A Guide to Brewing Non-Alcoholic/Ultra-Low Alcohol Beer
Vol. 1

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DISCLAIMER

This guide is meant as a guide only and is not to be considered a guaranteed way to create non-alcoholic/ultra-low beers. Due to induvial circumstances, equipment, ingredients and skill level, results may vary from person(s) to person(s) and care should be taken for consumption if you, or a recipient of the beer suffer from any medical conditions resulting from alcohol, or the inability to consume alcohol due to medical reasons, medication, or pregnancy. To be considered a "Non-Alcoholic" beverage, the alcohol content should be between 0.0% - 0.5% ABV but should not exceed 0.5% ABV, if the ABV content exceeds 0.5% it is considered an Ultra-Low Alcoholic beverage. This must be factored when storing the final product, whether it is bottle conditioned, naturally carbonated, or force carbonated.

Whilst a lot of information comes from multiple sources and personal experience to assist in the aim of creating the beer, some or part of the information provided may not reflect experiences that other brewers have encountered, and as such, the methods or information are open for interpretation to suit individual brewers.

INTRODUCTION

Welcome the exciting venture of brewing Non-alcoholic/Ultra-low alcohol beers, with the fast-growing global trend to reduce our consumption of alcohol becoming more and more popular for health or personal reason, a growing number of breweries are jumping on board. Whether brewing solely N/A beers, or adding them to their current brewhouse rotations, it is clear to see this movement is here to stay and not just a trend. People choosing to turn to N/A Beers may do so for many different reasons, some want to reduce their level of consumption, some may be on medication or pregnant preventing them from enjoying alcohol, some may have been diagnosed with an illness that may see them cut alcohol out indefinitely, whatever the reason, it is certainly a great option.

With more and more brewers joining the race to create a name for themselves as great N/A brewers, home brewers are also taking a leap into creating their own N/A and Ultra low alcohol beers. Due to the tight-lipped industry surrounding these beers, a lot of brewers have proprietary methods that are not shared amongst the homebrewing community, companies such as Brewdog are 1 exception that are happy to share their recipes and techniques with such brewers. In this guide I hope to share multiple different techniques and sorts of information to assist in creating your very own Non-Alcoholic/Ultra-low Alcohol beers, whether you are an entry level amateur, well-seasoned brewer or a professional, I am sure there will be something to take away from this guide for every level of experience.

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1.0 Methods and Techniques

There is more than one technique to brew a successful Non-Alcoholic/Ultra-Low alcohol beer, and these techniques will be covered as we go, the first thing you must consider is what you want to achieve, whether you want a Non-Alcoholic beer or an Ultra-Low beer, from there you can choose the appropriate method to brew the perfect beer.

1.1 Low Grain Bill Method

The low grain bill method, or as some refer to it as the Nannystate method, was popularised by the commercial craft brewery Brewdog, upon the release of their Nannystate Non-Alcoholic Hoppy Ale (Source. 10.1). It consists of a reduced grain bill that leads to less fermentables, in which gives a lower ABV at the cost of a thinner body and mouthfeel than a full grain bill used in regular mid to full strength beers. Additional specialty malts and adjuncts are used to help round out the flavour and add body to replicate the quintessential beer taste.

1.2 Cold Mashing/Non-Enzymatic Mashing (NEM)

Cold mashing, also known as Non-Enzymatic mashing (Source 10.2) or the Briess method (Source. 10.3), is the process of mashing a full grain bill that would be used for a full-strength beer ranging from 3.5% abv – 6% abv in a vessel of room temperature water or cold water from 8 - 24 hours to extract mainly colour and flavour from malted grain without converting and extracting a lot of fermentable sugars. It can also be used to improve body in a regular strength beer.

1.3 Boil Off/De-Alcoholising Method

The process of removing alcohol from fermented wort can be done in several different ways, the cheapest and easiest way for the home brewer is the boil off method, which consists of using a stove or oven, heating the “beer” to a certain temperature for a set time and cooling. Two other methods used by commercial breweries are ‘Reverse Osmosis’ and ‘Vacuum Distilling’, both of which are expensive beyond even the most generous of budgets of home brewers.

1.4 Low Attenuating Yeast/Arrested Fermentation

With the growing popularity of N/A brewing, companies producing the yeasts we have come to know, and love are isolating new strains that assist in the production of such beverages. White Labs and Fermentis have both added their own strains to the market, making it easier for brewers to achieve great results without too much headache.

Arrested fermentation is another option that some brewers are turning to halt the yeast during fermentation to prevent over attenuation, leaving behind residual sugars and a low abv.

2.0 Malts, Adjuncts, Hops, Yeast, Flavourings

2.1 Malts

When it comes to choosing the right malts, depending of which method the brewer chooses, it is better to not focus on a large percentage of base malt, but rather focus on what specialty malts can bring to the final product, when selecting a base malt, the brewer should know which method they will implement, for the 'Low grain bill' method (Ref. 1.1, 3.0) the brewer should aim for a full flavoured malt such as Munich, Rye, Maris Otter or Ale malt, as these will give a better chance of imparting colour, flavour and body, whilst the brewer can use 2 row Pale malt or Pilsner malt, it will not bring much in the way of flavour, colour or body. If using the 'Cold mash/NEM' method (Ref. 1.2, 4.0) the use of 2 row pale malts and Pilsner malts can be used due to the larger malt percentage required.

Specialty malts including Crystal and Caramel malts are a great source of colour and flavour that will help round out a beer by bringing sweetness, dextrins and added flavours to create a better body and mouthfeel. (HOT TIP: Melanoidins, dextrins and proteins from malt help with foam stability and increased mouthfeel.)

2.2 Adjuncts

Adjuncts can be divided into two broad groups: kettle adjuncts and mashable adjuncts. Kettle adjuncts, like honey, maple syrup or Candi sugar, contain fermentable sugar and are added to the kettle in the boil. Mashable adjuncts contain starch. This starch needs to be converted to sugar before the yeast can convert the sugars to alcohol. These starchy adjuncts must be mashed, which means that enzymes degrade the starch to fermentable and unfermentable sugars and dextrins.

Most adjuncts including rice, corn, and kettle sugars contain very little protein and they are reluctant to yield the protein they do have during mashing. All the protein in wort comes from wheat or barley, so adding a source of extract that carries no protein effectively dilutes the total protein in the wort. Protein in barley can cause haze. By diluting protein with the proper amount of adjuncts, brewers can increase clarity and stave off the onset of chill haze. (Source 10.4)

Flaked adjuncts such barley, wheat, oats, and quinoa help increase the depth of low and high alcohol beers, assisting in foam stability and a fuller body, adding other adjuncts such as lactose and maltodextrin, [Also known as corn syrup (not to be confused with corn sugar)] is a great way to increase mouthfeel and body of a beer.

2.3 Hops

Aside from malt, hops are a crucial ingredient to creating various styles of beer, ranging from a simple refreshing lager to a high impact IPA, they are more than just flavour and bitterness, they are a complex piece to the final outcome and storage capacity of beer. Hops are antibacterial and antimicrobial, meaning they help preserve a beer during fermentation and storage to aid in preventing unwanted bacteria, they also contain various essential oils and resins that attribute to the alpha acid and beta acid content, alpha acid analogues include humulone, cohumulone and adhumulone, which, when isomerized to isohumulones (iso-alpha acids) through the boiling process, contribute bitterness to beer.

Early foam tower experiments revealed hop resins, in particular isohumulone, enhance foam stability, although some reports suggest the effect to be minimal. More important than its effects on foam stability, is the role of hop resins in causing the beer foam to adhere to surfaces (Source 10.5).

Whilst high alpha acid varieties are typically used for bittering in most styles, low alpha acid varieties are common in styles such as lagers and pilsners for bitterness, so choosing the right hop is important to stick within a certain style. Bitterness in N/A and ultra/low alcohol beers become quite prominent due to the lack of malt and increased water quantity, so it is advisable to aim for lower than standard levels of bitterness ranging from 10-35 IBUs, focusing mainly on late additions or dry hopping to introduce softer fuller flavours.

2.4 Yeast

With yeast manufactures bringing out multiple new strains each year, it is no surprise they are venturing into low alcohol strains, White Labs have released 3 strains in previous years, WLP603, WLP618, WLP686 (Source 10.8), as have Fermentis with their Safbrew LA-01 strain (Source 10.9). More readily available strains that are quite useful in achieving low alcohol are Lallemand Windsor (Source 10.6) which is maltotriose negative, Fermentis Safale S-33 (Source 10.7), and some English ale strains know for low attenuation.

2.5 Flavourings

Adding additional flavours such as fruits or honey may work well with ordinary brewing processes, but due to their high sugar content, it is not suitable for N/A or Ultra-low alcohol beer, as the sugars are converted into additional alcohol. Instead, fruit extracts or essences can be used to add additional fruit flavours to suit different styles.

3.0 Low Grain Bill Method

The low grain bill method is possibly the easiest and most cost-effective way to brew N/A and Ultra-low alcohol beers, it can easily be done on a stovetop, or in standard brewing equipment due to the reduced amount of grain required. This method focuses on a lower percentage of base malt, and a higher percentage of specialty malt and adjuncts to help fill out the body of the beer, paired with high mash temperatures to extract more long chain sugars, dextrins, colours and flavours. One thing to note is hop bitterness becomes more prominent due to the lack of malt, so aim for an IBU range between 10-35 IBUs for a better-balanced beer.

3.1 Grain Selection

Selecting the right base malt and specialty malts is needed to create a good quality beer, choosing the wrong grains can lead to less than satisfactory results. Milling of grain can also determine the amount of fermentables extracted during a mash, a fine crush will yield better extraction of sugars, whereas a coarser crush will make it harder for sugars to be extracted from the grain.

- For base malts, choosing one that is high in malt flavour and character will yield better results than relying on lighter malts such as pale 2 row.
  Base malts including Rye, Munich, Traditional Ale, and even Maris Otter are a great base for bringing a full flavour.
- For specialty malts and grain, choosing which one to use will be dependant on the style the brewer is wanting to achieve, wheat malt is a great addition regardless of style, as it will aid in creating a better body and foaming properties, roasted malts such as biscuit malt is also a great option for adding a bready/malt flavour and deeper colour, crystal and caramel malts are great at adding sweetness and caramel notes to create a better body and deepen colour. Melanoidin malt and Caramel Pilsner malt help by adding dextrins to assist in adding body and foaming properties.
- For adjuncts, flaked wheat, flaked barley, flaked quinoa, flaked oats and biscuit rice malt, greatly improve the body and mouthfeel of beer, and improve foaming properties and lacing, they also add ‘Haze’ to a beer, which can be undesirable in styles such as pilsners and lagers, but welcome in pale ales, IPAs and NEIPAs. Other high impact adjuncts include corn syrup (also known as maltodextrin powder), and lactose which both aid in mouthfeel and body.

3.2 Mashing

Mash temperature plays a crucial part in extracting sugars, starches, flavours, and colour. It determines what percentage of the complex sugars are broken down into simpler sugars, there are two main enzymes active during a mash, alpha amylase, and beta amylase. Alpha amylase is most active in the temperature range between 154-167°F/68-75°C, creating longer sugar chains that are less fermentable, resulting in a beer

with more body. Beta amylase, which is most active in the temperature range between 130-150°F/54-65°C trims off single maltose sugar units that are more fermentable, resulting in a more complete fermentation, resulting in a cleaner beer with a thinner body (Source 10.10).
Aim for a high mash temperature between 154-174°F/68-79°C, emphasizing the alpha amylase enzymes which creates more unfermentable sugars, extracting a larger amount of dextrins and longer chain sugars resulting in a lower alcohol content and a full-bodied beer with a lot of mouthfeel. Long mash times are not required when mashing small grain bills at high temperatures, At a higher temperature, and a higher pH, the amylase is favoured, and starch conversion will be complete in 30 minutes or less. Longer times at these conditions will allow the beta amylase time to break down more of the longer chain sugars into shorter ones, resulting in a more fermentable wort, but the alpha favouring conditions are deactivating the beta; such a mash is self-limiting (Source 10.11). Too long of a mash at these temperatures will also impart unwanted tannins resulting in astringent, bitter, and grainy flavours.
Once the mash is complete, bring the wort to a boil and continue the brew day as usual.

4.0 Cold Mashing/Non-enzymatic Mashing (NEM)

Non-enzymatic mashing (NEM) is a process used to extract flavour and colour from malted grain without converting and extracting a lot of fermentable sugars. In order to accomplish this, all the grain for a brew is soaked in cold water, typically from 8 - 24 hours, before the wort is separated from the grain, and brought up to a standard mash temperature range, then boiled.

4.1 Grain Selection

Selecting the right malt for this technique is not as critical as the low grain bill method, but one should still consider aiming for fuller flavour malts. With cold mashing, grain bills are usually the same size and ingredients of beers made in the 3.5% - 4.5% ABV range. Due to the non-enzymatic process, less fermentable sugars are extracted, so using a larger percentage of base malts such as pilsner and 2 row pale is acceptable. Specialty malts and grains can also be added to suit specific styles. Keep in mind, some NEM mashes can have a slight grainy flavour.

4.2 Mashing

Using a bucket or other suitable container, mash in with cold water. Add enough water to adequately hydrate the grain. The brewer can measure how much they have added at this step and predict the total required water for the brew or wait until the wort is in the kettle to top off to the correct volume. Leave the mash to soak at refrigeration temperature for 8 hours or more. Gently move the bucket from the fridge to a position where the wort can be siphoned off. Siphon the wort into the boil kettle, it is important to not get all the gunk at the bottom of the bucket into the kettle. If added to the kettle, this will scorch, and be a pain to clean up. It will also add an acrid burnt flavour to the brew. Once in the kettle, raise the temperature to 149 F (65 C) and rest until conversion is complete. 60 minutes is fine, but it might not take that long. After conversion is complete, simply bring it to a boil and proceed with the brew day as usual (Source 10.2).

5.0 Boil Off/De-alcoholising

The boil off method is the process of brewing a beer as standard, then bringing the beer to the boiling point of ethanol for a desired amount of time until the alcohol has been reduced to the desired abv. Without expensive testing equipment, it is extremely difficult for the average home brewer to determine the percentage of alcohol left behind in the beer as it is not possible to completely remove all the alcohol due to the azeotrope that is formed (Source 10.12). Introducing heat after fermentation can also cause undesirable flavours or bitterness. Another similar process is that of vacuum distilling, where the beer solution is heated at a lower temperature under vacuum and removing alcohol through heat and evaporation.

De-alcoholising beer is a costly exercise for both, home brewers, and small breweries, it is a method generally seen in larger commercial breweries and wineries, that can facilitate the equipment and costs. One method is the Spinning Cone Column (SCC), a distillation or stripping column that uses a unique mechanical force that is an efficient, rapid, and cost-effective method in separating volatile compounds such as aroma and alcohol from a thin-film liquid system (Source 10.13).
Reverse osmosis is the second method, which consists of filtering the beer through filter membranes to separates alcohol, water and volatile aroma and flavour compounds.

5.1 Boil Off

Once the beer has finished fermenting, transfer to a large pot, from here the brewer can use an oven, stovetop or even a brewing kettle. Raise the temperature to 173.1°F/78.37°C and steadily hold at this temperature from 25 minutes to over 2 hours depending on the desired ABV. Below is a chart that shows the residual alcohol left behind after heating for multiple extended times (Source 10.14).

- 30 minutes cooking time / 35%
- 1 hour cooking time / 25%
- 1.5 hours cooking time / 20%
- 2 hours cooking time / 10%
- 2.5 hours cooking time / 5%

In theory, it would take 2.5 – 3 hours to reduce a 5.0% abv beer to 0.5% abv.
If choosing to boil off the alcohol, it is recommended to brew a beer with a low quantity of bittering hops, due to the extended hi-temperature contact time, the hops added for flavour and aroma shift to bitterness, which may result in an overly bitter, and un-palatable beer. Instead, adding the majority of hop to achieve flavour and aroma late in the boil off process as per standard, 30 minutes through to 0 minutes additions, or utilising hop teas and extracts once cooled. If bottle conditioning, addition of new yeast cells is required to carbonate due to the existing cells being pasteurised throughout the boil. Cold crashing or filtering the beer post fermentation is recommended to reduce the amount of suspended solids and yeast that will cause off flavours during the boil, another issue worth noting is oxygenation causing oxidization with-in the beer, due to transferring the beer from the fermenter to a pot, then a storage vessel.

5.2 De-Alcoholising

One method for the removal of alcohol is reverse osmosis, commonly used in the winemaking industry, In reverse osmosis, wine is pumped against the membrane at a pressure greater than the osmotic pressure, causing smaller-molecular-weight compounds such as ethanol and water to diffuse selectively through the membrane, thereby removing the alcohol from the wine. The membrane rejects or passes compounds based on their molecular weight and the membrane pore size. Since ethanol and water are small relative to the wine matrix, the larger compounds, such as organic acids and phenolics, are retained in the wine and are concentrated. Water is added back to the concentrated wine to restore the initial balance of these materials and produce a pleasing non-alcoholic or reduced-alcohol wine (Source 10.15).

A Spinning Cone Column (SCC) which was developed in Australia, uses a flow of high-quality stripping steam to remove the alcohol. If food grade steam is unavailable on site, a Steam Generator can be included in the system supply. This consists of a heat exchanger, controlled by the SCC automation system, to convert a supply of treated water (typically de-ionized water with <3ppm TDS) into stripping steam using factory steam as the heating medium. For production of Low Alcohol Beer, a two-stage process is used whereby the volatile beer flavour is first removed from the beer using the SCC. This flavour is stored separately while the de-flavoured beer is passed again through the SCC to remove the alcohol. The de-alcoholised beer is then blended with the flavour fraction and full-strength beer (if required) to produce the finished product at the desired alcohol level.
Several factors contribute to minimizing the thermal impact, with a short residence time. The time for the product to travel through the column is around 30 seconds, and Low operating temperatures – typically, in the range of 28°C (82.4°F) to 45°C (113°F). Moreover, there is very low pressure drop across the column, meaning low temperatures are maintained throughout. These low operating temperatures reduce thermal damage to the beer, resulting in a better tasting final product (Source 10.13).

6.0 Low Attenuating Yeasts/Arrested Fermentation

Low attenuating yeast strains have been another option some breweries have turned to, to create NA and ultra-low beers. Companies manufacturing yeast strains such as Whitelabs, Fermentis, and Lallemand have been creating their own strains that many commercial and craft brewers have added to their yeast banks. By carefully selecting yeast cells that are maltotriose and/or maltose negative, they can add to beer to attenuate only simple sugars, they can have greater control of the fermentability of wort, thus creating a low attenuation, leaving behind residual sugars resulting in a low alcohol content. Below (Ref. 6.1) is a list of commonly used low attenuating yeasts to achieve such results, some readily available, and some not so readily available, depending on which country each brewer is based. Ordinary yeast strains can also be used to ferment with, but low-attenuating strains will improve the flavour and overall taste of the beer.
Arrested fermentation is the process of halting fermentation once the desired alcohol content has been reached, commonly used in the cider and wine making industry. There are a few ways to arrest fermentation, the first being pasteurisation, where the beer is heated to a kill any living microbes and organisms. A second, being chilling the beer to near freezing point where yeast cells become inactive and using a filter to remove the yeast cells prior to completing fermentation, a third method is by adding sodium metabisulphite and potassium sorbate to cider or beer together to stop any further fermentation when back sweetening with a fermentable sugar, or once yeast cells have become in-active. While many suggest both will work independently to prevent further fermentation, the use of both will diminish yeast activity through attrition more effectively together (Source 10.18)

6.1 Low Attenuating Yeast Strains

It is advised by the manufactures of the maltose and maltotriose negative strains to pasteurise the finished beer to prevent further fermentation or secondary fermentation. Pasteurisation methods are covered further in the article (Ref. 7.6).

Strain:	**Characteristics:**
White Labs: (Source 10.8)	
WLP618 *Saccharomycodes ludwigii*	Limited maltose and maltotriose consumption. A more neutral strain with some ethyl acetate production.
WLP603 Torulaspora delbrueckii	Will not ferment maltose and maltotriose. Fruity, ideal for Belgian, Saison styles or IPAs.
WLP686 Zygosaccharomyces lentus	Partial inability to ferment maltose. More neutral but difficult to grow.

Fermentis: (Source 10.9, 10.7)

Safbrew LA-01	Does not assimilate maltose and maltotriose but assimilates simple sugars (glucose, fructose, and sucrose) and is characterized by a subtle aroma profile.
Safale S33	Fruity driven strain, gives a high mouthfeel and body to the beer.

Lallemand: (Source 10.6)

Windsor	Balanced fruity aroma and imparts a slight fresh yeasty flavour. Beers created with Windsor are usually described as full-bodied, fruity English ales. Maltotriose negative

6.2 Arrested Fermentation

Heat:

By heating the beer, reduction of microorganism activity from bacteria and yeast can be done to halt the fermentation process, providing the brewer the ability to maintain low alcohol levels with a desired amount of sweetness due to incomplete fermentation. Whilst some methods can be quite costly such as "Flash" pasteurisation, also known as "HTST" (High Temperature Short Time) Pasteurisation (Source 10.16), the home brewer can take a much simpler step to pasteurise their beer with heat. Placing bottles into a hot bath, pot or brewing kettle for a length of time can be used to pasteurise beer.

Cooling:

Cooling the beer to near freezing conditions, the yeast become in-active, from here, the yeast can be either filtered out or diminished through use of Sodium metabisulphite (Campden tablets), and Potassium sorbate (See below). Kegged beer is not normally pasteurised, and so it must be stored at 38°F/3°C in order to prevent secondary fermentation from occurring in the keg.

Chemically:

Adding campden and sorbate to beer together is an effective way to stop any further fermentation when back sweetening with a fermentable sugar, it is not suitable to halt the fermentation, more-as to prevent further fermentation after the yeast have become inactive. While many suggest both will work independently, the use of both will diminish yeast activity through attrition more effectively together.
A common misconception is that campden, AKA potassium metabisulfite, will kill the yeast. This is not totally true. Creating conditions where the yeast become inactive can be done, such as cold crashing or removal of nitrogen. For further information, refer to pasteurisation further in this article (Ref. 7.6).

7.0 Fermentation, Carbonation and Storage

The fermentation process can vary from brewer to brewer, some may only have access to simple plastic buckets, some may use pressure fermenters or kegs, and some may have state of the art equipment such as glycol temperature controlled conical fermenters. Whatever the equipment, they all make great beer suited to our budgets and space. One thing to consider, is the use of temperature-controlled chambers. Being able to control the temperatures throughout fermentation, will result in a better flavoured beer by producing esters to suit certain styles, or to prevent any unwanted esters causing off flavours. Once the brewer has made their beer, the next step is to consider how they are going to carbonate it, below are the methods to carbonate the beer, along with the risks they may encounter. Another key point that should be considered with some brewing methods is pasteurisation to prevent spoilage or secondary fermentation.

7.1 Fermentation

Whether the brewer uses a cheap plastic brewing bucket, or a state-of-the-art stainless-steel temperature controlled conical fermenter, one key factor to producing quality beer is the ability to control fermentation temperatures, investing in a cheap fridge, with a heat source and temperature controller such as an Inkbird temperature controller (Source 10.19) will greatly improve the quality of beer for the home brewer of any level of experience. Each yeast will have an optimum temperature range, that can be raised or lowered to contribute different esters during fermentation that will attribute to the overall flavour and aroma of the finished beer.

One factor to consider, is the risk of unwanted pathogens or bacteria growing in the beer, all equipment that will come into contact with the beer throughout any of the processes should be thoroughly washed and sanitised prior to brewing. Whilst it is extremely rare (Fewer than 10,000 cases per year in Australia), Clostridium Botulinum is one pathogen that some brewers take steps to reduce the risk of, beer wort is an ideal place for this pathogen to flourish. Beer wort has a high protein content and a pH permissive to the growth of botulism (>5.0). It is unclear whether hops inhibit growth of botulism, although inhibition has been observed with highly purified extracts. The good news for conventional beer brewers is that normal brewing practices will prevent botulism from growing. The oxygen levels achieved by normal oxygenation processes are inhibitory to growth, while the acidification during fermentation will suppress botulism long before it produces toxin. In other words, if the brewer quickly chills the beer, oxygenate well, and immediately pitch a good dose of yeast, the risk is essentially zero (Source 10.23). It is generally accepted that in Clostridium botulinum both growth and toxin formation are completely inhibited at pH values below 4.6. This critical pH value has been confirmed by many investigators using food as substrate or culture media (Source 10.24).

If the brewer, however, wants to take steps to prevent the growth, with the addition of lactic acid, phosphoric acid, or citric acid, they can acidify the wort to 4.6pH prior to pitching the yeast.

7.2 Natural Carbonation/Pressure Fermentation

If the brewer ferments using a purpose made pressure fermenter, or they have made a Kegmenter (Source 10.20) they can carbonate the beer naturally. By using the CO2 produced naturally from the fermenting stage, they can brew and dispense directly from the same vessel, or transfer oxygen free to another keg or directly into bottles and cans. Resulting in keeping the ultra-low abv and maintaining a NA/Ultra-low alcoholic beer.

7.3 Force Carbonation

If the brewer does not have access to a pressure fermenter, transferring the beer from an ordinary bucket or conical fermenter to a keg and attaching it to the brewers draught system to carbonate with the introduction of CO2 will also help in keeping the ultra-low abv and maintaining a NA/Ultra-low alcoholic beer. Thus, being the popular option amongst many home brewers.

7.4 Bottle Conditioning

If the brewer does not have access to either a draught system, or pressure fermenters, then bottling is the last option to package the beer. Bottle conditioning is essentially a secondary fermentation stage, where a priming sugar is added to each bottle, or bulk priming of the entire batch, bottled, and left to naturally carbonate inside the bottles. The disadvantage of bottle conditioning is the introduction of extra alcohol caused by the secondary fermentation of the sugars. This must be taken into consideration when designing a recipe the brewer intends to be non-alcoholic (<0.5%abv). Brewing websites and software have calculators for adding priming sugars to help the brewer determine the final abv of the finished beer. If the brewer has pasteurised their beer prior to packaging, then the addition of new yeast cells is required for the secondary fermentation. If the beer has been packaged without pasteurising, pasteurisation can be done once the desired carbonation level has been reached. An important warning of bottle conditioning is the risk of over carbonation due to excessive sugars, or an infection, causing extreme pressure inside the bottle, resulting in bottles exploding.

7.5 Storage

Storage of the finished beer is no different from regular beer, although keeping the serving containers at low temperatures to prevent spoilage, or secondary fermentation from wild yeasts or infections. If bottle conditioning, it is advised to store the bottles in an enclosed container, box, or cabinet, in the off chance a bottle explodes, the broken glass will be contained, preventing any harm.

7.6 Pasteurising

<u>Using additives:</u>

While stopping active fermentation is difficult, especially for the home brewer, it is easy to inhibit future fermentation of beer once the yeast has become inactive once they have eaten all of the available sugars. At this point, the yeast become inactive since they do not have a food source. Future fermentation can be inhibited by using a mix of campden and potassium sorbate to stabilize the beer. This method is common practice in the wine industry for making sweet wine and increasingly popular in commercial cider making. The first step to this process is to thoroughly cold crash the beer for a couple of days. This will allow a large portion of the yeast to settle to the bottom which can then be racked without transferring large amounts of yeast. Minimizing the amount of yeast in the beer will make it easier to stabilize. With the bulk of the yeast removed, the next step is to use Campden and Sorbates to manage the remaining yeast. Follow the manufacturer's recommendations that are found on the package. Recommendations will generally appear as follows:

Campden: 1 tablet per gallon/4.5 litres

Potassium Sorbate: ½ tsp. per gallon/4.5 litres

Of course, this method will retard all yeast, so natural carbonation will no longer be possible, the brewer will have to look into force carbonating or kegging (Source 10.18).

<u>Stove-top pasteurisation:</u>

Stove top pasteurisation can be done two ways, with low temp/long time being the safest method with better results, or high temp/short time which can affect the final taste. Care must be taken as to not overheat the bottles, as this can result in the bottles exploding, covering the brewer in hot liquid and broken glass. If the brewer decides on bottle or can pasteurisation, a single bottle or can should be added that has been filled with water of the same temperature as the beer, with an accurate thermometer inside the container to monitor the temperature, once the coldest part of the container has reached the desired temperature, the timing can commence.

For every minute the beer is held at 140°F/60°C it is said to be subject to one pasteurization unit (PU). For example, holding for 15 min at 60°C, therefore, is 15 PUs of treatment (Source 10.22). For higher temperatures, holding it at 162°F/72°C for 30 sec is equivalent to 26PUs.

A formula that maps time and temperature to PUs:

$PU = t \times 1.393 ^ {(T - 60)}$

Where **t** is the time in minutes and **T** is the temperature in Celsius (Source 10.17).

Let us assume a time of 1 minute, and a temperature of 60C, by using an Exponent calculator, the equation is as follows

$$PU = 1 * 1.393 ^ {(60 - 60)}$$

$$\mathbf{PU = 1}$$

From this equation, we can find that 1 minute at 60°C equals 1 pasteurisation unit, for a desired pasteurisation of 20PUs, we know it will take 20minutes at 60°C.

- Low temp/long time.

Fill a large pot, or a brew kettle with enough water to submerge the bottles to the fill line. Remembering that the bottles will displace quite a bit of water, the pot won't need to be as full beforehand as a result. With the water in place, it is time to bring in the stovetop portion of stovetop pasteurisation.

Heat the water on the stove top to 140°F/60°C. If the water is too hot, it could cause heat shock and shatter the bottles when placed into the hot water. Once the target temperature has been reached, turn off the heat and remove the pot from the burner. Even if the stove is turned off, the burner will still be hot and could shatter the bottles. With the water at 140°F/60°C, and the pot off the stove, start adding the bottles to be pasteurised. Do not put too many in at a time, they should not be touching. Maintaining temperature is important, if the temperature drops below 140°F/60°C, insufficient pasteurisation will occur, and the yeast may still be active. When all the bottles are in, cover and insulate the pot and leave it alone for 15 to 45 minutes, depending on the required PUs the brewer is intending, keeping larger bottles at the higher end to ensure adequate heating.

After that time, carefully remove the bottles, they will, of course, be hot. Use proper precautions as to not cause harm. Sit them aside to cool off, start reheating the water for the next set of bottles. This process can be repeated as many times as necessary. When the bottles are removed from the water, they may become cloudy, the yeast will no longer be settled at the bottom of the bottle. Everything will be mixed up, but do not worry, it will settle back out (Source 10.21).

- High temp/short time.

Fill a large pot, or a brew kettle with enough water to submerge the bottles to the fill line. Remembering that the bottles will displace quite a bit of water, the pot will not need to be as full beforehand as a result. With the water in place, it is time to bring in the stovetop portion of stovetop pasteurisation.

Heat the water on the stove top to 162°F/72°C. The temperature can be slightly higher, but make sure it does not reach 200°F/93.3°C, if the water is too hot, it could cause heat shock and shatter the bottles when placed into the hot water. Once the target temperature has been reached, turn off the heat and remove the pot from the burner. Even if the stove is turned off, the burner will still be hot and could shatter the bottles. With the water at 162°F/72°C, and the pot off the stove, start adding the bottles to be pasteurised. Do not put too many in at a time, they should not be touching. When all the bottles are in, leave them alone for 5 - 15 minutes to ensure proper heat through, keep larger bottles at the further end of time to ensure adequate heating.

After that time, carefully remove the bottles, they will, of course, be hot. Use proper precautions as to not cause harm. Sit them aside to cool off, start reheating the water for the next set of bottles. This process can be repeated as many times as necessary. When the bottles are removed from the water, they may become cloudy, the yeast will no longer be settled at the bottom of the bottle. Everything will be mixed up, but do not worry, it will settle back out (Source 10.21).

Flash pasteurisation:

"Flash" pasteurisation is another term for "HTST" (High Temperature Short Time) Pasteurisation. Flash pasteurisation is very energy efficient and has the least detectable flavour and colour effect on the product compared to other pasteurisation methods. In this process the product is rapidly heated to a pre-set temperature, held for a short time, and is then rapidly cooled prior to filling. This process provides the required 5-Log reduction of microorganisms with minimal impact on the flavour or colour of the product. The time and temperature of the process can be adjusted to suit the individual needs of the user. A flash pasteurizer for beer is usually a plate style pasteurization unit. The term 'plate' style refers to the type of heat transfer technology used. Plate style heat exchangers are used for products with very little to no solids present like beer, cider, and kombucha. Pasteurization temperatures typically range from 162°F to 180°F depending on the product and yeasts involved. Hold times are typically 15-20 seconds but can be as long as 60 seconds. (Source 10.16).

Cold pasteurising:

Cooling the beer to near freezing conditions, the yeast become in-active, from here, the yeast can be either filtered out or diminished through use of Sodium metabisulphite (Campden tablets), and Potassium sorbate (See below). Kegged beer is not normally pasteurised, and so it must be stored at 38°F/3°C in order to prevent secondary fermentation from occurring in the keg.

Filtering the beer can be done through a few multiple ways, whilst sterile filtration does not promise the complete absence of microorganisms and generally describes the reduction of organisms without the use of heat treatment of beer as used in tunnel or flash pasteurization. It can also be referred to as "cold sterilization" or "draught filtered." Sterile filtration can be accomplished in different ways. It can take place in successive depth filtrations using kieselguhr filters, with depth filtration via a single pass on a sheet filter, or with absolute filtration on a cartridge filter. Normally, any pore rating on a filter with 0.45 µm or less will yield sterile beer. A Candle Filter is a filter type of precoat or pressure filter and is predominantly used for clarification of beer that has been fermented and lagered, although other applications, such as sterile filtration or wort filtration, are possible. Most commonly, candles are fabricated from metal, almost exclusively stainless steel today or ceramic. Another is a sheet filter; this is a device for removing suspended particulate from beer. The filter construction consists of 4–5 mm (0.16–0.2 in) sheets pressed between plates with inlet and outlet channels. Modern filter sheets come in various nominally rated porosities, ranging from coarse to fine to sterile.

8.0 Building A Recipe

8.1 Choosing the Right Ingredients

Choosing the right ingredients is crucial to creating the highest quality beer. From colour, right through to taste and mouthfeel, each ingredient brings something to the beer to create a sensory wonder. Selecting the right grains, hops and yeast will also contribute to keeping within a particular style. One thing to consider, is which method the brewer will utilise, as this can adversely affect the final outcome, selecting the appropriate ingredients to the chosen method will inherently create better beer.
As this guide has been written with grain brewing in mind, it is possible to utilise some methods to create an NA/Ultra-low alcohol beer from extract brewing, especially with the release of Muntons Premium Alcohol-Free malt extract (Source 10.25).

Effects and uses of grains and adjuncts will be covered in-depth in further articles still to be tested and written.

Malts and adjuncts:
Selecting the right base malt is a key component to the flavour and body of beer, the use of standard pale malt/2 row malt, may work fine for cold mashing or boiling off, but due to the little flavour and colour of the malt, it is not recommended for the low grain method. The brewer can, if they desire, use this malt in their beer, but substituting it for another malt that has a higher flavour profile, such as, Munich, Traditional ale malt, rye or even Maris Otter, will provide greater flavours and colours. The addition of wheat malt, crystal malts, and/or caramel malts will help the brewer create depth and colour to the beer. Adding wheat malt is a great way to add body and texture to the beer, while adding foaming properties to aid in head retention and lacing. Crystal malts, and caramel malts will bring colour, flavour, and sweetness to the beer, creating a fuller palate that may otherwise feel thin and dry, as well as foaming properties. The use of adjuncts is highly recommended to increase the body and mouthfeel of the beer and assist in adding foaming properties. Adjuncts such as corn syrup (maltodextrin) and lactose will add sweetness and body to a beer, while flaked additions, such as oats, barley, wheat, quinoa, corn, and rice can provide haze and additional flavours to add to the complexity, also adding foaming properties to the beer to aid head retention and lacing.

Hops:
Selecting which hops to utilise will also determine the style, aroma, bitterness, and overall flavour of the finished beer. Traditional lagers, Pilsner, and other pale lager varieties use primarily noble hops, whereas traditional ales use primarily English variety hops, and modern pale ales and IPAs use mainly American varieties. One thing that is common amongst all types of beers, is the use of bittering hops, as mentioned earlier in this article (Ref. 2.3) alpha acid analogues include humulone, cohumulone and adhumulone, which, when isomerized to isohumulones (iso-alpha acids) through the boiling process, contribute bitterness to beer. Hop resins, in particular isohumulone,

enhance foam stability, although some reports suggest the effect to be minimal. More important than its effects on foam stability, is the role of hop resins in causing the beer foam to adhere to surfaces (Source 10.5).

Yeast:

The use of the correct yeast is just as crucial to choosing a style of beer, as different strains impart different flavour and aroma profiles. There are literally hundreds of varieties and strains of yeast. In the past, there were two types of beer yeast: ale yeast (the "top-fermenting" type, Saccharomyces cerevisiae) and lager yeast (the "bottom-fermenting" type, Saccharomyces uvarum, formerly known as Saccharomyces carlsbergensis). Top-fermenting yeasts are used for brewing ales, porters, stouts, Altbier, Kölsch, and wheat beers. Some of the lager styles made from bottom-fermenting yeasts are Pilsners, Dortmunders, Märzen, Bocks, and American malt liquors (Source 10.26).
The use of Low attenuating yeast strains from companies manufacturing yeast strains such as Whitelabs, Fermentis, and Lallemand are a great option. By selecting yeasts that are maltose and/or maltotriose negative, and only attenuate simple sugars, these strains for fantastic for creating a NA/Ultra-low alcohol beer.

The use of sodium metabisulphite or potassium metabisulphite tablets can be used to remove added chlorine from the brewers' water, to kill bacteria on brewing equipment, and to protect the beer by preventing unwanted foreign bacteria fermenting in the beer.

8.2 Using the Brewing Software

The use of brewing software such as Brewers Friend, Beersmith, and Brewfather will ultimately assist the brewer in creating a recipe that is reflective of style and desired abv of the finished beer. With the software doing the calculations for all aspects of brewing, it makes it easy for the user to adjust their ingredient amounts to achieve their chosen colour, IBU and specific gravity prior to brewing to help determine the final alcohol content and style of their beer. If the brewer has recipes that have a higher abv content, these programs can be used to scale the recipe down to the desired abv.

9.0 Summary

Hopefully after reading through this guide, you now have an understanding of the practice and procedures of brewing to create your very own non-alcoholic/ultra-low alcohol beer, whether you have never brewed before, or you are a professional. Whilst some of this information may not reflect the views or opinions of other brewers, it has been written to give an informed guide for anyone to follow. I hope that this guide has given you confidence to attempt your own beer and take advantage of this mysterious side of brewing in an industry that is booming globally. Although brewing can become quite involved when managing multiple aspects of the processes, it is important to have

fun. if you make a mistake, or you are not happy with a beer, do not become discouraged, instead, make a note of your fault, and move forward.
I would like to thank yourself, and anyone who reads this, for taking to time to read and learn about this wonderful way of brewing, and I hope you make fantastic beer from this day forward. I hope to continue sharing updated information and papers to better guide people along their journeys.
HAPPY BREWING!

Below are some key points that are worth remembering to help with your brewing, along with a recipe to attempt, courtesy of Brewdog (Source 10.1).

9.1 Key Points

- Select the right method to suit your individual experience and availability of equipment.
- Choosing the correct ingredients, will ultimately improve your beers flavour and experience.
- Assess how you are going to store your fermented beer and be aware of secondary fermentation.
- The use of brewing software will make it easier to assess how the beer will finish, resulting in better results, as well as keeping record of your recipes.
- Have fun, and remember the next brew is always better.

9.2 Recipe to try

(Source 10.1)

BREWDOG NANNY STATE

ALCOHOL FREE HOPPY ALE

ABV 0.5%   IBU 55   OG 1007.0

THIS BEER IS

Brewing a full flavoured craft beer at 0.5% is no easy task. Packed with loads of Centennial, Amarillo, Columbus, Cascade and Simcoe hops, dry hopped to the brink and back and sitting at 55 IBUs, Nanny State is a force to be reckoned with.
With a backbone of 8 different specialty malts, Nanny State will tantalise your taste buds and leave you yearning for more.

BASICS

Volume	20L 5.3gal	**Boil Volume**	25L 6.6gal
Target OG	1007.0	**Target FG**	1005.0
Attenuation Level	28.57%	**ABV**	0.5%
EBC	30.0	**SRM**	15.0
PH	4.4		

METHOD/TIMINGS

MASH TEMP

65°C 149°F 30mins

FERMENTATION

19°C 66°F

INGREDIENTS

MALT			HOPS			
Munich	**0.13kg**	**0.3lbs**	**Amarillo**	**6.3g**	**Start**	**Bitter**
Caramalt	0.19kg	0.4lbs	**Simcoe**	5.0g	Start	Bitter
Crystal 150	0.06kg	0.1lbs	**Centennial**	6.3g	Start	Bitter
Amber	0.03kg	0.1lbs	**Amarillo**	6.3g	Middle	Flavour
Dark Crystal	0.13kg	0.3lbs	**Simcoe**	2.5g	Middle	Flavour
Chocolate	0.06kg	0.1lbs	**Centennial**	6.3g	Middle	Flavour
Wheat	0.06kg	0.1lbs	**Amarillo**	5.0g	End	Flavour
Rye	0.13kg	0.3lbs	**Simcoe**	5.0g	End	Flavour
			Cascade	12.5g	End	Flavour

Ahtanum	12.5g	End	Flavour
Centennial	50.0g	Dry Hop	Aroma
Cascade	50.0g	Dry Hop	Aroma
Ahtanum	25.0g	Dry Hop	Aroma
Simcoe	25.0g	Dry Hop	Aroma
Columbus	37.5g	Dry Hop	Aroma

YEAST

- Wyeast 1056 - American Ale

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