

# Water consumption and wastewater generation and treatment in the Food and Beverage Industry

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## Abstract

Food and beverage industry is one of the major contributors to growth of all economies. In EU it constitutes the largest manufacturing sector in terms of turnover, value added and employment. However, the sector has been associated with various environmental issues including water usage and wastewater treatment. The present work is focused on presenting the production process, the water usage and the wastewater generation and treatment of representative manufacturing industries from selected sectors of the food and beverage industry such as: slaughterhouses (*meat production sector*), potato processing (*fruit & vegetables processing sector*), olive oil production (*vegetable & animal oils & fats manufacturing sector*), cheese production (*dairy industry*) and beer manufacturing (*beverage industry*). As expected between those different sectors water consumption and wastewater generation vary greatly. The same is observed even for the manufacturing of the same product from different industrial units. Wastewater pollution load depends on the type of product being processed, the process and equipment used, the cleaning system applied while the common characteristic is the high organic content in terms of COD. This fact is reflected to the wastewater treatment technology employed which in most of the cases is biological with special attention to the application of the anaerobic digestion process using UASB reactors.

## Keywords

Food and beverage industry; anaerobic digestion; slaughterhouse; potatoes; cheese; olive oil; beer.

## 1. Introduction

Food and beverage industry includes various sub-sectors aiming at manufacturing different types of products. Based on the *Statistical Classification of Economic Activities in the European Community*, food industry is identified by the two-digit numerical code C10 and includes the following sub-sectors: *processing & preserving of meat & production of meat products (10.1)*, *processing & preserving of fish, crustaceans & mollusks (10.2)*, *processing & preserving of fruit and vegetables (10.3)*, *manufacture of vegetable & animal oils and fats (10.4)*, *manufacture of dairy products (10.5)*, *manufacture of grain mill products, starches & starch products (10.6)*, *manufacture of bakery & farinaceous products (10.7)*, *manufacture of other food products (10.8)* & *manufacture of prepared animal feeds (10.9)*. The beverage industry is characterized as C11 and in four-digit analysis includes the following processes: *distilling, rectifying & blending of spirits (11.01)*, *manufacture of wine from grape (11.02)*, *manufacture of cider & other fruit wines (11.03)*, *manufacture of other non-distilled fermented beverages (11.04)*, *manufacture of beer (11.05)*, *manufacture of malt (11.06)* & *manufacture of soft drinks; production of mineral waters & other bottled waters (11.07)* [3].

The food and beverage industry is one of the most important sectors in EU in terms of financial and social significance owing to its continuous and constant growth. Based on the latest statistical insights published by the ‘European food and drink industry’ (*FoodDrinkEurope*), food and beverage industrial sector is the largest manufacturing sector in terms of turnover, value added and employment in the EU ahead of the automobile and chemical industries. Throughout the economic recession, while a sharp decrease was observed in other key manufacturing sectors, the food and drink industry continued to increase with a turnover €953 billion for the EU-27 in 2010 [2]. The EU food industry consists of 99% of SMEs (small and medium-sized enterprises) and only 1% of large companies; however the latter contributes almost half of the value added of the food sector (48%) [3]. Food and drink sector inevitably has impact on the environment, since it requires considerable resources such as water and energy and produces waste and wastewater. The European food and drink industry is responsible for approximately 1.8% of Europe’s total water use. Water is an essential input for the food and drink industry, as an ingredient, as a key processing element and as a cooling agent in many production

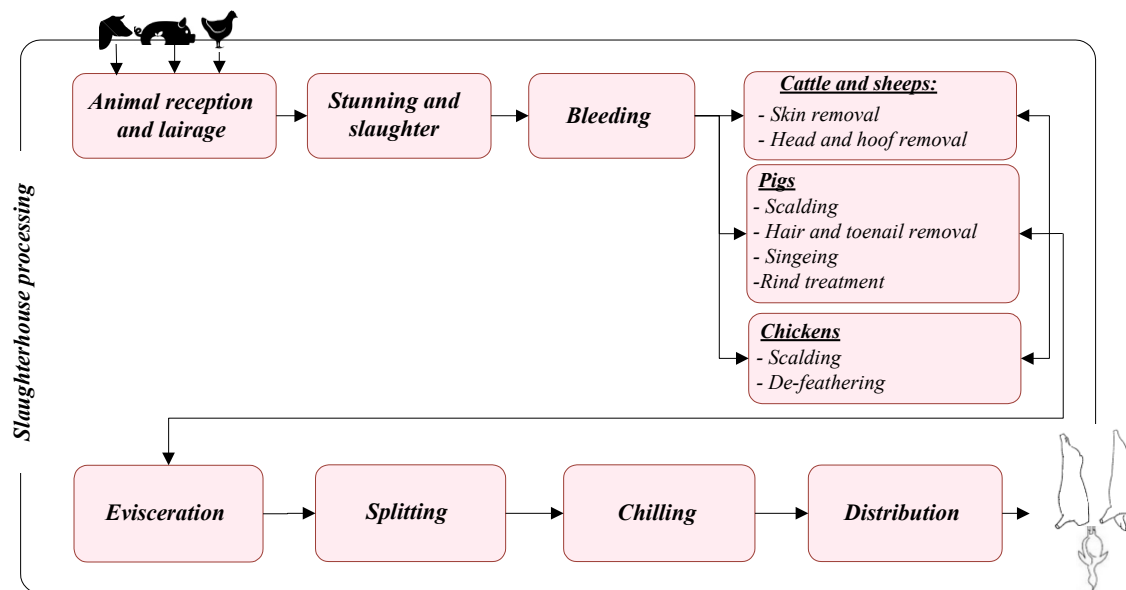
processes. Wastewater is the most common waste in the food and drink industry. It is characterized by organic contamination, and is generally biologically treated before discharge [4].

The present research aims at reviewing the water use and wastewater generation and treatment in the food and beverage industry. To this end, the following representative manufacturing industries of the food and beverage industry were analyzed: slaughterhouses (*meat production sector*), potato processing (*fruit & vegetables processing sector*), olive oil production (*vegetable & animal oils & fats manufacturing sector*), cheese production (*dairy industry*) and beer manufacturing (*beverage industry*). Crucial information included volume of water consumed either per raw material processed or per finished product, volume and characteristics of pollutant load of wastewater produced as well as predominant wastewater treatment processes employed.

### 3. Production process, water use and wastewater generation and treatment in the food and drink industry

#### 3.1. Slaughterhouses: production process, water consumption, wastewater production and treatment

Based on the ‘European food and drink industry’, in 2010 for EU-27 the meat processing sector was the largest sub-sector, representing 20% of the total turnover of the European food and drink industry with 40,000 companies 99% of which were SMEs. In 2011, exports were increased by 31% comparing to 2010 from €7,914 million to €10,379 million [2]. Beef, pork and poultry are the main types processed in Europe [5]. In meat processing, the first stages occur in the slaughterhouse (abattoir) irrespective of the species. At slaughterhouses, processing operations can vary depending on the species. For instance pig skins are usually retained although bristles are removed and the surface of the skin is singed while for cattle and sheep the hide is removed [6]. Despite that, there are many common processes for the different slaughterhouses as presented in **Figure 1**.

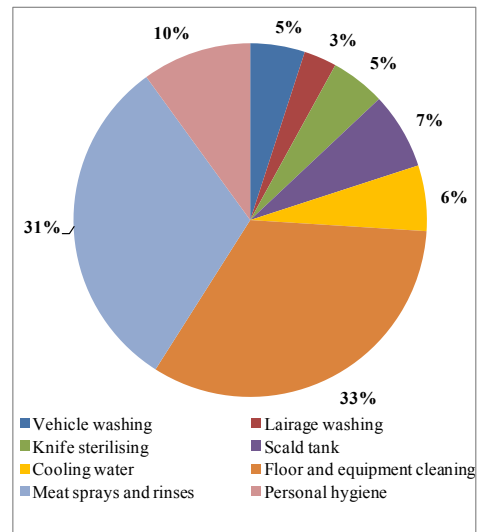


**Figure 1:** Unit operations in a slaughterhouse

Initially, animal reception and lairage take place, allowing the animals to recover from the stress of the journey. In most of the cases, the lorries which transferred the animals are cleaned in a dedicated wash area [6, 7]. Following, animals are taken from the lairage to where they are stunned, slaughtered and hung. Bleeding must be started as soon as possible after stunning and be carried out in such a way so as to bring about rapid, profuse and complete bleeding. Typically, a total of between 2-4 L of blood is collected from each pig and about 10-20 L per cattle [6, 7]. The blood is collected separately from the main wastewater stream. Then according to the type of animal being slaughtered different procedures are taking place as illustrated in **Figure 1**. For instance, in pig slaughterhouses scalding, removal of bristles and toenails, singeing and finally rind treatment are executed in sequence. The scalding aims to loosen the bristles and toenails which are removed afterwards and is done in a scalding tank filled with water (58-65°C) for 3–6 minutes. After hair and toenail removal pig carcasses are singed to remove residual hair and are then passed through a machine to polish the skin and to remove singe hair and other debris [7]. Evisceration, which follows, involves manual removal of the respiratory, pulmonary and digestive organs. After evisceration carcasses are split along the spine using a saw. In some slaughterhouses, the

carcase is given a final rinse with low-pressure water before chilling or freezing. The carcasses may then be held in a chilled meat store to further condition the meat prior to despatch to cutting plants, wholesalers, or on to further processing [6].

For slaughterhouses, the key environmental issues are water consumption, the emission of high organic strength liquids to water and the energy consumption associated with refrigeration and heating water [7]. Although the proportions of water used for each purpose can vary, a typical distribution of water consumption in a slaughterhouse killing pigs is illustrated in **Figure 2**. Typical water consumption expressed as m<sup>3</sup> per tonne of product is for pigs 1.5-10m<sup>3</sup>/t, for cattle 2.5-40 m<sup>3</sup>/t and for poultry 6-30 m<sup>3</sup>/t while the amount of wastewater generated and the pollutant load depend on the type and number of animals slaughtered. The wastewater from a slaughterhouse can contain blood, manure, hair, fat, feathers, and bones [9]. It has a high strength, in terms of Biochemical Oxygen Demand (BOD): 1,000 to 4,000 mg/L, Chemical Oxygen Demand (COD): 2,000 to 10,000 mg/L, Total Suspended Solids (TSS): 200 to 1,500 mg/L, Nitrogen and Phosphorus, compared to municipal wastewater [8].



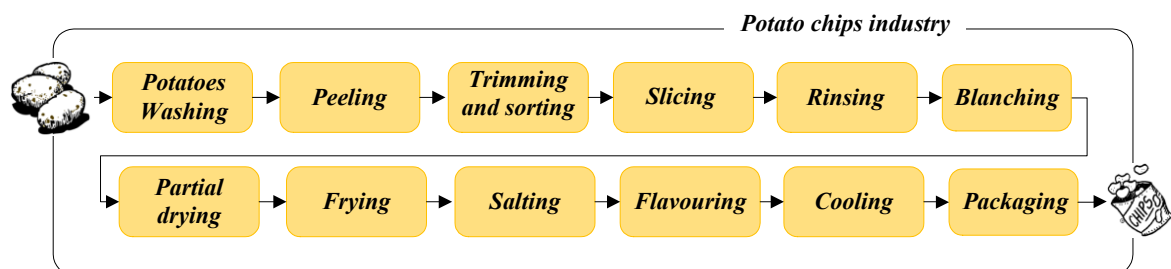
**Figure 2:** Water use between different operations in a pig slaughterhouse [7]

Wastewater from slaughterhouses is normally subjected to a primary treatment which generally includes the use of screens, settlers and fat separators [10]. Some slaughterhouse wastewater treatment plants have a secondary anaerobic reactor, usually based on Upflow Anaerobic Sludge Blanket (UASB) or Expanded Granular Sludge Bed (EGSB) reactor systems, due to the high organic content of the intake. Several successful experiments at laboratory, pilot and industrial scale with such wastewater and reactor configurations are reported in the literature [10].

### 3.2. Potato processing industry: production process, water consumption, wastewater production and treatment

The potato processing industry belongs to the sector of the processing and preserving of fruit and vegetables. This sector also includes the manufacture of fruit and vegetable juices as well as the processing and preserving of other fruit and vegetables such as marmalades, table jellies, mixed salads, packaged vegetables, tofu etc [1].

Various types of products can derive from potato including potato chips, frozen French fries and other frozen food, dehydrated mashed potatoes, dehydrated diced potatoes, potato flake, potato starch, potato flour, canned white potatoes, pre-peeled potatoes. As a consequence, depending on the end-product, the process lines can differ. In **Figure 3**, the process line of a potato chips processing industry is given.



**Figure 3:** Process flow diagram for a potato chips industry

Based on [5] the potato chip processing includes washing, peeling, trimming and sorting, slicing, rinsing, partial drying, frying, salting, flavouring, cooling and packaging. Potatoes are first washed with drum or flotation washers. Water use during the potato processing strongly depends on the type of product being processed and the equipment used. According to [12] for a chip potato processing industry 4.78tonnes of water are required per tonne of influent potato. Potato processing wastewater contains high concentrations of biodegradable components such as starch and proteins, in addition to high concentrations of COD, TSS and Total Kjeldahl Nitrogen (TKN). Some typical values are presented in **Table 1**.

**Table 1:** Characteristics of wastewater resulting from potato chips industry based on various sources [11, 12]

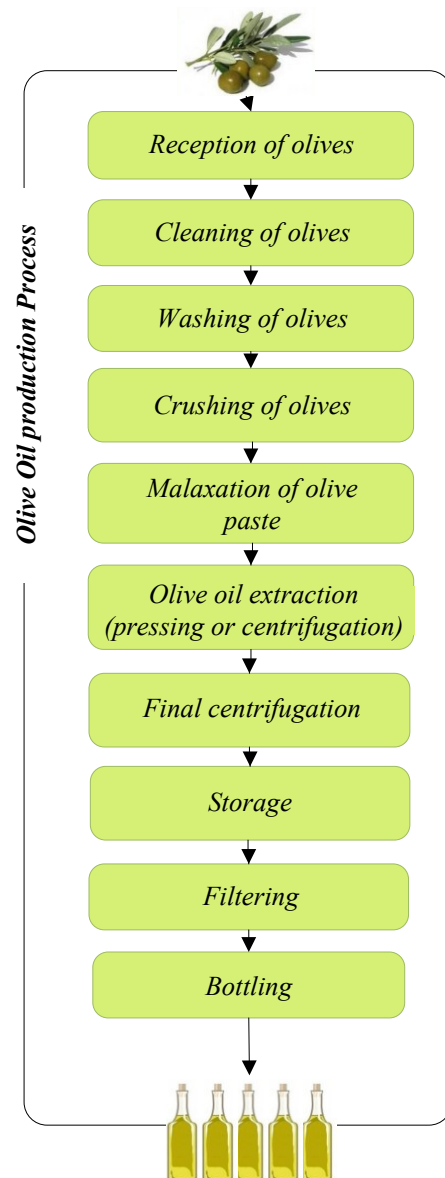
Parameter	[11]			[12]
COD (mg/L)	5,250 – 5,750	4,000 – 7,000	389 – 5,899	4,200 – 9,300
BOD (mg/L)	4,000 – 5,000	2,000 – 3,000	155 – 3,465	1,200 – 3,800
TSS (mg/L)	-	1,000 – 3,000	-	1,300 – 5,300
TKN (mg/L)	200 - 250	-	-	-

As indicated by [11,12], the majority of bioremediation processes reported for potato chips industry wastes are anaerobic digestion processes using mesophilic and thermophilic bacterial strains.

### 3.3. Olive oil production: production process, water consumption, wastewater production and treatment

Olive oil production belongs to the sector of vegetable and animal oils and fats manufacturing [1]. Olive oil is the main fatty component of the Mediterranean diet. Average olive oil production in the EU in recent years has been 2.2 million tonnes, representing around 73% of world production. Spain, Italy and Greece account for about 97% of EU olive oil production [14].

Olive oil is produced from olives in olive mills either by the discontinuous press method or by the continuous centrifugation method [15]. The production process is represented in **Figure 4**. After reception of olives, the first step includes cleaning in order to remove impurities such as stems, leaves, pieces of wood, twigs, and other debris left with the olives. Then the olives are washed with water to take away chemical impurities mainly pesticides and dirt. Cleaned and washed olives are then crushed either with stone mills, metal tooth grinders, or other types of hammer mills. The crushing process is important in order to guarantee the taste and aroma of the olive oil and also the yield of the extraction process. The paste, which is the result of crushing, undergoes malaxation. Through malaxation the paste is slowly stirred resulting in the coalescence of small drops into larger and favors the disruption of the unbroken cells containing oil [5, 16, 17]. The following step is the extraction of the oil which is generally employed through traditional pressing and modern centrifuging. Nowadays most olive oil mills use the centrifuging process through three-phase or two-phase decanters. The former separate the oil, the vegetable water, and the solids while the latter separate the oil from a wet paste. Furthermore, in contrast to the three-phase decanter process, the two-phase decanter does not require the addition of water to the ground olives [16]. In most cases, the oil coming out of the first centrifuge is further processed to eliminate any remaining water and solids by a second centrifuge that rotates faster. After final centrifugation, the olive oil is stored in large storage tanks that protect the oil from oxidation, and by-products. Before bottling, the olive oil is commonly filtered with diatomaceous earth [16].



**Figure 4:** Olive oil production process

In the olive oil production process water is mainly used for the washing of olives, malaxation, pressing or centrifugation to three-phase decanters, final centrifugation and for the general cleaning. In contrast to the three-phase decanters, in the two-phase decanters no water is added. As a consequence the two-phase production process is more ecological, not only because it reduces pollution but also because it is a less water demanding

process [16]. Indicatively, in a three-phase process the total effluent (L/kg olives processed) is 1.24 while for a two phase process this ratio accounts for 0.25 [18].

Wastewater from olive oil production is characterized to have a characteristic color ranging from intensive violet–dark brown to black and a strong olive oil odor; high degree of organic pollution (COD values up to 220,000 mg/L, and in some cases reaching 400,000 mg/L); pH between 3 and 5.9; high content of polyphenols and high content of solid matter (Total Solids up to 10%); high content of oil (up to 30,000 mg/L) [16, 18]. Differentiations on the pollutant characteristics of the olive oil process exist, depending on the internal variations of olives, use of pesticides and fertilizers during olive cultivation, extraction technology used etc. In the following table (**Table 2**) indicative values for maximum and minimum concentration values of olive oil wastewater according to applied type of technology as presented by [16], are illustrated.

**Table 2:** Indicative values for maximum and minimum concentration values of olive oil wastewater according to applied type of technology [16]

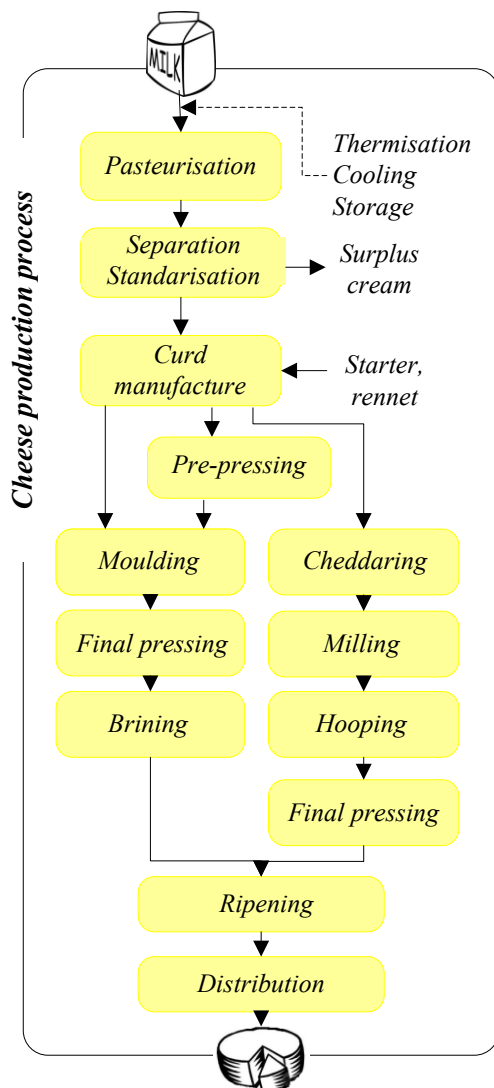
Effluent (L/kg olives processed)	Centrifuge	Pressing
pH	4.55–5.89	4.73–5.73
Total Solids (%)	0.95–16.12	1.55–2.66
Specific weight	1.007–1.046	1.02–1.09
Oil (mg/L)	410–2,980	120–11,500
Reducing sugars (mg/L)	1,600–34,700	9,700–67,100
Total polyphenols (mg/L)	400–7,100	1,400–14,300
O-diphenols (mg/L)	0.3–6	0.9–13.3
Hydroxytyrosol (mg/L)	43–426	71–937
COD (mg/L)	15,200–199,200	42,100–389,500
Organic nitrogen (mg/L)	140–966	154–1106
Total phosphorus (mg/L)	42–495	157–915

For the treatment of wastewater from olive oil mills several physicochemical, biological and combined processes have been examined. Biological processes, aerobic and anaerobic, including anaerobic co-digestion with other effluents and composting, are the predominant. Moreover, advanced oxidation processes have attracted much attention due to the strong oxidation potential of the agents used, which can result in a high degree of treatment [15].

### 3.4. Cheese production: production process, water consumption, wastewater production and treatment

The dairy industry involves processing raw milk into products such as consumer milk, butter, cheese, yogurt, condensed milk, milk powder and ice cream. Europe is the largest exporter of dairy products in the world, even excluding intra-EU trade. The EU dairy industry in 2010 was approximately 13% of the Food and Drink Sector turnover in the EU. World trade in dairy products is concentrated in cheese, butter and milk powder. In particular 40% of EU milk is consumed as cheese, with 75% of cheese production concentrated in Germany, France, Italy and the Netherlands [19].

Worldwide, there are over 500 different types of cheese. While the basic principles of cheese making are common, many variations exist in all stages of the process, resulting in the production of many different types, often from the same factory [20, 21]. In **Figure 5**, the cheese production flow diagram is presented. Cheese is produced by coagulation of the milk protein, casein, in a way that traps milk solids and fat into a curd matrix. Milk is mixed with a starter culture of bacteria, which convert milk sugars to lactic acid and the enzyme rennet which catalyses the conversion of casein to paracasein and causes the protein to form a curd on top of the milk [20]. Following, the curd is cut into cubes and the mixture is stirred slowly so as to collect as much protein as possible into the curd. The cheese yield is approximately 10% with the remaining 90% a liquid by-product called “whey” [21]. The liquid whey is separated and drained from the curd. The curd is salted, pressed, and cured, and packaged as cheese [20].



**Figure 5:** The cheese production process

Published data on water consumption during cheese production vary. As an example based on [5] the ratio of water consumed per milk processed is 1-60 L/L while based on [22] the ratio is 1-4L/L. As indicated by [22] wastewater generated per milk processed in the cheese production industry can range between 1.05 – 3.6 L/L. In summary, during cheese manufacturing three main types of effluents can be recognized; cheese whey (CW) which results from cheese production, second cheese whey (SCW) which results from cottage cheese production and the washing water of pipelines, storage, tanks and "clean in place" (CIP) systems. These three types generate a wastewater called cheese whey wastewater (CWW). CWW presents characteristics similar to CW; however, the contamination level of CWW is usually lower than CW. In general, CWW is characterized by high organic content, with values in a wide range from 8,000 to 77,000 mg/L COD and 6,000 to 16,000 mg/L BOD. The high biodegradability index suggests the suitability of biological process application. Lactose, protein and fat contents average concentrations of 45,000; 34,000 and 6,000 mg/L, respectively. The level of TSS is in the range of 100–5,000 mg/L while TS average values of roughly 65,000 mg/L. Sodium and chloride concentrations are also considerably high (2,100–2,800 mg/L) which is attributed to previous salt addition in the cheese and cottage cheese production. The values of total nitrogen (5–10.8 mg/L) and phosphorus (6–280 mg/L) are also high enough [21].

The conventional treatments of CWW effluents are based on anaerobic and aerobic digestion processes. A number of researchers have claimed that the anaerobic process is essentially the only viable method of wastewater treatment with high organic load from cheese making-plants and as a result the majority of studies have been conducted under anaerobic conditions using UASB reactors [20, 21].

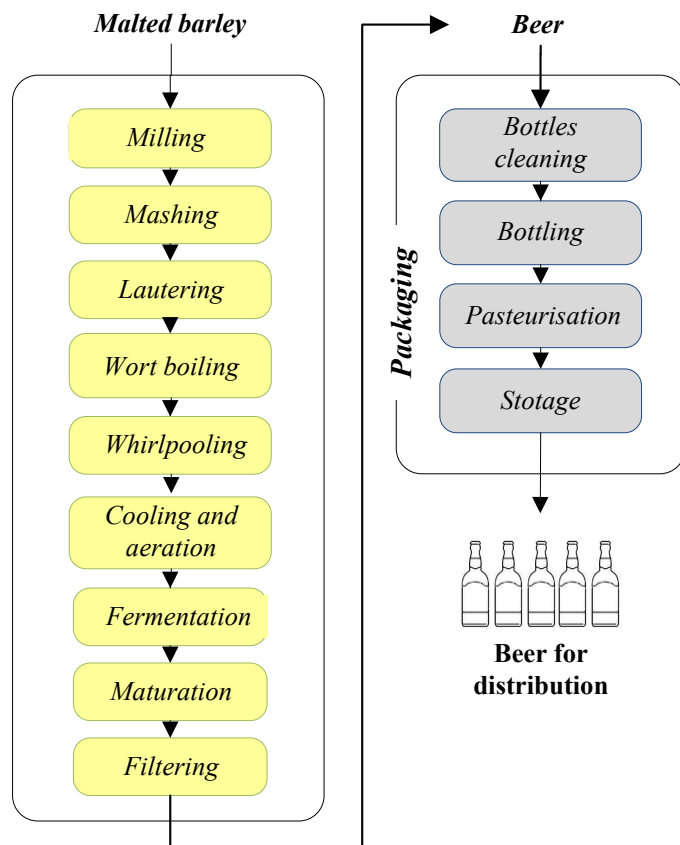
### 3.5. Beer production: production process, water consumption, wastewater production and treatment

The European brewing sector has a very positive impact on the European economy. In particular, based on the European Association ‘*The Brewers of Europe*’, the EU remains one of the major beer producing territories in the world producing yearly 383 million hl ( $1\text{hl}=0,1\text{m}^3$ ) of beer from 3,638 breweries. Germany is by far the first beer producer in EU-27 manufacturing the 25% of the total production (95million hl), followed by United Kingdom (12%), Poland (10%) and Spain (9%). In 2010 the value added from the sector in the EU-27 was estimated to be €50.6 billion while total sales reached €106 billion, including value added tax [25, 26].

Beer is a fermented drink with a relatively low alcohol, usually around 4 to 6%, which is produced from malted barley, hops, yeast and water while in some cases other ingredients such as fruit, wheat and spices are also included [25, 5]. Instead or additionally to barley other cereals can be also used such as maize, rice, millet, oats, rye and wheat [26]. The malted barley is the result of the malting process which mainly includes barley cleaning, barley size distribution, soaking, germination, kilning and final cleaning. Only very large breweries malt their own barley while most companies receive it already malted.

**Figure 6** outlines the process flow diagram at a malted barley brewery. Initially, the malted barley undergoes mixing so as to optimize the extraction of soluble substances such as starch and proteins [5, 25, 27]. The milled malted barley, known as grist, is then mashed in mash tuns. Mashing is the process of converting grist and water (mash) to a fermentable extract suitable for yeast growth and beer production in the presence of natural enzymes and temperature [27]. The product of mashing process enters the lauter tun where lautering takes place. This

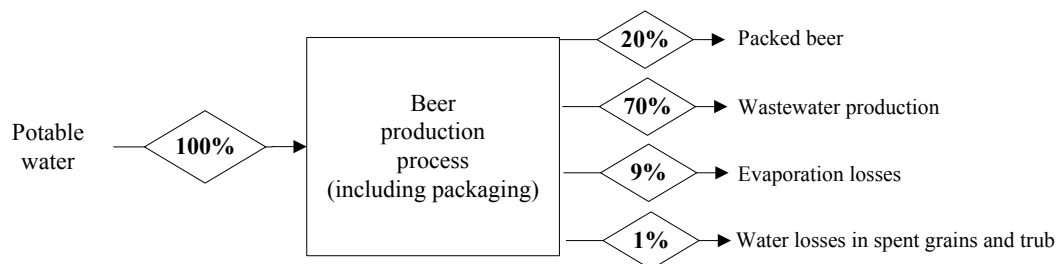
separation process results in the production of the mash liquor and the extracted (spent) grains. Spent grains are traditionally sold to farmers for use as cattle feed [25, 27, 28]. In order to recover any remaining liquor, additional water is sprayed over the bed of the lauter tun, a process called sparging [18, 15]. Then water is added to the mash liquor and temporarily stored in vessels called underbacks and following the mixture is introduced to the wort kettles for boiling [18]. Boiling ensures the sterility of the product, and thus prevents a lot of infections. During this process hops or hops extracts are also added releasing bitter substances that are dissolved while along with the heat of the boil, cause proteins in the wort to coagulate and the pH to fall [5, 25, 26, 27]. Finally, the vapors produced during the boil volatilise off unwanted flavors that would negatively affect the finished beer. After boiling, the coarse coagulum of proteinaceous precipitated material called hot trub is separated from the wort in the whirlpool vessels [5]. The wort leaving the whirlpool is then cooled from 95°C to approximately 9 and 10°C, aerated and a batch of yeast is pitched. The



**Figure 6:** Flow diagram at a malted barley brewery

The subsequent step is the fermentation process which lasts between 3- 6 days [29]. The fermentation is an anaerobic process during which the yeast utilizes wort sugars and converts them to ethanol and carbon dioxide. The characteristic flavor and aroma of any beer are, in large part, determined by the yeast strain and the fermentation conditions [22]. During the fermentation process, yeast, carbon dioxide, and trub not previously discharged, are removed. At the end of the fermentation, the product is called green beer or immature beer [27]. Afterwards the green beer is transferred to vessels for maturation. This process can take from 2 to 4 weeks and includes centrifugal separation, chilling and carbonation. Finally, the beer is filtered with mud-free kieselguhr, calcined and screened diatomaceous earth and perlite from ground and calcined glassy rock of volcanic origin [5]. Filtering the beer stabilizes the flavor, and gives beer its polished shine and brilliance. Finally the beer is packed. Finished beer is bottled, canned or filled into kegs. Bottled and canned beers undergo pasteurization so as to stop the growth of the yeast that might remain in the beer after packaging.

Beer production is a water consuming process as water is the most important raw material used by the brewing sector [5, 25, 27, 30, 31, 32]. The beer each self is composed of approximately 92% of water, while the remaining 8% is the ethanol and extract from raw materials [32]. The brewing industry is supplied water from private wells (groundwater), surface water or from the municipal water supply system. For brewing in Europe in 2010 most water was originated from wells (54%) and municipal water (42%) while only 4% was derived from surface water [32]. Based on the Brewers of Europe specific water consumption varied from 2.5 to 6.4 hl/hl with an average of 4.2 hl/hl in 2010 [32]. Water consumption varies depending on the type of beer, the number of beer brands, the size of brews, the existence of a bottle washer, how the beer is packaged and pasteurized, the age of the installation, the system used for cleaning and the type of equipment used [5, 25]. The main water use includes all water used in the product, vessel washing, general washing and CIP which are of considerable importance both in terms of water intake and effluent produced [27]. Based on water management investigation conducted at a malted barley brewery by [27] 58% of water consumed during beer production and the rest 42% for packaging. The latter contributed 56% to wastewater generation while the former less (56%) [27]. Based on the same research, water mass balance is presented in **Figure 7**.



**Figure 7:** Water mass balance at a malted barley brewery

As shown above the brewing industry is recording high wastewater production since almost 70% of used water ends up as wastewater. The amount of water produced depends on the water consumed while the pollution load depends on the processes that take place within a brewery [5, 33]. Based on the Brewers of Europe, in 2010, for every one litre of beer that was produced an average of 2.7 litres of wastewater was generated which is a reduction of 5.9% from 2008 [32]. The organic load of wastewater is generally easily biodegradable and it is mainly consists of sugars, soluble starches, ethanol, fatty acids etc while heavy metals are normally present in very low concentrations [5, 33]. **Table 3** illustrates some of the most important parameters [33].

**Table 3:** Environmental parameters of wastewater from beer production industry [33]

Parameter	Value
COD (mg/L)	2,000 – 6,000
BOD (mg/L)	1,200 – 3,600
TSS (mg/L)	200 - 1000
pH	4.5 – 12
Nitrogen (mg/L)	25 – 80
Phosphorous (mg/L)	10- 50

Since the pollution load is mainly organic biological processes, aerobic and anaerobic, are applied. It is common for breweries to use more than one type of treatment [32]. Based on [33], the most preferable option for the treatment of brewery wastewater is anaerobic pretreatment combined with subsequent aerobic post-treatment for organic or nutrient removal. While several types of anaerobic reactors can be applied, the most usual in full-scale systems are UASB combined with a Sequencing Batch Reactor (SBR) [33]. Other interesting applications regarding the aerobic step are fluidised bed reactors and membrane bioreactors (MBR) [33]. The German Brewers Association encourages wastewater treatment with the anaerobic digestion process since the brewery wastewater is the most suitable for anaerobic treatment [32]. Based on [32], anaerobic digestion has created over 23.6 million m<sup>3</sup> of biogas per year in Europe (2010), showing an increase of 7% in the period 2008-2010.

#### 4. Conclusions

Water is an essential input for the food and drink industry, as an ingredient, as a key processing element and as a cooling agent. Water consumption varies depending on the type and number of end-products, the capacity of the plant, the type of the processes applied, the equipment employed, the level of automation and the system used for cleaning. Water usage in the food and drink industry is expressed either in volume of water consumed per finished product or per raw material processed. For slaughterhouses great variations in water usage per end-product were observed depending on the animal been slaughtered i.e. 1.5 -10 m<sup>3</sup>/t, 2.5-40 m<sup>3</sup>/t and 6-30 m<sup>3</sup>/t for pig, cattle and poultry carcasses, respectively. During the production of potato chips approximately 5 m<sup>3</sup> of water are consumed for each tonne of raw potatoes processed. For olive oil production, less water is consumed if the two-phase centrifuge process is employed instead of the three-phase. Indicative values are 0.25 and 1.24 m<sup>3</sup>/t of olive oils. The manufacturing of cheese demands 1.05 – 3.6 m<sup>3</sup> of water per m<sup>3</sup> of milk processed while for the manufacturing of beer 2,5 – 6,4 hl of water are consumed for each hl of produced beer. Used water is eventually end up as wastewater except for the proportion which is used as a raw material e.g. for beer production. Although the pollution load depends on the type of industry, a common characteristic of all food and beverage



sectors studied was the high values of organic content of wastewater. The highest values in terms of COD were observed for the wastewater occurring from the olive oil production process (400g/L) and from the cheese production process (77g/L) while high values were also observed for slaughterhouses (2-10g/L, considering blood is gathered separately), chip production process (4.3-9.3g/L) and beer industry (2-6g/L). Due to the high organic content, the biological processes are commonly applied for the treatment of wastewater of those industries. In particular, the application of anaerobic process is the predominant treatment process using UASB reactors.

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