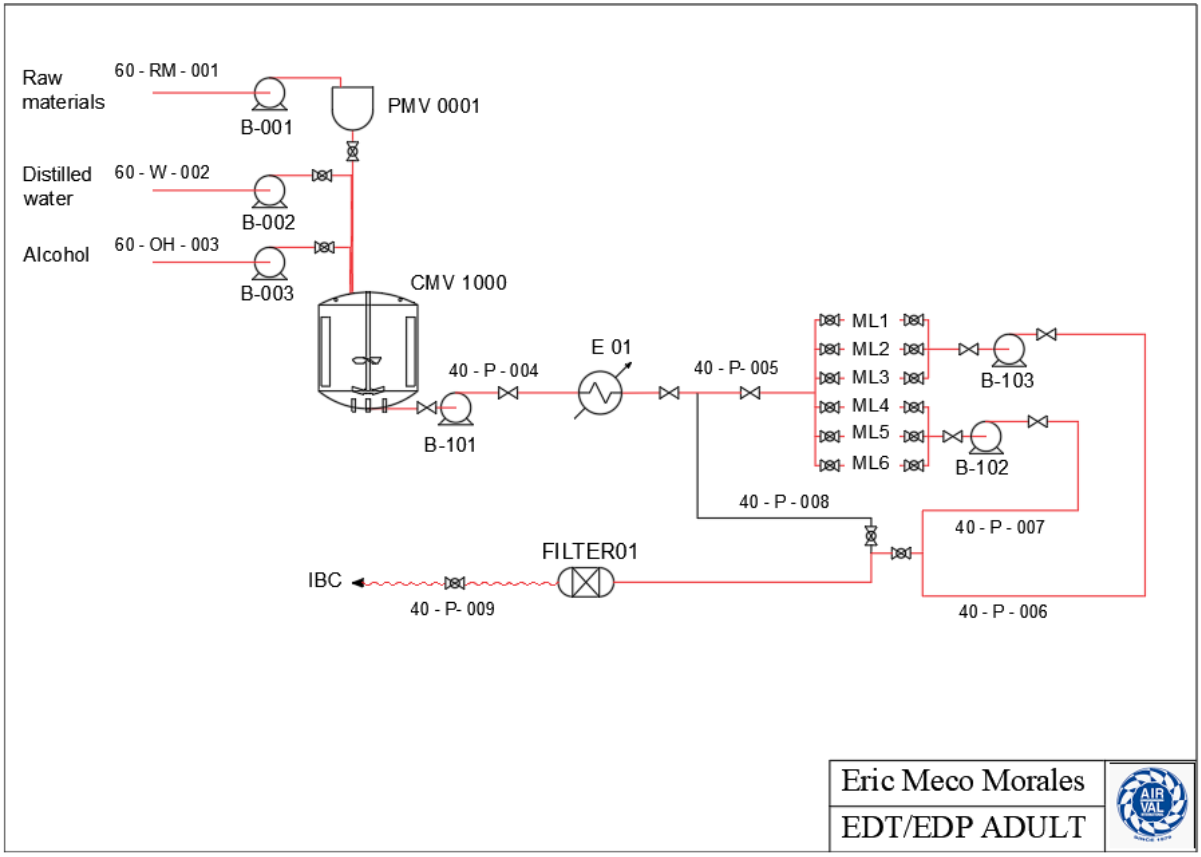


Figure 25. Piping and instrumentation diagram for an EDT: Adult

6. CONCLUSIONS

Of the conducted project, the following conclusions can be drawn:

- The conducted batch time study for each batch sizes currently reflects that it is impossible to cover the next years demand due to enterprise's growth and season operation. With the conducted studies made in section 4, a series of theoretically functions which relate the batch time according to each batch size are calculated. These are obtained from an experimentally process of a 2000 L batch time cologne (Table 4 and Table 5). With these batch times, the maximum number of batches attainable per day are two.
- Owing to seasonally demand, there are delays in the delivery deadlines. Therefore, in June, July, August, October and November among others, where the production is higher, the enterprise should do overtimes. The proposals to improve the organization consists in a series of overlapped activities made by different operators.
    - The first charge of alcohol can be done from the beginning of the process while raw materials are being prepared (15 min time saving).
    - Provided that there is more than 1 IBC of 1000 L, dyeing can be done during the next cologne charge (15 min time saving per IBC).

  These proposals offer a batch time reduction of (See functions in Table 8 and Table 9):
    - 11 % in the batch time reduction of the EDT Child
    - 7 % in the batch time reduction of the EDT adult (OT of the vessel)
    - 17 % in the reduction of the batch time in the EDT adult dyeing.

  With the batch time improvements aforementioned the current and until 2021 demand can be covered as the maximum number of batches attainable per day increases to three.

- To improve the low batch sizes production, the CMV 1000 vessel has been selected to produce the 1000 L or lower batch sizes. As the current DEM 3000 vessel could not perform a satisfactory mixing. The new vessel will have a total usable volume of 1170 L (1.36 m height and 1.15 m of diameter), build with stainless steel AISI 304 and covered with stainless steel AISI 316L for the areas exposed directly to contact with the product. The stirring mechanism is formed by a double blade mixer (semi-anchor and TRIVAK) and two deflectors to improve the mixing of the product. Furthermore, contrary to the DEM 3000 vessel, this one will have a cleaning system in the top head in order to improve the cleaning quality and automate it at the end of each batch, facilitating the operators' work from a security perspective. To transfer the products, two pumps (section 5.2.3.), pipes (section 5.2.2.) and filter (section 5.2.4.) have been selected.

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ACRONYMS

API: American Institute of Petroleum

BS: Batch size

BT: Batch time

CMV 1000: Cologne mixing vessel of 1000 L

DEM 3000: Mixing vessel of 3300 L

DT: Dyeing time

EDT: Eau de Toilette

IBC: Intermediate bulk container

OH: Alcohol

OT: Occupation time

P: Product (cologne)

PMV 0001: Pre-mixing vessel

RM: Raw materials

W: Water

APPENDICES

APPENDIX 1: PRODUCTION OF 2019

Table 15: Quantity of cologne produced in 2019

Annual production of 2019		
MONTH	Cologne and Perfume	
	DEP 3000 l	DEP 700 l
JANUARY	43550	14400
FEBRUARY	68100	5800
MARCH	77087	7700
APRIL	63283	5300
MAY	98052	6700
JUNE	87839	23000
JULY	132080	9500
AUGUST	99735	13400
SEPTEMBER	105010	8400
OCTOBER	94825	9700
NOVEMBER	84085	15800
DECEMBER	40640	5900
TOTAL	994286	125600

Table 16: Quantity of batches produced in 2019

Annual production of 2019		
MONTH	Batch	
	DEP 3000 l	DEP 700 l
JANUARY	32	23
FEBRUARY	40	10
MARCH	39	13
APRIL	36	14
MAY	60	9
JUNE	58	30
JULY	68	14
AUGUST	60	20
SEPTEMBER	61	18
OCTOBER	55	22
NOVEMBER	52	29
DECEMBER	29	3
TOTAL	590	205

Table 17: Prove table about the surmise done in batch time study

Gathered production of Colony (2019)							
100 L		300 L		500 L		600 L	
Quantity	Batches	Quantity	Batches	Quantity	Batches	Quantity	Batches
3300	33	14400	48	30000	60	28200	47
700 L		800 L		900 L		1000 L	
Quantity	Batches	Quantity	Batches	Quantity	Batches	Quantity	Batches
28700	41	26400	33	31500	35	76000	76
1200 L		1400 L		1500 L		1600 L	
Quantity	Batches	Quantity	Batches	Quantity	Batches	Quantity	Batches
54000	45	43400	31	99000	66	44800	28
2000 L		2200 L		3000 L		3300 L	
Quantity	Batches	Quantity	Batches	Quantity	Batches	Quantity	Batches
148000	74	145200	66	234000	78	112200	34
Total gathered colony production [L]				Total gathered batches			
1119100				795			
Total itemised colony production [L]				Total itemised batches			
1090121				795			
Error (%)	2,66	16 different volume production				0	Error (%)
e<3% -> acceptable						e<3% -> acceptable	

APPENDIX 2: BATCH TIME PER VOLUME

Table 18: Time required for each batch size (without improvements)

BS [L]	Child	Adult	
	Batch time [min]	Oc Time DEM 3000 [min]	Dyeing time [min]
100	112,9	96,4	18,0
300	124,7	105,2	24,0
500	136,5	114,0	30,0
600	142,4	118,4	33,0
700	148,3	122,8	36,0
800	154,2	127,2	39,0
900	160,1	131,6	42,0
1000	166,0	136,0	45,0
1200	192,8	144,8	66,0
1400	204,6	153,6	72,0
1500	210,5	158,0	75,0
1600	216,4	162,4	78,0
2000	240,0	180,0	90,0
2200	266,8	188,8	111,0
3000	314,0	224,0	135,0
3300	346,7	237,2	159,0

Table 19: Time required for each batch sizes (with improvements)

BS [L]	Child	Adult	
	Batch time [min]	Oc Time DEM 3000 [min]	Dyeing time [min]
100	111,9	95,4	18,0
300	121,7	102,2	24,0
500	131,5	109,0	30,0
600	136,4	112,4	33,0
700	141,3	115,8	36,0
800	146,2	119,2	39,0
900	151,1	122,6	42,0
1000	156,0	126,0	45,0
1200	168,8	132,8	51,0
1400	176,6	139,6	57,0
1500	180,5	143,0	60,0
1600	186,4	147,4	63,0
2000	210,0	165,0	75,0
2200	221,8	173,8	81,0
3000	269,0	209,0	105,0
3300	286,7	222,2	114,0