Control and monitoring of the production process with the aim of reducing product loss in the fermentation and filtration of beer.

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Preface

The work presented in this thesis was performed at the company Empresa de Cervejas da Madeira (Madeira, Portugal), during the period March-July 2019, under the supervision of Eng. Nuno Branco and Eng. Tomé Mendes. The thesis was co-supervised at Instituto Superior Técnico by Prof. Marília Mateus.

I declare that this document is an original work of my own authorship and that it fulfils all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

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Abstract

All the breweries face daily challenges in order to become more competitive in the brewery industry and for this reason new methodologies and new equipment are frequently introduced to the beer production process aiming to reduce the production cost per litre of beer. The introduction of the new methodologies and new equipment intend also to render a more uniform product at the exit of the different steps/processes to avoid the necessity of performing frequent alterations to the diverse parameters from batch to batch.

The aim of the present thesis was to study where would be possible to reduce the production cost, either by reducing the waste of beer or by reusing the latter in the production sector. Firstly, the reduction of beer waste in the daily temperature measurement in fermentation vessels was studied and implemented by changing an analog saccharimeter for a digital thermometer; secondly, the reutilization of high gravity beer that was being wasted between maturation process and kieselguhr filtration was addressed through the introduction of an industrial centrifuge.

The economic analysis confirms that the new equipment introduced had a positive impact in the production sector leading to a reduction of the production cost per litre of beer produced.

Keywords: Brewery, beer, production sector, production cost per litre, process economy analysis.

Resumo

Todas as cervejeiras enfrentam desafios diariamente visando tornar-se mais competitivas na indústria da produção de cerveja e graças a isso é necessário e frequente a introdução de novas metodologias e de novo equipamento com o intuito de reduzir o custo de produção por litro de cerveja. A introdução de novas metodologias e novos equipamentos tem também como objetivo obter um produto mais uniforme a sair dos diferentes passos/processos para que não seja necessária a alteração frequente de diversos parâmetros, de lote para lote.

Na tese realizada, foi estudado como seria possível reduzir o custo de produção, seja por redução de gasto de cerveja seja pela reutilização no sector de produção. Em primeiro lugar, foi estudada a oportunidade de redução do gasto de cerveja devido à medição diária da temperatura nas cubas de fermentação; depois, foi estudada a possibilidade de reutilização de cerveja de alta densidade que estava a ser desperdiçada entre o processo de maturação e a filtração de kieselguhr, devido as purgas realizadas, através da introdução de uma centrifuga industrial.

A analise económica realizada confirma que a introdução dos novos equipamentos teve um impacto positivo no sector de produção, levando a uma redução do custo de produção da cerveja.

Palavras-chave: Cervejeira, cerveja, sector de produção, custo de produção de cerveja, análise económica do processo.

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Glossary

List of acronyms

ADP – Adenosine diphosphate

ATP – Adenosine triphosphate

BBT – Bright beer tank

CCV – Cylindroconical vessel

ECM – Empresa de Cervejas da Madeira

HGB – High gravity beer

TAP – Tap Air Portugal

VDK – Vicinal Diketones

List of variables

η_{Loss}	Fraction of beer lost during the purges and filtration.	
$\eta_{Centrifuge}$	Yield of beer recovery with the introducing of centrifuge.	
C_{HGB}	Ratio of the high gravity beer in the recovered purge.	(g/L)
Cost price	Production cost price of the beer in the bright beer tank.	€/L
E_{Wort}	Original extract of the wort.	(g/100mL)
$E_{Final\ product}$	Original extract of the commercialized beer.	(g/100mL)
$F_{Correction\ factor}$	Correction factor to take in consideration the amount of beer that was not accounted for.	
$M_{Flask\ +\ 100\ mL\ sample}$	Mass of the centrifugation flask with 100 mL of sample from the recovered purge.	g
$M_{Flask\ +\ Remaining\ solids}$	Mass of the centrifugation flask plus the remaining solids after centrifugation.	g
$M_{supernatant}$	Mass of clarified supernatant that was recovered from a turbid beer sample of 100 mL.	g
M_{HGB}	Total mass of high gravity beer that was recovered from the purges.	kg
$M_{truly\ purged}$	Mass of high gravity beer and yeast that was in fact extracted from the CCV due to yeast cropping.	kg
$M_{Total\ yeast\&HGB\ cropped}$	Mass of high gravity beer and yeast that was recovered in yeast cropping from CCVs.	kg
$M_{Indroduced\ in\ pitching}$	Mass of high gravity beer and yeast that was introduced in the pitching.	kg
$\rho_{yeast\&HGB\ cropped}$	Density of the purge from the yeast cropping.	
SG_{HGB}	Specific gravity of HGB.	kg/L
SG_{wort}	Specific gravity of wort	kg/L
$V_{Commercial\ beer\ purged}$	Equivalent volume of the beer with commercial original extract that is purged.	L

V_{purged}	Volume of purge recovered.	L
$V_{Total\ yeast\ recovered}$	Volume of purge from yeast cropping.	L
$V_{HGB\ purged}$	Volume of high gravity beer that was purged.	L
$V_{Loss\ during\ purges}$	Total volume of beer with commercial original extract lost during the purges.	L
$V_{Entered\ in\ the\ tank}$	Volume of wort introduced in the fermentation vessel.	L
$V_{Recovered\ after\ dilution}$	Volume of beer recovered after dilution	L
$V_{Recovered\ from\ the\ tank}$	Volume of high gravity beer recovered from the fermentation vessel.	L
$V_{Loss\ purges\ \&\ filtration}$	Volume of beer with the commercial original extract lost during the purges and the filtration.	L
$V_{Supposed\ to\ be\ recovered}$	Volume of beer with commercial original extract that is supposed to be recovered.	L
$V_{Beer\ gain}$	Volume beer with commercial original extract that would be gained with the introduction of the centrifuge.	L
$V_{Beer\ purged\ before\ complete\ maturation}$	Volume of beer with commercial original extract that is purged before the maturation is completed.	L
$V_{sold\ to\ local\ company}$	Volume of beer with commercial original extract that is sold to a local company.	L
$V_{Beer\ lost\ by\ dragging}$	Volume of beer with commercial original extract lost by dragging with the yeast cropping.	L
$V_{Total\ loss\ in\ purges}$	Total volume lost in the purges in a determined timeline.	L
$V_{Gained\ with\ centrifuge}$	Total volume gained with the introduction of the centrifuge in a determined timeline.	L
$V_{Beer\ accounted}$	Volume of beer that was possible to account in a determined timeline.	L
$V_{Beer\ produced}$	Volume of beer that was produced in a determined timeline.	L

1. Introduction

1.1 Beginning of the Beer.

The production of beer is presumed to have started in Mesopotamia or Egypt. The making of the beer was then taught to the Greeks and Romans by the Egyptians, which was then passed throughout Europe (Max, 2005).The beer is known for being the oldest alcoholic drink in the world, presenting evidence of the production and use of beer in the Egypt back in the Predynastic era (5500-3100 BC). There are references to a few simply prepared and fermented beverages that might be the 'ancestors' of beer. One of those was known as braga, or bosa, and was mainly produced and consumed in the areas between Poland and the Balkans and eastwards to Siberia, being produced by soaking millet in water and then heating the mixture. Another beverage that had been produced across Europe was kvass and was prepared by (mixing) flour and water then heated for 24 hours and left to ferment for an equal period. Both these drinks presented low levels of alcohol (Hornsey, 2003).

The beer industry evolved through the years having a more rigorous procedure and sanitary conditions leading to more complex and above all more homogenous beer.

1.2. Raw materials.

In the pre-Neolithic era, the raw materials for the fermentation (sources of sugar) were found in the wild berries (and other fruits), tree sap, honey and possibly in the animals milk, providing the sucrose, glucose, fructose and possibly lactose in need for the procedure (Hornsey, 2003). Nowadays the sugar extraction occurs from malted barley, thought wheat, maize and rice can also be brewing adjuncts from which sugars can be extracted. To produce beer, three more components are needed: yeast, hops and water.

1.3. Malting.

Malting is the term used for the preparation of raw material in the brewery industry, where there is a controlled germination of grain in moist air. Barley (*Hordeum vulgare*) is the most malted cereal grain because it has high starch-to-protein ratio and adhering husk that provides a better economic yield, ease of processing in brewery and produces the flavour associated with malt for this purpose (MacLeod, 2004). The wheat (*Triticum aesticum*) and sorghum (*Sorghum vulgare*) are also malted in considerable quantity (Briggs, Boulton, Brookes, & Stevens, 2004).

The main goal of the malting is to convert the physical structure of the barley to allow the synthesis or activation of enzymes (which can degrade the polysaccharides in di- or monosaccharides) in order to facilitate their use in the following step of the beer production - wort fabrication. During this procedure, the hydrolytic enzymes production and release are increased.

These enzymes will be responsible for cereal grain cell-wall degradation and protein solubilization leading to a situation of minimal starch breakdown. With this aim, it is necessary to both accelerate germination and retard embryo growth.(MacLeod, 2004).

Steeping

The storage of the barley is made taking in consideration that the moisture level should be between 10% and 14%. Keeping the that level below 14% is beneficial, to avoid the formation of mold and germination loss.

In the steeping, the barley is immersed in water in order to increase the moister level until approximately 40%-45%, boosting the grains germination. This step aims at stimulating the embryo to respirate and start the hormone activity through the uptake of water and oxygen, which involves 2-4 immersion periods in water each time followed by an air-rest period.

This procedure is also used as a cleaning step where grain shells (outer hull) and impurities are removed.

Normally, steeping takes between 1 and 2 days, depending on the plant design, barley characteristics, conditions and the target malt specification (MacLeod, 2004).

Steeping washes out a wide range of compounds such as phenols, amino acids, sugar, mineral and microorganisms. Therefore, the post-steep water is biologically active. Since this water inhibits germination it cannot be reused without prior treatment (Fergus G. Priest, 2006, p. 151).

Germination

After the steeping the barley grains are transferred to germination vessels. This next procedure aims to initialize the enzyme synthesis and release, cell-wall breakdown while and solubilization of stored nitrogen (proteolysis).

Nowadays the barley is transferred to a tub (germination compartment) where temperature and aeration levels are controlled for 4-6 days. The germination unit involves the germination compartment, a plant able to produce cool humidified air and move it through the germinating grain. The principal structural characteristic of the germination compartment is its perforated stainless floor and a grain turnaround machine.(Ullrich, 2011).

During this stage, the moisture in the grains reaches levels above 45%. Throughout this stage enzyme accumulation occurs, including α-amylase, dextrinase, α-glucosidade, β-glucanase, xylanase, lipase and endo- and exo-proteinases (MacLeod, 2004).

Kilning

With the purpose of preventing further transformation and losses, the germination is interrupted by drying the malt and kilning. The water contend of the grains is decreased from over 40% to less than 5%, increasing the preservability and the easiness to store (Kunze, 2004). Kilning can take between 16 and 60 hours depending on the plant being used and the type of malt being produced. During this procedure, the temperature must be carefully controlled in order to dry the malt as quickly as possible but without inactivating the enzymes produced during malting (Hornsey, 1999, pp. 27–28). After submitting the malt to this step, it becomes friable and can be milled for brewery or stored in cool dry conditions.

Normally, there are three phases of moistures removal during the kilning. In the first phase, 'free drying', the grain's moisture level drops very fast until below 25% and under relatively low temperatures (50-60 ºC). After this step, the malt passes through the 'intermediate' phase where it will reach levels of moisture around 12% and in the final phase, 'curing phase', this level will reach its lowest value, 4%. The temperature increases in each phase (MacLeod, 2004).

1.4 Milling

The first process to take place in the brewhouse is milling of the malt and, if necessary, of the cereal adjunct as well.

Milling aim is to give the malt enzymes the opportunity, during mashing, to act on the malt contents and break them down, as the latter must be broken into small fragments. The malt used for a brew is denominated as grist and the amount used is the charge.

This step is done immediately before the usage of the malt in order to avoid oxidation. On one hand the usage of fine milling favours maximum extractions leading to better yields, on the other hand larger grist particles, with higher percentage of intact husks, benefits the lautering process. Depending on the separation process downstream, one choses the different methods of milling (roller, wet and hammer) (Ullrich, 2011).

1.5 Mashing

This brewing step intends first to convert the malt starch to soluble sugars, which will then be used by yeast to produce alcohol through fermentation. At the same time proteins are broken down into amino acids that the yeast can use as nutrients.

The grist is mixed with hot water in the mash tun and the whole mash is kept at approximately 65 ºC for an hour. This will allow the gelatinization of the malt starch making it more susceptible to the enzymes action. Also, in this step, occurs the activation of the malt enzymes. The brewery water originated from this procedure (mashing-in) is later filtrated to generate the beer wort (Hui, 2007).

Double mash process

Two of the principal starch-digesting enzymes are obtained through malting, the α- and β-amylase. The α-amylase activity is important given that it reduces the molecular weight of both starch polysaccharides and decrease mash viscosity. On the other hand, β-amylase hydrolysis amylose to maltose and a small amount of maltotriose.

The main factors that regulate the activity of the enzymes are the pH, temperature and concentration of the wort. Temperatures on the range of 60-65ºC maximize the activity of β-amylase while to maximize the activity of α- amylase a temperature in the range of 65-75ºC is necessary (Charles W Bamforth, 2000)(MacGregor, Bazin, Macri, & Babb, 1999).

Once that the α- and β-amylases activities being of greatest concern to the brewer, the temperature control and profile used during the mashing is of a tremendous importance.

The double mash system features both a cereal cooker and a mash tun. The adjunct mash is started first; the adjunct with water is first heated to around 70 ºC and then boiled aiming to gelatinize the starch. After temperature decrease, a small portion of malt or microbial amylase is added to reduce the viscosity of the adjunct mash. As alternative, pre-gelatinized adjuncts, for example flaked maize, or liquid adjuncts, for example corn syrup, can be introduced directly in the mash tun and mixed directly in the brew kettle.

After the cereal adjunct mash operation starts, water and malt are combined in the mash tun. The traditional mash-in temperatures range within 40-50 ºC which favours proteolysis. Thereafter the boiled cereal mash is transferred to the main mash and the temperature of the total mash is raised to around 60-65 ºC, so that the bulk of the maltose can be formed. Considerable variation in temperature ramps and rests used by the brewers in mashing can be seen in the industry aiming to control the composition and fermentability of the extract. In the final step, called mash-off, the temperature is increased to a point where enzymatic activity is stopped, approximately 78ºC (Ullrich, 2011, p. 485).

Wort separation

Once the mash has provided all the necessary components for the brew production, the separation of the spent grain particles from the liquid extract, wort, is required. In this step one can understand the importance of milling degree because, depending on the type of milling, different separation processes may become beneficial. For example, for using lauter tun is required that the milling operation crush the malt rather than grinding, to keep the malt husk intact. On the other hand if is used a mash tun the malt may be finer millet for better extraction (Hardwick, 1994, pp. 278–291). In this step occurs the recovery of the biggest by-product, dreche, which is sold to animal feeding.

Introduction of hops.

Hops (*Humulus lupulus L.*) are added to impart bitterness, odour and aroma. Both hop resins and essential oil are found in the lupulin glands of the female flower cone. The essential oil comprises the volatile components, usually isolated by distillation (Swift, 2002, pp. 57–83).

The iso-α-acids, originating from hop resins, are predominantly responsible for bitterness, whereas several compounds in the essential oil are responsible for imparting hoppy odour and aroma to beer.

Hops are normally added to wort during the boiling in the kettle in order to extract the bitterness and allow the chemical isomerization of the α-acids to the more bitter iso-α-acids. In an attempt to minimize evaporation of essential oil to retain aroma compounds, premium aroma hops extracts are added at the end of boiling, late hopping, or even in the whirlpool (Benitez et al., 1997).

Aside from their role as bittering components of beers, iso-α-acids are also a key component of the beer foam. Both cis- and trans-forms of the iso-α-acids contribute in foam formation and stabilization, in conjunction with particularly positive charged polypeptides derived from the malt and di- or tri-valent metal ions such as manganese and aluminium. The cis-forms of iso-α-acids are more bitter and stable when comparing with the trans-forms (Stewart, Russell, & Anstruther, 2018).

Whirlpool

The whirlpool vessel works as a receiver of the hot wort and is designed to obtain a good separation of the trub and spent hops from the liquid extract. Herein, the wort is pumped tangentially into the cylindrical vessel walls creating a rotating stream. The solid particles suspended in the rotating liquid will separate due to friction (teacup effect), migrate to the bottom centre and coalescence to form a cake (Eßlinger & Narziß, 2009).

Wort cooling

Significant energy is expended during the brew kettle boiling period. The energy of evaporation can be recovered through vapor collection systems. Wort cooling systems are used to bring the wort to a temperature suitable for fermentation (Hardwick, 1994, p. 312).

Hopped wort, which has been separated from the hop debris and trub, is now chilled before being introduced in the fermentation and pitched with yeast. In most breweries, to cool down the wort from 80ºC to 8ºC, a plate and frame heat exchanger is used whereby a series of vertical, indented, stainless steel plates bearing rubber gaskets are compressed together in a frame. The coolant normally used is chilled water in counter-current (Hornsey, 1999, pp. 95–98).

Wort aeration

The yeast requires oxygen for the formation of new cells, around 7-8 mg/L corresponding to 80% saturation of the wort with O_2. Meaning that obtaining an optimum aeration of the wort is fundamental to achieve a uniform fermentation process. This aeration can be reached through the injection of sterile air or oxygen into wort (Hardwick, 1994, p. 313).

Wort oxygenation is necessary given that the molecular oxygen is necessary for the synthesis of sterols and unsaturated fatty acids, which are essential components of cell membranes and are fundamental for subsequent yeast growth in anaerobic conditions (Briggs et al., 2004, pp. 400–475).

1.6 Fermentation

Fermentation is frequently considered as being the rate-determining step in the beer production, leading to a lot of effort to discover news ways of increasing the productivity. In this stage the enzymes in the yeast will convert the fermentable sugars present in the wort into alcohol and CO_2.

The first step in fermentation is the addition of 0.5-0.7 liters of concentrated yeast slurry per hectolitre of wort, corresponding to $(15 – 20) * 10^6$ yeast cells per millilitre of cooled and aerated wort (Eßlinger & Narziß, 2009).

There are two types of brewing yeast systems in the fermentation, top and bottom fermentation. Normally, the ales are fermented with 'top yeast', while the lagers with 'bottom yeast'. The top fermentation is conducted at a higher temperature leading to shorter fermentation time when compared with the bottom (Briggs et al., 2004, p. 5).

Extract

The extract has a major importance in the control process and is used in two senses: firstly, the potential extract that might be obtained from various brewing raw materials, and secondly, real measures of the extract present in the worts, beer or other process liquids such as syrups, and so on.

In order to assess commercial-scale brewery operations, extract measurements are made at various stages in the brewing process. Providing accurate measures of the total quantities of raw materials used, the volume and concentration of extract obtained provide an indication of the efficiency of the process. In any given brewery the standard reference wort for any given product is defined as that which is obtained at the completion of the boil when it is ready for transfer from the kettle. The wort concentration at this point with reference to the total volume is defined as the original extract. With regard to fermentation the total extract present is subdivided into two principal fractions, fermentable and non-fermentable. These describe those wort solids which under the conditions employed are either utilised by yeast or which remain in the beer when fermentation is completed. The presence of yeast and the resultant formation of ethanol have effects on extract measurements that require correction. Since ethanol is less dense than water it exerts a depressing effect, and for this reason uncorrected values are referred to as apparent extracts. Predictably measurements made after the removal of ethanol by distillation and correction for volume and temperature are referred to as real extracts (Boulton, 2013, p. 222).

Yeast pitching

The only way to maintain the integrity of a beer brand is by performing the fermentation with reproducibility; one of the vital steps to achieve that reproducibility is the addition of yeast into the wort.

The aim of the inoculation process is to deliver a defined suspended viable yeast count in wort at the start of fermentation (Boulton, 2001, pp. 338).

The yeast is kept in a vessel denominated ‘yeast brinks’, which provides cold and agitation in order to preserve a uniform concentration.

The wort is essentially sterile until proceeding with yeast inoculation, meaning that the contamination of pitching yeast must be prevented so that undesirable flavours do not appear in the final product.

Pitching rates, which refers to the number of cells inoculated per millilitre of wort, are calculated through the concentration of live cells and which are added in the flowing stream of the wort to the fermentation vessels.

Fermentation process

After the pitching step, the mixture of wort with yeast is placed in a fermenter with a temperature controlled around 8ºC, so that the temperature does not rise above 13ºC, and then is lowered, progressively, until around 5ºC. The temperature rise observed in the fermenter is due to the energy released during the fermentation is originated in the formation of adenosine triphosphate, ATP, during the consumption of glucose as demonstrated in equation (1).

$$C_6H_{12}O_6 + 2P_i + 2ADP \rightarrow 2C_2H_5OH + 2CO_2 + 2ATP + 2H_2 \qquad (1)$$

During this stage, the yeast cells are inoculated with limited amount of nutrients, being the most common situation in commercial fermentations. The cells undergo division through three distinct phases that are similar for microorganisms that reproduce by cell division, where the time of each phase is determined by the cultivation conditions.

The first one is lag phase, which represents a period of adaptation when the cells are exposed to a new condition, one of the examples is the need to synthetize different enzymes to perform the uptake and utilization of the substrate. The next phase is the exponential growth where the cells are already adapted to the medium and occurs the logarithmical increase of the population; normally this growth stops when there is depletion of an essential component from the medium. Following this phase comes the stationary phase during which there is not oscillation of biomass (Briggs et al., 2004, pp. 400–475).

The parameters that will determine the concentration of ethanol produced during the fermentation are the initial concentration and spectrum of the fermentable carbohydrates present in the wort. On the other hand, the range of carbohydrates that the yeast can ferment and the maximum amount of ethanol that it can tolerate is genetically determined.

During the fermentation other products are produced that will contribute to beer flavour and aroma.

The diacetyl and 2,3-pentanedione, vicinal diketones (VDK), are two of those by-products that impact the flavour and are formed in all brewery fermentations. The diacetyl has an intense sweet, butterscotch flavour which cannot be tolerated in lager beers and the final concentration on the beer should be inferior to 0.1 mg/L. The 2,3-pentanedione has a honey-like flavour. An effective way of reducing the concentration of diacetyl and 2,3-pentadione, is by warming a beer for a period of 2-3 days at 14-16 ºC rest, then when the concentration decreases until the acceptable threshold, a cold shock until 5ºC is applied. The concentration of diacetyl will also dictate when is the beer is ready to be filtrated (Briggs et al., 2004, pp. 400–475).

The cold shock is an important step leading to the sedimentation of the yeast in the bottom of the fermenter, in the case of lagers, permitting to separate these yeasts through a pipe in the bottom of the fermentation tank (cropping). This separation is necessary because, once there are no more sugars to ferment, the cells start the process of autolysis originating the release of harmful compounds to the beer.

The end of fermentation, for most lager fermentations, is the point which is defined in terms of achievement of a specified VKD, concentration. Normally, this is linked to the time of cropping in order to ensure that enough yeast is available to reabsorb diacetyl and 2,3-pentanedione and, possibly, also to the application of cooling (Boulton, 2011).

1.7 Maturation

Once the fermentation is finished, the beer must undergo a period of maturation; since it stills contains undesirable flavours compounds and these must be removed by conditioning. In the traditional lagering methods, the beer is transferred to a separate tank. Nowadays, the maturation occurs in the same vessel as the fermentation. The presence of a relatively small portion of yeast which remains in contact with the beer has two effects. Firstly, more carbon dioxide is produced leading to carbonating the beer and purging of unwanted volatile compounds.

Secondly, the yeast biochemically removes certain other flavour-active compounds, by catalysing the reduction of flavour-active vicinal diketones such as diacetyl (Hughes & Baxter, 2001, pp. 11–12). The total concentration of diacetyl is used to judge the maturity of the beer (Eßlinger & Narziß, 2009).

During the maturation there is an aspect to take in consideration, the beer should not be kept in the same vessel as the yeast that sediments (only the much less amount of suspended cells is adequate), meaning that one must purge it through the bottom pipe of the tank.

1.8 Beer treatment

The most effective beer treatment regarding the haze stability is the storage of beer for about a week at -1 to -2 ºC. This procedure allows a reduction of cost in the other beer treatments performed to remove potential haze-forming proteins and polyphenols. The formation of colloidal haze in beer arises from the formation of protein-polyphenol complexes during beer storage (Briggs et al., 2004, p. 557).

Complementary to low temperatures, polyvinylpolypyrrolidone (PVPP) is added as an adsorbent. The PVPP is dosed in the filtered beer and then retained in the filter; the loaded PVPP is then reprocessed and reused. (Eßlinger & Narziß, 2009).

1.9 Beer clarification

The final unit operation to take in consideration in the beer processing, prior to the packaging, is filtration. The bulk filtration duty in a brewery is a demanding unit operation, as it is essential for product clarification and for colloidal stability. Clarification of the beer to a standard that is acceptable by the legislation is necessary to introduce the product in the market. This process is responsible for the removal of any remaining yeast, precipitated protein and polyphenol haze material.

There are two main modes of filtration, namely surface and depth. Depth filtration describes the type of process in which the sieving action is achieved using a bed of material through which the fluid to be clarified passes. It is distinct from surface filters, which rely purely on the cut-off of the pores in the membrane for their sieving action. Depth filtration relies on a combination of three mechanisms. These are the pore size of the surface of the material, which limits the size of particle that can enter the filter bed, the ability of the interstices within the bed to trap particles, and electrostatic effects, whereby charged particles, which may be smaller than the pore size, become bound to components of the filter bed with an opposite charge. Compared with surface filters, depth filters have a greater capacity and are therefore suitable for the clarification of feedstocks with relatively high solids loadings. Depth cartridge filters are used for cold sterilisation of beer and powder filters are used for primary beer filtration and possibly colloidal stabilisation (Boulton, 2013, p. 174).

When aiming at a stable beer for its shelf life, which can be up to 52 weeks from the date of packaging, this implies that the concentration of yeast must remain inferior to 0.2 million cells per millilitre in the filtrated beer (Briggs et al., 2004, p. 574).

Beer Clarification through centrifugation

Centrifugation represents a measure available to increase the rate of sedimentation. In addition, the design of centrifuges is highly effective at minimizing the depth in which particles must settle.

To remove yeast and other particles from beer by centrifugation, the beer must have enough residence time in the machine for cells and flocs to fall through the average path length under the applied “g” force. Clearly, modern centrifuges are easily capable of achieving this. When smaller particle size is considered, the residence time or centrifuge speed become more critical. Disc bowl centrifuges can be tailored for beer treatment. These machines contain several disc plates onto which the deposited particles collect and then slide into the solids holding area.

In order to ensure maximum beer yield, minimum oxygen pickup, minimum temperature increase and minimum damage to yeast cells, the design and operation of the centrifuge are key aspects (Stewart et al., 2018).

Kieselguhr filtration

Kieselguhr, or diatomaceous earths, is a filter aid powder that consist of skeletons of marine algae containing silicon dioxide. This compound will act as filter; the finer the kieselguhr the better is the promoted clarification, but the speed of filtration will decrease (Freeman & McKechnie, 2003). However, this substance must be handled carefully, as is considered highly dangerous when inhaled giving rise to the silicosis disease.

Beer dilution

Many beers are produced using high-gravity brewing, where a wort of high concentration is fermented and then the derived beer is diluted at the end of the process, to reach the common beer gravity. The disadvantages that this process represent in beer production are the extra plan that is normally required for recycling of wort and for de-aeration of dilution liquor, the potential for increased production of flavoursome esters in fermentation and the poor extraction of the hops earlier in the brewing process. However, the disadvantages are outweighed by the advantages provided that with this process there is a much lower plant capacity requirement upstream of the bright beer tank and substantially lower cost of heating in the brewing process and of cooling during and after the fermentation. Also, the amount of yeast growth per unit of alcohol produced is less in high gravity fermentation (Freeman & McKechnie, 2003).

This dilution should be implemented after beer filtration and the quality of water used for this process is of the utmost importance; as it will be drunk by the consumer, it must be free from taint, sterile and deaerated (Briggs et al., 2004, p. 551).

Beer carbonation

The carbon dioxide is a very important compound of beer once it imparts sparkle, 'mouth feel' and sharpness associated with its properties as an acid gas. The concentration of this constituent must be carefully controlled to provide a consistent product to the consumer.

All processes after secondary fermentation should be designed to keep carbon dioxide solubilized in the beer, thus beer must be kept cold and under suitable pressure of carbon dioxide to avoid gas release (Kunze, 2004, pp. 579–581). The carbon dioxide concentration must be then readjusted in the beer before packaging but cannot be introduced upstream the filtration given that the CO_2 (bubbles) would disturb the filter aid layer bed. Normally, is introduced after the filtration during the transfer to the bright beer tank (BBT).

The carbonation is conducted while measuring the amount of dissolved CO_2 in the beer and passing the information of whether or not more CO_2 is needed and, if so, how much more (Briggs et al., 2004, p. 564).

1.10. Filling

Before being sold, packaging the beer is necessary. The most important package world-wide is the bottle: returnable and non-returnable. Beer can also be filled into cans, kegs and casks.

Three main aspects should be considered for successful packaging operations: prevent the introduction of air into the beer is essential, the beer pressure and temperature must be kept in values such that allow maintaining the CO_2 in solution and, finally, the cleanliness in the facilities and all the equipment must be of high standards (Briggs et al., 2004, p. 584).

1.11 Fermentation vessels for bottom fermentation.

The installation of cylindroconical vessels (CCVs) was particularly prevalent during the 60's and 70's. Introducing this type of tank was associated to a higher efficiency of lager production by combining primary fermentation and cold conditioning in a single tank.

Originally, the vessels were constructed from aluminium but, once understood the propensity of this metal to corrode, the material was exchanged to stainless steel. The essential feature of the CCV is the replacement of the lower dished end by a cone. The interior surface of this is highly polished in order to reduce the friction and thereby facilitate the yeast cropping.

Nowadays, the CCV are widely used in the production of lager beers since processing the fermentation and maturation in the same tank represents the decrease of operational cost and increase the quality of beer (Boulton & Quain, 2006). The modern forms of this vessels can range from 100 to 6000 hL and one of the most important characteristics is an angle of 70º in the cone, necessary so that the yeast settle into the base of the tank (Briggs et al., 2004, p. 514).

Figure 1 - A schematic drawing of a cylindroconical vessel, adapted from (C. Bamforth, 2003).

<u>Carbon dioxide recovery</u>

The carbon dioxide is an important by-product from the fermentation, as it can be used, for example, to re-carbonate the beer after purification. When fermenting and maturing in a CCV the CO_2 occurs in a concentrated form and can easily be extracted and collected (Briggs et al., 2004, p. 514).

The amount of carbon dioxide that is formed during the fermentation depends on the original gravity of the wort.

A recovery plant for this compound consists in a foam breaker (gas-separator) and a gas container, which is used as a reservoir for the collected CO_2. The CO_2 stream is then freed from water-soluble impurities in a gas scrubber (Eßlinger, 2006).

1.12. Yeast cells propagation

In theory, there is no limit to the times that a yeast can be cropped and re-pitched for a subsequent fermentation run. In the most modern breweries, there is a limited number of re-pitching. Therefore, periodically, inoculation (pitching) goes back to the propagation stage from the yeast cell banks, to guarantee a minimal level of identity and purity, when compared to the one stocked in the laboratory. These practices are done, mainly, to maintain the low levels of contamination and reduce the genetic instability verified in the yeasts after prolonged serial fermentations (Briggs et al., 2004, pp. 487–488).

The major driver for the development of aerobic propagation systems is the dissatisfaction with the performance of the ‘first generation’ fermentation. Normally, in ‘traditional’ anaerobic propagators, the cell yields are too low to achieve a satisfactory pitching rate (Quain, 2006, p. 174).

1.13 Flocculation and crop of yeast

Flocculation occurs because of interactions between surface proteins on one cell and carbohydrate receptors on another cell (Miki, Poon, James, & Seligy, 1982) and presents itself with an enormous importance in the process of brewing. The tendency of yeast to form flocs is an integral part of the process of separating the crop from ‘green’ beer, beer that passed through the first fermentation but had not passed through the maturation process (Boulton, 2013, p. 65). In the case of bottom fermentation, yeast creates flocs that will settle in the base of the vessel. The crop that remain in the bottom can be retrieved from the fermenter before the beer is racked.

Undoubtedly, the conditions experienced in the cone of a large fermenter are hostile to the yeast. Apart from adaptation being difficult, ethanol concentration is as high as hydrostatic pressure is. An early cropping is desired once that presents benefits to the yeast health (Boulton, 2011).

As mentioned before, the formation of flocs is an essential step to the crop formation. If occurs an inadequate flocculation, the cropping of yeast will not be enough for the re-pitching and the ‘green’ beer will remain with an unacceptably high number of cells.(Briggs et al., 2004, pp. 377–379).

1.14 Collecting yeast and storage (storage of pitching yeast)

Once fermentation in CCV ends, yeasts are sometimes stored in the cone of CCV due to operational reasons. However, there are disadvantages since this method results in the exposure of yeast to various stresses such as high temperature, high ethanol levels and undesired pH. Cumulative effects of these stress factors may damage the yeast physiological state.

Normally, the yeast is cooled and transferred directly to the storage container just after recovery from the fermentation vessel.

Between serial fermentations, pitching yeast slurries must be stored in a manner that preserves viability and minimizes physiological change. To achieve this goal, the key parameters to take in consideration are the maintenance of low temperatures (2-4 ºC), the exclusion from oxygen ingress (and microbial contamination) and control of the storage time to no more than one or two days (Boulton, 2011). The purpose of the cooling is to slow down the metabolism of yeast to a minimum.

A stirring system is used to secure yeast homogeneity during the storage. Since that in the stationary phase of growth the cells are much less sensitive to mechanical stress, eventual damage in the yeast will not be due to the length and intensity of stirring, but due to the actual physiological state of yeast and environment's pH.

Aiming to maintain yeast slurry without contamination, a step of acid washing is used. The most used acids are phosphoric, sulfuric and tartaric acid. This decontamination should be carried out at a pH 2.2 for 2-4 hours at 4 ºC (Matoulkov, 2017).

Metabolism

Metabolism is defined by all the chemical processes that occur in the cell and is divided into two areas. Catabolism, which include the pathways where the organic molecules are degraded liberating energy, and anabolism, including those that use the energy from catabolism to produce the synthetic reactions needed for the cell growth and proliferation.

The carbohydrates are the preferred sources of carbon and energy in the yeast.(Briggs et al., 2004, pp. 404–405).

During respiration the substrate, which is taken up, for example, sugar is totally broken down to CO_2 and water (equation 2):

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 \tag{2}$$

In the presence of sugar, yeasts are the only living organisms which convert it under an alcoholic fermentation. In this case, glucose is converted to ethanol and CO_2 (equation 3):

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 \tag{3}$$

The conversion of glucose into alcohol, or in the case of respiration, to CO_2 and water, results from numerous sequential reaction steps. Each reaction step is catalysed by a certain enzyme. Thus, the enzymes for glycolysis and alcoholic fermentation are in the cytoplasm, whereas the respiration occurs via enzymes in the mitochondria.

To produce new cell substances, sources of nitrogen are required, which are present in the wort mainly as amino acids. Only low molecular weight amino acids with up four C-atoms are absorbed (Kunze, 2004, pp. 418–425).

1.15 Serial re-pitching

Industrial fermentations performed to produce beer are unique within the alcoholic beverage industry in that the yeast is not discarded after use but is maintained and reused several times in a process termed ‘serial re-pitching’.

Normally, yeast is serially re-pitched between 5 and 20 times before is considered inappropriate for use in fermentation. The number of times that a yeast suffers the re-pitching reflects on the quality of the inoculum. Brewers rely on the activity of these inocula, which should be inspected upon microbiological and performance testing of the existing yeast (Briggs et al., 2004, p. 484).

The serial re-pitching leads to a gradual deterioration of yeast physiology, which will reflect in its performance during the fermentation. In the case of bottom-cropped fermenters, especially large-volume cylindroconical, there is a higher change of cropping yeast together with trub. Since the brewery industry intends to maximize the revenues, the use of very large vessels and high-gravity fermentation has increased, and so it has intensified the stress to which produced yeast is subject (Boulton & Quain, 2006, p. 475).

1.16 Yeast growth

Yeast growth is the coordinated uptake of nutrients from the medium and subsequent metabolism to yield new biomass. The new biomass is generated by increasing the size of individual cells and by cellular proliferation. During this proliferation the cells promulgate their genotype via the progeny. Since beer is a by-product of yeast growth, the brewer is aiming to manipulate process conditions in order to control the growth and metabolism of yeast to produce the intended product (Briggs et al., 2004, p. 469).

Ageing of yeast

The yeast has a finite life span measured by the number of divisions and not by chronological age. When the division stops, the cell becomes senescent and eventually dies.

The ageing of yeast presents morphological, metabolic and genetic modifications, altering as well the yeast progeny (Powell, Quain, & Smart, 2003),

During the ageing, the yeast presents changes in its physiology. Morphologically, the cell takes on an aged appearance, becoming granular, irregular and wrinkled (Mortimer & Johston, 1959).

With the re-pitching of the yeast in a fermentation occurs its ageing, which is accompanied with morphological changes, as described before. Is possible to obtain a positive correlation between the cell age and cell volume; the senescent cell (950 um3) can be six-fold larger (in size) than a young mother cell (163 um3) (Briggs et al., 2004, pp. 481–482)(Barker & Smart, 1996).

1.17 Storage and supply of yeast cultures

The storage and assure supply of brewing yeast strains is an important step in the propagation cycle.

There are many ways of storing the yeast for example by sub-culturing, by freeze-drying (some as lyophilisation) and by freezing in liquid nitrogen.

The simplest and more often used method is the periodic sub-culture using agar slopes, that consist in small bottles containing medium solidified with agar. Aiming to maximize the contact area, the agar is solidified with the bottle placed at a slant.

In more sophisticated storage methods, as freeze-drying, the storage is achieved by slowing down the metabolism and thereby prolonging storage period when comparing to the previous method. In lyophilisation, the cultures are rapidly frozen followed by dehydration under vacuum such that water is removed by sublimation which originate cultures that can be safely stored for several months. A major setback of this technique is the large overall reduction in viability.

Storage by freezing in liquid nitrogen is the most effective method but also the most expensive one. In this process, the cultures must be frozen, until -196 ºC, in a controlled manner. Once this is achieved the storage potential is measured in years (Briggs et al., 2004, pp. 485–486).

An alternative to in-house yeast supply and storage is to outsource the responsibility to a third party, a growing trend nowadays (Quain, 2006).

1.18 Vicinal diketones

Vicinal diketones (VDK) are ketones with two adjacent carbonyl groups. During fermentation, these flavour-active compounds are produced as by-products of the synthesis pathway of isoleucine, leucine, and valine (ILV pathway) and thus also linked to amino acid metabolism (Nakatani, 1984) and the synthesis of higher alcohols. The concentration of two VDKs, diacetyl (2,3-butanedione) and 2,3-pentanedione, are of critical importance in the fermentation of lager beers because that determines the length of the maturation process. Diacetyl relates to valine and 2,3-pentadione relates to isoleucine. Both compounds have strong 'butterscotch' or 'toffee' aromas and tastes. Their presence in lager at concentrations higher than their flavour detection thresholds of around 0.15 ppm and 0.9 ppm, respectively, causes and objectionable flavour defect (Briggs et al., 2004, pp. 456–457). The ten times lower threshold for the diacetyl highlights the need to perform a more controlled monitorization of this compound during fermentation.

As referred, both VDKs arise as an intermediate of the amino acid biosynthesis. The first intermediates in this metabolism are α -acetolactate and α-acetohydroxybutyrate. These compounds are released from the cell and undergo an oxidative decarboxylation to form diacetyl and 2,3-pentanedione, then the yeast takes-in these substances again and reduces them to 2,3-

butanediol and 2,3-pentanediol, respectively (C. W. Bamforth & Kanauchi, 2004, pp. 83–93). Figure 2 depicts a simplified pathway of the formation of diacetyl and 2,3-pentanedione.

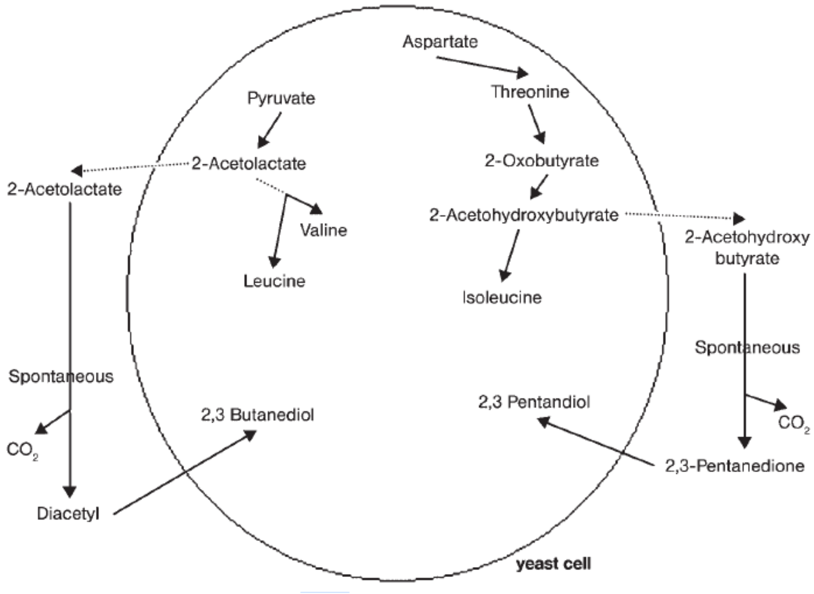

Figure 2 - Pathway of the formation of diacetyl and 2,3-pentanedione. Adapted from (Eßlinger, 2006).

1.19 Beer foam characteristics and stability

Beer foams are colloidal systems comprising a continuous liquid phase and a discontinuous gas phase. The physical characteristics of beer foam have been studied and researchers concluded that foam is determined by four main processes: bubble formation, drainage, coalescence and disproportionation (Briggs et al., 2004, pp. 703–704).

The interactions between iso-α-acids, which are formed during wort boiling from hop-derived precursors (α-acids), and barley polypeptides are generally known to be responsible for foam stability in beer. Regarding the high gravity beer, it was found that the proteolytic degradation is the major factor for the lack of foam stability (high levels of proteinase in yeast). The proteinase A, activity under increased wort gravity, is responsible for lack of foam-active hydrophobic polypeptides (Brey et al., 2003).

2. Materials and methods

The work performed in this study took place at the Empresa de Cervejas da Madeira (ECM), Funchal, Portugal, from the 3rd of March until the 31st of August of 2019.

All the process enhancement opportunities that were investigated focused on the reduction of product loss of the beer type produced that represents 90% of the revenues, regarding the beer market.

2.1 Temperature measurement analysis

Presently, to measure the temperature of lager beer in fermentation vessels, beer losses had to occur, by purging. High gravity beer samples were extracted from a pipe connected to the medium height of the fermentation vessel, and the temperature was therefore measured using an analog thermometer.

When the thermometer showed a constant temperature, that value was recorded in the temperature registry sheets. The volume withdrawn from the purge, necessary to measure the temperature, was recovered in a volumetric cylinder and then also written down in the temperature registry sheet.

Comparison of the impact of thermometers selection

Two types of thermometers and three thermometers were studied in order to verify if it was possible to reduce the volume of lager beer necessary to measure the temperature.

An analog thermometer (A), from VLB BERLIM reference 2-1600-35, was used to measure the temperature of beer in the fermentation vessel before this study begun. The study of the impact of using this thermometer on the losses of beer started in the 11th of March and went until the 10th of April of 2019, using the procedure explained above for the temperature measurement.

The next step was the introduction of a digital thermometer (B), HERTER reference 010204004, which was kindly borrowed by the University of Madeira. A second digital thermometer (C) was then used, this time acquired by the Empresa de Cervejas da Madeira and supplied by TFA, reference 010204017.

More information regarding the thermometers is presented in annex B.

In order to evaluate how much beer volume would be saved with the substitution of the thermometer, all the liters used daily for the measurement were summed with the different thermometers. This analysis was extended to all the fermentation vessels in usage each day. The average volume of beer lost daily with each thermometer was then calculated. All these volumes will have a cost associated, evaluated by multiplying the volumes per the unit production cost price of the product.

Impact of thermal insulation of the purging tube

Regarding the subject of this study, the influence of the thermal of insulation of the pipe from where the beer was recovered was analysed. The fermentation vessels to which purging pipe was insulated were numbered 9 and 30. As in the procedure performed in the study referred before, the volume of beer was recovered to the volumetric cylinder which provided the volume necessary to measure the temperature. The thermometer used for this analysis was the analog thermometer for which more data was available from the period without thermal insulation. Figure 3 shows one of the pipes with thermal insulation.

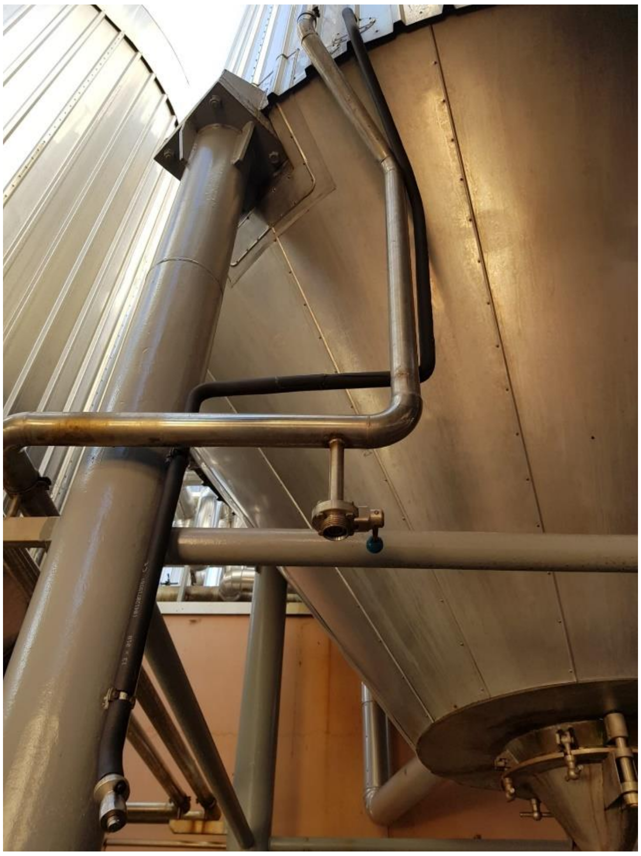

Figure 3 – Insulated pipe (black tube), from where HGB was recovered and its temperature measured.

2.2 Examination of HGB and yeast purges

As explained before, only the type of beer that is produced in more quantity was considered object of study.

Due to the high concentration of suspended solids in the 'green' beer, separation of phases through sedimentation was necessary. Therefore, 'green' beer remained an undetermined amount of time so that it could occur. Then all the sedimented yeast was removed from the CCV due to its negative effects on the beer, purging it from a pipe in the bottom of the fermentation vessel and purging it to an agitation tank (figure 4) through a hose-pipe.

The purged feeds recovered were introduced in a tank of 1200 liters with agitation (2700 rpm with agitator from SEW-EURODRIVE type RF40DT71D2Z) and kept for one hour aiming to obtain a representative sample of all the recovered purge. It is possible to know the volume purged using the level indicator of the tank, represented in figure 4. The sample then undergone the procedure explained in the 2.2.1 Centrifugation.

Figure 4 - Stirring tank used to receive and keep the purged yeast in a homogeneous suspension.

2.2.1 Centrifugation

Aiming to determine the quantity of yeast and HGB that was recovered from the purges a separation process, more precisely a laboratorial centrifugation, was used. The laboratorial centrifuge used is from Selecta, model Mixtasel-BLT.

Firstly, the empty centrifugation flask was weighed. The same flask was then filled with 100 mL of water and the operator marked the meniscus. Then the tube was filled with the sample, homogenous solution of the collected purges, until the marked meniscus and weighed. Next, the sample underwent a centrifugation with the duration of 12 minutes at 4000 rpm. Once the centrifugation was finished the supernatant was withdrawn from the tube. The tube was again weighed, this time with the solid, allowing to obtain the fraction of yeast and beer in the studied sample.

2.2.1.1 Ratio of HGB on the purges

Firstly, it was obtained the weight of HGB present in 100 millilitres of sample. For that, after the centrifugation the mass of the flask with the remaining solids was subtracted from the initial mass of the flask plus the one hundred millilitres of sample; the calculus explanation is represented in equation 4.

$$M_{supernatant}(g) = M_{Flask\,+\,100mL\,sample}(g) - M_{Flask+Remaining\,solids}(g) \tag{4}$$

Once the quantity (grams) of HGB in 100 mL was determined, it was then multiplied by a factor of ten to calculate the recovered HGB per unit volume of purge, as is it possible to see in the equation 5.

$$C_{HGB}\left(\frac{g}{L}\right) = M_{supernatant}\left(\frac{g}{100mL}\right) * 10 \tag{5}$$

2.2.1.2 Quantity of beer and yeast extracted in the purges

The next step was to determine the quantity of beer present in the overall purges and, with that purpose, the total mass of HGB was calculated using the HGB ratio of the sample, obtained from the equation above (equation 5), and the total volume recovered from the purges, as represented in equation 6.

$$M_{HGB}(kg) = \frac{C_{HGB}\ (g/L) * V_{Purged}\ (L)}{1000} \tag{6}$$

One needs to know the volume of purged beer instead of its mass, given that the production cost price value is given in euros per litre. For that reason, equation 7 was used to convert the mass of purged beer into volume.

$$V_{HGB\ purged}(L) = \frac{M_{HGB}\ (kg)}{SG_{HGB}} \tag{7}$$

Where SG is the volumic mass (also known as ‘specific gravity’) of HGB (obtained through the equation 22).

The beer recovered during the purge is high gravity beer meaning that is denser, i.e., more concentrated than the commercial product. Since the production cost price is given in accordance with the commercialized beer price, one needs to verify how much of this will be obtained after dilution of the HGB. For that reason, equation 8 was used.

$$V_{Commercial\ beer\ purged}(L) = V_{HGB\ purged}(L) * \frac{E_{Wort}}{E_{Final\ product}} \quad (8)$$

Where the variable E_{Wort} and $E_{Final\ product}$ represents the original extract from the HGB and original extract of the commercialized beer, respectively.

2.2.1.3. Pitching and cropping.

Also, to take in consideration is the HGB that was lost due to dragging during the separation of the yeast. This quantity of HGB and yeast collected in yeast cropping is not the total volume truly 'wasted', since in the pitching process both the HGB and yeast are introduced in CCVs for a new fermentation. To account for the true loss of HGB, it is firstly necessary to obtain the correct mass of suspension of yeast and HGB collected. The latter is obtained by subtracting the quantity that enters to the quantity that exits. (equation 9).

$$M_{Truly\ purged}(kg) = M_{Total\ yeast\&HGB\ cropped}\ (kg) - M_{Introduced\ in\ pitching}(kg) \quad (9)$$

The calculated mass was then transformed into volume using the density of the purge, through equation 10.

$$V_{Truly\ purged}(L) = \frac{M_{Truly\ purged}(kg)}{\rho_{yeast\&HGB\ cropped}\left(\frac{kg}{L}\right)} \quad (10)$$

After obtaining this volume and performing the centrifugation to a sample (homogenous solution of yeast and HGB cropped), the same computations/procedures were carried as above (centrifugation and equation 4 to equation 8) to obtain an equivalent estimated total volume of beer with the commercialized original extract wasted due to the dragging.

2.3 Fermentation sheet analyses

2.3.1 Fermentation and maturation days determination

Through the analysis of the fermentation sheets, provided by the company, the average number of days needed so that the correct fermentation occurs through the different temperature stages was determined. Thereafter, the maturation went on for 4 days at around 0ºC.

2.3.2 Losses associated with the purges.

The next information that was obtained through the treatment of data within the fermentation sheet was the quantity of beer that was lost to purges.

For this study, one considered that all the losses of product in the purges, performed after the fermentation and maturation processes were completed, were due to an insufficient sedimentation process, and analyses to the fermentation sheets were performed for acquiring the volume of HGB purged. The difference between the liters of fermentation wort that enter the fermentation vessel and the liters of HGB that are recovered from the vessel, were then multiplied by the ratio of extract value of the wort to the extract value intended for the final beer product, to originate the volume that is lost due to all the purges (equation 11).

$$V_{Loss\ during\ purges} = (V_{Entered\ in\ the\ tank} - V_{Recovered\ from\ the\ tank}) * \frac{E_{Wort}}{E_{Final\ product}} \tag{11}$$

With the extract value of the wort and the extract value intended in the final product, is possible to determine the volume of commercialized beer that is supposed to be produced from each tank, by multiplying the total volume entered in the fermentation vessel by the above ratio of the extract values (equation 12).

$$V_{Supposed\ to\ be\ recovered} = V_{Entered\ in\ the\ tank} * \frac{E_{Wort}}{E_{Final\ product}} \tag{12}$$

Calculating the difference between the volume that was supposed to obtain from each fermentation vessel and the volume that was actually recovered, one can determine the total volume of beer lost during the sedimentation and filtration processes (equation 13).

$$V_{Loss\ purges\ \&\ filtration} = V_{Supposed\ to\ be\ recovered} - V_{Recovered\ \mathrm{after\ dilution}} \tag{13}$$

From industrial data in fermentation sheets, the fraction of lost beer was estimated and the value compared with the company prediction to confirm the veracity of the calculus. For this purpose, the volume of beer that was lost in the purges and filtration was divided by the total volume that was supposed to be recovered, as described in equation 14.

$$\eta_{Loss} = \frac{V_{Loss\ purges\ \&\ filtration}}{V_{Supposed\ to\ be\ recovered}} \tag{14}$$

2.4 Evaluation of the gains with centrifuge

To know which portion of beer would be reused with the introduction of an industrial centrifuge, the total volume that would be purged from CCVs until the day of the correct fermentation and maturation processes cycles was calculated. The process to find the average number of days that are need for these processes is explained in the 2.3.1. Once this value is known, the purges that occurred during and before the range of these days, necessary for the fermentation/maturation cycles, were recovered and analysed through the procedures described in sections 2.2 and 2.2.1, respectively. Then, with the values of the fermentation sheet from the respective fermentation vessel, the total volume that was lost in the purges was calculated as indicated in section 2.3.2.

As described in equation 15, the volume lost in the purges before the average days of fermentation and maturation, the volume of beer sold to a local company (directly recovered from the fermentation vessel) and the volume of beer dragged during the sedimentation, were subtracted to the total volume lost in the purges. This made possible the verification of how many liters would be saved using the industrial centrifuge; since all the remaining volume lost in the purges was due to excessive purging, otherwise unnecessary if the referred equipment after the maturation process was in use.

$$V_{Beer\ gain} = V_{Loss\ during\ purges} - V_{Beer\ purged\ before\ complete\ maturation} - V_{Sold\ to\ local\ company} - V_{Beer\ lost\ by\ dragging} \tag{15}$$

Aiming to extrapolate the results obtained from the fermentation vessels studied, it was pivotal to find a factor which would be able to apply to all the productions of the company even for those from which no purges were recovered. Due to that need, the yield of recuperation that would be achieved with the use of an industrial centrifuge was calculated (equation 16).

$$\eta_{Centrifuge} = \frac{V_{Beer\ gain}}{V_{Loss\ during\ purges}} \tag{16}$$

2.4.1 Annual production of beer

With the purpose of discovering the quantity of beer that is purged annually, and could be reused with the centrifuge, leading to monetary savings for the company, the procedure explained in section 2.3.2 was performed for all the fermentation sheet of a determined year. The total volume that was lost due to the purges. The sum performed is explained in equation 17

$$V_{Total\ loss\ in\ the\ purges} = \sum_{Vessel\ 1}^{Vessel\ n} V_{Loss\ during\ purges\ in\ vessel\ n} \tag{17}$$

Then, the volume that would be possible to recover due to the introduction of the centrifugation equipment was obtained by multiplying the yield of recuperation by the centrifuge with the total volume lost during the purges (equation 18).

$$V_{Gained\ with\ centrifuge} = V_{Total\ loss\ in\ the\ purges} * \eta_{Centrifuge} \quad (18)$$

Multiplying the volume gained with the centrifuge by the production cost price of the beer gives the amount of money that will not be wasted by the purges (equation 19).

$$Cost\ price * V_{Gained\ with\ centrifuge} = Money\ recovered \quad (19)$$

Due to different causes, not all fermentation sheets permitted the procedure described in the section 2.3.2, which leads to an incorrect quantity of liters that would be reused with the introduction of the equipment. For that reason, a correction factor was introduced which was obtained through the division of the total volume of beer accounted in the study for the total volume of beer that was produced in the timeline of the study, as represented in equation 20.

$$f_{Correction\ factor} = \frac{V_{Beer\ accounted}}{V_{Beer\ produced}} \quad (20)$$

That correction factor was then applied to the amount of money that was previously determined as the total money that would be saved in a determined timeline (equation 21).

$$Money\ recovered\ (total) = \frac{Money\ recovered\ (accounted)}{f_{Correction\ factor}} \quad (21)$$

2.5 Dilution factor

Since all the volume of beer recovered was HGB, it was necessary to convert all HGB volumes to volumes of beer with the commercial original extract (11,25 g/100mL). With this purpose, a dilution factor was applied to the volume of high gravity beer, as described in equation 8.

All the values of extract provided from the fermentation sheets are indicated in Plato degree (˚P) units. However, the original extract of beer should be indicated in g/100mL. To convert the Plato degree (g/100g) to g/100 mL, the specific gravity (SG) of the respective wort must be known. The specific gravity can be estimated from the Plato degree through equation 22 (Charles W. Bamforth, 2016, p. 140)

$$SG_{Wort\ or\ HGB} = \frac{°P}{258,6 - [\frac{°P}{258,2} * 227.1]} + 1 \quad (22)$$

Thought equation 23 it is possible to obtain the desired value of original extract to use in equation 8

$$E_{Wort}(\frac{g}{100}mL) = SG_{Wort} * {}^{\circ}P \tag{23}$$

3. Results and discussion

3.1 Daily temperature measurement.

There are two lines of thought about which factors influence, negatively, the quantity of beer needed for a correct daily measurement of the temperature of the working fermentation vessels. The first one is that the waste is due to the slow time of response from the analog thermometer. The other one is that waste is due to the lack of insulation in the pipe, from which the sample is collected to read the temperature. In the present study, both hypotheses were studied. Figure 5 shows in which part of the process this step is located, the complete blocks diagram of the company processes is presented in annex A. For both studies, the production cost price of the product was assumed to be 0,15 euros per litre, according to the company.

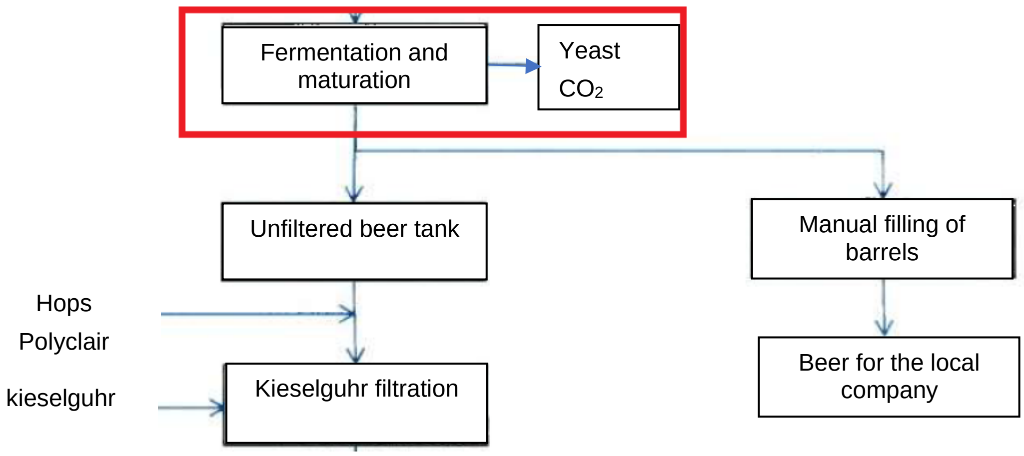

Figure 5- Zoom of the blocks diagram, highlighting the location of the purges to measure the temperature during the fermentation.

3.1.1 Thermometer study: Analog thermometer comparison with a digital thermometer.

The first issue tackled in this thesis, the daily amount of money (in euros) needed in order to perform a correct measurement of the fermentation vessels temperature for each one of the thermometers, was compared. Firstly, was tested the saccharimeter for beer/wort (thermometer A), secondly the thermometer borrowed by the University of Madeira (thermometer B) and finally the thermometer acquired by the ECM (thermometer C). Additional information can be found in annex B.

Table 1 shows and compares the price that was being wasted daily by using the thermometers A, B and C. One can see that there was an improvement with the introduction of the thermometer B as the volume of waste had a significant decrease, around 18% (which is directly proportional to the amount of money wasted). After verifying that the introduction of a digital thermometer in the process allowed to decrease the waste associated with the procedure, then, thermometer C was purchased and the tests were repeated to see if the results corroborated the first analysis. There was still a decrease in the daily waste of beer when compared with the thermometer A, this time of around 12%. The reason why the thermometer B was not purchased, was that the thermometer C is more precise and accurate.

Table 1- - Daily price that cost to the enterprise in order to measure the daily temperature from all the fermentation vessels.

Measurement number	Thermometer A	Thermometer B	Thermometer C
1	12.55 €	10.78 €	13.15 €
2	13.42 €	10.53 €	11.62 €
3	11.89 €	9.32 €	11.66 €
4	12.35 €	10.33 €	11.93 €
5	11.61 €	8.43 €	12.53 €
6	12.17 €	10.15 €	13.15 €
7	12.59 €	10.46 €	14.62 €
8	11.62 €	10.62 €	11.82 €
9	9.83 €	10.51 €	12.95 €
10	13.82 €	11.17 €	12.40 €
11	10.6 €	10.35 €	10.17 €
12	11.15 €	10.95 €	10.23 €
13	12.06 €	10.22 €	11.42 €
14	11.8 €	9.84 €	11.55 €
15	13.79 €	9.33 €	9.77 €
16	13.6 €	11.13 €	10.06 €
17	15.42 €	11.13 €	9.15 €
18	14.75 €	10.57 €	9.26 €
19	14.31 €	12.09 €	9.17 €
20	13.44 €	10.71 €	11.08 €
21	13.3 €	13.02 €	11.64 €
22	9.95 €		10.11 €
23	17.42 €		11.56 €
24	12.77 €		11.29 €
25			11.86 €
Average value	12.78 €	10.56 €	11.23 €

The breakeven point of the thermometer bought by the company was then calculated. For that, the amount of money that would be possible to save daily with the new thermometer was then estimated, by comparison with the use of thermometer A. The money saved daily would be around 1,55€ and the cost of the thermometer C was 26,40 €, meaning that it was possible to achieve the breakeven point 17 days after the thermometer was introduced.

Another hypothesis raised was the calibration of all the existent thermometers in the fermentation vessels. With that purpose the TAP team, who performs an annual calibration of all the company temperature instruments, was asked which would be the cost of an annual calibration of all the 64 thermostat probes already integrated in the 28 working fermentation vessels. Each thermometer calibration costs 62 euros, which means that the cost of the annual calibration would be 3968 euros. Since this hypothesis was more expensive than the introduction of a new digital thermometer, this was not further considered.

The next step was to verify if the insulation of the pipe, from which the beer is withdrawn to measure its temperature, would influence the quantity of beer needed for the daily temperature measurement. For this purpose, the pipe was insulated thermally in the fermentation vessel 9 and 30 and then the situation of these two tanks analysed. The thermometer used to perform this study was thermometer A, as that was the one with more data available for comparison (when there was no thermal insulation on the pipes).

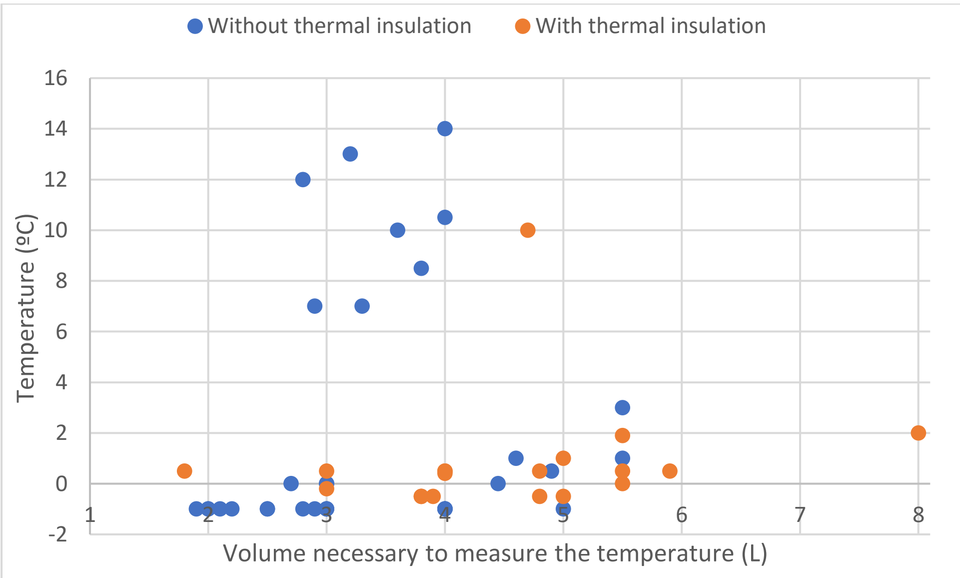

Figure 6- Volume required to measure the temperature with and without thermal insulation of the pipe of the fermentation vessel 9.

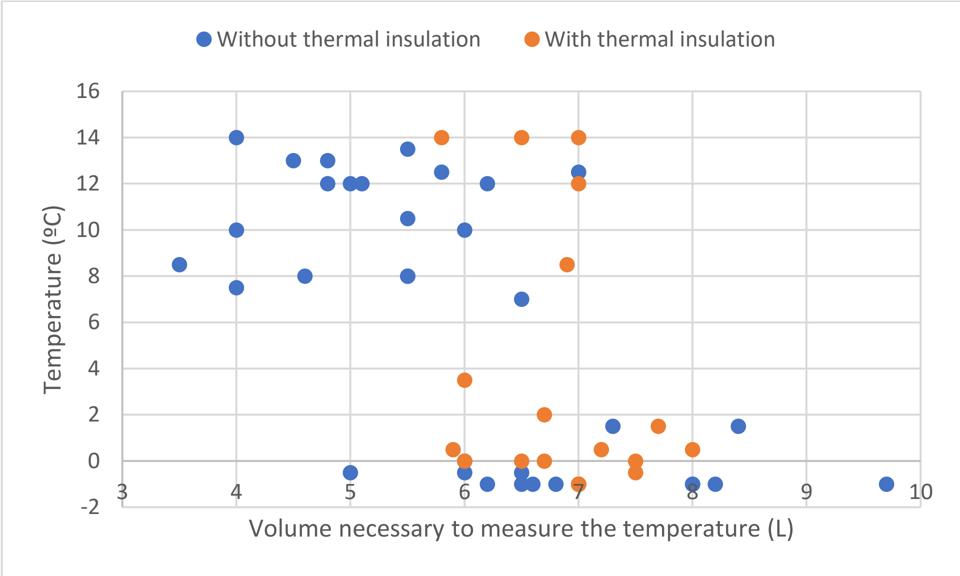

Figure 7- Volume required to measure the temperature with and without thermal insulation of the pipe of the fermentation vessel 30.

From figures 6 and 7, is possible to conclude that the thermal insulation of beer withdrawal pipes does not represent a decrease in the volume necessary to obtain the precise temperature of the fermentation wort/beer in the vessels.

Conversely, one can verify and increase in the volumes needed for such measurement. This may have been due to the fact that the data which corresponds to the measure of the temperature when there was no thermal insulation was performed by a more experienced operator which lead to less product waste (perhaps, thanks to acquired knowledge on the behaviour of the thermometer).

3.2. Centrifugation study for suspended solids reduction

One of the major challenges verified in the brewery, where the study was performed, was the excessive high concentration of suspended solids left in the ‘green’ beer after gravital sedimentation, which led to an earlier clogging in the posterior filtration. This problem might be solved by introducing a centrifuge between the maturation and filtration processes.

The utilization of the centrifuge has a main goal - the reduction of the suspended solids in the feed stream of the kieselguhr filtration, leading to a significant decrease in the operation time and to a decrease in the diatomaceous earth usage per volume of filtrated beer. Because quantifying the benefits of such additional operation would be difficult, an economic analysis regarding the introduction of the centrifuge was performed.

Another prospective benefit linked to the introduction of a centrifuge would be the reduction of the utilities cost in the fermentation area, since it would not be needed to keep the ‘green’ beer in the fermentation vessels at low temperatures for so long waiting to reach an acceptable concentration of the suspended solids to proceed to filtration.

Figure 8 highlights the position in the process for the centrifugation step/equipment to be introduced. As mentioned before, the complete blocks diagram of the brewery processes is present in annex A. In the present study, as in the previous one, the production cost price of the beer was considered to be 0,15 euros per litre.

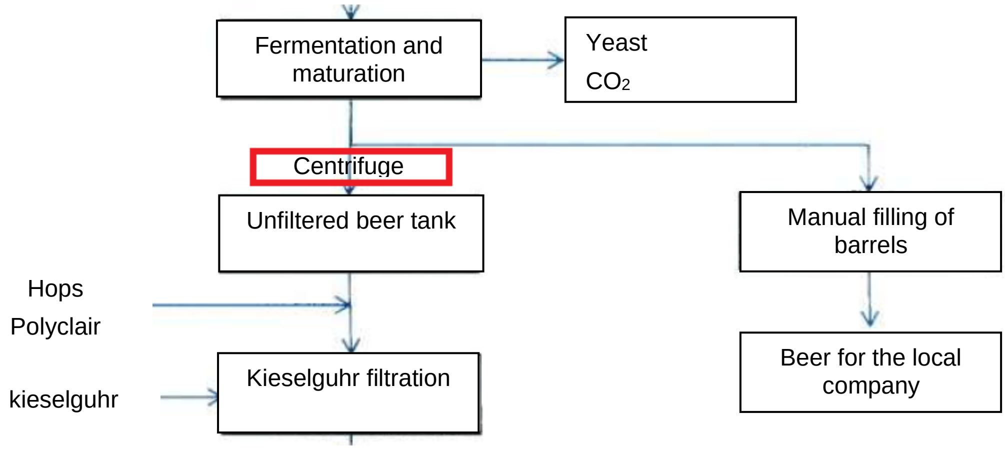

Figure 8- Zoom of the blocks diagram, highlighting the place where the centrifuge would be introduced.

3.2.1 Fermentation and maturation days

The first step to comprehend how much beer was wasted due to the excessive purges was to discover how much of the purges were necessary, to obtain a beer which had undergone both fermentation and maturation processes correctly and then was ready to undergo filtration, packaging and commercialization, according to the procedure in section 2.3.1.

Aiming to achieve this goal, all the fermentations sheets from the year 2018 were studied to get to know the average number of days used so that the fermentation and maturation processes occurred correctly. This would allow to estimate the number of production days gained if the HGB would be sent to the centrifugation, prior to filtration, without compromising the beer quality.

Table 2 - Average number of days used for the fermentation and maturation processes with and without interposed centrifugation step and production days gained.

	Months of 2018	jan	fev	mar	abr	mai	jun	jul	ago	set	out	nov	dez
Average days needed for fermentation + maturation	Current set-up	30.7	39.1	29.82	29.1	28.5	27.1	20.9	29.3	34.6	35.1	43.0	44.8
	Set-up with centrifuge	18.7	20.0	18.3	20.1	20.2	19.7	19.5	21.1	21.2	20.1	20.5	20.8
Days gained		12.0	19.1	11.6	9.1	8.3	7.4	1.4	8.2	13.4	15	22.5	24

As represented in table 2, the average number of days needed so that the beer would be ready for filtration by interposing a centrifuge ranged between 18 and 21 days. Data in this table allows one to understand that all the purges performed without need could be avoided if the centrifuge was installed in the factory set-up, as the beer would be automatically ready to be filtrated. In order to ease the calculus and the recovery of the samples, all the purges performed after the 21st day are considered excessive, meaning that the fermentation and maturation processes had proceeded correctly until the referred day. Afterwards, the HGB is left in the CCV with the sole purpose of reducing the suspended solids concentration so that is possible to execute a filtration with an acceptable efficiency. To clarify, all the purges done after those days were only performed to collect the sedimented yeast in the bottom of the fermentation vessel.

3.2.2 Total Purges

The volume of total purges carried out correspond both to the purges done aiming to measure the temperature daily and the purges performed to collect the sedimented yeast. The volume of product used to daily measure the temperature from each fermentation vessel, previous to the period of the study, could not be recovered and this portion was neglected. The accounted volume lost in the total purges was only due to the purges done to collect the sedimented yeast. This was possible since the total volume of product lost in the temperature measurements is significantly lower than the total volume of product lost in the other purges.

The quantity of total purges necessary is high since the sedimentation was the only separation process used prior to the kieselguhr filtration. During this sedimentation there is beer dragged with the sedimented yeast then purged through the bottom pipe and, therefore, cannot be commercialized.

As seen in table 2 and discussed above (section 3.2.1), the beer would be ready for filtration between day 18th and 21st, meaning that all the other purges done after these days would be needless, reducing this way the volume of beer that would be dragged during the sedimentation of the suspended solids in the .

The next step was to determine the total volume of beer that was wasted in the purges, the necessary and the unnecessary if there was a centrifuge, during each fermentation in the diverse fermentation vessels. The example which will be presented is the analysis performed to the fermentation vessel 28 which started the fermentation in the 28th of March of 2019.

Firstly, the specific gravity, in Plato degrees (g/100g) was measured and then equations 22 and 23 were used to convert those units into g/100mL.

This analysis was carried out throughout the fermentation and registered in the respective sheet by the company operators. There, one can acquire important data such as the numbers of batches of wort that entered the fermentation vessel and the respective extract. It was also possible to know the liters that exit the fermentation vessel, the original extract and the liters that were obtained after the dilution. In table 3 the values of the parameters just referred are highlighted in the green boxes.

Using equation 11, and the information from the fermentation sheet, the total volume of commercial beer lost during the purges was obtained. The results presented in table 3 are, as referred, from the fermentation which started in the 28th of March of 2019 in vessel 28; where the total volume of beer lost that could have been commercialized (loss in the purges (L)) due to the purges is 4 694,74 liters.

Equation 12 is used to determine the total liters that should be obtained after the dilution (volume that should be obtained (L)) so that one can acquire the total volume lost during the purges and filtration (total loss (L)) through equation 13. For that is also necessary the volume recovered after the dilution.

The extract from commercial beer that is used in order to obtain the equivalent beer volume from the HGB volume is 11.25 g/100mL.

Table 3- Information imported from the fermentation sheet (highlighted in green) and derived using the equations. In this case data reports to the fermentation which started the fermentation in the 28 of March of 2019 in vessel 28.

CCV28		
Entry		
Number of Batch	Volume introduced (L)	Extract (mg/100mg)
131	14 800	13.37
132	14 800	13.46
133	14 600	13.7
134	14 600	13.61
135	14 600	13.68
Total	73 400	13.56
Extract (g/100mg)		12.87
Specific Gravity		1.052
Extract (g/100mL)		13.54
Exit		
	Volume that exit (L)	Volume after dilution (L)
1st withdrawn	26 2000	30 000
2nd withdrawn	43 300	50 000
Total	69 500	80 000
Volume that should be obtained (L)		88 357.43
Total loss (L)	Loss in the purges (L)	Loss in the filtration (L)
8 357.43	4 694.74	3 662.69
Percentual product loss (%)		9.46

The percentual production loss was also analysed in order to verify if the respective results obtained through the calculus coincide with the information provided by the company. This worked as a confirmation that calculation procedures were correct. For that purpose, equations 12, 13 and 14 were used to all the fermentation sheets. In the case of CCV28, the percentual product loss reached 9,46%, which was a similar value when compared with the company's predictions. The fermentation sheet from where was possible to achieve the data from the table above is in annex E.

3.2.3. Volume reused with centrifuge

After knowing the total volume of HGB that was being purged, it was necessary to discover which portion wouldn't be purged if there was a centrifuge. This means that all the liters of beer purged after the 21st are considered a gain that would be achieved with the equipment introduction.

So, the next object of study was to know the exact quantity of beer that was being wasted in the purges performed after the 21st day. Since the production sector works 24 hours a day, and the purges can occur in any shift, it was not feasible to be present in all the purges done. For that reason, this problem was approached from a different angle.

3.2.3.1 Beer lost in the purges before the fermentation and maturation processes were concluded

Because the purges carried out before the 21st day are more monitored than the subsequent, the approach chosen was to recover all the purges done in the different fermentation vessels before the 21st day, since the respective worts entered the fermentation vessels, and then proceed with the analysis of the sample. The purges were collected to a tank, as explained in section 2.2. Then, a sample was recovered from the tank and the composition of beer and yeast were analysed after laboratorial centrifugation, as explained in 2.2.1.

The procedure will be explained making use of the same example of the fermentation vessel 28 which started the fermentation in the 28th of March of 2019.

Firstly, for the present problem two main pieces of information about the purges were needed: the volume collected in the purge and the number of days from start of fermentation until the referred purge was done in the fermentation vessel. The measurement of the volume was conducted with the recovering tank and the counting of the fermentation days was carried out on account of the fermentation sheet, the values for the parameters of the example referred above are in table 4.

Table 4 -- Information about the purge performed in the 19th day of the fermentation vessel 28 which started the fermentation in the 28th of March of 2019.

CCV28	
Number of days from start of fermentation till the referred purge was done	19th
Volume collected in the purge (L)	560

Secondly, the necessary data was the mass fraction of beer and yeast present in the purge collected, and for that reason the recovered sample underwent a centrifugation, as explained in section 2.2.1.

The results from centrifuging the sample purged of the fermentation vessel 28 on the 19th day of fermentation are represented in table 5.

Table 5- Mass fraction obtained from the laboratorial centrifugation of the sample from the purge performed in the 19th day in the fermentation vessel 28 which started the fermentation in the 28th of March of 2019.

CCV28		
Flask (g)	Flask + 100 mL sample (g)	Flask + Remaining solids (g)
70.13	142.63	95.31

Using equations 4 and 5, the concentration of high gravity beer in the purge was calculated, which in this case was 473,2 g/L.

Knowing the concentration of HGB in the purge and the volume that was recovered, one can estimate the mass of HGB purged, as explained in equation 6. In the present example, the mass obtained was 265 kg, from which was then obtained the volume of high gravity beer through equation 7.

The HGB specific gravity used for the current investigation was equal in all the purges. The aforementioned was possible given that all the purges were only performed after the extract had achieved a stable value in and around 2.5 P˚, which was then converted in specific gravity using the equation 22. The value of the parameter is expressed in table 6. The volume of HGB collected in the purge in the referred example was 262,4 L and, finally, to achieve the wasted volume of beer with the commercial original extract, which in this case was 315.9 L, equation 8 was used. All the results and constants are represented in table 6.

Table 6- Data pertaining to the purge performed in the 19th day in the fermentation vessel 28 which started the fermentation in the 28th of March of 2019.

Mass of HGB recovered (kg)	265
Specific gravity HGB (g/cm^3)	1.01
Volume of HGB recovered (L)	262.43
Original extract of HGB	13,53
Extract from commercial beer (g/100mL)	11.25
Equivalent volume of commercialized beer recovered	315.91

The volume of commercialized beer that is purged before the complete maturation, before the 21th day, is then subtracted from the total volume lost in the purges, as described in equation 15.

3.2.3.1.1 Beer lost due to the yeast cropping

The next parameter that was studied was the volume of beer that was dragged with the first purge, where the goal is to extract the majority of the sedimented yeast after the ‘cold shock’ (cropping).

A centrifugation procedure was performed to a sample from such purge, as explained in the section 2.2.1, originating the values represented in the table 7.

Table 7- Mass fractions obtained from the laboratorial centrifugation of the sample from the first purge performed to extract the total yeast from the fermentation vessel 28 which started the fermentation in the 28th of March of 2019.

Recovered yeast		
Flask (g)	Flask + 100 mL sample (g)	Flask + remaining solids (g)
70.37	156.78	121.88

Given that the yeast cropped from the fermentation vessel was weighted with the scale incorporated in the recovering tank for yeast, this weight had to be converted in volume, in order for equations 6, 7 and 8 from the previous section to be used.

Therefore, it was necessary to obtain the density of the yeast cropped. For that purpose, it was recovered a specific volume and weighted, allowing for the value of the parameter to be determined, as displayed in table 8. In order to facilitate the calculus, the density for all the first purges executed, with the purpose of extracting most of the yeast, were considered constant. It was then possible to know the volume of the purge using the mass of the recovered purge and the density of the respective purge on account of equation 10. This allowed one to obtain the volume of beer that could be commercialized but was dragged with the yeast during the sedimentation.

It was taken in considered that the introduced yeast (pitching) contained also HGB. So, aiming to ease the calculus, it was considered that the yeast introduced and the one purged had the same composition of beer and yeast, changing only the volume. This was only possible to assume since the yeast introduced in one fermentation vessel was in fact a yeast that was purged from another fermentation vessel. Taking this into account, the mass of yeast and high gravity beer that effectively exit the vessel are obtained through equation 9.

To obtain all the other values was through the same equations used in the previous chapter, where the different parameters represented in table 8 correspond to the example of the fermentation vessel 28 which started the fermentation in the 28th of March of 2019.

Table 8- Information about the first purge to collect the total yeast of the fermentation vessel 28 that started the fermentation in the 28th of March of 2019.

Mass of purge (kg)	1620
Mass of yeast and beer pitched (kg)	640
Mass of yeast and beer that effectively exits (kg)	980
Specific gravity of first purge (kg/L)	0.92
Volume of first purge (L)	1065.21
HGB concentration (g/L)	371.44
Mass of HGB (kg)	395.81
Specific gravity of HGB (kg/L)	1.01
Volume of HGB (L)	391.99
Original extract (g/100g)	12.87
Original extract (g/100mL)	13.54
Equivalent volume of beer with commercial original extract (L)	471.87

The volume of beer with the commercialized original extract lost due to dragging in the first purge was also subtracted to the total volume lost in the purges, described in equation 15. Because the fermentation vessel in consideration is the same as the one referred in 3.2.2., the dilution factor will be the same.

3.2.3.2. Beer sold to a local company

Other parameters that would take part in the study of what would be the gain with the introduction of the centrifuge, was the volume of high gravity beer that was sold to a local company. This beer was collected directly from the fermentation vessel as a high gravity beer. So, in order to account the right volume of beer that appears in the losses as purges but are in fact beer that was sold to the local company, equation 8 is needed. Continuing with the example given in the previous section for the fermentation vessel 28, 30 barrels of 30 liters of HGB were collected from this fermentation vessel. Since the beer was high gravity beer, the dilution factor needed to be applied in order to obtain the total volume of beer with the commercial original extract.

$$V_{Sold\ to\ the\ local\ company} = 30 * 30 * \frac{13{,}54}{11{,}25} = 1083{,}4\ L$$

In this case, the total volume that was sold to the local company was 1083,4 liters which was also subtracted to the total volume of beer lost during the purges (equation 15).

3.2.3.3. Volume of beer gained with the centrifuge.

After obtaining all the needed parameters - the total volume of beer that was wasted in the purges, the volume of commercialized beer that is collected before the 21^{th} day, the volume of beer sold to the local company and the volume of beer that was dragged due to the sedimentation process - equation 15 could be used to acquire the volume that would be gained if there was a centrifuge prior to the kieselguhr filtration and after the maturation process of the 'green' beer.

$$V_{Beer\ gained} = 4\,694.74 - 315.91 - 1\,083.4 - 471.87 = 2\,823.56\ L$$

In the case of the fermentation vessel 28, an amount of commercial beer of 2 823.56 liters would be saved with the introduction of the industrial centrifugation in the process to substitute the yeast sedimentation. Besides the benefits already referred, this will lead also to a more uniform product as the income stream of the filtration would always have approximately the same concentration of remaining suspended solids.

3.2.3.4 Yield of recuperation with the centrifuge.

Once the quantity of product that would be saved for a singular fermentation vessel was discovered, it was necessary to find a viable way to extrapolate the gains with the centrifuge to all the other sedimentation processes in the factory. The industrial data was available and could be obtained through the fermentation sheets, but that has not been studied yet.

With that purpose, the fraction of lost beer that would not be purged out once a centrifuge had been introduced was calculated using equation 16. In the present example the yield of recovery was 60%.

Thereafter, all the procedures explained in sections 2.2 until 2.4 were performed to another 24 fermentations vessels operating in the facilities during the present study. The values of yields obtained are presented in table 9. The value of yield that was used to extrapolate to all the fermentation vessels was the average of the yields obtained from the 25 fermentation vessels, i.e. 62% and it is also represented in table 9.

Table 9 - Yield of the introduction of the centrifuge for the 25 fermentations studied during the study and the average of those values.

	Beer recovery yield
	0.29
	0.87
	0.74
	0.52
	0.87
	0.33
	0.43
	0.60
	0.70
	0.80
	0.79
	0.64
	0.59
	0.73
	0.51
	0.85
	0.51
	0.55
	0.86
	0.52
	0.80
	0.30
	0.70
	0.15
	0.85
Average	0.62

It was not possible to observe any tendency in the yield of beer recovery with the centrifuge since the process was mainly manual, leading to an enormous oscillation in the data.

3.2.4 Annual loss in the purges

Finally, all the 184 fermentation sheets from the year 2018 were studied in order to obtain the volume that was purged during the referred year from each fermentation vessel, aiming to apply the yield of centrifugation to all the beer purged so that the total volume that would be recovered in a specific timeline with the implementation of this operation could be obtained.

So, to obtain the total volume lost in the purges in 2018, equation 17 was used. After obtaining the total volume lost in the purges, equation 18 was applied with the goal of acquiring the total quantity of beer that would be recovered with the introduction of the centrifuge. Thereafter, equation 19 was used in order to achieve the exact amount of money that would be saved by the centrifuge. All results are expressed in table 10.

Table 10 – Data from the year 2018 that allowed to calculate the money that would be recovered in the referred timeline.

$V_{\text{Total volume lost in the purges in 2018}}$ (hL)	5 492.23
Cost price (€)	0.15
Price of beer lost due to the purges (€)	82 383.41
Average yield of recovery with the centrifuge	62%
Price of beer recovered due to centrifuge (€)	51 062.49

3.2.4.1 Correction factor

Due to various factors, a few parameters necessary for the computations were illegible in the fermentation sheets. Therefore, not all the fermentations that took place in 2018 were taken in consideration for a correct analysis of the fermentations. So, it was necessary to introduce a correction factor and, for that, equation 20 was used. All results obtained are presented in table 11.

Table 11- Data that allowed the determination of the correction factor for the 2018 year.

Volume of beer that was accounted (hL)	96 359.40
Volume of beer that was produced (hL)	107 742.40
Correction factor	0.89

With the correction factor presented in table 11 and using the equation 21, it was possible to estimate that the money that would be recovered in 2018 with the use of centrifuge would be 57 354.05€.

The same procedure explained in the present and previous section was done to the year 2017 and the result obtained was 48 829.47€. In this case it was used the same correction factor that was obtained from the year 2018.

Increase in the facilities' efficiency

The introduction of the centrifuge in the process would allow a reduction of product loss verified in the production sector. For that reason, the fermentation sheets of the year 2018 were analysed in order to obtain the percentage of product loss reduction with the new equipment.

The values, which correspond to the product loss of the purges and the filtration, for each month of 2018, are represented in annex D. The average percentage of product loss due to the purges and filtration, as well as the sum of both percentages were calculated. The values for these variables are expressed in table 12.

Table 12- Percentage of product loss due to purges, filtration and the total verified in the year 2018.

Percentage of product loss due to purges (%)	6.47
Percentage of product loss due to filtration (%)	4.16
Percentage of total Product loss (%)	10.63

Knowing the recovery yield of product from the centrifuge, it was possible to predict which would be the reduction in the percentage of product loss of the purges (table 13).

Table 13 – Percentage of product loss verified in the year 2018 and with the introduction of the centrifuge respective reduction.

Percentage of product loss due to the purges with centrifuge (%)	2.46
Percentage of product loss due to the filtration (%)	4.16
Percentage of total product loss with centrifuge (%)	6.62
Percentage of reduction of the total product loss with introduction of centrifuge (%)	37.74

It would be possible to reduce the total breakage of the production sector from 10.63% to 6.62%, representing a reduction of 37.74%, for the year 2018.

The same calculus was performed for the year 2017 and in that year, it would have been possible to reduce the percentage of total product loss from 10.1% to 6.93%, representing a reduction of 31.42%.

This reduction presents itself as an important marker to one of the main goals of the company: reducing the losses and achieving efficiency levels similar to those verified in the bigger breweries.

3.2.5 Centrifuge quotation

The next step was to inquire the centrifuge manufacturers about the price of the necessary equipment. Several companies who provide this type of equipment were reached out, but only two companies answered.

The first company that which was possible to approach was the Flottweg which redirected the question to the Sales Engineer Beverage, who provided an informal quotation through the email. The value proposed by the Flottweg was 205 000.00 € for the equipment, 2 500.00 € for the transport and 6 000.00 € for the operation start-up for one week with a process technician from Germany, having a total cost of 213 500.00 €.

The second company to which was possible to contact was GEA. From this one, the quotation delivered was more formal and is presented in annex C. The price for the centrifuge was 228 400.00€ and the costs of transport and start-up were similar (both companies are from Germany), performing a total cost of 236 900.00 €.

Although the quotation from the second company is more expensive, this was the one that was chosen for a breakeven point estimation. The choice was based in two factors: firstly, through the conversation/negotiation it was possible to see that this company could give a better support in Portugal in case of a needed backup; secondly, and even if the breakeven is done with the higher equipment cost, it would still be favourable if the cheaper equipment were to be acquired.

3.2.5.1 Breakeven point of the investment

So, supposing that the centrifuge from the company GEA would be chosen, the next step was the calculation of the breakeven point to verify how long it would take to get enough earning to pay off the investment. Three types of scenarios were thought: the optimistic, the pessimistic and the middle ground.

In the optimistic, the value of beer recovered in the year 2018 was used to calculate the breakeven. Accordingly, the investment would be paid off in a time span of 5 years.

On the other hand, the pessimistic scenario was based on the computation of the breakeven with the value of beer recovered in the year 2017. In order to achieve the breakeven point, approximately 5 years and 10 months would be needed in this situation.

In the last scenario, that would be the average value of beer reused in the years 2017 and 2018 was assumed, and the breakeven point would be accomplished in 5 years and 5 months.

All scenarios taken in consideration had a security factor of 20% associated to the breakeven time.

3.3 Centrifuge for hot wort, suspended solids and yeasty beer.

Regarding the introduction of a centrifuge in the process, it was advised by the GEA company that instead of the proposed one, a different centrifuge model with a wider range of features would be implemented. In this second centrifuge, it would be possible to recover even more wort by separating the trub from the hot wort after the wort kettle. It would be possible to remove the beer that is dragged during the sedimentation and finally it would also allow to reduce the suspended solids in the HGB prior to the kieselguhr filtration although with a lower efficiency than that obtained with the previous centrifuge analysed.

Due to several reasons, this kind of centrifuge was not considered, mainly because in the ECM brewery both process – wort production and beer clarification – occur simultaneously.

4. Conclusion and Future work.

During all the study performed, different approaches were discussed and studied which would lead to a reduction of product loss in the production sector in the brewery industry. Firstly, the main challenges that the company was facing in this sector were investigated. Production loss was essentially observed in the volume lost during the daily measurement of temperature from the fermentation vessels and in the volume that was being purged from the fermentation vessels to reduce the concentration of suspended solids.

Then, the influence of the analog thermometer used and the thermal insulation of the purging pipe, from which was recovered the sample of beer to read the temperature, in the product loss verified during the temperature measurement was studied. Regarding the thermometer it was determined that the introduction of a digital thermometer provided a decrease of volume loss of approximately 12%, leading to a breakeven point of the investment of 17 days. The thermal insulation of pipe did not show any impact in the reduction of the volume lost.

Concerning the product loss due to the excessive purges, the necessary and unnecessary purges were discriminated. An alternative separation process to the current set-up plant (just sedimentation to separate the HGB from, mainly, the yeast) was analysed. Introduction of an industrial centrifuge would be the most interesting equipment to proceed to the separation of high gravity beer and yeast prior to the kieselguhr filtration. An economic analysis confirmed that the gains with the introduction of the centrifuge would allow an achievement of the breakeven point of such investment in approximately 5 years with 20% of security factor, considering the beer that would be recovered in the year 2018.

With the investment chosen, it was possible to estimate that once the equipment is installed and working, for production similar to those of the years 2018 and 2017 will be possible to reduce the percentage of production loss in the production sector by 37.74% and 31.42%, respectively.

As for future work that could be done, a practical study of the introduction of the centrifuge is suggested. The alternatively proposed centrifuge, the one with the lower throughput, could also be analysed, regarding its ability to clarify the yeasty beer, to reduce the suspended solids concentration with lower efficiency and also extract the trub from the wort. Furthermore, the change of the wort kettle configuration could also be considered in order to enhance its efficiency.

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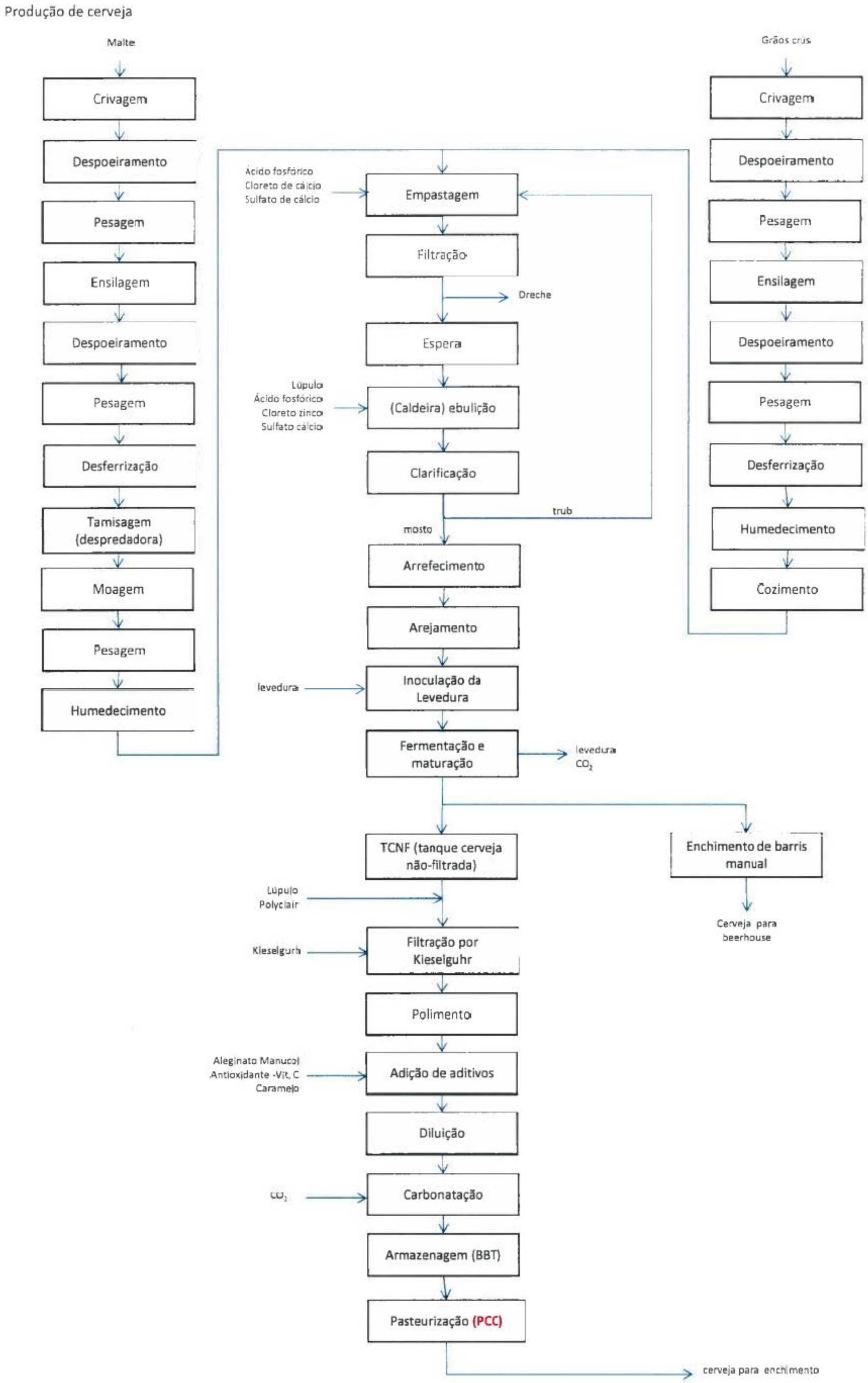
Annex A


Produção de cerveja
Malte
Crivagem
Despoeiramento
Pesagem
Ensilagem
Despoeiramento
Pesagem
Desferrização
Tamisagem (despredadora)
Moagem
Pesagem
Humedecimento
Grãos crus
Crivagem
Despoeiramento
Pesagem
Ensilagem
Despoeiramento
Pesagem
Desferrização
Humedecimento
Cozimento
Ácido fosfórico
Cloreto de cálcio
Sulfato de cálcio
Empastagem
Filtração
Dreche
Espera
Lúpulo
Ácido fosfórico
Cloreto zinco
Sulfato cálcio
(Caldeira) ebulição
Clarificação
trub
mosto
Arrefecimento
Arejamento
levedura
Inoculação da Levedura
Fermentação e maturação
levedura
CO_2
TCNF (tanque cerveja não-filtrada)
Enchimento de barris manual
Cerveja para beerhouse
Lúpulo
Polyclair
Kieselgurh
Filtração por Kieselguhr
Polimento
Aleginato Manucol
Antioxidante -Vit. C
Caramelo
Adição de aditivos
Diluição
CO_2
Carbonatação
Armazenagem (BBT)
Pasteurização (PCC)
cerveja para enchimento

Annex B

Thermometer A

VLB BERLIN
LaboTech GmbH

VLB LaboTech GmbH Seestraße 13 D-13353 Berlin
im Institut für Gärungsgewerbe und Biotechnologie zu Berlin

Empresa de Cervejas da Madeira
Sociedade Unipessoal, Lda
PEZO-Parque Empresarial Zona Oeste
Madeira

9304-003 Camara de Lobos / Portugal

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Fax	:	(030) 4535517
Side	:	1
Date	:	19.05.2017
Customer number	:	1409150
VAT number	:	PT 511001720
Project number	:	20170157

I N V O I C E - Nr.: 20175238
your order : 4500059300 -- 13.04.2017
by order of : Maria Joao Abreu
per : email

1 cardboard box, marked address customs-tariff-no.: 9025 8080

Pos.	quantity	article description	cost centre	price per unit(€)	total price(€)
001	22,00	Art-Nr.: 2-1600-35 **SACHARIMETER FOR BEER WORT** 0...10 : 0,1 %mas., upper level read-off, with thermometer **-4..+26 : 0,2°C** with blue alcohol filling and correction, approx. 420 mmm length		50,00	1.100,00
002	22,00	Art-Nr.: 2-1600-36 **ditto range 10...20**		50,00	1.100,00
003	1,00	Art-Nr.: PACKING CHARGES		10,00	10,00
		total amount		EUR	2.210,00

Payabale after receipt of invoice net.
The title for the goods is retained by us until paid in full.
Delivery was effected on acc. to §6 VAT-Law 1993.
Tax-free acc. to § 4 no. 1a VATL. Export to foreign country.

PRODUCTION HAS CREATE ONE FURTHER INSTRUMENT WHICH WE WOULD FORWARD TO YOU, TOO.

net: 5,3 kg

CIP Camara de Lobos

VLB LaboTech GmbH
Seestraße 13 D-13353 Berlin

T +49 30 450 80-220 /-221
F +49 30 453 55 17
labotech@vlb-berlin.org
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GESCHÄFTSFÜHRER
Dr.-Ing. Josef Fontaine

Ust-IdNr: DE 177 316 516
Steuernummer: 30/571/33879
Amtsgericht Berlin-Charlottenburg
HRB 57908 B

BANKVERBINDUNGEN
Deutsche Bank Privat- und Geschäftskunden AG
IBAN: DE41 1007 0024 0241 0215 00
Swift Code (BIC): DEUTDEDBBER

Thermometer B

010204002 **5989**
Termómetro con sonda fija de acero inoxidable de 120 mm de longitud
Rango: -50+150:0,1ºC
Precisión: -20+120ºC ± 1ºC / resto del rango ± 2ºC
Funciones: Hold. Cabezal recto
Alimentación: 1 Pila G13 de botón
Incluye: Funda de protección
Tamaño: 200x20x20mm. Peso: 22 gr

5989

Thermometer C

ANTÓNIO MOUTINHO, Lda.
instrumentos de precisão
Desde 1957

INSTRUMENTOS DE PRECISAO - MATERIAL DE LABORATORIO
www.antoniomoutinho.pt - info@antoniomoutinho.pt
CGD - IBAN: PT50003507870003532143023 - SWIFT/BIC: CGDIPTPL
BPI - IBAN: PT50001000002397737000171 - SWIFT/BIC: BBPIPTPL
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PME líder'18

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Domicílio:

EMPRESA DE CERVEJAS DA MADEIRA, SOC.UNIPESSOAL, LDA.
Sub-Dep.Tes./Forn.-Pizo-Parque Ind. Zona Oeste
9304-003 CAMARA DE LOBOS

Orçamento nº O 2019.4/1564 **Válido por 30 Dias**

Data	Cliente nº	NIF	Original Pág. 1/ 1
07-05-2019	10163	511001720	Op: joaquim santos
Condição Pagamento	**Data Vencimento**	**Vendedor**	**Requisição nº**
Transferencia Bancar	07-05-2019	JOAQUIM SANTOS	

Artigo	Descrição	Quant.	Preço Unit.	%Desc.	IVA	Líquido	Prazo Entrega
110020032	TERMOMETRO DIGITAL SONDA RIGIDA -40/250ºC 30.1040	2,00	21,40		23	42,80	Imediato
	** Portes	1,00	10,00		23	10,00	

Annex C

engineering for
a better world

Exmo. Sr. Tiago Soares

EMPRESA DE CERVEJAS DE MADEIRA
PEZO - Parque Empresarial Zona Oeste
9304-003 Câmara de Lobos, Portugal

Javier Madina
Sales Equipment
Market Manager Beverage & Dairy

Tel. +34 938 617 100
Móvil +34 619 783 941
javier.madina@gea.com

29.07.2019

Quotation nr.: 1907116. 1x Separator GEA type GSI 75-06-772

Dear Mr Soares,

In response to your inquiry we hereby take pleasure in submitting you our enclosed offer.

We are confident that this offer provides an optimal solution that exactly meets your requirements. If the requirements should have changed or if you wish any modifications, we'll be pleased to revise our offer accordingly.

The quotation has been prepared as a non-binding offer on the basis of the information available thus far and with reference to GEA Westfalia Separator Group's Terms of Supply and Site Services.

If you are interested, we will be pleased to enter into more detailed negotiations to set up the individual conditions of the contract.

GEA Westfalia Separator Ibérica, S.A.

Javier Madina
Market Manager Beverage & Dairy

GEA Westfalia Separator Ibérica, S.A.
Av. de Sant Julia, 147. Aptdo. Correos 187
08403 Granollers, Barcelona (Spain)
+34 938 617 100 Fax +34 938 494 447
www.gea.com
Registro Mercantil de Barcelona: H. 15.425-F.220. T. 1.715. S 2ª. L 1.137
NIF. A-08203812

engineering for a better world

Our proposed solution

1x GSI 75-06-772

Key features and benefits

This **self cleaning** disc type centrifuge is designed for liquid / solid separation.
The product is discharged under pressure by the means of a centripetal pump while the solids are discharged by regularly ejections.
The **hydro hermetic sealing** system provides gas-tight sealing without mechanical seals and ensures a minimum oxygen intake. Additionally the bowl can be covered with CO2. The hermetic feed system ensures gentle product handling and consequently the advanced clarification efficiency. The in- and outlet sealing system is maintenance free.
The robust "short spindle drive" guarantees vibration free running as well as high insensitivity to bowl imbalance and ensures an optimum service life.
Consistent realization of the hygienic design, means all product contacting parts are designed for optimum CIP conditions.
This machine type is optimized to provide a **high clarifying performance at a maximum capacity. (HyVOl)**

Delivered with an **eccentric-screw pump for an enclosed discharge** and transport of theejected solids.

The components for the feed and discharge lines are mounted on a **valve block** for reliable operation as well as for an easy and fast installation. All components are pneumatically and electrically connected to a valve-cabinet.
The feed-flow and the back-pressure is intended to be adjusted automatically.

Delivered with the necessary components for the feed and discharge lines to ensure a reliable operation in the desired application. The feed-flow and the back-pressure is intended to be adjusted automatically.

Incl. a **recirculation line** for increasing the overall clarification efficiency of the beer which is send to the filter / tank.

The machine can be operated from a control-room via **bus communication**.

The desired haziness in the clarified beer is achieved by **adjustment of the bowl speed**.

Technical specification

1 Separator GSI 75-06-772
for clarification of beer prior to filtration

Flow rate	200 Hl/h
Yeast content:	Feed < 20 million cells/ml Discharge: 0.5 million cells/ml
Bowl	self-ejecting bowl with hydraulic operation
Hydraulic system	piston valve
Ejection-volume	adaptable via metering-piston during operation
Product discharge	closed discharge with centripetal pump
Sealing system	hydro hermetic sealing by a deaerated water ring, combined with a CO2 blanketing of the hood
Hood and solids-catcher	stainless steel, both coolable
Solids cyclone	stainless steel, flange-design for enclosed discharge, with level-probes and spray-ball for cleaning
Frame	cast iron, varnished in dusty grey RAL 7037
Drive system	integrated direct drive without clutch
Motor operation via	frequency converter
Motor-cooling method	liquid-cooled, in-line with the hood-cooling water
Motor power	30 kW, 400 V, 3-Ph.
Feed & discharge connections	DIN 11851, DN 50
Prod. feed pressure	min. 1.0 bar (before feed-valve)
Prod. discharge pressure	max. 3.5 bar (after back pressure valve)
Speed monitoring	via inductive proximity switch
Vibration monitoring	via sensor with two limit-switches
Lubrication monitoring	via flow-switch
Operating-water monitoring	via pressure-switch
Motor-cooling water monitoring	via flow-meter
Dimensions	L 1.160 mm x W 1.000 mm x H 1.650 mm
Bowl / total weight	400 kg / 1.400 kg
Required hoist	500 kg, hook clearance 2.500 mm

Delivered with the necessary components for the feed and discharge lines to ensure a reliable operation in the desired application. The feed-flow and the back-pressure is intended to be adjusted automatically.

Incl. a **recirculation line** for increasing the overall clarification efficiency of the beer which is send to the filter / tank.

The machine can be operated from a control-room via **bus communication**.

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Sealing system	hydro hermetic sealing by a deaerated water ring, combined with a CO_2 blanketing of the hood
Hood and solids-catcher	stainless steel, both coolable
Solids cyclone	stainless steel, flange-design for enclosed discharge, with level-probes and spray-ball for cleaning
Frame	cast iron, varnished in dusty grey RAL 7037
Drive system	integrated direct drive without clutch
Motor operation via	frequency converter
Motor-cooling method	liquid-cooled, in-line with the hood-cooling water
Motor power	30 kW, 400 V, 3-Ph.
Feed & discharge connections	DIN 11851, DN 50
Prod. feed pressure	min. 1.0 bar (before feed-valve)
Prod. discharge pressure	max. 3.5 bar (after back pressure valve)
Speed monitoring	via inductive proximity switch
Vibration monitoring	via sensor with two limit-switches
Lubrication monitoring	via flow-switch
Operating-water monitoring	via pressure-switch
Motor-cooling water monitoring	via flow-meter
Dimensions	L 1.160 mm x W 1.000 mm x H 1.650 mm
Bowl / total weight	400 kg / 1.400 kg
Required hoist	500 kg, hook clearance 2.500 mm

Including:

1 Foundation frame to be integrated in the floor structure

1 Set of special tools for dismantling, lifting and assembling of the machine

1 Set of spare parts for commissioning (e.g. bowl gaskets, lubricants)

1 Set of pre-assembled components for supply line of
- Hydrohermetic sealing water
- CO_2 bowl / hood covering
- Level-probe flushing

2. Accessories

1 Eccentric screw pump for an enclosed solids discharge
The control of the pump is integrated into the control cabinet of the machine.

Manufacturer:	Seepex
Motor power:	1.5 kW; 380-420V; 50/60Hz; direct started
Capacity:	1.200 l/h; against max. 4 bar
Connection pressure side:	DN40
Stator material:	NBR

1 Set of single components for the solids line
for switching the solids-discharge between tank and sewer

- 2x automatic butter-fly valves
- 1x non-return valve

1 Set of single components for the solids line
for switching the solids-discharge between tank and sewer and protecting the equipment when the pump is running but the route is blocked.

- 1 x automatic pressure relief valve
- 1 x automatic butterfly valve
- 1 x non- return valve

1 Valve block assembly

The components for the feed and discharge lines, mentioned before in this quotation, are mounted on a plate for wall-mounting or (depending on the size) on a rack for floor-standing. Both are made of stainless-steel and make an easy and fast installation possible. The components are electrically and pneumatically pre-connected to a stainless-steel valve cabinet. Butterfly-valves are equipped with one proximity-switch for position feed-back.
The connections for the supply and discharge lines are equipped with dairy-couplings according to DIN11851.

Note:
Certain flushing-valves are not installed on the valve-block, but delivered as lose items. This is because they should be placed as close as possible to the machine. Anyhow, pneumatically and electronically these components will be connected to the valve-cabinet.

1 Set of standard components for the product feed and discharge lines
(delivered as loose items, if no valve-block assembly is selected)

The listed components are selected to ensure a reliable operation of the centrifuge in the desired process. The flow-rate and the discharge-pressure are controlled and adjusted by the control-unit. An ejection can be triggered automatically on demand by the control-unit when the turbidity increases.

Product feed-line consisting of:
- Automatic butter-fly valve for the CIP-bypass
- Automatic butter-fly valve for the product supply
- 3 Automatic butter-fly valves for the water supply
- Automatic control-valve

- Manual sample-valve
- Illuminated sight-glass
- Magnetic-inductive flow-meter
- Pressure gauge

Product discharge-line consisting of:
- Illuminated sight-glass
- Pressure sensor
- Automatic control-valve
- Manual sample-valve
- 2 Automatic butter-fly valves for switching between tank and sewer
- 2 Automatic butter-fly valves for CIP connections at the centrifuge and solids-cyclone

- Turbidity sensor (brand OPTEK, type AF16)
  incl. evaluation unit OPTEK type 126 (installed inside the electrical cabinet)
  incl. a set of special cable with a length of 20m

1 Valve cabinet:
- Stainless steel housing, IP65
- Service unit located outside the cabinet
- Pressure switch for monitoring
- Pilot valves for the pneumatic actuated valves
- Proximity switches for single feedback of the shut off valves

Dimensions: (H) 380 mm x (W) 380 mm x (D) 210 mm

1 Recirculation line

The discharged product is recirculated back into the feed line when the turbidity exceeds a certain limit and / or an ejection is executed. That avoids possible spill-over of particles and increases the overall efficiency.
The equipment would be implemented into a valve-block assembly (if selected).

Recirculation line consisting of:
- Automatic butter-fly valve
- Non-return-valve

1 Mounting plate for supply lines (hydrohermetic, CO2)

The set of pre-assembled components for supply lines of hydrohermetic sealing water, CO2 bowl / hood covering ,etc. are mounted on a stainless steel plate for a clearly arranged installation.

3. Control system

1 Compact control cabinet, consisting of:

- Control Unit GEA IO 9

GEA IO is the new control panel generation for all GEA Centrifuge applications, focusing on intuitive handling, efficient process and reliable operation. The control unit is used for the automatic program control of separators with a self-cleaning bowl and consists of a PLC and a HMI (details see below). The operator panel allows an observation of the machine incl. the surrounding equipment in graphics and the adjustment of various timers and parameters. Explicit alarm messages are provided as well. The unit controls and monitors the Production, CIP, Water-flush and stand-by modes as well as the triggered ejections and the delivered equipment around the machine.
Further possible functions (depending on the selected scope) are:
Flow-control, discharge pressure-control, discharge turbidity monitoring, Solids-freight monitoring (Flow-ramping), Bowl-displacements, Bowl-speed adjustments, etc.

- Motor control

The motor of the centrifuge is operated via a frequency converter and protected by means of PTC resistors. Depending on the selected scope the control and protection of additional pumps are implemented as well. The power switch has an overload release for line protection and instantaneous short-circuit trip. Transformers provides internal and external control voltages. The emergency button is installed into the front door of the cabinet.

Technical data:

Brand of cabinet:	Rittal
Housing:	stainless steel
Protection class:	IP54
Cable entry:	from bottom
Dimension:	W 800 mm x H 2.100 mm x D 600 mm
Installation:	floor standing
Cooling:	via fan (for surrounding temperature of < 35°C)
Frequency converter(s):	Danfoss, FC300 series
PLC / CPU:	Siemens, S7-1200
HMI / Operator panel:	Siemens, TP900 comfort (9" TFT wide-screen, multicolour touch-display)

Power supply:	3 Ph.; 380 - 420 V; 50/60 Hz
Internal control voltage:	220/230V AC and 24V DC
External control voltage:	24V DC

Note: The dimension is based on the standard-scope and might change depending on the selected configuration and final scope of supply. If selected, the fan is replaced by a climate unit for air-condition.

1 Signal exchange via gateway

The signal exchange is realized via a HMS anybus gateway, which allows an easy implementation into the customer's network without requiring any changes of the GEA's PLC program. The standard signal exchange includes several commands and set-points send to the machine as well as the status of the machine, feed-backs of valves, alarms and analogue values received from the machine.

The following protocols are available and have to be confirmed by the customer: Profibus, Profinet IO, Ethernet/IP (Rockwell), Modbus TCP / Modbus RTU

1 Software upgrade for the automatic turbidity adjustment via bowl speed control
For maintaining a stable cloudiness in the final product, the bowl speed is automatically adjusted in dependence of the turbidity of the discharged beer.

Note:
This option is only available for centrifuges with automatic feed flow and discharge pressure control. The ejection interval shouldn't be higher than 10 ejections per hour.
The increase of haziness is limited, as the bowl speed can only be reduced to approx. 80% of the nominal speed. Therefore a bypass turbidity control is recommended when high turbidities are desired.

4. Standard components

Our quotation is based on the use of the following standard components:

Equipment	Brand	Type
Valves and Devices/Fittings for products:		
Double seated valve	GEA	
Automatic butterfly valve	GEA	T-smart 7
Manual butterfly valve	GEA	T-smart 7
Automatic control valve	GEA	Varivent Type P
Constant-pressure valve	GEA	DHV
Sample valve	M&S	
Automatic sample valve	GEA	VARILINE
Manual ball valve:	END	
Manual diaphragm throttle valve	GEMÜ	
Non-return valve	M&S	
Spill valve	GEA	VARIVENT Type Q
Measuring- and control technology:		
Magn.-induct flow-meter	GEA	IZMAG
Magn.-induct flow-meter (for mashes)	ABB	FSM 4000
Mass flow-meter (for viscous prod.)	E&H	Promass
Mass flow-meter (for liquid prod.)	KROHNE	Optimass
Float-type Flow-meter (for Product)	KROHNE	H250
Float-type Flow-meter (for Water)	ABB	
Pressure-gauge	AB, WIKA	
Pressure-sensor	E&H	Cerabar M Hart
Turbidity-sensor	SELI (for Juice, Wine and Plug & Win)	STS-3
	OPTEK (for Beer)	AF16, AS16
Valves and Devices/Fittings for utilities:		
Pressure-reducer	END	DM
Service unit for compressed air	FESTO	
Solenoid valve block for control air	BÜRKERT	6014
Pumps:		
Eccentric screw pump	SEEPEX	
Booster pump	ELWA	

Product pump	GEA	
Pipeline elements:		
Compensator	HSI	Lactopal L
Sight-glass	GEA	VARILINE

All components are selected in consideration of the process conditions and product safety by GEA Westfalia Separator Group GmbH. Subject to technical changes and availability from suppliers. The use of other components and suppliers on customer's request are possible but will be invoiced separately.

5. Documentation

The scope of supply described in this offer, includes our standard set of technical documentation in English language* (1x paper / 2x digital medium), consisting of:

- Instruction Manuals
- Safety Instructions
- Spare parts catalogue
- P&ID
- Dimensional drawing

*If the country of destination is a member of the European Union, the instruction manual and safety instructions will be provided in local language.

Any additional documentation is available on request at extra costs.

6. Price

GSI 75-06-772

- Solids pump
- Butterfly valves for solids pump
- Pressure relief valve for solids pump
- Valve-block assembly
- Standard components for the feed and discharge lines
- Recirculation line
- Mounting plate for supply lines (hydrohermetic, CO2)
- Compact Control, GEA IO 9
- Signal-exchange via bus system
- Turbidity adjustment via bowl speed control

Total SALE price for machine and equipment as specified **228.400,00 €**

The price shall be understood net incl. packing.
The packing is suitable for the offered transport and a maximum storage period of 6 months.

7. CONDIÇÕES GERAIS DE VENDA

Preços:
Os preços indicados, no âmbito do fornecimento dos equipamentos e serviços especificados na oferta, são LÍQUIDOS e não incluem IVA nem qualquer outra taxa, imposto ou tarifa, e são válidos para os equipamentos colocados nas n/instalações em Barcelona (Spain) , segundo o Incoterms CPT 2010, e incluem a embalagem que permita o seu correcto manuseamento, transporte e armazenamento.

Condições de Pagamento:
O preço total estipulado na proposta será pago da seguinte forma:

- 30% com a confirmação do pedido através de transferência bancária.
- 40% com entrega dos equipamentos através de transferência bancária
- 30% a 30 dias da data de entrega dos equipamentos através de cheque

- Todos os pagamentos serão efectuados para a conta do banco Millennium BCP, n.º00 33 0000 4528 4924 040 05.

As obrigações de pagamento por parte do comprador dar-se-ão como cumpridas somente quando a GEA Westfalia Separator Ibérica tiver recebido a totalidade da quantia.

Prazos de entrega:
O prazo de entrega actual é de cerca de 5 meses Ex Works, a contar desde o momento da recepção e aceitação do documento de pedido e uma vez clarificados todos os detalhes técnicos e comerciais, e o pagamento inicial tenha sido realizado.
(PRAZO MAIS CURTO A CONFIRMAR)

Garantia Mecânica:
GEA Westfalia Separator Ibérica dá a garantia de que os materiais e equipamentos estão livres de defeitos à data da entrega no que diz respeito a defeitos materiais, defeitos de montagem e falhas de construção.

A responsabilidade da GEA Westfalia Separator Ibérica é de 12 meses a contar desde o arranque do equipamento ou até 18 meses desde a entrega.

Se o defeito ocorrer durante o período de garantia, o cliente deverá notificá-lo à GEA Westfalia Separator Ibérica imediatamente para que esta possa solucioná-lo a seu cargo e escolha, reparando ou substituindo as partes defeituosas que serão entregues à GEA Westfalia.

O comprador proporcionará os serviços e os meios necessários para realizar o serviço de garantia no local onde estão instalados os equipamentos sujeitos a garantia.
A responsabilidade sobre um defeito dentro do período de garantia será assumida pela GEA Westfalia Separator Ibérica desde que o comprador tenha tido em conta o procedimento e instruções de uso, operação e manutenção dos equipamentos e sempre que utilize peças sobressalentes originais da GEA Westfalia Separator.

As partes sujeitas a desgaste ou deterioração, como consequência do normal uso e funcionamento dos equipamentos, tais como vedantes em geral, embraiagens, partes de travagem, casquilhos, etc., estão excluídas desta cláusula de garantia

Reserva de Direitos
O vendedor reserva os seus direitos de propriedade no que diz respeito à mercadoria entregue até que todos os pagamentos previstos no contrato tenham sido satisfeitos pela parte do cliente.

Responsabilidade do vendedor para danos consequentes:
Excepto no caso de dolo, negligencia grave ou imprudência temerária, a Westfalia Separator Ibérica não será responsável por danos indirectos ou consequenciais como perda de lucro ou perda de utilização, entre outros

Limite de responsabilidade Máxima
A responsabilidade máxima da Westfalia Separator Ibérica pelo conjunto dos conceitos está limitada a 10% do preço do contrato.

Exclusão de outras reclamações
Os direitos, obrigações e responsabilidades do comprador e da Westfalia Separator Ibérica são as derivadas das condições anteriores e representam os seus direitos exclusivos, obrigações e responsabilidades.

Alterações de Fornecimento:
A GEA Westfalia Separator reserva-se no direito de alterar os componentes especificados na proposta por outros de similar ou de maior qualidade sempre que existam razões de mercado ou de melhoria de processos tecnológicos.

Instalação mecânica, eléctrica, tubagens, encanamentos:
Não incluída.

Posta em marcha:
Não incluída.

Exclusões
Especialmente, mas não exclusivamente, os seguintes pontos não estão incluídos na extensão de fornecimento.

- material de embalagem
- Obras de construção civil
- Alvenaria metálica
- Cimentação
- Iluminação
- Material e acessórios de tubagens
- Cabos
- Bandejas e protecções para cabos.
- Instalação da maquinaria
- Trabalhos de programação para comunicação de sinais
- Materiais e serviços que não estejam particularmente detalhados na Extensão de fornecimento.

Validade da proposta:
A presente proposta tem uma validade **de 60 dias**.

Melhores cumprimentos / Best regards

Javier Madina
Market Manager Food & Industry

GEA
Westfalia Separator Ibérica, S.A.
Avda. de Sant Juliá 147
08403 Granollers (Spain)

Tel. / phone: +34 938 617 100
Móvil/ mobile: +34 619 783 941
Mail: javier.madina@gea.com
www.gea.com

Annex D

01.18		
Volume total	6 751,40	hL
Perdas totais	697,64	hL
Percentagem de perdas	10,33	%
Perdas nas purgas totais	541,60	hL
Percentagem de perdida na purga	8,02	%
Perdas na filtração	156,05	hL
Percentagem de perdida na filtração	2,31	%
Preço total perdido	10 464,62	€

02.18		
Volume total	6 825,00	hL
Perdas totais	718,26	hL
Percentagem de perdas	10,52	%
Perdas nas purgas totais	490,24	hL
Percentagem de perdida na purga	7,18	%
Perdas na filtração	228,02	hL
Percentagem de perdida na filtração	3,34	%
Preço total perdido	10 773,85	€

03.18		
Volume total	5 541,00	hL
Perdas totais	555,24	hL
Percentagem de perdas	10,02	%
Perdas nas purgas totais	363,59	hL
Percentagem de perdida na purga	6,56	%
Perdas na filtração	191,65	hL
Percentagem de perdida na filtração	3,46	%
Preço total perdido	8 328,67	€

04.18		
Volume total	9 864,00	hL
Perdas totais	998,20	hL
Percentagem de perdas	10,12	%
Perdas nas purgas totais	643,04	hL
Percentagem de perdida na purga	6,52	%
Perdas na filtração	355,16	hL
Percentagem de perdida na filtração	3,60%	%
Preço total perdido	14 972,96	€

05.18		
Volume total	9 965,00	hL

Perdas totais	1 215,74	hL
Percentagem de perdas	12,20	hL
Perdas nas purgas totais	861,49	%
Percentagem de perdida na purga	8,65%	hL
Perdas na filtração	354,24	%
Percentagem de perdida na filtração	3,55	hL
		%
Preço total perdido	18 236,04	
		€

06.18		
Volume total	9 087,00	hL
Perdas totais	1 095,20	hL
Percentagem de perdas	12,05	%
Perdas nas purgas totais	611,94	hL
Percentagem de perdida na purga	6,73	%
Perdas na filtração	483,26	hL
Percentagem de perdida na filtração	5,32	%
Preço total perdido	16 427,96	€

07.18		
Volume total	12 429,00	hL
Perdas totais	1 191,40	hL
Percentagem de perdas	9,59	%
Perdas nas purgas totais	684,17	hL
Percentagem de perdida na purga	5,50	%
Perdas na filtração	507,23	hL
Percentagem de perdida na filtração	4,08%	%
Preço total perdido	17 870,98	€

08.18		
Volume total	10 274,00	hL
Perdas totais	1 126,91	hL
Percentagem de perdas	10,97	%
Perdas nas purgas totais	629,67	hL
Percentagem de perdida na purga	6,13	%
Perdas na filtração	497,24	hL
Percentagem de perdida na filtração	4,84	%
Preço total perdido	16 903,65	€

09.18		
Volume total	5 878,00	hL
Perdas totais	556,45	hL
Percentagem de perdas	9,47	%
Perdas nas purgas totais	259,16	hL
Percentagem de perdida na purga	4,41	%

Perdas na filtração	297,29	hL
Percentagem de perdida na filtração	5,06%	%
Preço total perdido	8 346,68	€

10.18		
Volume total	7 861,00	hL
Perdas totais	780,52	hL
Percentagem de perdas	9,93	%
Perdas nas purgas totais	408,00	hL
Percentagem de perdida na purga	5,19	%
Perdas na filtração	372,53	hL
Percentagem de perdida na filtração	4,74	%
Preço total perdido	11 707,83	€

11.18		
Volume total	9 019,00	hL
Perdas totais	905,17	hL
Percentagem de perdas	10,04	%
Perdas nas purgas totais	420,42	hL
Percentagem de perdida na purga	4,66	%
Perdas na filtração	484,75	hL
Percentagem de perdida na filtração	5,37	%
Preço total perdido	13 577,54	€

12.18		
Volume total	2 429,00	hL
Perdas totais	297,66	hL
Percentagem de perdas	12,25	%
Perdas nas purgas totais	195,81	hL
Percentagem de perdida na purga	8,06	%
Perdas na filtração	101,85	hL
Percentagem de perdida na filtração	4,19	%
Preço total perdido	4 464,97	€

Annexe D

Exmo. Sr. Tiago Soares

EMPRESA DE CERVEJAS DE MADEIRA
PEZO - Parque Empresarial Zona Oeste
9304-003 Câmara de Lobos, Portugal

Javier Madina
Sales Equipment
Market Manager Beverage & Dairy

Tel. +34 938 617 100
Móvil +34 619 783 941
javier.madina@gea.com

31.07.2019

Quotation nr.: 1907116- 60. PLUG&WIN 180

Dear Mr Soares,

In response to your inquiry we hereby take pleasure in submitting you our enclosed offer.

We are confident that this offer provides an optimal solution that exactly meets your requirements. If the requirements should have changed or if you wish any modifications, we'll be pleased to revise our offer accordingly.

The quotation has been prepared as a non-binding offer on the basis of the information available thus far and with reference to GEA Westfalia Separator Group's Terms of Supply and Site Services.

If you are interested, we will be pleased to enter into more detailed negotiations to set up the individual conditions of the contract.

GEA Westfalia Separator Ibérica, S.A.

Javier Madina
Market Manager Beverage & Dairy

GEA Westfalia Separator Ibérica, S.A.
Av. de Sant Julia, 147. Aptdo. Correos 187
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+34 938 617 100 Fax +34 938 494 447
www.gea.com

Registro Mercantil de Barcelona: H. 15.425-F.220. T. 1.715. S 2ª. L 1.137
NIF. A-08203812

Our proposed solution

1x PLUG&WIN 180

Key features and benefits

This skid mounted unit is designed for multipurpose use within breweries and will be delivered ready to use.
It consists of a self cleaning disc type centrifuge and all components, necessary for a reliable operation. The solids are discharged by regular ejections. The product is discharged under pressure by a centripetal pump, so no additional pump is required.
The machine is equipped with a hydro-stop ejection system, which ensures very fast and precise ejections. This reduces the losses to a minimum. The volume of the ejection can be adjusted by exchanging an insert ring when the bowl is disassembled.
The hydro hermetic sealing system provides gas-tight sealing without mechanical seals and ensures a minimum oxygen intake. Aditionally the bowl can be covered with CO2. The hermetic feed system ensures gentle product handling and consequently the advanced clarification efficiency. The in- and outlet sealing system is maintenance free.
The robust "short spindle drive" guarantees vibration free running as well as high insensitivity to bowl imbalance and ensures an optimum service life.
The separator and the parts of the plant are CIP applicable.
The turbidity of the clarified beer can be influenced by manual adjustment of the bowl speed. The ejections are triggered by turbidity increases and by timer. The discharge pressure is adjusted automatically in accordance to the flow-rate by a control valve.

Delivered with an eccentric-screw pump for an enclosed discharge and transport of the ejected solids.

A booster pump unit for operating water is included and ensures safe and reliable machine operation, in case of eventual undesired fluctuations in the water supply.

The feed flow is controlled via a automatic control valve and can be easily adjusted via the control panel. It will be modified automatically in accordance to the ejection intervals.

Delivered with a centrifugal pump for the product feed.

Technical specification

1 Skid unit **Plug & Win 180**
for multipurpose use in breweries

Application and flow rate:	Beer clarification up to 180 hl/h Tank Bottoms recovery up to 6 hl/h Wort clarification up to 100 hl/h Exact capacity depends on process conditions

1 Skid-mounted centrifuge with the following details:

Bowl	self-ejecting bowl with hydraulic operation
Hydraulic system	hydrostop, type hydry
Ejection-volume	adaptable via control-unit during operation
Product discharge	closed discharge with centripetal pump
Sealing system	hydro hermetic sealing by a deaerated water ring, combined with a CO_2 blanketing of the hood
Hood and solids-catcher	stainless steel
Solids cyclone	stainless steel, flange-design for enclosed discharge, with level-probes and spray-ball for cleaning
Speed monitoring	via inductive proximity switch
Variable bowl-speed	for manual adjustment of the beer-turbidity
Frame	cast iron, varnished in dusty grey RAL 7037
Drive system	flat belt drive without clutch
Motor operation via	frequency converter
Motor power	22 kW, IP 55, IE3

1 Skid mounted equipment for feed and discharge lines for automatic operation (feed flow and back-pressure are intended to be adjusted automatically)

Components in the product feed line
- Magnetic inductive flow meter
- Sample valve
- Automatic control valve for automatic flow adjustments
- Automatic control valve for feed flow adjustment
- Illuminated sight glass
- Pressure gauge
- Automatic butterfly valve

Components in the water feed line
- Automatic butterfly valve

Components in the product discharge line
- Turbidity sensor (Brand SELI, Type STS 03)
- Illuminated sight glass
- Pressure sensor
- Automatic control valve for back pressure control
- Sample valve
- Non-return valve
- 2 Automatic butterfly valves for switching between tank and sewer

Components in the solids discharge
- Automatic butterfly valve for flushing the solids cyclone during CIP

Various components for the supply lines of…
- Operating and level-probe flushing water
- Hydrohermetic sealing water
- CO2 hood covering

Pneumatic components installed in the compact control cabinet
- Service unit for control air

1 Skid mounted compact control cabinet (as described under chapter “Control Cabinet”)

Connections, Dimensions and weights of the skid:

Product feed and discharge	DN 50, DIN 11851
Solids discharge	DN 40, DIN 11851
Operation water	DN 25, DIN 11851
Degassed water	DN 10, DIN 11851
CO2	DN 10, DIN 11851

Complete skid	L 2.400 mm x W 1.600 mm x H 1.800 mm
Bowl alone / skid without bowl	400 kg / 1.550 kg
Required hoist	2.500 mm
Including:	

1 Set of tools for dismantling, lifting and assembling of the machine
1 Set of spare parts for commissioning (e.g. bowl gaskets, lubricants)

Accessories

1 Eccentric screw pump for an enclosed solids discharge
The control of the pump is integrated into the control cabinet of the machine.

Manufacturer:	Seepex
Motor power:	1.5 kW; 380-420V; 50/60Hz; direct started
Capacity:	1.200 l/h; against max. 4 bar
Connection pressure side:	DN40
Stator material:	NBR

1 Booster pump unit for operating water supply

The unit consists of a pressure tank with a sufficient volume for at least two ejections and a self priming pump (0,6 kW; 3 Ph.; 380-420V; 50/60Hz) as well as an integrated pressure switch for the automatic control. The power supply is protected via the control cabinet of the machine.
This pump is not in tropical design!

1 Automatic control valve for the feed line

2 Illuminated sight-glasses

1 Centrifugal pump for the product feed

Type of pump:	Centrifugal pump
Manufacturer:	GEA
Motor power:	4,0 kW; 380-420V; 50/60Hz
Motor operation:	via frequency converter
Capacity:	180 hl/h
Connection pressure side:	DN50

Control system

1 Compact control cabinet, consisting of:

- Control Unit GEA IO 7
GEA IO is the new control panel generation for all GEA Centrifuge applications, focusing on intuitive handling, efficient process and reliable operation. The control unit is used for the automatic program control of separators with a self-cleaning bowl and consists of a PLC and a HMI (details see below). The operator panel allows an observation of the machine incl. the surrounding equipment in graphics and the adjustment of various timers and parameters. Explicit alarm messages are provided as well. The unit controls and monitors the Production, CIP, Water-flush and stand-by modes as well as the triggered ejections and the delivered equipment around the machine.
Further possible functions (depending on the selected scope) are:

Flow-control, discharge pressure-control, discharge turbidity monitoring, Solids-freight monitoring (Flow-ramping), Bowl-displacements, Bowl-speed adjustments, etc.

- Motor control
The motor of the centrifuge is operated via a frequency converter and protected by means of PTC resistors. Depending on the selected scope the control and protection of additional pumps are implemented as well. The power switch has an overload release for line protection and instantaneous short-circuit trip. Transformers provides internal and external control voltages. The emergency button is installed into the front door of the cabinet.

Technical data:

Brand of cabinet:	Rittal
Housing:	stainless steel
Protection class:	IP54
Cable entry:	from bottom
Dimension:	W 800 mm x H 1.200 mm x D 300/600 mm
Installation:	wall-mounted
Cooling:	via fan (for surrounding temperature of < 35°C)
Frequency converter(s):	Schneider
PLC / CPU:	Siemens, S7-1200
HMI / Operator panel:	Siemens, TP700 comfort (7" TFT wide-screen, multicolour touch-display)

Power supply:	3 Ph.; 380 - 420 V; 50/60 Hz
Internal control voltage:	220/230V AC and 24V DC
External control voltage:	24V DC

Note:
The dimension is based on the standard-scope and might change depending on the selected configuration and final scope of supply. If selected, the fan is replaced by a climate unit for air-condition.

4. Standard components

Our quotation is based on the use of the following standard components:

Equipment	Brand	Type
Valves and Devices/Fittings for products:		
Double seated valve	GEA	
Automatic butterfly valve	GEA	T-smart 7
Manual butterfly valve	GEA	T-smart 7
Automatic control valve	GEA	Varivent Type P
Constant-pressure valve	GEA	DHV
Sample valve	M&S	
Automatic sample valve	GEA	VARILINE
Manual ball valve:	END	
Manual diaphragm throttle valve	GEMÜ	
Non-return valve	M&S	
Spill valve	GEA	VARIVENT Type Q
Measuring- and control technology:		
Magn.-induct flow-meter	GEA	IZMAG
Magn.-induct flow-meter (for mashes)	ABB	FSM 4000
Mass flow-meter (for viscous prod.)	E&H	Promass
Mass flow-meter (for liquid prod.)	KROHNE	Optimass
Float-type Flow-meter (for Product)	KROHNE	H250
Float-type Flow-meter (for Water)	ABB	
Pressure-gauge	AB, WIKA	
Pressure-sensor	E&H	Cerabar M Hart
Turbidity-sensor	SELI (for Juice, Wine and Plug & Win)	STS-3
	OPTEK (for Beer)	AF16, AS16
Valves and Devices/Fittings for utilities:		
Pressure-reducer	END	DM
Service unit for compressed air	FESTO	
Solenoid valve block for control air	BÜRKERT	6014
Pumps:		
Eccentric screw pump	SEEPEX	
Booster pump	ELWA	

Product pump	GEA	
Pipeline elements:		
Compensator	HSI	Lactopal L
Sight-glass	GEA	VARILINE

All components are selected in consideration of the process conditions and product safety by GEA Westfalia Separator Group GmbH. Subject to technical changes and availability from suppliers. The use of other components and suppliers on customer's request are possible but will be invoiced separately.

5. Documentation

The scope of supply described in this offer, includes our standard set of technical documentation in English language* (1x paper / 2x digital medium), consisting of:

- Instruction Manuals
- Safety Instructions
- Spare parts catalogue
- P&ID
- Dimensional drawing

*If the country of destination is a member of the European Union, the instruction manual and safety instructions will be provided in local language.

Any additional documentation is available on request at extra costs.

6. Price

Plug & Win 180
- Solids pump 1,5 kW
- Booster pump unit for operating water supply
- Upgrade to automatic feed control
- Illumination for sight-glasses
- Product feed pump
- Compact Control, GEA IO 7

Total SALE price for machine and equipment as specified **133.900.- €**

The price shall be understood net incl. packing.
The packing is suitable for the offered transport and a maximum storage period of 6 months.

7. CONDIÇÕES GERAIS DE VENDA

Preços:
Os preços indicados, no âmbito do fornecimento dos equipamentos e serviços especificados na oferta, são LÍQUIDOS e não incluem IVA nem qualquer outra taxa, imposto ou tarifa, e são válidos para os equipamentos colocados nas n/instalações em Barcelona (Spain) , segundo o Incoterms CPT 2010, e incluem a embalagem que permita o seu correcto manuseamento, transporte e armazenamento.

Condições de Pagamento:
O preço total estipulado na proposta será pago da seguinte forma:

- 30% com a confirmação do pedido através de transferência bancária.
- 40% com entrega dos equipamentos através de transferência bancária
- 30% a 30 dias da data de entrega dos equipamentos através de cheque

- Todos os pagamentos serão efectuados para a conta do banco Millennium BCP, n.º00 33 0000 4528 4924 040 05.

As obrigações de pagamento por parte do comprador dar-se-ão como cumpridas somente quando a GEA Westfalia Separator Ibérica tiver recebido a totalidade da quantia.

Prazos de entrega:
O prazo de entrega actual é de cerca de 4 - 5 meses Ex Works, a contar desde o momento da recepção e aceitação do documento de pedido e uma vez clarificados todos os detalhes técnicos e comerciais, e o pagamento inicial tenha sido realizado.
(PRAZO MAIS CURTO A CONFIRMAR)

Garantia Mecânica:
GEA Westfalia Separator Ibérica dá a garantia de que os materiais e equipamentos estão livres de defeitos à data da entrega no que diz respeito a defeitos materiais, defeitos de montagem e falhas de construção.

A responsabilidade da GEA Westfalia Separator Ibérica é de 12 meses a contar desde o arranque do equipamento ou até 18 meses desde a entrega.

Se o defeito ocorrer durante o período de garantia, o cliente deverá notificá-lo à GEA Westfalia Separator Ibérica imediatamente para que esta possa solucioná-lo a seu cargo e escolha, reparando ou substituindo as partes defeituosas que serão entregues à GEA Westfalia.

O comprador proporcionará os serviços e os meios necessários para realizar o serviço de garantia no local onde estão instalados os equipamentos sujeitos a garantia.
A responsabilidade sobre um defeito dentro do período de garantia será assumida pela GEA Westfalia Separator Ibérica desde que o comprador tenha tido em conta o procedimento e instruções de uso, operação e manutenção dos equipamentos e sempre que utilize peças sobressalentes originais da GEA Westfalia Separator.

As partes sujeitas a desgaste ou deterioração, como consequência do normal uso e funcionamento dos equipamentos, tais como vedantes em geral, embraiagens, partes de travagem, casquilhos, etc., estão excluídas desta cláusula de garantia

Reserva de Direitos
O vendedor reserva os seus direitos de propriedade no que diz respeito à mercadoria entregue até que todos os pagamentos previstos no contrato tenham sido satisfeitos pela parte do cliente.

Responsabilidade do vendedor para danos consequentes:
Excepto no caso de dolo, negligencia grave ou imprudência temerária, a Westfalia Separator Ibérica não será responsável por danos indirectos ou consequenciais como perda de lucro ou perda de utilização, entre outros

Limite de responsabilidade Máxima
A responsabilidade máxima da Westfalia Separator Ibérica pelo conjunto dos conceitos está limitada a 10% do preço do contrato.

Exclusão de outras reclamações
Os direitos, obrigações e responsabilidades do comprador e da Westfalia Separator Ibérica são as derivadas das condições anteriores e representam os seus direitos exclusivos, obrigações e responsabilidades.

Alterações de Fornecimento:
A GEA Westfalia Separator reserva-se no direito de alterar os componentes especificados na proposta por outros de similar ou de maior qualidade sempre que existam razões de mercado ou de melhoria de processos tecnológicos.

Instalação mecânica, eléctrica, tubagens, encanamentos:
Não incluída.

Posta em marcha:
Não incluída.

Exclusões
Especialmente, mas não exclusivamente, os seguintes pontos não estão incluídos na extensão de fornecimento.

- material de embalagem
- Obras de construção civil
- Alvenaria metálica
- Cimentação
- Iluminação
- Material e acessórios de tubagens
- Cabos
- Bandejas e protecções para cabos.
- Instalação da maquinaria
- Trabalhos de programação para comunicação de sinais
- Materiais e serviços que não estejam particularmente detalhados na Extensão de fornecimento.

Validade da proposta:
A presente proposta tem uma validade **de 60 dias**.

Melhores cumprimentos / Best regards

Javier Madina
Market Manager Food & Industry

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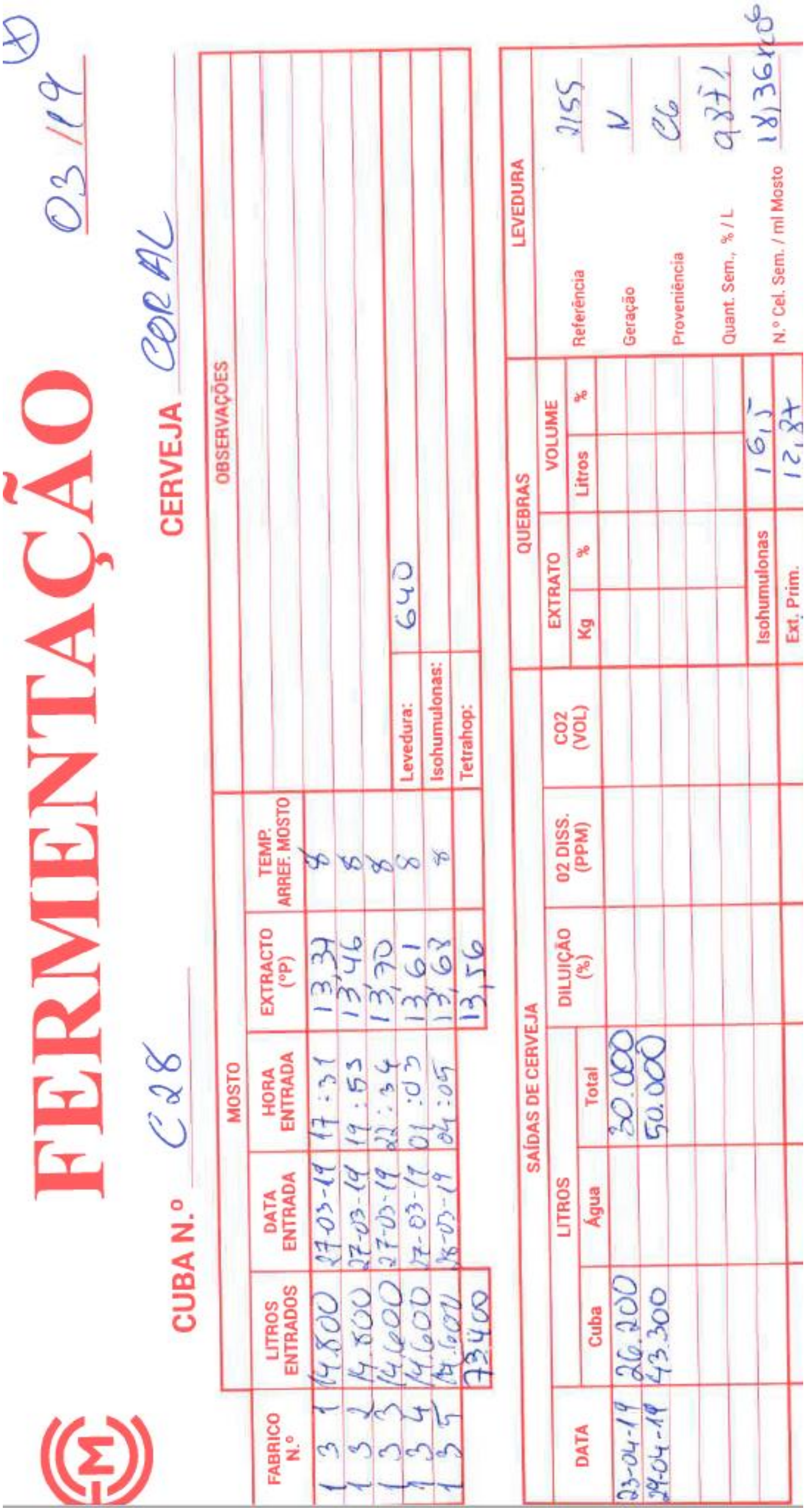
Annex E



FERMENTAÇÃO

03 /19 (X)

CUBA N.º C28

CERVEJA CORAL

FABRICO N.º	MOSTO: LITROS ENTRADOS	MOSTO: DATA ENTRADA	MOSTO: HORA ENTRADA	MOSTO: EXTRACTO (ºP)	MOSTO: TEMP. ARREF. MOSTO
1 3 1	14.800	27-03-19	17:31	13,34	8
1 3 2	14.800	27-03-19	19:53	13,46	8
1 3 3	14600	27-03-19	22:34	13,70	8
1 3 4	14600	27-03-19	01:03	13,61	8
1 3 5	14.600	28-03-19	04:05	13,68	8
	73400			13,56	

OBSERVAÇÕES	
Levedura:	640
Isohumulonas:	
Tetrahop:	

DATA	SAÍDAS DE CERVEJA: LITROS Cuba	Água	Total	DILUIÇÃO (%)	02 DISS. (PPM)	CO2 (VOL)
23-04-19	26.200		30.000			
24-04-19	43.300		50.000			

QUEBRAS: EXTRATO Kg	%	VOLUME Litros	%

Isohumulonas	16,5
Ext. Prim.	12,87

LEVEDURA	
Referência	2155
Geração	N
Proveniência	C6
Quant. Sem., % / L	9871
N.º Cel. Sem. / ml Mosto	18,36x10⁶