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SOPs FOR A SMALL SIZE BREWERY

Kahakka Brewery

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ABSTRACT

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The aim of this thesis was conceiving an exclusive and acceptable SOPs system for Kahakka brewery, SOPs are very important component for a successful industry, not only for the quality control, but also for all the workers who are capable of carrying out the whole process and making all steps standardized. These SOPs will apply in the whole brewing process and it will be a standard manual for employees to refer to.

SOPs for a small brewery is an assurance for beer consistency, fermentation rates prediction, and contaminants control and monitoring system to improve the quality control management. These SOPs are based on the brewing process of Kahakka daily brewing. During the brewing process there are many elements that will affect the final beer flavor, before writing SOPs brewers have to understand what happens in each step to eliminate error operations and be able to react quickly to changing settings.

Key words
Brewing, Fermentation, Mashing, Milling, Quality control, SOPs, Wort,

CONCEPT DEFINITIONS

ABV – Alcohol by volume

ATTENUATION – Measurement of the percentage of sugars converted to alcohol and CO_2.

BOIL VOLUME – Target amount of liquid to be collected through mashing and mixing.

CIP – Clean in place

DMS – Dimethyl sulfide

FAN – Free amino nitrogen

FERMENTATION – Conversion of sugar to alcohol by yeast.

FG – Final gravity; measurement of relative density of the beer at end of fermentation.

HACCP – Hazard analysis and critical control points

IBU – International Bitterness Units

MC – Moisture content

OG – Original gravity; measurement of the relative density of the wort before fermentation.

PITCHING – Addition of yeast to the fermenter.

QC – Quality control

SOPs – Standard Operation Procedures

TQM – Total quality management

TSN – Total soluble nitrogen

ABSTRACT
CONCEPT DEFINITIONS
CONTENTS

1 INTRODUCTION

The main reason behind quality control is that the products of craft brewing industry are very exquisite, due to the fact that most production steps are operated manually, any small mistakes have huge possibilities to influence the quality of the final product. Besides, according to customer praxeology, when a customer comes to the craft beer shelf, they tend to choose the same product repeatedly which is due to good quality and appropriate price. Quality is very important when several products have the same price. That is why an acceptable and applicable quality control plan is highly necessary for craft breweries. QC is a changing and improving process and aiming for identify potential impacts for the final product. It is expressed by SOPs (the standard operation procedure) to develop the operation efficiency. This thesis discusses quality specifications of each procedure in brewing, from the chemistry perspective to explain the potential impacts during each stage.

Kahakka brewery is a craft brewery based in Kokkola, Finland. It was established in2017, the owners of Kahakka brewery are aiming to craft beer of high-quality standard and bringing a new beer drinking experience to customers. Now Kahakka brewery is in its developing stage and they are refining the flavor profile for each product, dedicating to have a better flavor profile to improve the quality of the product and to form the unique beer characteristics of Kahakka brewery. SOPs as a quality control tool can help Kahakka to optimize the quality of the product to meet customers' demands and to have powerful competitiveness. Furthermore, an implementable SOP can develop the production process by improving technology and working skills of employees.

2 QUALITY CONTROL PROGRAMME

Quality control program consists three main parts: quality requirements, quality control and quality assurance. These three parts have built a stable, applicable and reliable quality management system. Quality requirements is the basic outline of this system which determined the standard quality of final products.

2.1 Defining quality requirements

Quality requirements of food and safety in a brewery are granted by HACCP (Hazard Analysis and Critical Control Points), which demonstrate that the production area is uninvolved with any contaminations and it is necessary to have a sanitation protocol to verify the cleanness of the brewery before brewing. For meeting these requirements, there are several microbiological samples that must be taken from the equipment, raw materials and ingredients. If a small craft brewery is aiming to ensure the beer consistency from batch to batch, quality requirements are imperative for brewers to have proper measurements within the brewing process to standardize the operations and to control the production process (Pellettieri, 2015).

Before starting to brew, according to quality control parameters, some quality control requirements of beer in general must be detailed. Those requirements must consist of acceptable flavor, decent color, pleasant aroma, and no contaminants. But there are always more details that need to be considered if brewers wish to keep these requirements more precisely and accurately. For instance, it is important to confine the beer style before brewing, such as the ABV, bitterness, mouthfeel, maximum and minimum values and so on. All these parameters stand for each beer itself, they should be decided in a set of applicable norms in each recipe (Pellettieri, 2015).

2.2 Quality control

In brewing industries, the whole brewing process and beer must follow different requirements in many areas. For example: the final product must meet food safety standards due to that beer is made from grains; product specific standards which depend on beer styles; beverage analyzations, and environmental impacts. On the other hand, brewers also have to consider the economic side, such as production costs, selling profits and customer satisfactions to make adjustments if needed. It is mandatory to record crucial information (how the samples have been taken and how quality parameters have been measured) during the process to compare and as a reference for the next batch (Wunderlich & Back, 2009).

In the brewery industries, the quality control of beer is one of the most crucial things in quality control management. Beer being the final product of the brewing process which should be defined and precisely performed to the brewer's expectations. The quality control parameters have a direct impact on different quality requirements and final product quality. An applicable quality control metrics system should include at least these five parts: control parameters, measurements, tools and measure methods, limitation of each parameter (max & min values) and remedial methods. Once a beer recipe is settled, it should contain every specification for this beer style. Before starting to brew, brewers have to analyze the quality factors which have a potential impact on the final product, including raw materials (ingredients), equipment and technology, and brewing process (Wunderlich & Back, 2009). Quality control will go through the whole brewing process, from preparing the raw materials to finally bottling the beer. According to tested values for each parameter, brewers should understand if the beer quality was under control and if there is any necessary adjustment to be made.

2.3 Quality assurance

The process aimed at improving quality control management through monitoring process regularly is called quality assurance. It is connected to the whole quality management system to identify and analyze the possibilities for development. Quality assurance demand brewers to keep a list of plans to develop the metrics in quality controls, thus the beer quality is regulated and enhanced regularly at all steps to ensure that the standard is met. Quality assurance system is commonly applied in large brew industries, for craft beer brewers it can be divided into small similar principles and aims, the quality assurance system in a small brewery will be covered by written SOPs (Mary, 2015).

3 STANDARD OPERATING PROCEDURES (SOPs)

SOPs are also called standard operation procedures, which are the elemental instruction for the industrial production process. Meanwhile, SOPs also can be used as a process controlling tool, to make sure the production achieve the expected outcome, convenient for employees to check the work task step by step during the production process and to avoid potentially dangerous accidents (Bizmanualz, 2017).

SOPs are not only an instruction for the operating production process, but also the main objective of SOPs is to help employees, or anyone involved in the production to perform their job with standard and certainty, to accomplish or handle all the emergency situation during work. Each SOP should include the following fundamental elements:

- Name: there are many practices that need SOPs in brewery, each of them need a particular name to describe the work.
- Sequence Number: SOPs can be reedited during practice working, so each version should have a sequence number for easy identification.
- Time (date)
- Involved Equipment: if there is any equipment involved in the SOP, it should be listed or specified.
- Involved Materials: included ingredients should be listed in the SOP.
- Checking List: there should be a list for employees to check before daily work which includes materials preparation, machine setting and the person in charge.
- Guidance: should be clear and repeatable, also need to make sure it is written step-by-step and easy to follow (Palmer, 2006).

Basically, each SOP needs to be approved by the quality control department before implemented in the practical working process, and it could be reedited by people who work with this SOPs during the whole process to develop more effectively SOPs (Palmer, 2006).

3.1 Purpose and benefits of SOPs

The main purpose of making a set of SOPs for industry production is to improve the efficiency and safety level of the whole production process. Furthermore, SOPs can help craft breweries to reduce the possibilities of beer quality impact to guarantee the beer consistency batch to batch. When an industry has a set of standard applicable SOPs, it will have a good influence on many aspects, such as quality controlling, diminishing impacts, increasing productivity, and reducing the costs (Environmental Protection Agency, 2007).

Applying SOPs in industries will develop the technology of production and advance the products' quality. It will guarantee there is no effect on the production and quality even if there are personnel variations. Therefore, SOPs can also be used as a good material for personnel training, to assist new personnel to familiarize themselves with process rapidly and allow them to check the tasks step by step anytime during the process. Last, SOPs can reduce the miscommunications and uncertainties during work, it will help employees to operate standardly (Environmental Protection Agency, 2007).

4 BREWING QUALITY CONTROL

Beer brewing history is a combination of humans themselves and advancement of scientific and technological know-how. Beer, this word does not only stand for a beverage produced by fermentation from grain but also contains a tremendous meaning of beer culture and the fundamentals of beer production which is brewing technology (Bai J, Huang J, Rozelle S, Boswell M. 2012).

Beer has a significant connection with human society. Thousand years ago, this magical beverage was fermented based on grain by accident. After all these years of technology development, breweries still maintained the whole original procession of producing beer. In some researchers' opinion this fermented drink was found in China in 7000 BC (Bai J, Huang J, Rozelle S, Boswell M. 2012), but in 2800 BC, Mesopotamia, people found evidence of beer. Furthermore, as early as 9000 BC during the Neolithic Revolution (Hornsey 2004) there were other evidences to prove the first beer in the world was produced there. However, from history, only monasteries produced beer in amounts and to be treated as commercial brewing. The brewing industry started to develop later, the development was based on the urban large markets growing. Meanwhile many brewers began to provide fermented drinks to pubs, inns and other public places regularly (Hornsey 2004).

To demonstrate the brewing process clearly, this thesis will take the main product in Kahakka brewery, Kahakka PALE, as an example to demonstrate the whole picture of brewing to explain the quality control during the whole production. Basically, from the chemistry side brewing can be divided into four main parts which are: extracting sugars from malts, collecting them; boiling wort which collected from the first part and adding specific hops; transferring this sweet and hopped liquid to a tank to add yeast; and fermentation.

4.1 Definition of brewing requirements

Apparently, the key to characterize brewing quality requirements over each stage of the brewing process is to specify the measuring parameters for each step, measuring methods, and the tolerable values of the metrics. It is necessary to save the records after each examination, and compare it between not only the same productions but also the different productions. The comparation between the same production is means to check the accuracy of the process operations, and make sure the consistency in the same beer.

The purpose to compare records between different productions is to confirm the equipment settings and to make it easily for brewers to modify the original recipe if there any fluctuating changes (Bank, 1992).

There are many factors that have to be included to define brewing quality requirements, since the production already has been divided into following four sections:

a) Milling and Mashing (extracting sugars from malts, collecting wort)
   Quality requirements need to define: water hardness, malt type, additional adjunctions, machine settings, temperatures, gravity, time
b) Filtering and Boiling (boiling wort and adding specific hops)
   Quality requirements need to define: gravity, mixed hops, temperatures, pH, time
c) Whirlpool and Cooling (transferring this sweet and hopped liquid to a tank to add yeast)
   Quality requirements need to define: gravity, temperatures, pH, time
d) Fermentation and Maturation
   Quality requirements need to define: OG, FG, temperatures, pH, turbidity, color, bitterness, ABV, attenuation

4.2 Quality requirments in milling

The principle of milling is to ground up the malts into small suitable sizes for mashing and milling. This will affect beer quality from two main aspects: restrict husks from entering the kettle and prevent uncracked kernels. So, during the milling step, malts need to be dismantled and broken into appropriate size to obtain the greatest yield of soluble sugar extract. There are different standards for the milling gap of each beer due to the alcohol content level varies, so the coarseness of malts always depends on milling specifications. The milling specification will involve a standard also called optimal milling, which is not easy to achieve, because of the settings of the mill needs to be adjusted when brewing different beers or the raw material has changed (Kunze, 1996).

FIGURE 1 Two-roller mill (Franklin miller, 2018)

Roller milling is the most common dry milling system for a small size brewery, and to maintain the performance of the mill, sieve analyses must be checked regularly. This kind of mill is only suitable for the malts which have been pretreated. The work efficiency of a two-roller mill is low and working capacity is limited (Kunze, 1996). The roller mill used in Kahakka brewery is a two-roller and single-pass dry mill. According to the brew logs for Kahakka pale, mill specifications for the mill gap is 1.5 mm to 1.5 mm. The recent milling analysis done in January 2019 which be listed in TABLE 1, the testing scale was between 1.2 mm to 1.7 mm with an interval of 0.05 mm. Due to the mashing efficiency will be impacted by the quality of milling, it is good to record the weight of malts accurately every time for calculating the brewhouse efficiency.

Mill gap	Unit	Visual Evaluation
1.2	mm	fine flour
1.25	mm	fine flour
1.3	mm	fine flour
1.35	mm	flour
1.4	mm	fine grits
1.45	mm	fine grits
1.5	mm	coarse grits
1.55	mm	coarse grits
1.6	mm	coarse grits
1.65	mm	coarse grits + husks
1.7	mm	coarse grits + husks

Table 1 Milling analysis result of 2019 of Kahakka Brewery (Kavilo, 2018)

After milling, the milled malts will be transferred to a mashing tun and mixed with hot water, and this step is also called mashing in and is the most crucial part of mashing, in this step both the temperature of water and ratio of milled grist and hot water must be on the right level. The standard for this step is to make sure that every single malt will be mixed in the mash evenly without any clumping, otherwise clumping will decrease the recovery of sugar extraction (Sambrook, 1996).

The important procedure before mashing is aiming at mixing hot brew water and the milled grist together evenly in the mash tun. The crucial factors of this step are how evenly the milled grist and hot liquor are mixed and the temperature of the mixture. Clumps and balls are not acceptable because they will decrease the extract efficiency. Usually in decoction mashing for making a thinner mash, there is always a pre-masher after milling by mashing hydrator (Briggs, Boulton, Brookes, Stevens, 2004).

4.3 Quality requirements in mashing

The crucial elements in the mashing process are enzymes, temperature and correct mashing pH. Temperature and pH will affect the activities of enzymes and sugar concentration in wort, and activity of enzymes will affect the degradation processes, such like: starch degradation, β-glucan degradation, protein degradation, the rest degradations (Hough, 1991.)

The enzymes of starch degradation and protein degradation in mashing are performed by hydrolysis. TABLE 2 shows how the temperature affect the activity of all enzymes involved in the mashing process.

The main enzymes for starch conversion are α-amylase and β-amylase, and the main enzymes for protein degradation are proteinase and peptidase.

	Starch Degradation		Protein Degradation	
	α-amylase	β-amylase	proteinase	peptidase
Op Temp.°C	72-75	60-65	50-60	45-53
Distroy Temp.°C	80	70		
pH	5.6-5.8	5.4-5.5	4.2-5.3	4.2-5-3
Function	breaking long starch molecules into smaller chains for β-amylase	breaks maltose off and produces maltotriose and glucose	degrading complex molecules into simpler proteins	degrading medium size molecules into peptides or amino acids

Table 2 Mashing enzymes (Adapted from Hough, 1991)

The specifications for mashing focus on controlling temperature, time, and pH. The temperature influences the fermentability due to the amount of extraction is determined by temperature: higher fermentability happens with lower extraction and lower temperature, on the contrary lower fermentability happens with higher temperature and high extraction. In the starch degradation stage, the ratio of maltose/dextrin is determined by temperature selection. Starch will start to break down from gelatinization at 60°C, gelatinization is where the complex soluble starch starts to form, then it breaks down into small molecules in the liquefication process, finally saccharification converts all liquefied molecules to maltose and dextrin. One decision must be made before mashing; how much is the ratio of maltose/dextrin which means what kind of flavor will appear in the final product, more dextrin will bring a mouthful feel, likewise, more maltose will bring along more alcohol (Goldammer, 2008).

Malt is the traditional natural enzymes source for the mashing process. According to U.S. Food and Drug Administration in May 2006, barley was confirmed as a raw material to produce valuable healthy food and beverages. Usually in brewing industries grains are the main raw material, especially barley, but there are also other cereal grains such as oats, millets, rye and wheat, for brewing beer, based on different recipes, and the brewer always adjusts the ratio of different barleys in milling to get the desired flavor in the end. For the malting process, there are two species of barley mainly used in the brewing industry: one is two-row barley and another one is six-row barley. So, if the brewer, especially a small size brewery, aims to increase their extract elements, the former barley is the best choice, otherwise to increase the strength of the enzyme, then the later one is the best option (Wunderlich & Back 2009). In Europe, most brewers are using American two-row barley as the main material due to its greater enzyme potential. And the crucial key for producing good malt is the correct extent of germination. In Kahakka brewery, they used fine malts, and skipped the malting process. After milling, all malts will be transferred to a mixing tank, as soon as the malts contact suitable hot water, all enzymes will be released gradually. And all those enzymes will be activated to break the starch and proteins as much as they can. (Schmitt, Skadsen, Budde A, 2013).

To classify the likely impacts on a recipe due to different malt specifications, brewers should manage to understand the analysis sheet of the malt because any small change of malts specifications will cause distinguishable consequences. It can easily change the final product profile if brewers combined the different malts which have slightly changed in the specifications (Ted, 2008). This analysis sheet will publish the main information of malt including: MC, color, extract, diastatic power (for basic malts), alpha-amylase, total protein, TSN, FAN, DMS, mealiness, friability, size. According to different function of malt, malt can be categorized into basic malt and specialty malt. In the brewing process, basic malts are the foundation of beer and play a very important role as a diastatic power generator, specialty malts act as special ingredient which will contribute to a unique tone to the product, such as color, flavor. The basic malt of Kahakka Pale is Pilsner malt, blended with Munich malt in limited ratio. FIGURE 1 shows the specifications of Pilsner malt and specifications for malted pilsner malt are (Kunze 1996):

- The scale of color should be between 2.5-3.5 EBC
- Ratio of soluble nitrogen around 40%
- Do not contain uniformly germinating barley
- Viscosity < 1.55 mPas

Specifications

Physical	**Data**	**Unit**	**Chemical**	**Data**	**Unit**
Malt Color	4.5	EBC	Wort pH	5.85	
Boiled Wort Color	5.3	EBC	Saccharification	15	min
Viscosity calc. 8.6°P	1.53	mPas	Total Protein	10.6	%
Moisture Content	4.2	%	Soluble Nitrogen Dry Base	709	mg/100g
Extract Dry Basis	81.6	%	Kolbach index	41.8	%

Table 3 Malt Analysis Sheet of Pilsner (Adapted from Weyermann® malt company malt analysis sheets, 2018)

The quality control should start from checking raw material preparing. The malt analysis sheet is a reliable resource for malt quality evaluation. For example, TABLE 3 shows the moisture content of Pilsner is 4.2%, it is a standard lager malt. Brewers always need to consider MC changes of each lot and re-calculate the extract potential and prepare the compensation plan for the possible consequences, like color changing and flavor consistency changing due to any difference could bring huge changes in the final product. The extract yield is inversely proportional to moisture content. The higher extract yield per kilogram, the lower the moisture content should be, and the possibility of losing aroma, flavor and mold growth risk is increasing if moisture content of a malt closes to 1.5% (Ted, 2008). The moisture content usually indicates the quality of the malting process (Noonan, 1996).

Except the malt analysis sheet, malt also can be evaluated by other methods. According to Central European Brewing Analysis Commission, to make sure the accuracy of malt evaluation and various demands on malt evaluation there are three main methods: hand evaluation, mechanical examination and chemical- technological method (Kunze, 1996).

4.4 Quality requirements of water

In the entirely brewing process water plays a very important role as a raw material of beer not only during the process but also after brewing for cleaning, rinsing, and other purposes. Thus, the quality of water determines the quality of the final product, due to this reason it is necessary to have specifications for controlling the quality of the brewing liquor. So, when water is being used in brewing industry as a raw material it must always be adjusted early to be prepared as a qualified brewing liquor. Water adjustment usually involve several parts: suspended solids remove; and unwanted mineral reduction; and contamination remove (Kunze 1996).

Because the brewing process will be affected by different mineral ions, those ions even will affect the final beer flavor. During mineral reduction, due to calcium's contribution is to protect α-amylase to optimum enzymatic activity by decreasing pH in the early stage, so calcium is the most important element in the brewing liquor. On the other hand, calcium also plays a crucial role in the fermentation part, because it is mandatory for yeast flocculation (Stratford 1989).

The specifications of brew water: must be safe to drink, contains no pathogens as well as exquisitly controlled by chemicals; due to that different beer flavors demand different chemical composition of the brewing liquor, a certain pH, alkalinity of water and water hardness should be considered and be measured if needed (Kunze 1996).

The brew water characteristics and verification for different type of beer is necessary to be analyzed monthly or weekly (Sanchez, Gil, 1999). Water annual report is a good reference for a brewer when considering how to select the water to brew with. There are four things contributing to brew water evaluation: pH, alkalinity, water hardness and mineral in water. Because of the geological distinctive and variety of chemicals, different ions, minerals detected in the local water source, beer types have been advanced in differences response to the various water source (Bamforth & Charles 2006). TABLE 4 is the water quality report of Kokkola 2019, the Kahakka pale ale brew water source. Kahakka Pale is aiming to provide a flavor with balanced hops and malts. (Kavilo, 2018) To achieve this target, the water mineral composition needs to be adjusted.

Mineral ions	Pilsen	Munich	Dublin	Dortmund	Burton-on-Trent	Vienna	Kokkola	Unit
Calcium	7	75	115-200	250-260	265-350	160-200	44	mg/L
Sulfates	5-7	10	55	120-280	450-820	125-215	61	mg/L
Magnesium	2-8	18-20	4	20-40	25-60	60-65	26.7	mg/L
Sodium	2-30	2-10	12	60-70	25-55	8	15	mg/L
Chloride	5	2	20	60-105	15-35	10-40	20	mg/L
Bicarbonate	10-35	150-200	125-320	180-550	140-320	120-240		mg/L
Hardness	30	250-265	300	750	850-875	750	120	mg/L
TDS	35	275	350	1000	1100	850		mg/L

Table 4 Mineral content of classic brewing water and Kokkola water profile (Adapted from Kokkola water report, 2019 and Bamforth & Charles 2006)

After recognizing the concentration of different ions in brew water source and the water characteristics from the water report, the first move is calculating the additions that should be needed for correcting the pH of mashing which has to be controlled between 5.2-5.6. As seen in TABLE 4 and TABLE 5, the hardness of the local water in Kokkola is considered as medium-soft water. Calcium needs to be added due to the recommend brewing range for calcium is 50-150 mg/l. Calcium in appropriate range can contribute to the fermentation stage, function as an assistant yeast health and growth, and for the final product it develops color clarity and flavor profile and product stability. TABLE 4 above shows sulfate and magnesium are in the normal range, but if the brewer wants a sour bitter taste, magnesium should be increased to over 50 mg/L, if the brewer wants very bitter flavor, sulfate should be increased to 150-

350 mg/L. Because sodium is the common ion in soft water it always contributes to accentuate the malt sweetness and round out the final flavor, the brewing range should be between 70-150 mg/L which means sodium salt (baking soda) needs to be added (Palmer, 2006).

Scale ($CaCO_3$)	Unit	Hardness Level
<50	mg/L	Very soft
50-100	mg/L	Soft
100-200	mg/L	Medium soft
200-400	mg/L	Moderately hard
400-600	mg/L	Hard
>600	mg/L	Very hard

Table 5 Water Hardness Scale (Goldammer, 2008)

Time	Chloride	Sulfates	Cl/SO_4^-2
2016	26	74	0.35
2018	27	68	0.40
2019	20	61	0.33

Table 6 Chloride/Sulfates of Kahakka brew water (Adapted from Kokkola water report 2019)

Standards of Chloride/Sulfates	
Scale	**Results**
>0.5	very bitter
0.5-0.77	bitter
0.77-1.3	balanced
1.3-2.0	malty
<2.0	very malty

Table 7 Standards of Chloride/Sulfates in brew industry

In addition, it is valuable to focus on the ratio of chloride and sulfate because these reflect the beer flavor, according to different recipes the flavor profile of beer style is different. TABLE 6 indicates the chloride/sulphates ratio from year 2016 to 2019 of local brew water, compared to the results in TABLE 7, the standard chloride/sulphates ratio, the brewer needs to consider appropriate adjustments for each recipe to optimize the flavor profile. Water chemistry is not an absolute rule in brewing process, according to different situations and different recipes, it can be reedited all the time. To ensure the beer quality, water checking should be included in the SOPs' checking list.

4.5 Mashing biochemistry

From the chemistry perspective, most biochemistry changes in the brew process are involved the mixture of enzymes. The mashing condition has significant influence of the wort quality, thereby affecting beer quality. Due to the mashes being made from different mill gap, and brew water adjustment with salts and pH changing the main enzymes which showed in TABLE 8 in the wort have a higher possibility to stay active much longer than what brewers expected. In the brewing process mashing temperatures are changed due to its needs to be measured manually in Kahakka brewery, in consequences, when the temperature is not high enough to destroy some temperature sensitive enzymes, they will start to act. Along with the temperature increasing, the chemical reaction rate and enzyme catalyzed reaction will increase which will accelerate the rate of protein denaturation and precipitation, mixing process, and the most important thing is if temperature passes a set level starch will begin to gelatinize, and it will promote starch degrading enzymes to decrease the large molecules of sugar (Bamforth, 2006).

ENZYMES

Protein	Starch	Cell wall
Endo-pepdiases	α-amylase	Xylanase
Exo-petidases	β-amylase	Arabinofuranosidase
	Limit dextrinase	Feruloylesterase
	α-Glucosidase	Acetoxylanesterse
		Carboxypeptidases
		Endo-glucanases
		Exo-glucanases
		Glucosidases

Table 8 Enzyme list (Adapted from Kunze, 1996)

5 QUALITY REQUIREMENTS IN FILTERING AND BOILING

After mashing, the next stage is collecting all the sweet liquid to a kettle for boiling with hops. Meanwhile according to the recipe, one could also add other seasonings in this step if needed. This process entirely takes 90 minutes tops and the important processes that will take place during wort boiling are enzymes inactivated, sterilization and proteins are precipitated. The process of collecting wort and separating wort liquid from husks and other insoluble matters as completely as possible is called lautering which basically is a filtration process. There are two steps of lautering: transferring the first wort and washing the spent grains (circulating). The standard for wort concentration of sugar should be 4 to 6% more than the final target. Based on the first wort concentration, brewers can determine how much hot water will be involved in the sparging step to help the wort concentration reach the right level (Kunze 1996).

The specifications for this stage are that they need to pay attention to wort concentration, wort pH and spent grains removing, all these three factors are the main measurements for checking the quality of wort. The reason is that wort quality will affect the gravity before fermentation, because there still are multiple processes happening during wort boiling, like the protein formation, destruction of enzymes, extraction of hops, flavor and color formation and purification of the wort to remove volatile compounds from the last step and hops (Dennis et al. 2004).

5.1 Wort cooling and aeration

After boiling the wort needs to be cooled down to appropriate temperature for aeration and yeast pitching, thereby making the wort ready to ferment. Usually yeast pitching temperature is around 20 °C. In this stage the most important thing is wort aeration. The function of aeration is to develop the activity of yeast. Plenty of factors including the temperature of wort, sugar content of wort and yeast characteristics will determine the amount of oxygen that should be pumped into the wort. The specification of aeration is based on the oxygen demanding, oxygen level affecting the fermentation durations, abnormal flavor and the FG of beer. (Munroe, 2006)

5.2 Wort boiling chemistry

Wort boiling should always be treated as a key point in brewing due to many minor processes taking place in this stage. The completeness of these minor processes will contribute to the final product. For instance, the basic structure of protein is the amino acid which can build up the polypeptide chain, during mashing with an appropriate temperature will be broken down by enzymes. The standard protein contents is showed in TABLE 9. One target of wort boiling it to remove high weight protein. If there is incomplete coagulation involved, it is difficult to remove, furthermore will affect fermentation process like pH drop insufficient, and cause beer clarification degree and abnormal harsh flavor. Although a moderate amount of protein will have significant contribution of acceptable flavor, after bottling, if there is excess protein remaining, the life of the bottled beer will reduce dramatically (Colby, 2014).

Nitrogen and Amino acid	Wort	Hopped Wort	Beer	Beer refermented	Unit
Total protein	88.0	84.8	62.6	47.0	%
Low molecular nitrogen alcohol soluble	63.4	69.5	50.7	35.1	%
Total α-amino nitrogen	42.7	38.0	21.0	13.0	%
Alcohol soluble α-amino nitrogen	37.6	30.8	18.2	2.5	%
Alanine	9.8	10.2	7.7	1.8	%
γ-Amino butyric acid	8.3	7.9	9.6	2.5	%
Arginine	13.8	5.9	3.0	0.6	%
Aspartic acid	7.0	9.8	1.6	1.0	%
Glutamic acid	6.4	3.3	0.8	0.7	%
Glycine	2.3	2.6	2.1	1.3	%
Histidine	5.7	3.8	2.8	0.2	%
Isoleucine	6.2	6.5	2.1	0.3	%
Leucine	18.1	17.5	4.7	0.7	%
Lysine	14.9	10.7	2.2	0.5	%
Phenylanlanie	13.7	14.0	4.4	0.6	%
Proline (imino acid)	45.7	48.3	31.8	33.3	%
Threonine	5.9	7.3	0.3	0.3	%
Tyrosine	10.6	9.3	5.9	1.1	%
Valine	11.9	16.0	6.8	0.4	%
Serine+Asparagine mM in 100mL	168.6	171.8	7.9	5.6	%
Ammonia	2.4	2.4	1.7	1.0	%

Table 9 Standard protein contents variation (Check from Dennis et.al. 2004)

6 QUALITY REQUIREMENTS IN FERMENTATION AND MATURATION

Before the fermentation there is yeast preparation, from ancient times saccharomyces have been used in the brewing industry. Yeast is responsible for the entirely fermentation process, so the brewing yeast will give crucial characteristics to the beer. To avoid contaminants after cooling and aeration the wort should be pitched as soon as possible meanwhile adding yeast to the chilled and aerated wort, it will start to assimilate fermentable sugars, amino acids, minerals, and other nutrients for fermentation officially. The fermentation is aiming to convert the sugar into alcohol and CO_2. And during the fermentation the yeast will also contribute to the flavor by producing esters, acids. (Landaud S, Latrille E, Corrieu G, 2001)

The attenuation of wort is usually determined by the amount of fermented extract, and the amount of fermented extract is a crucial parameter for indicating the qualification of fermentation. According to ferment extract concentration standard (Nguyen, 1996), regular wort should contain about 80 % of fermentable extract and during beer transfer, from kiln to batch the green beer should contain approximately 10 % of unfermented fermentable extract to obtain sufficient formation of dissolved CO_2 during maturation. In the maturation process, it will take several weeks and there are other processes happening at the same time, like clarification, formation of flavor, sedimentation of yeast (Malherbe, Bauer, Du, 2007).

6.1 Fermentation chemistry

According to Gay-Lussac' s law, the fermentation process can be expressed as the following formula which represents the growth of yeast:

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

During fermentation, yeast metabolism will produce many side products, apart from ethanol and CO_2 which are contributing to the final flavor and character of the beer like aroma. Thus, the condition of fermentation needs to be controlled strictly to guarantee these minor products are blended as expected. Before transferring hopped wort into the fermentation tank, it needs to be oxygenated due to oxygen being the crucial elements for sterols and unsaturated fatty acid synthetization which is the crucial elements for yeast growing. The common metabolites having the ability to contribute flavor are fatty acids, aldehydes, and aliphatic alcohol which come from metabolism of protein and sugar. (Wainwright, 1971)

7 CONCLUSION

For craft breweries the description of quality beer is that all essential elements of the final product meet all quality requirements that are defined for this beer. To meet all quality requirements of the beer, the main object of quality control in craft breweries is to optimize the effectiveness of the process, consistent beer production and contaminants prevention. So, the quality control is not just applied in the process, there is finished beer quality checking before bottling to make sure the final product is desired and ready to bottle.

To ensure the correction of the brewing operation and easily identify the potential quality impacts in each brew stage, continuous recording can help brewers find a way to adjust the recipe and process. Besides records, brewers can predict the next episode in case they need to make adjustment or compensate actions to ensure beer consistency.

There are different parameters in different stages of the process, breweries should have their own quality control sheet which contains: introductions, frequency, testing methods, and results. The specification of each step should be listed in a quality control sheet: such as water report including chemical contents; malt analysis sheet; yeast pitching rate, yeast viability. Except material checking, equipment is also important to be kept clean and to run microbiological tests regularly to ensure no contaminants exist. A graphic method can easily compare the results and evaluate if every parameter is in an acceptable range to make the adjustments promptly.

BREWDAY S.O.P _____/_____/____ (Adapted from Original version, Chacon, 2019)

READ WHOLE DOCUMENT BEFORE PROCEEDING

CHECKING LIST:

- BREWHOUSE MUST BE READY FOR BREWING
- FILL MASH TUN WITH WATER UNTIL APROXIMATELY 2.5 CM ABOVE FILTER PLATES (hot water only)
- WINGMAN READY FOR MILLING (20 MINUTES BEFORE)
- CAST OUT LINE SHOULD BE READY FOR HOT PASTEURIZATION (ASSEMBLED, CONNECTED, FILL WITH PERACETIC ACID AND CLOSED)
- CHECK TEMPERATURE IN HOT LIQUOR TANK (HLT) ~ ________
- CHECK HLT WATER LEVEL
- CHECK MASH TUN MANHOLE IS CLOSE TIGHT
- REMOVE WHIRLPOOLING PIPE FROM HLT, LEAVE ONLY RECIRCULATION ARM
- MEASURE MINERALS (500g $CaCl_2$, 50 g SODA $NaHCO_3$)
- 1 cm from HLT = 12,5 L
- Total cold water added ~ 600 L
- MILL GAP ____/_____
- AIM AT _____ ° end of boil PLATO
- END OF BOIL LITERAGE ______ L
- BATCH N#_____

*FROM POINT 1 UNTIL 1.8 YOU WILL BE CONSTANTLY TAKING TEMPERATURE MEASUREMENTS

***steam valves are numbered from left to right (most left valve is 1st, most right valve is 4th)**

1 adjust brewing clock / check Mash tun valves

1. Filling Mash tun water level 2.5 cm above filter plates to start grains-in
   1.1. Rake ON, hot pump ON recirculating in HLT (keep hot pump running)
   1.2. Close cold water valves.
   1.3. Open hot pump to Mash tun valve just 45 degrees, not fully open (keep HLT re-circulating)
   1.4. Run hot pump first, open mixer valve (prime it)
   1.5. Prepare for mashing in:
      1.5.1. Measuring spoon + thermometer
      1.5.2. A thick mash wanted but not dry!
      1.5.3. Check thickness with measuring spoon.
   1.6. Open mixer valve
   1.7. Open hopper
   1.8. Adjust with cold water. When you see similar temperature, you can close lid for a while but check again soon later.
   1.9. Add strike water from HLT while adding grains (aim at 62-63 °C)
   1.10. Toss in minerals after grains completely covered filter plates.
   1.11. Bring pistol hose, hose grains from wall of Mash tun
   1.12. Grains-in completed in about 15-20 minutes. Burst mixer with water
   1.13. Mash tun level must be above rake
   1.14. Aim at 63 °C (about)
   1.15. Add hot water from HLT to reach 65 °C

AVOID REACHING 66 – 67 °C.

1.16. Stop strike water @ about 20 minutes in. Check cold water valve is closed.

(remove excess water from mash tun if necessary)

1.17. Grain level in MASH TUN above rake level is ok

1.18. Turn boiler ON

2. Stop rake @ 00:30

2.1. Leave cake to settle for 30 minutes. Take measurements.

2.2. Take measurements from different points

2.2.1 React to temperature by adding hot or cold water if too cold

or too hot

3. Give cake 30 minutes rest (point 2.1)
4. Hot pump OFF. Stop HLT recirculation
5. Check wort pump knob is working!
6. Prime HLT steam line (open 1st steam valve)
7. Prime wort pump to **start recirculating**. First dump whatever is in wort pump

4.1 Do not open mash tun bottom valve to sight-glass completely (open slightly)

4.2 Start pump slowly, about 16 rpm

4.3 Recirculate for 10 minutes. Air inlet in sight-glass open

4.4 Rrepare BK (priming)

4.4.1 install mesh bag in BK inlet (at brew deck manhole)

4.4.2 empty BK of peracetic acid

4.4.3 connect mobile pump to BK outlet

5 TRANSFER TO BK

5.1 Close recirculation valve in mash tun and open wort pump to BK valve (below brew deck stairs)

5.2 Open BK inlet in top of brew deck (check that all valves are open)

5.3 Check sight-glass flow, you might have to open mash tun outlet valve (little by little)

5.4 Give wort pump just enough power to transfer (not high rpm)

5.5 Start sparging (add hot water from HLT to match outlet flow into BK)

6 Remove mesh bag from BK inlet

6.1 At this point, keep check of 3 things:

- Inside mash tun, water level must be above grains, grains should not be visible
- Flow in sight-glass must not stop nor be too low (regulate with point 5.3-5.4)
- Pump is transferring into BK (check BK inlet through BK manhole in brew deck)

7 Start recirculating HLT until it reaches 90 °C

8 Check pressure in boiler

9 Once BK level is above bottom, open steam line for bottom jacket (3rd valve)

10 Connect mobile pump outlet to whirlpool valve in BK

11 Start whirlpooling (start mobile pump)

12 Once BK level is above steam jacket line **(@800 L**), open 4th steam valve.

12.1 Towards end of transferring, keep mash tun level at rake level (that is about 250 liters left in mash tun)

12.2 Once BK total level -250 liters is reached (~1060L), stop sparging →Remaining water in mash tun will complete total amount (+250 L)

12.3 After **sparging is done**, heat HLT (1st steam valve ON)

13 when **BK is full**

13.1 Add ANTIFOAM

13.2 Prepare hops

13.3 Let mash tun run empty (dump any remaining) and add cold water.

13.4 Dump water and let it cool down.

13.5 Waiting time for boiling is good lunch break time

14 When **reach boiling**, close 3rd steam valve for bottom of BK

14.1 Keep only side jacket ON in BK (4th valve). Measurements can be done while whirlpooling

14.2 Do a 60 minutes boil. Add enough steam to have a vigorous boil

15 HOT PAUSTERIZATION // HOPS ADDITION

15.1 Connect long hose from HLT to Heat exchanger (HX) inlet (filter)

15.2 Connect cast out line to FV

15.3 Run hot water from HLT through HX & cast out line. You can start grains out at the same time

15.4 Connect medium short hose to end of cast out line

15.5 Run hot water through line until reach 85 °C water at outlet (measure with thermometer)

15.6 When reach 85 °C flow can close valves.

16 1st hops addition at 15 min after boiling. 2nd hops at 30 min boiling. **Last hops at 15** before end of boil.

17 When 1-hour boil is ready, close steam valve (4th valve)

18 Let BK whirlpooling for a while. (dilution/concentration depends on measurements!)

19 Rehydrate yeast

20 CAST OUT

20.1 Connect mobile pump outlet to HX inlet (filter)

20.2 Connect water lock tubes in CIP arms of FV1 & FV2. Fill a bucket with peracetic acid at the end

20.3 Connect HX water outlet to HLT inlet (use long hose)

20.4 Run mobile pump. Run cold water through HX (cold water valve fully open).

20.5 Open dump valve in cast out line

20.6 You can open transfer valve, keep FV valve close

20.7 Run through dump until beer starts coming through

20.8 Close dump valve. Open FV valve & open gas valve in HX outlet (gas flow at 5 l/s)

20.9 Start filling FV. OPEN WATERLOCK IN CIP ARM!

20.10 Aim at HX outlet temperature ~ 25-30 °C

20.11 Check that cold water is running through HX when transferring into FV

20.12 Check that gas is being added in HX outlet

20.13 You can add yeast from top of FV while is filling.

20.14 624 L to each vessel (accounting for shrinkage)

20.15 Once cast out is done, close cold-water valve. Close gas line

20.16 Close FV valves

8 REFERENCES

Bai J, Huang J, Rozelle S, Boswell M. 2012. Beer battles in China: the struggle over the world's largest beer market.

Bamforth, Charles W. 2006, Scientific Principles of malting and brewing, American Society of brewing Chemists. United States.

Bank, John. 1992. The Essence of Total Quality. 2nd Edition, Upper Saddle River, United States

Bizmanualz. 2017. What Is a Standard Operating Procedure (SOP)?
Available: https://www.bizmanualz.com/save-time-writing-procedures/what-are-policies-and-procedures-sop.html Accessed on 13.2.2019

Briggs Dennis E., Boulton Chris A., Brookes Peter A., Stevens Roger, 2004. Brewing Science and Practice. CRC Press LLC, North America.

Chacon Tomas, 2019. SOPs of Brew day in Kahakka, Centria University of Applied Science, Kokkola

Comrie A.1967. BREWING LIQUOR—A REVIEW. Vol.73, Journal of the institute of brewing. P323-405

Colby Chris, 2014, Barley Starch for brewers (V:Gelatinization), Beer&Wine Journal.
Available http://beerandwinejournal.com/starch-v/ Accessed on 16.5.2019

EPA. 2007. Guidance for Preparing Standard Operating Procedures (SOPs) Environmental Protection Agency Available: https://www.epa.gov/sites/production/files/2015-06/documents/g6-final.pdf Accessed on 13.2.2019

Goldammer Ted. 2008. The brewer's handbook, 2nd edition, Apex Publishers, Clifton, Virginia.

Hornsey I. 2004. A history of beer and brewing, vol 1. Royal Society of Chemistry, Cambridge

Hough, J.S, 1991. The Biotechnology of Malting and Brewing, Cambridge University Press, London
John J. Palmer & Colin Kaminski, 2013, Water: A Comprehensive Guide for Brewers, Brewers Publications, United States.

Kunze, Wolfgang. 1996. Technology Brewing and Malting. (Wainwright, T. Transl.) Berlin, VLB.

Landaud S, Latrille E, Corrieu G, 2001. Top pressure and temperature control the fusel alcohol/ ester ratio through yeast growth in beer fermentation.

Munroe, James H. 2006. Handbook of Brewing ---`fermentation´, 2nd Edition, CRC/ Taylor & Francis

Nguyen, M. T. 1996, The universal Nortek mash filter, Ferment, 9 (6), 329.

Noonan Gregory J. 1996. New Brewing Lager Beer: The Most comprehensive book for Home- and Microbrewers, Brewers Publications, United States.

Palmer John J, 2006, How to Brew: everything you need to know to brew beer right the first time. 3rd edition, Brewer publications, United States.

Pellettieri Mary. 2015 Quality Management: essential planning for brewers, Brewers Publications, United States.

Sambrook, P. 1996 Country House Brewing in England. The Hambledon Press, London.

Sanchez, Gil W, 1999. The practical brewer. Master Brewer Association of the Americas, United States.

Schmitt M, Skadsen R, Budde A.2013 Protein mobilization and malting-specific proteinase expression during barley germination. J Cereal Sci 58.

Malherbe S, Bauer F.F, Du Toit M. 2007. Understanding Problem Fermentation ---A review, Stellenbosch University, South Africa.

Stratford Malcolm.1989 Yeast flocculation: calcium specificity. Volume5, Issue 6. P487-496

Wainwright, T. 1971, Biochemistry of Brewing, The Macmillian Press, United States.

Weyermann®, 2018. Malt analysis sheet of T 005-21111025-01 Plisner malt bag, Am Hafen.

Wunderlich S, Back W. 2009. Overview of manufacturing beer: ingredients, processes, and quality criteria. In: Preedy VR (ed) Beer in health and disease prevention. Elsevier, London

APPENDIX 1 MALT ANALYSIS SHEET OF PILSNER

Malt Analysis

Weyermann® Specialty Malts

Quality Department

Phone:	+49 951 - 93 22 0 - 22
Fax:	+49 951 - 9322 0 - 922
eMail:	QS@weyermann.de

Batch Analysis

Page 1 of 1

Batchcode:	T005-21110025-01	Sample Type:	F/F
Item:	Weyermann® Pilsner Malt Bag 25kg/55lbs	Analysis Number:	34998/2.2
		Date of Analysis:	05.01.2018
Item Number:	21110025	Operator:	laute
Date of Production:	05.01.2018	Production site:	Bamberg
Best before:	05.07.2019		

Specification		Unit
Physical		
Malt Color	4.5	EBC
Malt Color	2.1	°L
Boiled Wort Color	5.3	EBC
Boiled Wort Color	2.4	°L
Viscosity calc. 8.6°P	1.53	mPas
Viscosity calc. 12°P	1.83	mPas
Moisture content	4.2	%
Extract fine grind (as is)	78.2	%
Extract dry basis	81.6	%

Specification		Unit
Friability	87.8	%
Glassy Kernels	1.8	%
Chemical		
Wort pH	5.85	.
Saccharification	15	min.
Hartong Index VZ 45°C	37.0	%
Total protein	10.6	%
Soluble Nitrogen dry base	709	mg/100g
Kolbach Index	41.8	%

This products meets all valid food safety regulations in the European Union (including residue limits for mycotoxins).
Nitrosamines(NDMA): < 2.5 ppb (technical guideline).
The malt is free from insects, fungus, foreign bodies and pest damage: absence.
Total impuritites: < 0.5%
Cadmium: not detectable
T2-Toxin: not detectable

APPENDIX 2 WARER PROFIL OF KOKKOLA

kvvy **KVVY Tutkimus Oy**

TESTAUSSELOSTE 19-5180 1 (4)
¤Talousvesi #2
19.3.2019

FINAS
Finnish Accreditation Service
T064 (EN ISO/IEC 17025)

Kokkolan kaupunki
Kokkolan Vesi
Vesilaitos
Varastotie 4
67100 KOKKOLA

Tilausnro 354873 (10KOKVES/LÄHTEVÄ), saapunut 5.3.2019, näytteet otettu 5.3.2019 (10:20)
Näytteenottaja: Marjo Lehtinen

NÄYTTEET

Lab.nro	Näytteen kuvaus
12497	Verkostoon lähtevä

MÄÄRITYSTULOKSET / NÄYTTEET

Määritys	Yksikkö	12497	STM1352/15
*Escherichia coli	MPN/100 ml	0	<1 (v)
*Koliformiset bakteerit	MPN/100 ml	0	<1 (t)
*Heterotrofinen pesäkeluku 22°C	pmy/100 ml	0	
*Kokonaiskloori	mg/l	0,30	
*Vapaa kloori	mg/l	0,09	
*pH		8,2	«9,5, »6,5 (t)
*Alkaliniteetti, granin menetelmä	mmol/l	1,2	
*Väri	mg/l Pt	8	
*Sähkönjohtavuus (25°C)	µS/cm	320	<2500 (t)
*Liuennut happi	mg/l	9,7	
Happikyllästys %	%	79	
*Kokonaiskovuus CaMg-summa	mmol/l	1,1	
*Kloridi	mg/l	20	<250 (t)
*Sulfaatti	mg/l	61	<250 (t)
*Ammonium	mg/l	0,079	<0,5 (t)
*Nitriitti	mg/l	<0,02	<0,5 (v)
*Nitraatti	mg/l	1,00	<50 (v)
*Rauta	µg/l	80	<200 (t)
*Mangaani	µg/l	4,8	<50 (t)
*Alumiini	µg/l	<10	<200 (t)
*Natrium	mg/l	15	<200 (t)
*Nikkeli	µg/l	0,80	<20 (v)
Lämpötila näytteenotossa	°C	6,5	

Merkintöjen selityksiä: P = määritys kesken, E = ei tehty, ~ = noin, < = pienempi kuin, « = pienempi tai yhtäsuuri kuin, > = suurempi kuin, » = suurempi tai yhtäsuuri kuin.
STM1352/15 = STM:n asetus 1352/2015 (verkostovedet) v=laatuvaatimus t=laatutavoite
*-merkitty on akkreditoitu menetelmä.

Ca ~~Hg~~ = 44 mg/L $CaCO_3$ = 120 mg/L
Mg: 26,7mg/L

Tässä testausselosteessa esitetyt testaustulokset pätevät ainoastaan testatulle näytteelle. Akkreditointi ei koske lausuntoa. Testausselosteen saa kopioida vain kokonaan.

LAUSUNTO

Talousveden laatuvaatimukset: Sosiaali- ja terveysministeriön asetus 1352/2015.

Vesi täyttää talousveden terveydelliset laatuvaatimukset ja on laatusuositusten mukaista tutkituilta osin.

Timo Järvenpää
Kemisti

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Torppa Ritva/ritva.torppa@ely-keskus.fi

MENETELMÄTIEDOT

Määritys	Menetelmän nimi ja tutkimuslaitos (suluissa)
*Escherichia coli	SFS-EN ISO 9308-2 (TL67)
*Koliformiset bakteerit	SFS-EN ISO 9308-2 (TL67)
*Heterotrofinen pesäkeluku 22°C	SFS-EN ISO 6222:1999 (TL67)
*Kokonaiskloori	SFS-EN ISO 7393-2:2000 (TL67)
*Vapaa kloori	SFS-EN ISO 7393-2:2000 (TL67)
*pH	SFS 3021:1979 (TL67)
*Alkaliniteetti, granin menetelmä	Sis. men., perustuu Vyh ohje v. 1987 (TL67)
*Väri	SFS-EN ISO 7887:2012 (TL67)
*Sähkönjohtavuus (25°C)	SFS-EN 27888:1994 (TL67)
*Liuennut happi	SFS-EN 25813:1993 (TL67)
Happikyllästys %	SFS-EN 25813:1993 (TL67)
*Kokonaiskovuus CaMg-summa	SFS 3003:1987 (TL67)
*Kloridi	SFS-EN ISO 10304-1:2009 (TL25)
*Sulfaatti	SFS-EN ISO 10304-1:2009 (TL25)
*Ammonium	SFS-EN ISO 11732:2005 (TL67)
*Nitriitti	SFS 3029:1976, muunneltu (TL67)
*Nitraatti	SFS 3029:1976 ja SFS-EN ISO 13395:1997, laskennallinen (TL67)
*Rauta	SFS-EN ISO 11885, 2009 (TL25)
*Mangaani	SFS-EN ISO 11885, 2009 (TL25)
*Alumiini	SFS-EN ISO 11885, 2009 (TL25)
*Natrium	SFS-EN ISO 11885, 2009 (TL25)
*Nikkeli	SFS-EN ISO 17294-1;2006 ja SFS-EN ISO 17294-2;2016 (TL25)
Lämpötila näytteenotossa	Lämpötila (TL67)

TUTKIMUSLAITOSTIEDOT

Tunnus	Tutkimuslaitoksen nimi
TL25	KVVY/Tampere (FINAS T064)
TL67	KVVY Botnialab (FINAS T064)

MITTAUSEPÄVARMUUSTIEDOT

Määritys	Näyte	Tuloksen epävarmuus	Määrityspvm.
*Escherichia coli	2019/12497	Määritysrajan alitus	6.3.2019
*Koliformiset bakteerit	2019/12497	Määritysrajan alitus	6.3.2019
*Heterotrofinen pesäkeluku 22°C	2019/12497	Määritysrajan alitus	6.3.2019
*Kokonaiskloori	2019/12497	±42 %	5.3.2019
*Vapaa kloori	2019/12497	±42 %	5.3.2019
*pH	2019/12497	±3 %	6.3.2019
*Alkaliniteetti, granin menetelmä	2019/12497	±7 %	6.3.2019
*Väri	2019/12497	±16 %	6.3.2019
*Sähkönjohtavuus (25°C)	2019/12497	±3 %	6.3.2019
*Liuennut happi	2019/12497	±6 %	7.3.2019
Happikyllästys %	2019/12497	±6 %	7.3.2019
*Kokonaiskovuus CaMg-summa	2019/12497	±6 %	6.3.2019
*Kloridi	2019/12497	±10 %	6.3.2019
*Sulfaatti	2019/12497	±10 %	6.3.2019
*Ammonium	2019/12497	±10 %	7.3.2019
*Nitriitti	2019/12497	Määritysrajan alitus	6.3.2019
*Nitraatti	2019/12497	±17 %	11.3.2019
*Rauta	2019/12497	±15 %	8.3.2019
*Mangaani	2019/12497	±15 %	8.3.2019
*Alumiini	2019/12497	Määritysrajan alitus	8.3.2019
*Natrium	2019/12497	±10 %	8.3.2019

MITTAUSEPÄVARMUUSTIEDOT (jatkoa edelliseltä sivulta)

Määritys	Näyte	Tuloksen epävarmuus	Määrityspvm.
*Natrium	2019/12497	±25 %	15.3.2019