
12.1 What Is Quality?

We briefly touched on the definition of this word in Chap. 4. Let us look at the subject again, but in a more detailed way. As we saw in Chap. 4, quality is a loaded word. It means different things to different people. A high-quality beer has one meaning to the customer and a different meaning to the brewer. To the customer, the measure of quality is likely linked to their level of satisfaction with the beer. This satisfaction comes from their perception of the taste, how they feel the beer looks in the glass, and, believe it or not, how much money they pay for the beer. In fact, there are many factors that lead into the customer's decision about the quality of a particular beer. And, a beer that one person believes is high quality may be considered quite the opposite by another person. The expert taster and beer judge may consider a beer to be high quality if it conforms adequately to a particular beer style. If it is out of style the beer judge may consider the beer as low quality. Even if everyone believed a beer was high quality, the brewer may disagree.

That disagreement arises because quality has a different meaning to the brewer. To the brewer, the cellarman, the packaging specialist, and everyone else working in the brewery, quality may imply adherence to a particular style or even agreement with the design specifications. A brew that falls outside of those specifications or style guidelines may be rejected by the brewer and discarded. It may be perfectly fine to drink, but the brewer may consider it to be low quality. It may be tasteful enough to sell in the taproom, but because it is classed as a low-quality product, the brewer does not do so.

The discrepancy between quality to the consumer and quality to the brewer gives rise to a quandary. Who is right? Is everyone correct? The answer is based in the meaning of the word. Every individual determines the quality of a beer using his or her own metrics. So a high-quality beer to the brewer may not be high quality to others. Just because the beer judge classifies a homebrewed ale as high quality, drinkers may completely disagree.

But then, how do we determine whether a beer is high quality or low quality? It is obvious that the perception of quality lies with the individual, so determining the quality of the beer would be nearly impossible (unless, of course, everyone agrees). Instead of worrying about the quality of the beer, the brewer focuses on creating a product that will sell to the customer. If there is a demand for the beer, the brewer has made a good product. If the demand is lackluster or nonexistent, the brewer does not repeat that beer.

Not all breweries look at quality this way. Some are fixated on the production of beers that match their specifications for a particular style. Others focus on the design parameters and require their beers meet them every batch. Still others ignore all of this and just make beer, likely figuring that if they make it, people will drink it. Most of these breweries struggle to stay in business or close their doors permanently.

So while high quality is something that every brewer tries to make, customers are the ones that make the decision. Focusing on making high-quality beers, then, requires that the brewer includes the customer in the equation. Brewers still need to ensure that the current batch of beer is the same as the previous batches. The focus is on consistency. Consistently making a beer requires systematic approaches to the control of the parameters of the beer. Everyone in the brewery must be following that plan. Measurements must be taken and decisions on the next steps made in order to maintain that consistency. However, in the end, it all boils down to the decision of the customer. In other words, a brewery could manufacture a beer very consistently such that every parameter of the beer was within the specifications, but it could still not sell because the customer has decided that the beer is not high quality.

12.2 Quality Control

To ensure that a particular beer is the same as others, the brewery often institutes a plan that measures key features of the beer as it goes through the brewing process. Simply measuring a parameter and then writing it down will not work. Even if the best analytical techniques are used and the value of the parameter is accurate and precise to the greatest number of significant figures, the process is not complete. The plan must include a way to use the measured values of the beer's parameters to adjust, evaluate, and inform the brewer about the state of affairs on a particular batch. There is no point in measuring a particular parameter if the end result is to have a record of it.

In addition, as we will see in the next section, measuring those parameters must have a relational feedback into a process. A plan to maintain the consistency, any quality control process, works well only if it is part of the bigger picture. For example, let us assume a brewer measures and keeps track of the mash temperature in every batch. Adjustments can be made to the temperature of a particular mash in order to maintain the consistency in the batch versus other batches. However, unless

feedback into the brewery exists where those values are evaluated by the entire brewery, the variability in mash temperature may become commonplace. That would imply that the brewer would need to measure and adjust the mash temperature for every batch. Constant adjustment of the batches does not always put the particular batch back on track to be consistent with earlier batches. For example, let us say the brewer notes that the current mash-in resulted in a temperature of 60 °C (140 °F) when it was supposed to be 67 °C (153 °F). The time it takes to raise the mash temperature to the specified 67 °C means that the current batch has rested at β -amylase's optimum temperature. Even a short time at this temperature has adjusted the ratio of fermentable to unfermentable sugars in the resulting wort. This could cause significant variations that would need adjustment at every stage after the mash. However, with feedback to the entire brewery, it might be found that an earlier step is not being monitored and is the reason for the variability.

Quality control is necessary. It is the working end of the process, where different control parameters are monitored and measured. It is the physical measurement of properties of the product as it goes through the brewing process. But without integration of those measurements into a larger plan, quality control becomes more of a knee-jerk reaction to what is going on. While breweries that perform only quality control can react and make adjustments to values that fall outside of the specifications for a particular brew, the overall consistency that all brewers try to attain will fail to be adequately achieved.

12.2.1 Safety in the Brewery

Quality control requires an adequate safety program for the brewery. Monitoring and measuring different parameters must include monitoring of the safety processes as well. Safety means not only the safety of the workers and the processes, but also the safety of the final product that the brewery produces.

12.2.1.1 Worker Safety

It is essential that every worker in the brewery is trained. The process of making beer involves, at a minimum, working with hot liquids (~ 100 °C, ~ 212 °F), electricity, natural gas, and caustic and acidic cleaning agents. While the brewing process can be fairly predictable, accidents do happen. The most common of these accidents typically results in someone getting burned from contact with a hot liquid or surface. Signage that reminds or warns people about a particularly hazardous area or process should also be plainly posted.

Any apprenticing or training in the brewery should include extensive safety training. Most people would recommend regular safety meetings and periodic safety retraining. Such practice can significantly reduce the chance of an accident. Yes, these programs require an investment of time and money, but the payback far exceeds the investment. For example, if a worker is accidentally electrocuted because the safety protocols were not known or practiced in the brewery, the cost to

the brewery alone (not counting the harm done to the worker) in legal fees, judgments against the brewery if they lose a legal case, and medical expenses can be a catastrophic expense. In some cases, without proper insurance, the brewery may have to be sold to pay for the damages. With that in mind, the cost to run a safety program is a very wise investment.

Any safety training must provide the workers with standard operating procedures (SOPs) that describe in very specific steps what should be done at each stage of the brewing process. For example, when using a portable pump, the worker must understand and follow each step in the SOP in order to safely use the pump. These SOPs must be written down, posted, and distributed to each worker. It also is a good practice to remind and practice those working in the brewery about the SOPs to ensure that everyone is familiar with them. The lack of SOPs in a brewery setting is not an excusable omission from a successful operation.

In addition, every person allowed on the brewery floor must be trained in the SOP for every step in the brewing process. For larger breweries, this training may be limited to the points of access for the workers. This mass training is required because it may be necessary for someone to step in and do a job that they do not typically perform. And if they are not trained or know the SOP by heart, they probably should not be stepping into help in that area. Let us go back to our example of the portable pump. If one worker sets up and begins the transfer of hot wort to the boil kettle using a portable pump, but then leaves the area to accomplish another task elsewhere in the brewery, any worker that steps into turn off and tear down the pump must be familiar with the SOP. It could be disastrous if an untrained worker incorrectly detached the hose to the pump without closing out the valves on either end.

Any safety training must also include the use of personal protective equipment (PPE). This category of equipment includes goggles, face shields, gloves, steel-toed boots, aprons, long pants, and other items designed to protect the wearer from hazards in the brewery. For example, under no circumstances should a worker be allowed to wear sandals while they work in the brewery. Yes, the wearer will argue that the goggles are uncomfortable, that it is too hot to wear jeans or coveralls, or that they will only be doing the task for a couple of minutes. All of their statements may be true (likely they are just inconvenienced by the use of PPE), but the protective equipment must be worn or used in order to work in the brewery. There should never be an exception to anyone about the use of PPE.

Any safety training must include steps on what to do in case of an emergency. This includes the standard training on what to do in the event of a fire, but also should include tornado drills and active shooter drills. Moreover, and just as importantly, the training should provide every worker with the tools they need to assist others in the event that an accident occurs. For example, if a worker slips and falls down the stairs to the boil kettle, the nearby workers are likely the first on the scene. They should know how to provide at least minimal first aid, know whether it's safe to move the patient, and know how to seek assistance in the most efficient manner. They should be aware of how to crash (rapidly turn off) any process with which they are engaged in order to lend assistance (it is better to lose a batch of beer

to provide assistance, comfort, and care for an injured worker, than to ignore the worker because its time to add hops to the boil). Some brewers may disagree with that practice, but they should not. Yes, the loss of a batch may impact the bottom line, but the safety, comfort, and health of the workforce is significantly more valuable. And every brewer would not want the bad publicity of the injured and disgruntled worker should they be ignored or placed second to the brewing process after an accident.

Trainings should address the proper use of safety equipment, such as fire blankets, fire extinguishers, eye wash stations, and safety showers. Each of these pieces of equipment should also be readily available in the brewery such that a worker would be able to obtain them for use immediately. In other words, storing all of the fire extinguishers in the main office when the fire is on the other end of the building is not good practice.

As we noted, regular trainings to go through each of the safety aspects of working in a brewery are also essential. Everyone tends to forget the little tricks and nuances of steps, and refreshing their memory is the best practice. The trainings, depending upon many different factors, should be no less than once a month. This gives time as well to providing feedback on accidents to the entire brewery. For example, an accident in a brewery can be used as a teaching tool to inform others about potential hazards. An accident can also inform everyone and potentially reveal a hazardous condition that was previously unseen.

Overall, the best practice is to promote a “culture of safety” in the operation of the brewery. Safety should be first in everyone’s mind. Safety should be thought of at all times. General operations without thinking about safety should not be performed. And if every worker is thinking about safety first, the chance of an accident is greatly reduced.

12.2.1.2 Food Safety

Food safety and hygiene is paramount to any operation that makes and sells products that will be consumed by others. This is often referred to as wholesomeness—although the connotation of wholesomeness is that the product somehow is nutritious. This may be the case, especially when beer is the product, but that is not the intent of the word. Instead, wholesomeness is a measure of all of the practices that are in place to ensure the product being made is safe and fit for human consumption.

The biggest issue with determining the safety of a product and how fit it is for consumption is being able to verify that it has not been contaminated during production. Specifically, the product must be free of foreign objects, chemical contaminants, or pathogenic microbes.

Foreign Objects It is possible that a foreign object becomes introduced into the product during its manufacture. This could be a metal shard from a machine, a piece of glass from a bottle, a spider or other insect, or a rock or stone that somehow falls into the product. There are many locations in the process where it would be possible for a foreign object to get added into the stream. For example, a piece of glass could

get introduced into a bottle if the capper accidentally hits the side of the bottle. A piece of the finish or a portion of the sealing surface could flake off and land in the beer. (Good practice when drinking beers is to not drink one where the finish, sealing surface, or lip has been damaged. Pouring the beer into a glass first is also a good idea.)

Foreign objects can also be introduced in the ingredients that come from other suppliers. For this reason alone, it is important that the brewer understands their ingredients and where they come from, works with suppliers to build a relationship of trust, and verifies the quality of the ingredients periodically. For example, it is possible that a metal shard is mixed into the malt used to make the beer. In this case, it is likely that the metal shard will be removed during the sparge step, but it is possible that it could make its way through to a consumer's glass at the end of the process.

Chemical Contaminants The job of the brewer involves about 90 % cleaning, 15 % paperwork, and 5 % brewing. Yes, that does add up to over 100 %, but the emphasis is on cleaning. Most brewers spend considerable time cleaning and sanitizing. The advent of CIP means that brewers do not have to babysit the cleaning process, but it is still a process that requires a significant amount of time. With the number of pipes, hoses, and tanks in the brewery, it is possible that one of these is not rinsed as well as it should be. The result could be the addition of some cleaner in the finished beer. Mixproof valves, for instance, control the flow of multiple streams of liquids. With poor maintenance, it is possible that the valve leaks liquid from one stream into another.

Many of the possible chemical contaminants in the brewery are fairly toxic. After all, they are used to scrub residues off of stainless steel and kill microbes easily. They do have a flavor in large concentrations, but diluted into a large batch of beer, and it might be impossible to taste that they are present. More importantly, many of the chemical contaminants can react with the flavor components in beer and end up changing the flavor of the product. Therefore, it is prudent to use the least toxic cleaners possible and to periodically test batches with laboratory analyses to ensure that no contamination exists. That and a thorough and regular maintenance program will help ensure none of these compounds ends up in the finished product.

Pathogenic microbes The good news is that most pathogenic microbes that are harmful to human health tend not to survive in beer. The concentrations of alcohol and the presence of hop oil constituents (including the iso- α -acids) work as sterilizing agents for these microbes. While nonpathogenic microbes such as lactobacillus and pediococcus can be found in beer, their only damage is to sour the beer by producing production of acids and create other off-flavors that make the beer not taste good. Consumption of these microbes is not considered a human hazard (lactobacillus is one of the bacteria used to make yogurt and exists as living bacteria in yogurt with "active cultures"). Other nonpathogenic bacteria can make their way

into the finished beer, but each tends to produce an odor or flavor that would immediately signal the end of the consumer's enjoyment. For example, contamination of beer from *Megasphaera cerevisiae* would be signaled with the aroma of rotten eggs and the flavor of vomit. Not many consumers would even swallow the first taste of a beer contaminated with this bacterium.

Some of the pathogenic bacteria, such as *Escherichia coli* (*E. coli*), also produce rancid odors that would make the beer very unpalatable. *Salmonella* and *E. coli* are potential issues in beer, but only when the alcohol concentration is very low (<1 % ABV). Both cause health hazards if consumed, so care must be taken to avoid their entry into the product. Other potential pathogenic microbes include *cryptosporidium* and *Clostridium botulinum*. *Cryptosporidium*, which causes diarrhea, can enter the brewery through the use of untreated or unboiled water in the brewery. For example, if a hose is cleaned and then rinsed with municipal water, traces of *cryptosporidium* could remain in the hose. If the hose is then used to transfer beer, it is likely that the microbe could end up in the finished beer. The same is true for *C. botulinum*, a microbe responsible for the production of botulinum toxin. This toxin is extremely lethal. A dose of about 75 ng (1/4 the mass of a single grain of sand) gives the victim about a 50 % chance of survival. This microbe is very common in soils across the globe and could enter the product stream if, for instance, unwashed and dirty strawberries were added to a beer just before packaging. Luckily, the acidity of the beer is the saving grace that should kill most microbes.

The preservative properties of beer have been a useful protection from the introduction of many of the more harmful microbes. In the USA, this is why the Food and Drug Administration (FDA) tends to allow other federal agencies to monitor the production of beer, wine, and other alcoholic beverages. However, any low- or non-alcoholic beverage is monitored by the FDA. For example, if a brewery also manufactures root beer to sell to those that are designated drivers, the product must adhere to the FDA standards for wholesomeness. These standards are much more stringent than the monitoring standards for beer production.

Best practices in the production of beer, however, will ensure the wholesomeness of the product. Having a stringent quality control program that ensures consistency in production will then evaluate and inform about the presence of things that may be classified as food safety hazards.

12.2.1.3 Methods in Quality Control

Quality control methods require not only measuring the parameter of a particular process, but also recording that measurement for use in the quality assurance portion of the management of the brewery. Charting is one of those methods that can be employed and used on the brewery floor for rapid "go-no-go" determinations of product quality. Charting is the process of adding measurements to a graph and noticing the result of the placement of the measurement.

For example, a chart could be constructed that illustrated the mash-in temperature for a particular beer. Figure 12.1 illustrates an example of a chart that could be used. The chart contains maximum and minimum permissible values of the

measurement. It also contains a line drawn in the middle of the chart that indicates the quality standard for that parameter. Each measurement is placed on the chart as the next entry.

Note that this chart indicates that over the last 10 batches, none of the mash-in temperatures have been above the maximum permissible or below the minimum permissible value. This would immediately indicate that in each batch, there was no need to adjust the temperature of the batch.

Note as well that selection of the maximum and minimum permissible values must be well thought out. The brewer could have indicated the maximum temperature as 82 °C (180 °F), but this would be unusable in the brewery. Why? Because if the mash-in occurs at 81 °C (179 °F), still below the maximum, all of the enzymes would be denatured and no mashing would take place. Similarly, if the brewer required the maximum temperature as 67.278 °C (153.10 °F) and the minimum permissible temperature as 67.272 °C (153.09 °F), it may be extremely difficult or even impossible to accurately measure the temperature of the entire mash to that level of significance.

Another charting example that is more useful is the CUSUM chart. CUSUM stands for CUMulative SUM. In this chart, the difference between the measurement and the target quality standard is added to the previous difference. The chart still contains maximum deviations from the quality standard, and these still act as action levels. But, the difference in this chart is that trends in the data appear. Figure 12.2 shows exactly the same data as does Fig. 12.1, but here, we notice a problem indicating action. In other words, the temperature of the mash-in has been consistently running lower than the desired. This appears easily on the CUSUM chart indicating an issue somewhere in the overall process.

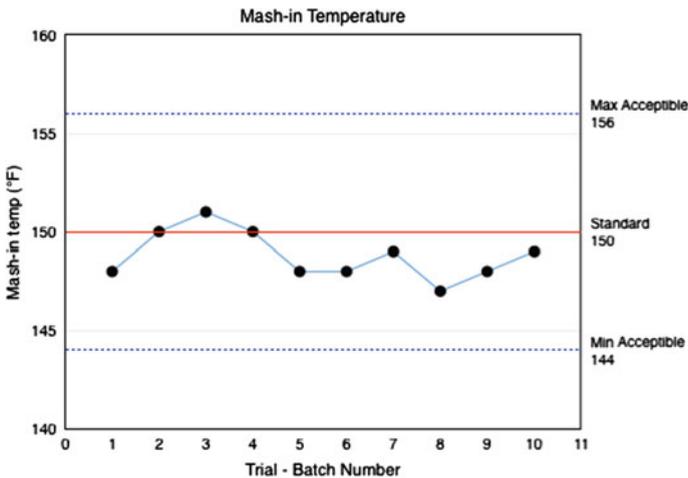


Fig. 12.1 Charting example. Here, the example is the plot of mash-in temperatures for a porter, obtained during each batch made in the brewery

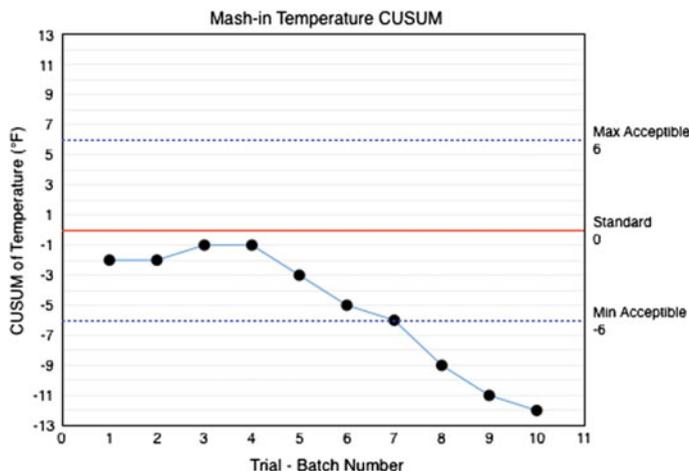


Fig. 12.2 CUSUM chart of mash-in temperatures. Data are taken from Fig. 12.1

The trends found in a CUSUM chart are very useful in determining issues in the overall process. If an issue exists, it will show up as a trend going either up or down on the chart. That provides a very good signal to the brewer that something is not right and needs to be adjusted.

CHECKPOINT 12.1

Outline the key features of a successful worker safety program.
Define an SOP and explain why it is useful to have in the brewery.

12.3 Quality Assurance

As we discovered in the previous section, the quality control program is simply not enough to produce a quality product consistently. That is where quality assurance comes into play. Quality assurance is the plan that implements the quality control program and combines it with good manufacturing practices. Where quality control is the inspection of the process, quality assurance is the process where the results of the inspection feed back into the overall operation of the brewery. Quality assurance works to prevent mistakes in production that effect product quality by considering the operation of the entire system. Quality control, on the other hand, detects and adjusts or rejects an individual process product.

Quality assurance compares the outcomes of the well-performed quality control program to specified quality standards. Deviations from those standards dictates courses of action that may require re-examination of the particular processes in the brewery, retooling of equipment, replacement of processes with better ones, or re-evaluation of the process as a whole. Remember that quality assurance is a system-wide examination of the process, whereas quality control is involved only in the individual product output.

Quality standards are part of the equation in quality assurance. These are parameters determined from the brewer's specifications and customer preferences. They cannot be set by only one of these two groups of people. They must include the brewer because the brewer is the one that is developing the product and producing it. Only the brewer knows the capabilities of the process and the limitations of what can and cannot be accomplished. The quality standards must include customer preferences. Only the customer can talk to the level of quality of the beer from a purchasing standpoint. And input should not be limited to just one customer group. For example, a beer that is made in one town should not only seek the customer preference from that town. The brewery should also seek input from nearby towns based on their distribution pattern. If the brewery plans to increase sales in a different town, they should first seek customer preferences in that town and develop quality standards that speak to those preferences.

Approaches to quality assurance reflect the systemic examination of the process. They include the following:

- Stress testing—examination of the shelf life of a beer may indicate a systemic issue in its production.
- Total quality management—a four-pronged approach to quality where:
 - Quality is determined by customers.
 - Management has responsibility to ensure quality.
 - Systematic evaluation of all processes is required.
 - Improvements must be made at all times.
- Statistical analysis and control—evaluation of all quality control data to recognize and eliminate defects in production before they occur.
- ISO—The International Organization for Standardization (ISO) is a group of over 130 member national standards organizations. After training and an external audit, a brewery can be registered as ISO-9001 compliant. The basic principles of ISO-9001 are focused on the following:
 - Customer focus;
 - Leadership;
 - Engagement of people;
 - Process approach;

- Improvement;
- Evidence-based decision making; and
- Relationship management.

Other quality assurance methods and practices exist. But all focus on essentially the same things. How those practices are applied dictates which of the systems that a particular brewery is using. The basic principles in each of these systematic methods of quality assurance are customer, improvement, and management focused.

So, does a brewery have to have and follow a quality assurance protocol in order to produce a high-quality product? The answer is no. But, without a protocol in place, it is very difficult to be consistent in that production of high-quality products. And in these days of rapid growth in the craft brewery industry in the USA, customers with little disposable cash, and adventurous customers that do not mind trying new things, lack of consistency in beer production may end up resulting in a lack of customers. While the question has not been fully decided, it would be interesting to poll those customers of failed microbreweries and ask them why they believed the brewery went out of business.

12.4 HACCP Analysis

One method of system-wide evaluation is the application of the principles of HACCP (hazard analysis and critical control points) to the brewing process. This approach focuses on food safety, but the overall principles can be applied to the production of any material, product, or service by simply adjusting the definition of hazard. In general, a hazard is anything that can harm the quality of the finished product. In food safety, this could be microbial, chemical, or physical in nature. For example, a microbial hazard would be the introduction of lactobacillus into the wort stream after the boil. A chemical hazard might be the introduction of caustic cleaning solution into the product. And a physical hazard might be the presence of glass fragments in the finished beer.

HACCP evaluates the entire process stream from the inputs of ingredients coming into the brewery to the end of the stream where the consumer is sipping on the beer. Every point along that path is evaluated for a hazard to the quality of the final product. And if a hazard is identified, it is further evaluated to determine whether a critical control point exists at that location. If one does exist, then monitoring the brewing process occurs at that point. If it does not exist, then there is no need to monitor the brewing process there.

A critical control point is a location, process, or step in the production process where some control could be made to prevent a hazard from entering the process. Evaluation of each point in the process requires asking questions about the potential critical point to decide if it truly exists at the point. Typically, a flow chart can aid in making the decision. Questions such as “Does a hazard exist at this point?”, “Could

a hazard be introduced at this point?”, “Will a future step reduce the hazard?”, and “Does this step require control for safety?” can be helpful in determining if the point is a critical control point.

In some cases, determining a critical control point may involve determining the relative impact of the step or process on the final product quality versus the chance that the hazard will exist. In these cases, a risk assessment is performed. This bases the risk of the hazard happening versus the risk to product safety. Once performed, it may be determined that the risk of both things happening is high, and a critical control point should be considered. If the risk to both things happening is low, the step or process may not be a critical control point. The assessment comes about when the risk to one or both is intermediate. Then, a decision must be made whether to apply resources to the monitoring, recording, and reporting for the step or process.

Once the critical control points are identified, each of them is further evaluated and delineated into a SOP for monitoring and reporting. Specifically, the hazard is identified, the limits of the analysis are determined, corrective actions are identified if the limits are exceeded, and a reporting and verification plans are outlined. An example of a critical control point is shown in Fig. 12.3. This example illustrates a critical control point for diacetyl in the conditioning tank.

Once the HACCP plan is in place, it must be followed. It will generate data from monitoring each of the steps or processes. The data need to be evaluated periodically to systematically assess the overall process and each of the critical control points. Verification that each of the corrective actions has been successful in mitigating the hazards is needed. This may be supported by further, more detailed, analyses at the critical control points to ensure that the process and its corrective actions are appropriately controlling the particular hazards. Finally, the HACCP plan itself needs to be assessed to ensure that the plan itself is working. In addition, if any changes to the process have been made since the plan was created, the periodic review allows those changes to be implemented into the plan.

Diacetyl HACCP

Process	Hazard	Standard	Corrective Action	Followup	Recording
Conditioning Tank	Diacetyl	< 0.10 ppm after 24 h in tank	add kreusen from next batch	repeat measurement 24 h after correction	Indicate value and corrective action if taken in brewer's log
			warm condition at +5°C for 24 h	repeat measurement 48 h after correction	

Record all diacetyl measurements in brewer's log and in conditioning tank log in the appropriate column. For all measurements that exceed the standard, highlight the value in the logs by drawing a box around the value. These values should be reported at the weekly review of the cellar.

Verification of the measurements by running duplicate analyses should be performed at least three times per week.

Fig. 12.3 Critical control point for diacetyl

CHECKPOINT 12.2

Use the Internet to look up and describe a quality assurance method that differs from the ones listed in this chapter.

Is a HACCP plan a form of quality control or quality assurance? Explain.

12.5 Sensory Analyses

While monitoring the hazards may seem like the entire process is complete, we must remember that the customer needs to be included in any quality management program. This means that the brewer needs to get information from the consumer so that it can be fed back into the system. In fact, in a HACCP plan, this information may be considered as verification of the data (it cannot be a critical control point, because there is no corrective action that can be taken once the consumer is tasting the beer).

One way to provide that consumer feedback is to use sensory analyses. Sensory analysis means exactly what it says: The beer is evaluated for its taste and appearance. Sensory analyses provide quality control information, product development for experimental batches, and troubleshooting for potential off-flavors. Some sensory analyses can provide basic information on consumer preferences, but they are not designed to give that information. For detailed information on customer preferences, specific testing geared to the desired outcomes must be undertaken. These tests include comparison tests using the brewer's and competitor's beers.

There are many different sensory analyses that can be performed by the brewer. Each of these treats the analyzer as a variable measuring instrument. As discovered by Arthur Fox in the early 1930s, every individual is different. We all have different numbers of taste buds and the sensitivity of these buds differs. For example, 6-*n*-propylthiouracil is an intensely bitter compound that is only detected by some people. To others, it is tasteless. Because of the variability, the brewer must be well versed in statistical analysis, especially in the field of bias.

Standard sensory analyses include the following evaluative tests. Each is further described in this section below:

- Paired comparison test;
- Difference from control test;
- Triangular test;
- Duo-trio test;
- Threshold test; and
- Descriptive test.

Paired comparison test This analysis is one of the easiest to perform. It provides information about two samples. This test can be used to determine whether a preference for one or the other exists, or to determine whether one has a different given flavor characteristic such as hoppiness. Each tester is only asked one question, such as “Which sample tastes more hoppy?” Statistical analysis to provide significance requires at least seven (7) evaluators. At the minimum number of tasters, however, all must agree for any significance to be found in the test. The level of agreement is less strict when more testers are used in the analysis.

Difference from control test This analysis is more advanced than the paired comparison test. It asks the tester to determine which of two samples has more of a flavor in it and then indicate the magnitude of the difference on a scale of 1–10. At least 20 testers are needed in order to obtain good information with statistical significance.

Triangular test This is often one of the more common analyses employed in sensory studies. In this test, each evaluator is provided with three samples. Two of the samples are identical, and the tester is asked to identify the one that is different. Comments can also be taken on why the selection was made. A rather simple test to perform, it provides usable information with only five testers. However, just as in the paired comparison test, twenty or more testers will provide better statistical analysis of the results.

Duo-Trio test A variation of the triangular test is to provide the evaluator with one sample denoted as the reference sample. Then, two additional samples are provided and the evaluator must identify the one that is identical to the reference. This test allows the brewer to determine whether there is a difference in flavor between the two samples. Only nine testers are needed to perform this analysis, but error is high until about 20 testers are included in the analysis.

Threshold test This is a more advanced test that uses the triangle test method to determine the threshold at which a particular flavor can affect the flavor of the beer. It is performed by a giving the tester an array of 18 samples in six columns. Each column of the array contains two identical control samples that have not been modified. The third sample in each column is the adulterated sample. The amount of the additive is increased from left to right. The tester is then asked to identify which of the three samples contains the one with the additive. The tester is also asked to give the identity of the additive flavor. This test requires at least 20 evaluators in order to give statistically useful information. Smaller numbers, such as 15 evaluators, have been shown to only provide useful information about themselves rather than about the flavor threshold of the general population.

Descriptive test This is the most advanced test in the sensory analysis arsenal. In the test, the evaluators are provided a sample and asked to rate (typically using a Likert scale) the specific flavors or compounds in the sample. For example, the tester could be asked to analyze the diacetyl, bitterness, hoppiness, sweetness, aroma, and fruitiness of the sample. They would rate each of the categories.

Because this test requires trained evaluators, it can provide statistically significant results with only three people; however, twenty or more are needed to reduce the error of the measurement.

Customer preference test A very simple customer preference test is to provide two kegs of equal weight to a bar-like setting. Evaluators should number at least 15–20 and should be provided with games and other social activities that are completely unstructured. The evaluators should be allowed to drink either beer and obtain additional samples as they wish. At the end of the event, the weight of the two kegs is determined. The one with the lighter weight was the beer that was more preferred.

These sensory analysis procedures were put together by an international coalition of organizations in the 1980s. Specific testing procedures and methods for analysis of the results are found in the ASBC Methods of Analysis. Additional sensory evaluation methods can be found in other sources.

To perform any of the analyses, the brewer must take precautions to ensure that any bias is removed from the testing procedure. Bias in this type of analytical measurement occurs when the testing is not completely random. For example, if the first beer sample in a triangle test is always the different beer and the second and third samples are always the identical beers, a bias will exist. The person who evaluates the data from the test would also have to consider whether the testers were just simply picking the first one as the different beer, or whether they actually could taste that the first one was different.

That bias can also exist in the facilities and way that the samples are presented. Thus, it is very important that the testing center be organized in such a way that the only things being evaluated are the samples. The facility itself must be as follows:

- Easy to access and find in the brewery.
- Free from noise, including background noise from the factory floor.
- Free from unwanted odors such as those from nearby cafeterias.
- Comfortable and well equipped.
- Decorated in neutral soothing colors.
- Well lit but not with overly bright lights, spot lights, or flood lamps.
- Held at a constant comfortable temperature free from drafts and air-conditioning noise.
- Equipped with identical booths for each evaluator that provide privacy to evaluators.

Bias can also exist in the evaluators themselves. Anyone with a cold, allergies, or other issues with their ability to smell should be excused from the testing. Similarly, anyone with dental issues should be asked to come back when those issues have been addressed. If visual examinations are required as part of the testing, it is important that each of the evaluators is not experiencing problems with their eyesight. Since odors can hinder any testing, it is imperative that none of the evaluators

is wearing perfume, cologne, scented hand creams, or has washed with heavily scented soaps. Finally, any evaluator that appears to be upset, sad, or otherwise emotionally compromised should be asked to reschedule their visit to complete the analysis.

So who makes a good sample evaluator? Everyone can be a good evaluator of beer samples. Those that are untrained can provide valuable information, but care must be taken to use these people in sensory analyses that do not require identification of particular aromas or flavors. For example, untrained evaluators may not be able to discern a particular fusel alcohol in a beer. Trained evaluators can also be used in sensory analyses and are required in some sensory tests. However, they should not be part of a sensory analysis that also contains untrained evaluators.

Chapter Summary

Section 12.1

Quality is a subjective term that has different meanings to different people. Because the determination of “high-quality” beer is ultimately made by the consumer, the brewer must include the customer’s opinions and suggestions in the brewing process.

Section 12.2

Quality control evaluates and provides information to correct or reject a particular batch in the brewing process.

Safety in the laboratory is paramount to the successful production of a consistent product.

Food safety requires diligence in the identification of potential hazards in the brewery.

Charting allows brewers to visually identify measurements in the brewery and their comparison to a quality standard.

Section 12.3

Quality assurance is a system-wide approach to the evaluation of the brewery and the consistent production of high-quality beer.

Section 12.4

HACCP analysis provides a useful quality management system for a brewery.

Section 12.5

Sensory analysis can provide useful information to the brewer about specific aspects of their beers.

Specific tests can either compare beer samples or can focus on the development of a flavor profile for the beer.

Questions to Consider

1. Define the term “quality” in your own words. Can you think of another word that has subjective meaning based upon who uses that word?
2. What is likely the main reason why start-up microbreweries fail?
3. A brewery is considering whether to conduct a sensory analysis using only its employees. Describe the pros and cons of doing this.
4. Describe the differences between a quality control program and a quality assurance program.
5. Can a quality control program be sufficient to operate a brewery? Why or why not?
6. Outline a decision tree that would provide information on whether a particular process or step could be a critical control point.
7. Explain why an evaluator wearing heavy cologne could cause a bias in a sensory analysis.
8. Which of the sensory analyses would be best if the brewer wanted to verify that the current batch of beer was the same as a previously made batch? Explain.
9. Which of the sensory analyses would be best if the brewer wanted to identify why the current batch of beer was different than a previously made batch? Explain.
10. Why are pathogenic bacteria typically not found in beer?
11. Which sensory analysis requires the fewest number of evaluators to provide statistically useful information?
12. Describe the pros and cons for a CUSUM chart.
13. Does motivation to do a good job influence the outcome of an evaluator in a sensory analysis?
14. A particular off-flavor compound can be measured in a beer sample if its concentration is 1 ppm. This compound has a flavor threshold of 2 ppm. What should be the quality standard for this compound?
15. Would it be acceptable for a brewer to set the maximum limit for action to 0.5 ppm for the compound in question 14?
16. Assume that only 10 % of all people can detect the compound in question 14. Describe the challenges in implementing a sensory analysis to check for this compound in beer.
17. If a future step in the brewing process will allow correction of a particular hazard, why is an earlier step that does the same thing not considered a critical control point?
18. How can stress testing provide information related to quality assurance?
19. What principles appear to be common among quality assurance programs?
20. Describe what is meant by a “culture of safety.”
21. A particular measurement in the brewery appears to vary at each measurement equally. One day, the measurement is higher than the quality standard, and the

next, it is lower the same amount. Describe the appearance of the CUSUM chart.

22. A brewery hires a worker who is super sensitive to diacetyl. This person appears to find diacetyl in every beer sample that the brewery manufactures. Would this person be good to have on a sensory analysis? Why or why not?
23. Use the Internet to look up *Cryptosporidium*. Describe where it comes from, what health hazards are associated with it and what the brewer needs to do if this organism is found in the brewery.
24. Use the Internet to determine background information on botulinum toxin. If a grain shipment was contaminated with this toxin, would it be safe to use in the brewery? Should it be used? Why or why not?

Laboratory Exercises

Turbidity in Beer

This laboratory-based experiment allows the measurement of haze in the finished beer. It may be part of a quality control analysis to determine whether the beer needs to be treated with de hazing compounds in the conditioning tank.

Equipment

- Hydrazine sulfate solution—0.24 g dissolved in 25 mL water.
- Hexamethylenetetramine solution—2.4 g dissolved in 25 mL water.
- 10,000 FTU solution—add both the hydrazine sulfate solution and the hexamethylenetetramine solutions together, swirl, and let sit overnight at room temperature in a stoppered flask.
- Erlenmeyer flasks, 125 mL.
- Graduated cylinders, 10, 25, 100 mL.
- A selection of beers of varying haze.

Experiment

Create a 1000 FTU stock solution by diluting 10 mL of the 10,000 FTU solution to 100 mL using graduated cylinders. The solution should be stored in an Erlenmeyer flask and used to make standards.

Create at least four standards by dilution of the 1000 FTU stock solution. The best standards are made by diluting the amount of the stock solution indicated in the table below to 100 mL using graduated cylinders. The solution is then placed into an Erlenmeyer flask.

Amount of 1000 FTU diluted to 100 mL	FTU of resulting solution
5 mL	50
10 mL	100
20 mL	200
50 mL	500

The solutions are then placed into a cuvette and their absorbance measured at 580 nm. A plot of the absorbance (y -axis) and the FTU value (x -axis) is created, and the equation of a straight line is determined. This equation is then used to determine the FTU of a series of beer samples.

To measure the beer samples, a measurement of the turbidity is taken by adding the beer at room temperature to the cuvette and the absorbance at 580 nm recorded. This measurement is indicative of the permanent haze in the beer. A second measurement is taken at 0 °C by cooling the beer in an ice bath immediately prior to the measurement at 580 nm.

Do the beer samples contain permanent haze? ...chill haze?