Beer Production

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Brewing

- Beer is more than just water, hops, malt and yeast. In the beer making process various ingredients are mixed, processed and sometimes the structure of the raw materials is altered.
- Beer is widely considered the most complex fermented beverage in the world.
- Its flavor, color, mouthfeel, and strength can vary in more ways than any other craft drink.
- Beer uses a greater array of ingredients, which creates complexities beyond the reach of distilled spirits, wine, cider, mead and others.
- **Brewing** is the production of beer by steeping a starch source (commonly cereal grains, the most popular of which is barley) in water and fermenting the resulting sweet liquid with yeast.
- It may be done in a brewery by a commercial brewer, at home by a homebrewer, or by a variety of traditional methods such as communally by the indigenous peoples in Brazil when making cauim.
- The brewing process is made up of ten production steps from the fresh barley to the finished beer.

Beer

- From the technological point of view, beer has four main properties based on its contents and manufacturing processes. It is (i) pure, (ii) wholesome, (iii) valuable, and (iv) it displays a variety of styles and genres:

1. The purity is guaranteed by the natural ingredients: hops, malt, yeast, and water. No pathogenic germs are found in beer because of the pH-value, presence of hop substances, the anaerobic environment, the alcohol content and also the fact that yeast metabolizes nearly all fermentable sugars. Additionally, the manufacturing process is a clarifying process. Mashing, lautering, boiling, fermentation, and filtration separate harmful or exogenous substances.
2. Beer is wholesome because of the variability and the balance of its contents. For example, 1 l of beer has low carbohydrate contents and fewer calories than the equivalent amount of apple juice or milk. It contains no preserving agents but valuable amino acids at a moderate acidity.
3. Beer is a valuable source of vitamins (especially in form of B-complexes), minerals and antioxidants.
4. All over the world more than 100 beer varieties are produced, from Pilsener to lager and wheat beer, as well as non-alcoholic varieties. Differences are based on the careful selection of raw materials and variations of the brewing process.

Raw Materials

- Water, malt, hops, and yeast are the four main ingredients for manufacturing beer.

Water: In brewing water is distinguished by contents and salt concentration.

- It has to be potable, pure, and free of pathogens, as measured by chemical and microbial analyses.
- For some types of beer "hard water" (high in salt) fits better (for example, for Munich).
- There are types made solely with water that has low salt content; that's pilsner.
- Modern technologies allow brewers to regulate the concentration of salts in water with a very high level of accuracy.

Malt: a product obtained from the germination of grain seeds.

- In order to produce beer, barley is used which passes malting – a process that facilitates the germination of grain.
- After soaking barley seeds swell and chemical reactions start which causes starch-splitting to obtain malt sugar required for fermentation.
- Other crops like wheat, rye, triticale, spelt, and emmer are also suitable for brewing. Mostly they are added to barley malt.

… Raw Materials

Hops: It gives the beer a distinctive bitter taste and fragrant aroma.

- It is also responsible for the foaming.
- This is a unique plant which contains more than 200 substances responsible for the taste.
- Interestingly enough, only cones of pistillate hop plants are suitable for beer.
- Three groups of substances are interesting: hop resins, flavoring agents, and polyphenols.
- Hop resins constitute about 10–20% of the hop dry weight.
- Their important components are the α- and β-acids, whose bittering potential differs markedly. α-Acids are transformed into iso-α-acids during boiling.
- These iso-α-acids and their derivates have significant bittering potential.
- β-Acids have a low solubility in wort and beer. Thus, they contribute only a little to bitterness.
- Hop resins enhance physiological digestibility, foam stability, and bacteriostatic nature of wort and beer over and above the bittering potential.
- Hop possesses approximately 0.4–2.0% flavoring agents per dry weight.
- These are essential oils that are responsible for the hop aroma and bouquet.
- More than 300 volatile substances have been identified up to now.
- Polyphenols (4–14% hop dry weight) also impact on beer quality.
- Additionally, low molecular polyphenols show antioxidative properties.
- The hop polyphenol xanthohumol has been identified as a possible anticarcinogenic agent.
- Amounts and composition of polyphenols depend on hop variety, cultivation area, and climatic conditions

… Raw Materials

Yeast:

- The following are the main criteria for a good brewing yeast: fermentation behavior (bottom or top fermentation), flocculation (powdery or flocculent yeast), fermentation performance (fermentation rate, degree of fermentation), production, and degradation of side products (aroma development, diacetyl removal), as well as intensity of propagation.
- As of today special brewer's yeast family Saccharomycetaceae are used.
- There are two types of yeasts depending on fermentation technology used in the beer production:
  - Top fermentation (*Saccharomyces cerevisiae*) – are found in such kinds of beer as porter, ale and stout. Top fermenting yeast mostly is cultivated at 15–26°C.
  - Bottom-fermented (*Saccharomyces carlsbergensis*) – are used in the production of lager and Central European beer. In the brewery, bottom fermenting yeast mostly is cultivated at 8–14°C.
- The difference between these types of brewer's yeasts is in that the final stage of fermentation top fermentation yeast are gathered on the surface (float up) and bottom-fermented – at the bottom of the beer must.
- This significantly affects the taste.

Making Beer: Malting & Brewing

- **Malting:** Beer is produced from barley grains.
- Protein content of barley grains between 11 to 11.5% are sufficient for conventional beers.
- Barley that has a higher protein content may be the cause of colloidal instability in beer.
- Malting with grains of different sizes results in heterogeneous malt because small grains have increased protein contents and germinate faster compared to larger ones.
- Heterogeneous malt causes problems during processing and reduces beer quality

Malting Process : Malting is the artificially induced germination of a crop.

- *Steeping and Germination :* Barley needs sufficient oxygen, heat, and humidity for germination.
- Water input induces changes in grain. Water content in grain of between 42% and 48% has to occur for the desired substantial translations within a defined time frame.
- Germination temperatures range between 14°C and 18°C.
- Oxygen is essential for respiration, otherwise the embryo dies. CO_2 has to be removed.
- At first, development of the embryo is visible at the root germ and acrospire.
- The germination steps allow the formation of highly active α-amylase, β-amylase and proteases enzymes as well as various flavor and color components.
- Reserving substances are degraded by enzymes and transferred into soluble forms in endosperm.
- Six days are considered to be optimum for steeping and germination.

Malting

- *Kilning Malt*: Kilning removes water, fixes substantial translations, and creates typical malt colors and aromas.
- Kilning is subdivided into withering and curing.
- Water content from 45% to 10% is reduced at low temperatures during withering.
- Curing needs temperatures in a range between 80°C and 105°C.
- High curing temperatures (95°C) result in a typical dark malt aroma.
- Curing temperatures range between 76°C and 80°C for pale color and conserving enzymes.
- Essential chemical transformations take place during kilning.
- Growing is ongoing at temperatures below 40°C and water content above 20% (growing phase).
- Enzymes cause dissolution of the grain and the amount of degradation products increases.
- Further enzymatic degradation occurs at temperatures between 40°C and 70°C (enzymatic phase).
- Degradation processes stop with decreasing water content. The embryo’ s growth is discontinued and degradation products accumulate.
- If kilning temperature is higher, darker will be the beer produced (due to less amount of dimethyl sulfite).
- Radicles are removed after kilning because it rapidly adsorbs water again.
- Additionally, it causes bitter taste and increased coloring.

...Malting

- **Malt adjuncts:**
- Barley contains considerable amount of protein.
- So, if only barley are used for beer production, the final beer will be dark and unstable.
- Therefore, protein present in malt should be diluted by adding additional starch or sugary materials.
- Such sugary or starchy materials are called malt adjuncts and includes dextrose sugar syrup.

Brewing process

- There are four main steps during the brewing process:
  (i) wort preparation that includes mashing and boiling,
  (ii) fermentation,
  (iii) maturation, and
  (iv) filtration and/or stabilization

Milling: Prior to mashing malt has to be milled.

- The dried barley grains are then crushed between rollers to produced coarse powder called grist.
- Milling increases reactive surfaces for enzymes, thus malt ingredients are easier to dissolve.
- Malt can be fine milled in a hammer mill.
- The quality of milling has an impact on mashing and lautering and thus on quality of the resulting beer.
- For example, undissolved malt should be milled finer than well-dissolved malt because physical and enzymatic degradation processes are eased then

Mashing

- Grist is mixed with warm water and the resulting materials is maintained at 65°C for about 1 hour.
- In doing so, starch is hydrolyzed by amylase enzyme to produce single sugar, maltose, dextrose etc. similarly, protein is hydrolyzed by proteolytic enzymes into small fragments and amino acids.
- The degree of enzymatic hydrolysis is strongly depends on pH and temperature.

Amylolysis: Starch occurs as amylose and amylopectin. Their dissolution proceeds in three steps: (1) gelatinizing starch, (2) liquefaction, and (3) saccharification.

- Starch molecules adsorb water during gelatinizing. They first swell and later explode.
- Starch originated from malt gelatinizes at 60°C with the presence of amylases.
- Other starch suppliers like rice, corn, rye, sorghum, etc., have different optimum temperatures for gelatinization.
- Gelatinized starch is mostly digested by amylases during liquefaction. α-Amylase splits α -1,4 bonds of amylose and amylopectin.
- Starch cracks from the inside and larger fragments result.
- Viscosity decreases at the same time and new reactive surfaces are created for β-amylase.
- Dextrins are broken down to maltose during saccharification.
- β-amylase has optimum activity at temperature 57-65°C whereas α-amylase has optimum activity at temperature 70-75° C.

…Mashing

Proteolysis: Enzymes for proteolysis are divided in endo and exo-peptidases and are characterized by different effective optima.

- Endo-peptidases break down proteins from the inner and increase soluble nitrogen content.
- Exoenzymes attack ends of protein chains and set free amino acids.
- Some proteins precipitate already during mashing as a result of temperature and pH-value.
- The greatest protein degradation occurs at 50°C.
- Medium and high molecular breakdown products arise at 60–70°C and are important for fullness of flavor and foam.

Cytolysis: Breakdown products of hemicelluloses dissolute and increase viscosity during cytolysis.

- Main breakdown occurs at temperatures below 50°C.
- Breakdown decreases rapidly with increasing temperature.
- β-Glucan degradation stops at temperatures in a range between 60°C and 70°C.
- Mostly lipids are insoluble and are removed via spent grist.

Mash preparation: Mash is prepared in special mashing containers (mash tun).

- Addition of much water (3–4 hl/kg malt) accelerates enzymatic reactions.
- An adequate mashing procedure is the "high-short-mashing-procedure." It includes mash in at 60–63°C. This temperature is kept for 30–45 min.
- Then mash is heated at 1°C/min to 72°C. Rest at this temperature is retained until iodine normality is reached. (Brewers control starch breakdown by 0.2 N iodine tincture. Starch and larger dextrins result in blue to red color. Sugar and small dextrins show no color. In this case, mash is "iodine normal")
- **The liquid obtained by mashing is called wort.**

Lautering

- The aim of lautern is separation of liquids (wort) and solids (spent grist).
- Husks act as a filter during this procedure.
- At first, liquid drains off (first wort, extract content: 16–20%).
- Then, residual spent grist is flushed several times with hot water (last runnings, last extract concentration: 0.5–1%).
- First wort and last runnings represent wort.
- The volume of last runnings depends on aimed extract concentration.
- Temperature is important during lautern, because increasing temperature decreases viscosity and lautern is accelerated.
- However, temperatures above 80°C are unfavorable.
- Then, α-amylase is destroyed and undissolved starch cannot be saccharified.
- Generally, lautern is processed in a lauter tun or mash filter. Mash has to rest after transfer into the lauter tun to build a grain bed.
- First wort run off contains a lot of particles, so it is removed into the lauter tun.
- Then, first wort runs off and water is added continuously or stepwise for last runnings.
- Polypropylene filter sheets separate wort and spent grist in a mash filter.

Wort Boiling

- After lautern, wort is transferred to a boiling device (kettle).
- International brewers may add liquid sugar adjuncts like invert, dextrose, corn syrup, etc., in country specific maximum amounts (e.g. United States 2.5%).
- Hop is added during wort boiling.
- Aims of wort boiling are:
  - water evaporation, adjustment of extract content in cast wort (original gravity),
  - evaporation of unwanted flavor substances like DMS,
  - formation of color and flavor substances,
  - isomerization of hop bitter substances,
  - precipitation of coagulated proteins (flocculation),
  - wort sterilization,
  - enzyme inactivation.
- Hot trub (hop particles and precipitated proteins) has to be removed after boiling.
- The wort has to be cooled down as fast as possible to minimize infection risk.
- The temperatures aimed at 5–10°C for bottom fermentation and 15–25°C for top fermentation.

Fermentation

- Beer production utilize strain of *Saccharomyces carlsbergens* and *S. varum* which are bottom yeast and *S. cerevisiae* which is a top yeast.
- Yeast cells for inoculation are usually recover from previous fermentation tank by treatment with phosphoric acid, tartaric acid or ammonium persulphate to reduce the pH and removed considerable bacterial contamination.
- Fermentation is usually carried out at 3-4 °C but it may range from 3- 14° C. Fermentation usually completes in 14 days.
- During fermentation yeast converts sugar mainly into ethanol and CO_2 plus some amount of glycerol and acetic acid.
- For fermentation open tank fermenter can be used however closed fermenter tank is preferred, so that CO_2 liberated during fermentation can be collected for later carbonation step.
- CO_2 evolution is maximum by fifth day of fermentation, there is no evolution of CO_2 by 7-9 days because yeast cells become inactive and flocculate.
- Most beer contains 3.5-5% alcohol.

Maturation and Carbonation

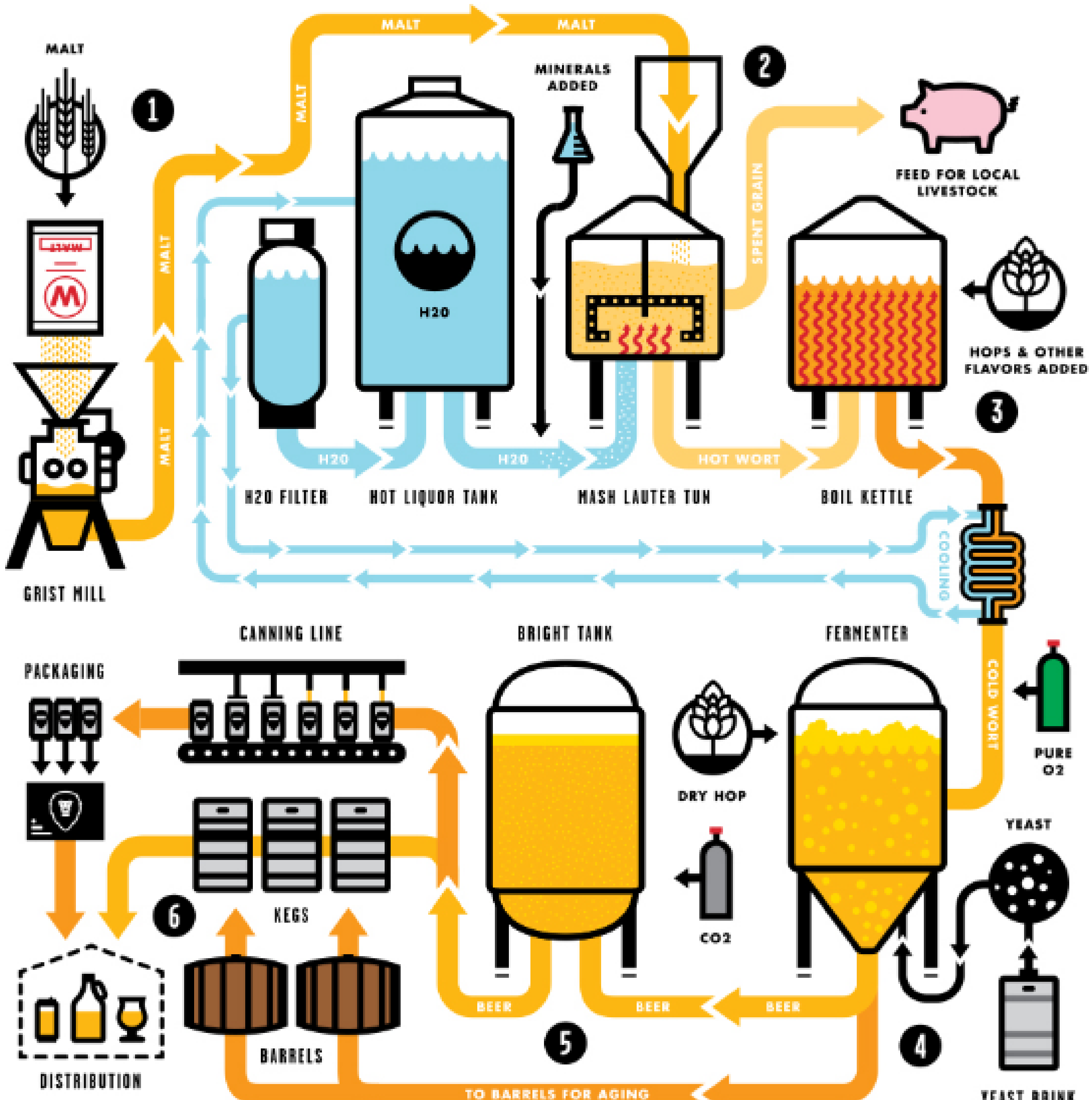
- The young and green beer is stored in vat at 0°C for several weeks to several months.
- During this period, precipitation of protein, yeast, resin and other undesirable substances take place and beer become clear.
- Ester and other compounds are also produced during ageing which gives taste and aroma.
- After ageing, the beer is carbonated by carbondioxide of 0.45-0.52%.
- The beer is then cooled, clarified, filtered and packed in bottles, barrels and cans.

Pasteurization, Filtration & Packaging

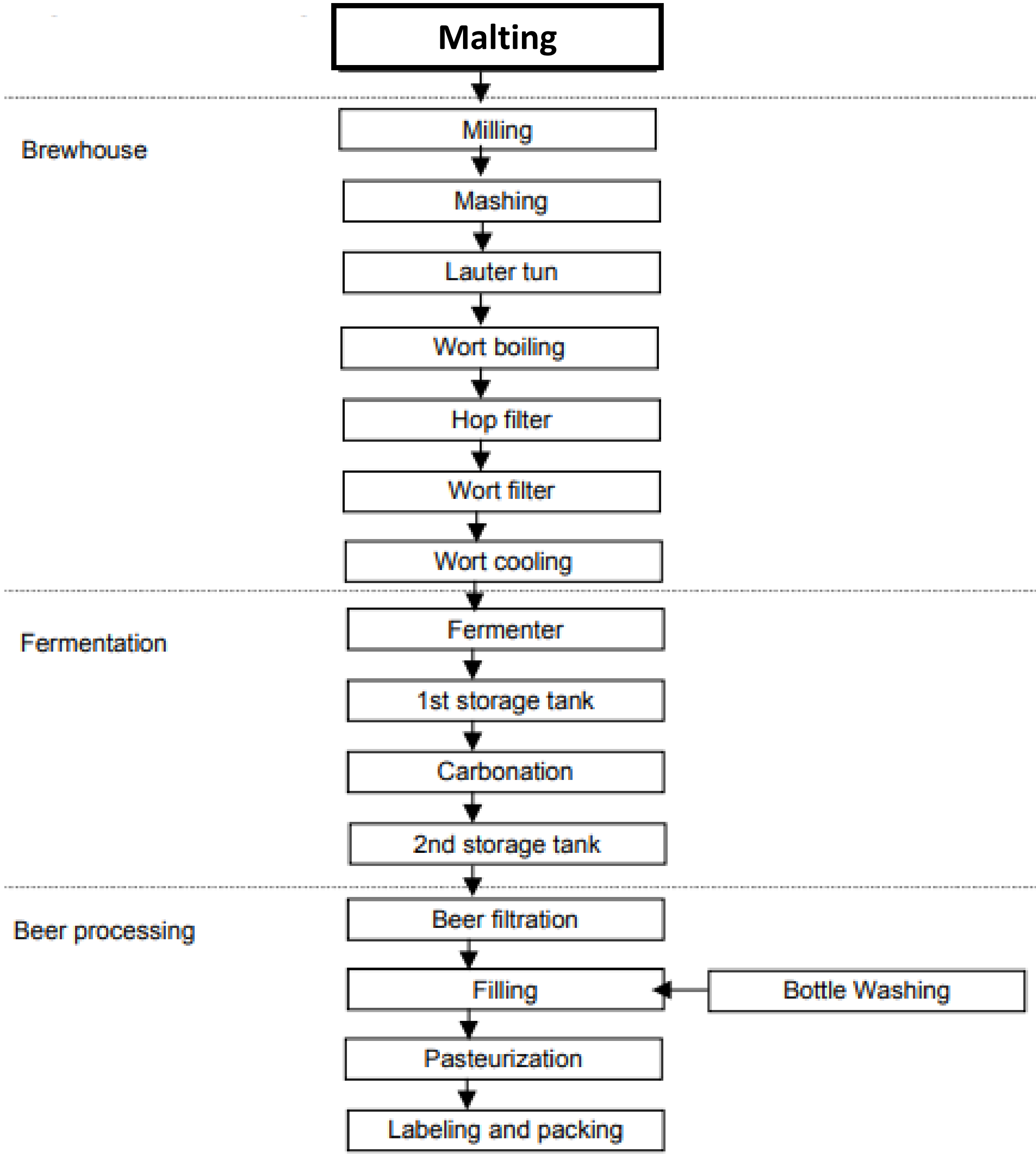
- After aging, the beer can be pasteurized to kill the remaining yeast and prevent further alcohol production.
- This is accomplished by heating the beer above 135°F (57°C).
- Pasteurization, however, is not used in the production of genuine draft beers.
- These beers are also known as "ice" beers, since they must be kept refrigerated to preserve their flavor and slow the remaining yeast activity.
- Many consider the draft beers best in aroma as well as taste.
- In this case after maturation, the beer passes another filtering with two different filters designed to remove large and small particles.
- After this the foamy beverage is absolutely transparent and ready for bottling.
- During the final stage of production, beer is poured into containers of different kinds.
- Before filling bottles, kegs, barrels should be washed thoroughly.
- Then you should remove the air that got inside.
- Beer is a short-life beverage which requires sterile conditions.
- Without them, the shelf-life of the finished product is very small and its taste noticeably deteriorates.
- During the bottling glass containers are pasteurized in advance – slowly heated up to 149°F/65°C, which significantly extends the shelf-life of beer.

Byproducts/Waste

- Beer brewing produces several byproducts that can be used by other industries.
- During the malting of the barley, rootlets form on the grain and drip off.
- These can be collected and used for animal feed.
- The hops that is filtered out from the finished wort can also be collected and used again as fertilizer.
- The residual yeast from the brewing process is a rich source of B vitamins.
- It can be put to use by pharmaceutical companies to make vitamins or drugs, or used as a food additive.
- Used beer cans and beer bottles are routinely recycled.


MALT
1
MALT
MALT
MALT
MALT
MALT
MINERALS ADDED
2
SPENT GRAIN
FEED FOR LOCAL LIVESTOCK
H2O
HOPS & OTHER FLAVORS ADDED
3
H2O
H2O
HOT WORT
H2O FILTER
HOT LIQUOR TANK
MASH LAUTER TUN
BOIL KETTLE
COOLING
GRIST MILL
CANNING LINE
BRIGHT TANK
FERMENTER
COLD WORT
PACKAGING
DRY HOP
PURE O2
YEAST
CO2
6
KEGS
BEER
BEER
BEER
BARRELS
5
4
DISTRIBUTION
TO BARRELS FOR AGING
YEAST BRINK

Process stages in beer production



Source: UNIDO, 2000

Questions

- Discuss in detail about the preparation of wort and the fermentation for beer production.
- What are the different steps of brewing, explain in detail.
- What is mashing? How it control the quality of beer?
- Write a short note on role of hops in beer.
- What are the different components of wort?
- Write short note on Malting.
- Explain effects of maturation and carbonation on beer.