Bottle Conditioned Cider Guide

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1.Introduction

Bottle conditioning is regularly used in home brewing and also if you are making CAMRA approved real ale in a bottle. In bottle conditioning as opposed to méthode champenoise the yeast is left in the bottle after fermentation. This makes the procedure easier to achieve with modest equipment although care must be taken on pouring to avoid pouring the sediment into the glass.

Most online guides and books tend to either have a table or online calculator showing the required sugar addition without explaining the fundamental workings of the procedure. The aim of this guide is to produce a safe naturally carbonated product consistently and to limit the chance of unwanted microbial contamination by considering the fundamentals of the procedure. To do this we need to understand the fermentation process and carbonation requirements for different styles as well as the potential pitfalls.

In general terms we take a finished cider and add a quantity of priming sugar and yeast to it and bottle the cider. The yeast then ferments the added sugar in the cider and produces Carbon Dioxide carbonating the cider.

Another method is to predict when a cider is going to finish fermenting and bottle it just beforehand allowing the fermentation to finish in the bottle. This procedure can work very well if you can accurately estimate how much farther the fermentation has to go consistently. This guide will not cover this procedure and personally I would advise against it until a level of experience has been obtained as inconsistent levels of carbonation plagues the brewing industry where it is practised and as a consumer it is frankly infuriating when one of the bottles you have just bought foams everywhere mixing the yeast back into the product ruining the drink.

If you are determined to do this I would advise you to take into account ciders with a reasonably high alcohol content (7%+) will finish **BELOW** SG 1.000. In these situations it is best to rack off a sample of the cider in question and keep it at 20ºc with some added nutrient and yeast to encourage it to rapidly finish fermenting so you can accurately calculate the real final gravity.

Below we will now consider each of the points in the bottle conditioning process in depth followed by a troubleshooting section and a concise worksheet of the process to achieve a satisfactory product.

2. Fermentation and production of CO_2

During fermentation yeast converts sugar to alcohol and CO_2 as well as other metabolic products and new yeast cells. Pasteur studied it and produced the following relation:

100 grams of sugar yields:

- 48.6g ethanol
- 46.6g carbon dioxide
- 3.2g glycerin
- 0.6g succinic acid
- 1.2g yeast cells

*Later studies showed **48g ethanol and 47g CO_2 per 100g sugar** to be a more correct figure.*

From the above we can calculate the grammes sugar required to produce any given quantity of CO_2:

- 100g sugar yields 47g CO_2.
- Therefore Sugar grammes = (carbon dioxide grammes / 47) * 100
- This can be simplified as **Sugar grammes = Carbon Dioxide grammes * 2.128**

Two other points to note with bottle conditioning:

- *The malolactic fermentation also produces $C0_2$ which could alter carbonation level.*
- *Sugar added for bottle conditioning raises the ABV of the product.*
- **ABV increase = (SG after sugar addition – SG before addition) * 125**

It is advisable to test the SG of the cider before and after the sugar addition to confirm it is at the expected level before proceeding to ensure against any issues such as the volume of cider being calculated incorrectly prior to addition. It should be noted this will give an approximation only.

We can make an approximation of the increase in Specific Gravity as follows:

- 2.4 – 3 grammes of sugar raises the SG of a litre of cider by 0.001.
- **SG Increase = ((sugar addition in grammes / volume of cider in litres) / 2.7) * 0.001**
- ie 5.4g sugar dissolved in 2 L of cider = ((5.4 / 2) / 2.7) * 0.001 = SG raised 0.001

One final point. If we are performing a sugar addition to get to a specified g/L sugar we are actually increasing the volume of the solution when we add the sugar so we need slightly more sugar to get to the required g/L. In the case of bottle conditioning the increase is minimal and as such does not need to be taken into account. For completenesses sake here is an equation to calculate it to demonstrate.

$$A = \frac{Vi(Sf - Si)}{\left(1 - \frac{Sf}{b}\right)}$$

A = the quantity of sugar to add to the must [g]
Vi = the initial volume of must [L]
Si = the initial sugar concentration in the must [g/l]
Sf = the desired (final) sugar concentration in the must [g/l]
b = number of grams of sugar required to raise volume by 1 litre [g] = 1600

To give an example say we wish to add priming sugar to 200L cider to give 10g/L. The basic assumption is we would need 2000g of sugar. Below is the calculation of required sugar from the equation.

$$A = \frac{200(10 - 0)}{\left(1 - \frac{10}{1600}\right)} = 2012.6\,g\ Sugar\ needed$$

From the above we can see we need 2012.6g of sugar. Realistically the difference in values is marginal and is not an issue in practice.

3. Volumes of CO_2

The carbonation of cider is measured in volumes of CO_2. One Volume of CO_2 (1 vol) equates to the quantity of CO_2 gas at 0ºc and atmospheric pressure that would occupy the same volume as the liquid in which it is dissolved.

Density of gaseous CO_2 = 1.977 g/L at 0ºc.

From the above we can calculate the required grammes of Carbon Dioxide for a given volume of cider at a given vols carbonation:

- **CO_2 grammes = CO_2 vols * (1.977 * Cider litres)**
- Example: 500ml cider at 3 vol = 3 * (1.977 * 0.5) = 2.9655 grammes CO_2.
- If we consider part one we can calculate the sugar needed for the above example. **Sugar grammes = Carbon Dioxide grammes * 2.128** – i.e. Sugar grammes = 2.9655 * 2.128 = 6.311g sugar need to be added to the 500ml bottle.

A cider that is fermenting or has only just finished can be considered to be saturated with CO_2. The Malolactic fermentation also produces CO_2.

- **CO2 Saturation of cider just after fermentation is 2 g/L CO_2 at 15ºC**
- **Malolactic fermentation may produce 2g/L CO_2**
- **When bottle conditioning the above should be taken into account and the quantity of priming sugar reduced accordingly.**

4. Style of product

Depending upon the product and method of presentation the desired carbonation rate can differ. Below is a table of standard drink types and required carbonation levels.

Style of Product	Vessel	Vols CO_2
British Real Ale	Cask	1-1.5
American Ales & Lager	Keg	2.2-2.8
American Ale Bottle	12 oz Bottle	2.2
German Lager Bottle	500ml Bottle	2.5
Belgian Triple	33cl Bottle	3.3
Draught Cider	Keg	3-4
Bottle Conditioned Cider	500ml Bottle	2.5-3
Méthode Champenoise	75cl Champagne Bottle	3.5-5.5

5. Bottles

Different styles of bottle have various maximum safe pressures they can tolerate. The list is non-exhaustive and if in doubt contact your glass manufacturer/supplier.

Bottle Type	Max Vols CO_2
12 oz American	3
33cl Belgian	3.5
500ml European	3.5
Swing Top	4
Champagne	7
PET	10

6. Yeast

Yeast is needed for the carbonation. Yeast may already be present however it's state and characteristics are unknown and may perform inconsistently. As such it is recommended to pitch a quantity of known yeast to perform the fermentation to guarantee consistency.

First we need to decide on the yeast. For bottle conditioning a champagne style yeast such as **Lalvin EC-1118** is usually chosen. These kinds of yeast will ferment to high alcohol and form a compact sediment (lees) at the end of fermentation aiding pouring. Below are some facts about dry yeast.

- A packet of Lalvin EC-1118 is 5g in weight
- Each gramme of dry yeast contains 20 billion yeast cells, not all of which will be active.
- **6 billion active yeast cells per gramme is a good minimum estimate.**
- **If the yeast is not rehydrated as per the packet before use half the active cells will die.**
- After rehydrating for 15 mins use within 30 mins.
- Use tap water not distilled or deionised water to rehydrate else some cells will die.
- After two years you would expect only a 10% drop in active cell count in the packet.

From the earlier facts we can deduce an equation to calculate the number of active yeast cells in any quantity of dry yeast after rehydration as follows:

- **Viable cell count = grammes dry yeast * 6 billion.**
- i.e. Lalvin EC-1118 5g packet = 5g * 6 billion = **30 billion viable cells per packet.**

If we rehydrate a yeast of known quantity in a known quantity of water we can calculate viable cell count per ml of starter as in the below equation:

- **Viable cells per ml starter = (grammes dry yeast * 6 billion) / ml water**
- i.e. 5g lalvin EC-1118 in 100ml water = (5 * 6 billion) / 100ml = 300 milion viable cells/ml

Next we need to know the number of yeast cells required. Below is a table of common bottle conditioned products and the required number of cells.

Style	Cells per ml	Total cells per 5 Gal
English & American Beer	~100,000 cells/ml	~2.3 billion
German Beer	~100,000 cells/ml	~2.3 billion
Belgian Beer	1-3,000,000 cells/ml	~23-68 billion
Cider	~100,000 cells/ml	~2.3 billion

From the above we can calculate the required number of yeast cells for any given volume of cider using the below equation:

- **Active cells required = (Cider Litres * required cells per ml) * 1000**
- i.e. 500ml bottle to 100,000 cells/ml = (0.5 * 100,000) * 1000 = 50 million yeast cells.

From the active cells required combined with the viable cells per ml starter equations we can calculate the number of ml of starter needed for any quantity of cider as follows:

- **Starter(ml) = active cells required / viable cells per ml starter**
- i.e. 50 million cells required / 300 million viable cells per ml starter = 0.167ml of starter.

Given the small quantities required per bottle it is generally better to pitch starter into the bulk cider and thoroughly mix than pitch into individual bottles. If it is desired to pitch into each bottle in turn either the starter could be diluted down with water or a laboratory pipettor could be used to accurately dispense very small volumes of liquid.

7. Sulphite

Sulphite is often added prior to bottling to aid in quality control. In the bottling process it can have several purposes:

- Sulphite can mop up any free oxygen introduced during bottling reducing oxidation.
- Inhibits certain spoilage organisms.
- It inhibits malolactic bacteria and their subsequent carbonation.
- If the product is to be pasteurised it reduces Maillard reactions (cooked flavours).
- **NOTE: Film yeasts are not controlled with sulphite, pasteurise suspect ciders first.**
- **200ppm sulphite is the legal limit of total additions to a cider.**

During bottle conditioning yeast binds all the sulphites as part of it's fermentation so you should not consider there to be free sulphite preserving the cider in the bottle - as opposed to a still bottled cider say where you could assume some of the sulphite to still be in it's free form.

Sulphite is not a magic bullet and several spoilage organisms will not be deterred by it. **If the cider you are bottling has any suspect microbial qualities pasteurise the cider after adding the sulphite but before pitching the yeast to guarantee a successful bottle conditioning.**

30 parts per million (ppm) Sulphite is a good figure to use in bottling as it is not excessive enough to noticeably alter the flavour or inhibit the pitched yeast.

To add sulphite to the cider we first make up a 10% sulphite solution then we calculate the required volume as follows:

- **10% Sulphite Solution = 100g sulphite dissolved in 1L water.**
- **Sulphite solution(ml) = (sulphite required ppm / 50) * volume of cider in litres.**
- i.e. 30 ppm sulphite in 20L = (30/50) * 20 = 12ml of 10% Sulphite solution required.

Sulphite is also often used as a sterilising bottle rinse during processing. **If sulphite is used as a 'no-rinse' steriliser for caps and bottles it can potentially add excessive amounts of sulphite to the cider inhibiting the yeast if any remains.**

For example:

- Imagine we use a 2% solution to rinse the bottles and caps in prior to bottling.
- 2% sulphite solution is equivalent to 20,000 ppm Sulphite per ml.
- 1ml of this solution could remain in the bottle and a similar amount in the cap.
- 2ml of this solution remaining in a 500ml bottle would give 80 ppm sulphite (40,000 / 500).
- If we added sulphite to the cider as well we could now have over 100ppm sulphite.
- **Over 100 ppm sulphite added could inhibit the yeast spoiling our product.**

From the above example we can see **all bottles and caps should be rinsed with water thoroughly before bottling.**

8. Pasteurisation

Pasteurisation although technically unnecessary can be a useful tool during the bottle conditioning process to remove any unwanted spoilage organisms present in the cider before pitching the yeast and bottling.

As stated earlier, sulphite alone will not inhibit film yeasts if they are already present in the cider as well as certain wild yeasts such as Brettanomyces which can give rise to spoilage flavours.

If film yeasts or other suspect micro-organisms are present in the cider prior to bottling pasteurise the cider and allow it to cool before adding the yeast starter.

Pasteurisation after bottle conditioning is not recommended as the pressure exerted on the bottle by the carbonated cider may well cause the bottle to explosively fail

Pasteurisation is measured in Pasteurisation Units or PUs.

- **A PU is defined as the sterilising effect observed when the product is held for one minute at a temperature termed the base value – in our case 60ºC - resulting in one PU.**
- **There is a ten-fold increase in sterilising effect for every 7ºC rise in temperature for ciders and beers. This value is called the z value.**
- If we held one cider at 60ºC for a minute and another at 67ºC for a minute the cider at 67ºC would received 10 times the number of PUs as the cider at 60ºC.
- Any temperature over 50ºC will cause an accumulation of PU's although for temperatures below the base value the accumulation will be negligible.
- **For beers and ciders 30-50 PUs is deemed an acceptable figure.**
- When pasteurising the PU's gained during the heating and cooling of the product up to the target temperature should be taken into account.
- **To calculate the total PU's received during pasteurising the temperature should be taken every minute over 60ºC during both the heating and cooling of the cider and the PU's generated for a minute at that temperature recorded and accumulated.**

The formula for calculating PUs is as follows:

$$PUs = t \times 10^{\frac{T-60}{7}}$$

Where:

- PUs = Pasteurisation units.
- t = time in minutes.
- T = temperature in 'C.
- *Note this assumes a base value of 60'c and a z value of 7'c*
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For example say we held a cider at 66ºC for 5 minutes. PUs = 5*10^((66-60)/7) = 36 PUs.

If we are pasteurising a bulk of cider before bottle conditioning a good ball park value to shoot for would be to heat the cider to 66ºC then allow it to cool. This will easily achieve the required number of PUs in anything other than a flash pasteuriser and if the temperatures are recorded per minute the total PUs accumulated can be calculated for record keeping.

9. Troubleshooting

As shown in the earlier sections of the document there are several potential pitfalls during the bottle conditioning process.

To give an example I will describe a cider I have bottle conditioned which encountered some issues. Followed by a simple HAACP Plan for bottle conditioning.

- The cider came from an oak barrel which unknown to me had a film yeast infection.
- The cider had priming sugar, 30ppm sulphite and yeast pitched in and was bottled.
- The cider was not pasteurised.
- The bottles were rinsed with 2% SO_2 and drained on a bottle tree.
- The caps were kept in 2% SO_2 solution and removed on capping.
- After checking 3 months later no fermentation had occurred and a white oily film was present on the cider (film yeast).
- The cider was left at the back of the barn for 9 months (cider maker may have been miffed…).
- When checked 9 months later a bottle conditioning had occurred and the cider tasted very good but unfortunately still had a film on top.

Illustration 1: If you look closely you can see a white film yeast film on the clear glass neck.

On consideration what most likely occurred is an excessive quantity of SO_2 was added to the cider as the bottles and caps were not rinsed in water after sterilising. This inhibited the yeast until enough sulphite had been bound and the carbonation proceeded sluggishly afterwards. During the intervening period a film yeast was able to grow in the cider. If the cider had been pasteurised it would most likely have stopped the film yeast and if the bottles and caps had been rinsed in water the carbonation would have proceeded rapidly.

HAACP Plan for bottle conditioning cider

STEP NO	PROCESS STEP	FOOD SAFETY HAZARD & CAUSE	CONTROL MEASURE	CRITICAL LIMIT	MONITORING PROCEDURES	CORRECTIVE ACTION
1	Selecting cider – state of fermentation.	Cider that is still fermenting could produce an excessive quantity of CO2 resulting in explosive failure of bottles and injury.	Do not proceed until the cider has completely finished fermenting.	Is the cider fermenting?	Take SG with hydrometer and observe for CO2 bubbles rising.	Wait until fermentation has stopped before proceeding.
2	Selecting cider – microbial faults.	Microbial faults such as Brettanomyces, film yeasts or unwanted malolactic fermentations will infect the bottles altering the flavour.	Pasteurise suspect ciders before proceeding.	Are there off flavours or a visible film on the cider?	Visual Inspection and taste.	Pasteurise the cider before bottle conditioning.
3	Selecting cider – present carbonation.	Cider just finished fermenting will be saturated with CO2. As such a lower degree of carbonation is required to avoid excessive CO2.	Reduce CO2 needed for carbonation for ciders that have just finished fermenting.	Is the cider saturated with CO2	Check if the cider finished fermenting in the last fortnight.	Reduce quantity of CO2 needed by 2g/L.
4	Sugar addition	Excessive sugar addition will result in explosive failure of bottles. Insufficient sugar results in inadequate carbonation.	Calculate required sugar addition. Check SG before and after addition to confirm value.	SG increase after addition not as predicted.	Hydrometer	Add sugar if SG below value. Do not use cider if SG noticeably above value.
5	SO2 addition	Excess SO2 can cause an allergic reaction in susceptible people. The total SO2 added during the life of the cider must be recorded prior to addition.	Check records for total SO2 additions for the cider before adding SO2 prior to bottling.	Total SO2 added to cider > 200 ppm	Calculation based on SO2 additions recorded during production.	Do not use ciders above the legal limit. Do not add SO2 if it raises it above limit.
6	Pasteurisation	Inadequate pasteurisation will not kill unwanted spoilage organisms. Excessive pasteurisation will alter the flavour.	Calculate required PUs and pasteurise to hit that value without pasteurising excessively.	Have we hit required PUs?	Take regular temperature readings and add up PUs accumulated.	Re-pasteurise ciders that have received inadequate pasteurisation
7	Pitching yeast	Excessive yeast leads to excessive deposit in bottle harming appearance. Inadequate yeast leads to inadequate carbonation.	Calculate required yeast accurately. Hydrate the yeast and measure accurately	Excessive deposit or lack of carbonation	Visual inspection of finished product.	Recondition the cider in new bottles.
8	Bottling	Excessive SO2 or other no rinse sterilisers remaining in bottles prior to filling killing yeast and/or giving excessive SO2.	Rinse bottles in water prior to filling.	Is there steriliser remaining in the bottles?	Visual inspection and smell of bottles	Rinse suspect bottles in water again.

10. Bottle Conditioning Worksheet

Ingredients List

- Completely finished fermenting cider or perry.
- Priming sugar – caster sugar, fructose, glucose, sucrose brewing sugar etc.
- 10% SO2 solution.
- Yeast – preferably a champagne yeast such as Lalvin EC-1118.
- Strong beer bottles and crown caps – do not use screw cap bottles.

Equipment list

- Accurate weighing scale to weight sugar addition.
- Measuring cylinder or other container to accurately measure water to make yeast starter.
- Syringe, pippettor or other device to accurately measure yeast starter dosage.
- Hydrometer to check SG.
- Bottle filling aids to fill the bottles with the cider.
- Bulk pasteuriser if being used.
- Crown capper to seal the bottles.

Procedure

1. First check the cider has finished fermenting using a hydrometer / visual inspection of bubbles. Do not proceed if it is still fermenting.
2. Next decide on the required level of carbonation of your cider and check your beer bottles will be able to take the pressure from the tables in parts 4 and 5.
3. Then calculate the volume of the cider in litres you wish to bottle condition.
4. Now using the volume of cider calculate the required grammes of CO_2 needed to carbonate to the desired vols of CO_2 using the formula **CO_2 grammes = CO_2 vols * (1.977 * Cider litres).**
5. Using the weight of CO_2 needed calculate the weight of sugar needed using the formula **Sugar grammes = Carbon Dioxide grammes * 2.128.**
6. Test the specific gravity of the cider then dissolve the sugar into the cider and test the specific gravity again and compare it to what you would expect from the formula given to ensure it is as expected. **SG Increase = ((sugar addition in grammes / volume of cider in litres) / 2.7) * 0.001**
7. Check the total additions of SO_2 including the 30ppm you are about to add do not exceed 200ppm for the cider. If not add SO_2 to the cider to give 30ppm SO_2 using the formula below and stock 10% SO_2 solution. **Sulphite solution(ml) = (sulphite required ppm / 50) * volume of cider in litres.**
8. Check the cider for film yeast / other microbial faults and pasteurise if any are encountered.
9. Rehydrate the yeast as per packet instructions making a starter solution up using 100ml tap water.
10. Calculate viable cells per ml starter using the formula **Viable cells per ml starter = (grammes dry yeast * 6 billion) / ml water.**
11. Calculate the active cells required inputting the required cells per ml from the table in section 5 using the formula **Active cells required = (Cider Litres * required cells per ml) * 1000**
12. Calculate the ml of starter required and dose the cider using the formula ensuring the yeast is thoroughly mixed into the cider **Starter(ml) = active cells required / viable cells per ml starter**
13. Sterilise and rinse the bottles thoroughly then bottle and cap the cider.
14. Leave the cider for a couple of weeks in a warm place 15-18ºC on their side for the fermentation to proceed then transfer to a cooler place and leave to mature for 2-3 months before serving / selling.

11. Example

1 gallon (4.5L) of 2 year old Brandy Perry in 500ml crown capped beer bottles.

1. Cider has finished fermenting by inspection via hydrometer.
2. We will carbonate our example perry to 3 vols CO_2. Our 500ml beer bottles can take 3.5 vols pressure so it will be within acceptable limits.
3. One gallon (4.5L) of perry.
4. CO_2 grammes = 3 vols * (1.977 * 4.5L) = 26.6895g CO_2 needed.
5. Sugar grammes = 26.6895g CO2 * 2.128 = 56.80g sugar needed.
6. SG Increase = ((56.8g / 4.5L) / 2.7) * 0.001 = 0.005.
7. Sulphite solution(ml) = (30 ppm / 50) * 4.5L = 2.7ml SO_2 required.
8. We will assume we do not need to pasteurise here.
9. 5g packet of lalvin EC-1118 rehydrated in 100ml of tap water for 15 mins at 40ºC.
10. Viable cells per ml starter = (5g * 6 billion) /100ml = 300 million viable cells per ml.
11. Active cells required = (4.5L * 100,000 cells/ml) * 1000 = 450 million cells required.
12. Starter(ml) = 450 million cells required / 300 million viable cells = 1.5 ml required.

The finished product was kept in an airing cupboard for a fortnight and then moved to a cooler location and matured for another month before opening. All bottles were successfully carbonated and pronounced very good. Although at 9% they were definitely alcoholic and only fit for personal consumption!

Below are photographs of the finished Brandy perry produced via the above procedure.

Illustration 2: Brandy perry illustrating the yeast sediment at the bottom. Notice it is very small and compact.

Illustration 3: The final product ready for sampling. Cheers!

12. Acknowledgements / References

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