THE SCIENCE OF CIDERMAKING

Part 1 - Introduction

There has been a tremendous resurgence of interest in cidermaking over the last few years. The CAMRA 'Good Cider Guide' lists well over 100 small commercial cidermakers in addition to the 'Big 3' of Bulmers, Taunton and Showerings and Merrydown - and a general interest in all things 'green' has fostered the growth of small-scale cidermaking (author's note - there's only the 'Big 2' now, since Taunton and Showerings were swallowed up by Matthew Clarke and Merrydown fell on hard times). However, there is a quasi-religious zeal about some of the 'new' cidermaking, whose Ayatollahs proclaim the dogma on 'sinful' topics such as apple juice concentrate, yeast, sulphur dioxide and pasteurisation. Such dogma can be confusing and misleading to the novice, and seems to result from an almost wilful ignorance of the scientific principles of cidermaking. In part, this stems from a general lack of accessible information about the subject. Since the Long Ashton Research Station closed its Cider Section in 1986 there has been no 'official' source of advice for cidermakers, and the few books on the topic are mostly out of date and out of print.

This series of articles tries to fill the gap and to put the science of cidermaking into its proper perspective, so that potential small-scale cidermakers can make their own choices from the options available. There are, after all, as many different ways of making cider as there are people who make it.

Definition and History

First of all, what is cider? In the UK it is understood (and legally defined) to be a beverage made "wholly or partly from the fermented juice of apples". Similar words (cidre, sidra) are also used in France and Spain. In Germany and Switzerland, although cider is made there, there is no specific word and the term 'Apfelwein' is used instead. In the USA and Canada, 'cider' commonly refers to a cloudy but unfermented 'farmgate' apple juice, unless qualified by the term 'hard cider' to denote that it has been fermented. The word 'cider' itself is supposed to be derived from Greek or even Hebrew sources and simply means 'strong drink', although a millenium of usage now ties it in with apples.

Presently, most commercial cider is made in the UK (ca 90 million gallons annually) followed by France, Spain, Germany and Switzerland. Production in other countries is vanishingly small. Although it seems to have been made in the Mediterranean basin around the time of Pliny (1st century AD), it became well-established in Normandy and Brittany in early medieval times (from 800 AD onwards). Shortly afterwards it seems to have taken hold in Britain, and the first mention of established production in this country is from 1205.

The centre of UK cider production was (and still is) in a band stretching northwards from Devon, through Somerset, Gloucestershire, Worcestershire and Herefordshire, with sporadic local operations in Suffolk, Kent and Sussex. In the 17th and 18th centuries it seemed to have reached something of a zenith, with cider being compared

to the best French wines and exported from the West Country to London. A number of manuals on the subject were published at this time, including Worlidge's famous 'Vinum Britannicum - a treatise on Cider and Perry'. John Evelyn, the diarist, politician and arboriculturalist, published his 'Pomona' in 1670, which discusses fruit growing in general and cider making in particular, and includes contributions from authors throughout the country. This book (part of his epic 'Sylva') went through several editions and is still in print in facsimile today.

Cider did not seem to last as a serious competitor to wine (possibly due to punitive taxation), and by the end of the 19th century it seems to have been made without much care on most West Country farms. It was often considered as part of the labourers' wages, particularly at harvest time when last season's cider would be consumed. The growth of rail transport and bottling technology, however, enabled a new market to be established in towns and cities throughout the 20th century, dominated by a few large manufacturers. Now in the 1990's there is a new divergence, between the mass-market producers on the one hand and the smaller specialist producers on the other.

The Fruit

It has to be said that cider of a sort can be made from almost any type of apple. In Suffolk, Kent and Sussex, surplus dessert apples (mainly 'Cox') are used with great success. In Germany and Switzerland, little distinction is made between dessert, cider and juice apples and the ciders are very acceptable locally although somewhat thin and acidic to an English palate. In the USA (upstate New York) 'Golden Russetts' have been used to make high quality commercial ciders.

Despite this, much of the present mystique of cider making lies with the selection of 'true' cider apples - that is, those cultivars grown for no other purpose. In the West Country and in Northwest France, where arguably the finest ciders are made, these are centred on the high-tannin 'bittersweet' and 'bittersharp' varieties (if low in tannin, these are correspondingly described as 'sweets' or 'sharps'). Since these are generally unavailable on the open market except in glut years (or as concentrate from France), anyone planting a new cider orchard would be well-advised to go for these 'true' cider apples. Not only do they have the extra 'body' and 'bite' due to high tannin, but they also press much more easily than dessert apples due to their fibrous structure. Some of these varieties, at least, also possess the elusive character of 'vintage quality' which sets apart the best cider from the run of the mill. But if you do not have these apples, do not despair - just make sure you select full flavoured dessert varieties like 'Cox' and 'Russett' rather than 'Bramley' and 'Golden Delicious', with a modicum of crab apples (to supply the tannin) if you can get any.

A word about 'tannin' is probably in order here, since it is so frequently mentioned in connection with cider and yet is so frequently confused with acidity. This is perhaps because in most 'crab' apples (which are not a true species, merely domestic apples which have gone wild from seed) both acidity and tannin are high. Acidity is easy to understand - a lemon provides a good example of this. Tannin is exemplified by the mouth-puckering taste of strong tea, or by the taste of a sloe - it can be both bitter and/or astringent ('hard' or 'soft'), depending on its chemical structure and molecular size. In cider making, we need both tannin and acidity in moderate amounts, as will

appear later. The other major component we need is sugar to ferment into alcohol. This can of course come in a bag from Tate and Lyle but is better for our purpose if it comes from a bittersweet cider apple!

Milling and Pressing

Whatever kind of apples are used, they must first be milled to a pulp before the juice can be pressed out. This is rather different from winemaking where the grapes need only a light crushing to break the skins before expressing the juice. Traditionally, apple milling was done in a circular stone trough by a rotating stone wheel drawn round by a horse. From the 18th century onwards, roller mills based on two closely spaced but contra-rotating shafts were used, either hand or steam powered. Resourceful people have managed to adapt domestic mangles for this purpose, fitting the rollers with stainless steel screws to break up the fruit! Scratcher or grater mills, in which a wheel bearing coarse knives or graters rotates against a fixed surface, are also popular and form the basis of the high speed mills used in most modern cider factories. Domestic versions of this mill are also available. At worst, a food processor or a thick lump of timber may be used to smash the fruit to a pulp, or a rotating blade ('Pulpmaster') may be harnessed to the end of an electric drill.

To extract the juice from the pulp, wooden screw 'pack' presses were used from medieval times onwards. The apple pulp had first to be built into a 'cheese' using alternate thin layers of pulp and straw. Pressure was then applied to the cheese, the straw providing drainage channels so that juice could flow to a receiving tray and thence to a barrel as the compressed pulp diminished in volume. This principle is still used in many modern cider presses, large and small. The straw has long been replaced by wooden slats and terylene cloths, and the pressure is provided by an hydraulic pump, but the principle of making the cheese still remains. Small-scale versions of this press are readily available from specialist suppliers.

In the horizontal piston press (Bucher-Guyer) which is now used in large cider factories, flexible nylon drainage channels are provided throughout an enclosed steel cylinder which is filled with pulp and gradually compressed. New types of belt press, where a thin layer of pulp is squeezed continuously between two endless woven steel and nylon belts, were originally developed for sewage sludge dewatering, but have recently become popular in commercial juice and cider factories!

Small-scale basket presses are relatively cheap and widely available for domestic use, being commonly used for grapes, but they do not always give good juice yields on apples because no allowance is made for drainage channels in the pulp and not all the juice can find a pathway out. Problems with 'slimy pulp' will be discussed in a later section.

The interval between milling and pressing is nowadays kept very short by most cidermakers and is usually only a matter of minutes, the pulp being fed straight to the press. However, this was not always the case in traditional cidermaking, particularly in France, and various interesting and useful enzymic changes take place if this period lasts for several hours ('cuvage'). Similarly, the way in which the juice is treated before fermentation ('keeving') can also have important implications for cider quality. These aspects are considered in a later article.

Fermentation and storage

Once the juice is expressed, the 'new traditionalist' and the large cider maker tend to part company. The 'new traditionalist' adds nothing, doesn't interfere with the natural course of fermentation at all, and is quite at the mercy of the wild yeast and bacteria that get to his juice first! The factory cider maker manipulates the process completely, adds cultured yeast and sugar syrups, and has total technical control!

The 'new traditionalist' may by good luck produce a superb cider but all too often it is acetic, murky, full of strange odours and really quite unpleasant to drink, except to the committed fanatic or to the unsuspecting tourist who expects no better of his 'scrumpy'. The factory maker always produces a consistent product, but it is bland and undistinguished, competing with the lager market in suburban pubs and clubs. Somewhere between these two extremes lies the middle ground of highest quality where the small-scale 'craft' cider maker is aiming to operate.

Whether traditional or otherwise, certain features should remain the same. The right sort of yeast must be present, and must dominate other less desirable organisms. There must be sufficient nutrient in addition to sugar for the yeast to grow, it must convert much of the sugar to alcohol, and it must generate desirable flavour characteristics as it does so. After fermentation, most or all of the yeast should be removed and the cider should be stored in the absence of air, protected from spoilage yeasts and bacteria. Otherwise it acquires peculiar off-flavours and eventually turns to vinegar.

Exactly how we achieve these objectives is the subject of the following articles. To conclude this introduction, we list an outline flow chart for cider making, with options which any individual cider maker may choose to exercise as he wishes. These options are discussed in detail as the series proceeds.

Flow Chart for Cidermaking

MAIN PROCESS	OPTIONS
APPLES	Varietal selection Nutrient levels
HARVEST	.
STORAGE	Fruit blending
WASHING	.
MILLING	'Cuvage' of pulp Pectinase addition
PRESSING	Keeving Pectinase addition pH (acidity) adjustment SO2 addition Yeast addition Nutrient addition
FERMENTATION	Use of concentrate Addition of sugar

RACKING	Malo-lactic fermentation SO2 addition Natural (arrested) sweetening.
STORAGE IN BOTTLE OR CASK	Fining Filtration Added sweetener and preservative SO2 addition Pasteurisation

THE SCIENCE OF CIDERMAKING

Part 2 - Fruit and Cultivation

This section is aimed at the cidermaker who plans to grow his own fruit. I have assumed that he is planting up from scratch but already knows something about apple cultivation, or is able to read up the subject from one of the excellent books on dessert apple growing (such as Harry Baker's 'The Fruit Garden Displayed' published by Cassell for the Royal Horticultural Society).

To decide what cider fruit to grow we need to know a little about fruit composition. About 80% of the apple is water soluble in the form of juice, and the approximate composition of that juice in different varieties is shown in the table below.

The Composition of Apple Juice

[Figures in percent by weight]

Component	Bramley	Cox	Typical bittersweet	Ideal cider apple
Sugar	10	12	15	15
Malic acid	> 1	0.5	< 0.2	0.4
Tannin	< 0.05	0.1	> 0.2	0.2
Amino nitrogen	0 - 300 parts per million depending on cultivation			
Starch	0 - 2%, depending on fruit maturity			
Pectin	0 - 1%, depending on fruit storage period			

For reasons which will become apparent in a later section, the composition of the 'ideal' cider juice should be similar to the figures in the last column. Unfortunately, very few 'true' cider apples match this ideal, and therefore a blend of cider apples is nearly always necessary. A renowned cultivar that does approximate to the ideal is the bittersharp 'Kingston Black', but this is scarcely grown commercially nowadays on account of its susceptibility to canker. It has become more usual to plant a range of bittersweet varieties, using 'sharps' to balance the acidity or, more commonly these days, using 'Bramley' which always seems to be readily available. There is some merit, in any case, in not putting all one's eggs in the same basket as far as cider varieties are concerned.

Vintage Quality

In addition to the figures quoted in the Table, there is another elusive characteristic which can only be described as 'vintage quality'. There is no clear understanding of what this means in chemical terms - it is probably due to minute amounts of certain flavour precursors or possibly the presence of micronutrients which cause the

fermentation yeast and bacteria to act in particular ways. Nevertheless, there is general agreement that certain cultivars produce a superior quality of cider to others, even though they may not give the highest yields nor be the easiest to grow. The same is true of wine-making - in France for instance the 'Cabernet Sauvignon' is rated a far superior red-wine grape than is 'Carignan', although of course soil type and climate also play a major role. An apple successful in one area may perform indifferently in another.

Not all 'true' cider apples necessarily produce 'vintage quality'. The cultivar 'Michelin', which is widely planted for cidermaking in Hereford and Somerset, is a good example of this. As a sort of 'Golden Delicious' of the cider world, it is easy to grow and to process but provides mere bulk without any distinction. A list of high quality cider cultivars is given in the Table below.

Vintage Quality Cider Apple Cultivars

Name	Growing Habit	Flowers	Harvest	Comments
Sharps				
FREDERICK	Growth moderate, light crop, drooping and awkwardly placed growth	Early/mid	mid Oct	Very fruity and characteristic high quality, but may not store long
BROWNS APPLE	Vigorous, tends to biennialism	Mid/late	end Oct	Fruity aroma
CRIMSON KING	Large triploid	Mid	mid Oct	Large fruits but better for cider than Bramley
Mild bittersharp				
KINGSTON BLACK	Growth and cropping moderate. Slow to start bearing	Mid	mid Oct	Excellent distinctive flavour, allegedly the 'perfect' cider apple!
Medium bittersharp				
BROXWOOD FOXWHELP	Growth moderate, biennial	Early	Sept/Oct	Full body, good blender
DYMOCK RED	Moderate, spreading, biennial	Early	Sept/Oct	Good allround bittersharp
STOKE RED	Slow and very twiggy	Mid/late	end Oct	Fruity aroma, high quality, for single variety cider or blending
Medium bittersweet				
DABINETT	Small tree, precocious but grows neatly. Needs high potash	Mid/late	end Oct/Nov	Soft but full-bodied tannin. A "must have" for behaviour and blending!
MAJOR	Growth spreading.	Mid	end Sept	Excellent soft tannin

	Annual cropper			
YARLINGTON MILL	Tends to droop. Good biennial cropper	Mid	Nov	Good light aromatic cider
Full bittersweet				
ASHTON BROWN JERSEY	Moderate growth, spurs well. Good yields but biennial	Mid/late	Nov	Pronounced hard tannin
HARRY MASTERS JERSEY	Compact, good annual cropper	Mid/late	end Oct/Nov	High sugar, high tannin but fruit may not store
MEDAILLE D'OR	Smallish tree, wood tends to split. Strongly biennial	Late	end Oct/Nov	Very high but 'soft' tannin
Sweet				
SWEET ALFORD	Strong annual cropper, tip-bearer and prone to scab	Mid	end Oct	High sugar, good bulk for fermentation
SWEET COPPIN	Strong large tree. Mildew susceptible and biennial	Mid	end Oct	Good allround sweet

Generally it is considered wise to grow a selection of cultivars to hedge your bets. If you live in a traditional cider-growing area, you may already know which cultivars do best in your locality and so you may decide on these. Otherwise, you can plant a few of each and assess them as time goes on. At worst, you can always 'topwork' over the poor varieties to the better ones in later years. But do bear in mind the ultimate blend of fruit you need - a cider made entirely from heavy bittersweets may have insufficient acid and too much tannin to produce good cider, unless you blend it with the ubiquitous 'Bramley' or with synthetic malic acid from a bag!

Remember also considerations like the fruit harvesting period. Few small cidermakers can have a need for the early cultivar 'Nehou', whose fruit is ready in late August but which bruises easily and does not store. As with dessert apples, mid- to late-season varieties generally store better and produce superior quality ciders.

Location and Shelter

For orchard location, the same considerations apply as with dessert apples. Cider apples tend to flower late, so frost is not usually a problem, although overt frost pockets are best avoided. Ensure that all your trees will find a pollen partner locally by matching flowering times, or plant a few *Malus* crabs as pollinators to ensure this. Depending on exposure, a windbreak might be useful. For a small site, fast growing willows such as *Salix 'Bowles hybrid'* will reach 12 ft in 3 yrs when planted from cuttings through black polythene, and can be trimmed annually thereafter. Evergreen cypress *'Leylandii'* is also another possibility, perhaps interplanted with alder *Alnus cordata* to provide a semi-permeable screen which is more efficient than a solid wall

of vegetation. Early-leafing hybrid poplars (e.g. *TxT 32*) should only be used on the largest sites, since they are greedy feeders. Hawthorn hedges are best avoided since they are alternative hosts to the 'fireblight' bacterium *Erwinia amylovora* which sometimes affects cider plantations.

Spacing and Yield

Tree size is an important consideration. Most people nowadays go for a semi-intensive bush orchard e.g. on MM106 rootstock at 12 - 15 ft spacing or on M26 at 8 - 12 ft spacing. If the soil is poor, go for the MM106 or even MM111. These trees should start to bear after 3 - 4 years and will bear fully from year 10 - 25. If you take a longer term view, and you have space for a truly traditional orchard as a landscape feature, go for standard trees on M25, spaced 30 - 40 ft apart. They may take a decade to come into bearing, but will go on for a century thereafter! (Author's note: Consider a quincunx' planting plan in a dwarf orchard, which will allow you the possibility of strategic tree removal in future years if they get too big. I didn't do this and I regret it!!)

A reasonable yield for all trees is an average of 5 tons per acre, but this can vary hugely due to biennial bearing ('on' one year and 'off' the next) and to the extent of fertiliser application. In commercial cider orchards, 120 lbs/acre of N and 80 lbs/acre of K is typically applied annually, perhaps with the addition of phosphate and magnesium. The actual levels required are often determined by leaf and soil analysis. In an organic system, FYM might be used instead. For high quality cider, it is undesirable to feed the trees more than is absolutely necessary, and it is particularly important not to apply excess nitrogen. Yield may go up but quality certainly comes down, and there is ample evidence that the best ciders are produced from orchards low in nutrients. Aim to keep your trees just healthy, but not in the 'lap of luxury'!

Buying and Planting the Trees

Obtaining the stock and planting it follows normal orcharding practice. However, there are only a few specialist nurseries selling cider trees and you may have to wait for them to be grafted (budded) to order onto the rootstock you want. It is always best to start with maiden trees so you can train them properly from the start. Make sure you get virus-tested EMLA rootstocks and scions. Although traditional orchards were usually virus-ridden, there seems little point in repeating this tradition now that healthy stock is available. If possible, pit-plant trees individually with plenty of organic matter and bonemeal - good preparation is never wasted. They will need good stakes and rabbit/hare guards, certainly for the first few years of life.

The best orchard floor is grass, although the immediate base of the trees should be kept clear of vegetation. If sowing a new sward, a slow growing mixture of chewings fescue (60%) and browntop bent (40%) has recently been recommended, or a slow-growing perennial ryegrass (sports turf mix) may be used. Some growers like to add white clover for its nitrogen fixing abilities. The grass should be cut as frequently as required, with the mowings allowed to rot *in situ* or used as a mulch at the base of the trees. Grass should never be removed from the orchard because this can lead to severe potassium deficiency and subsequent defoliation. A final cut can be made just prior to harvest, so that the fruit has a short clean sward on which to fall. You can run

livestock e.g. sheep in traditional orchards although the tree trunks must be well protected by fencing. This is more difficult in bush orchards since both trunks and lower branches are vulnerable to browsing. As the trees mature, however, the lower tier of branches can be removed to allow for grazing if required. Chickens are an excellent alternative to sheep in dwarf orchards (and they greatly enjoy the blossoms on the lower branches!). Livestock should always be removed a couple of months before harvest to reduce the risk of bacterial contamination of fruit by animal droppings (author's note: I don't actually remove my chickens, but I DO wash my fruit throroughly!).

Pruning and Management

Pruning of bush cider trees is rather different from that of dessert apples. There is no need to go for the 'open goblet' shape, pruning of laterals etc. - in fact, pruning should be fairly minimal. Fruit size and finish is not tremendously important, and hard pruning of most cider varieties tends to stimulate excessive growth and can encourage biennial bearing. Current commercial practice favours a 'hedgerow wall' which is really designed for convenience during spraying and mechanical harvesting of the fruit. For the smaller grower, the objective should still be to maintain a good central leader with fruitful side branches as near horizontal as possible, although not all cultivars will respond equally readily to this ideal.

At planting, prune the maiden tree to a good bud about 3 ft above ground level, rubbing out the two buds below as they break in spring. Existing side branches ('feathers') below 2 ft should be cut off flush with the stem, but those above 2 ft may be retained as part of the first tier of permanent branches. In subsequent springs, the leader may be tipped slightly back to a good growth bud and the two buds below should be rubbed out. This will help more horizontal laterals to break further down, and reduce competition with the leader. Branches that do begin to compete vigorously with the leader should be cut out during the summer. Do not allow more than 2 side-branches per 4 ins vertical run of stem. In autumn, it will be worth tying down any upward pointing side-branches to a more horizontal position. Not only will this increase their fruitfullness by reducing their vigour, but by developing wide branch angles it will prevent them splitting under heavy loads when carrying fruit later.

Pests and diseases of cider trees are similar to those of dessert fruit, although the severity of attacks may be less. Scab and codling moth damage are scarcely important to the cider maker unless extremely severe, and even large cider growers may only spray routinely against mildew. Frequently, no spraying at all is required and cider apples are therefore well suited to organic cultivation. Fireblight, though, is a potential problem and is spread from blossom to blossom by pollinating insects which carry the bacterium. There is no easy solution and affected limbs should be cut out and burnt as soon as the disease is noted. MAFF should also be informed.

Biennial bearing is perhaps the biggest single headache for the cider grower. It is caused by a large crop in one year (the 'on' year) supressing flower-bud formation for the next year (the 'off' year). This pattern is often set by external climatic factors, such as a warm summer, so that all the trees in a locality tend to go 'in phase' with each other. For the UK as a whole, there is a strong biennial trend. For instance, crops in the years 1980, 82, 84 were about twice those in 1981, 83, 85. This is one of the

factors which has led many manufacturers to rely so much more on concentrated juice to even out supplies from year to year. There are various potential remedies for biennial bearing, mostly using hormone sprays to control flower bud initiation, or even using hand removal of part of the blossom in an 'on' year to ensure some crop in the subsequent 'off' year. However, most growers are understandably reluctant to substitute less 'jam today' for an uncertain 'jam tomorrow'!

Harvesting

Cider fruit should never be harvested until it is fully ripe and it is usual for much of the crop to fall on the floor before harvesting commences - the tree can be shaken to bring down the rest. Large growers use tractor mounted tree shakers, air blowers and mechanical brushes to sweep up the fruit from the orchard alleyways. This can cause some fruit damage but a small amount of bruising is usually acceptable. Smaller growers will usually be hand harvesting using buckets and barrows. Spiked-roller harvesters ('hedgehogs') should never be used because the tines penetrate the fruit which leads to inoculation with undesirable soil micro-organisms. The fruit should ideally be harvested into slatted wooden or plastic boxes for storage, although in large operations tipper trucks and concrete silos are used.

Once harvested, mid- to late-season fruit need not be processed at once. In fact it has traditionally been considered necessary to store the fruit up to a month or so after harvesting. The major reason for this is that starch in the fruit is still being converted into sugar even once the fruit is off the tree, and it is desirable that this process should be complete before fermentation. Changes in flavour precursors also probably occur. However, soluble pectin is also produced as the fruit is stored, which may eventually cause problems of sliminess when the fruit is being pressed. So it is unwise to store the fruit for too long - two to four weeks is probably a reasonable period. Traditionally, the apples are ready for milling when they retain the impression of a thumbprint after squeezing in the hand!

Before milling, fruit should be washed to remove soil, dead insects, leaves, stones, and rotten apples. It is fortunate that healthy apples float in water (pears don't!), thus providing an easy way to wash and clean the fruit. Clean water should be used to wash each batch of fruit - if the water is recycled, the dirt is recycled too! Don't be afraid of washing away the yeast - you won't! It is a popular fallacy that desirable fermenting yeasts are present on the fruit skin. There are indeed some types of yeast on the skin and in fact there can be up to 45,000 yeast cells per gram of fruit actually inside the apple itself, which get there through the open eye (where the flower petals once were). However, scientific study has shown that these yeasts (species such as *Kloeckera* and *Candida*) have only weak fermenting power and they soon die in more than a couple of percent of alcohol. They are not the *Saccharomyces* yeasts which are required for the successful completion of fermentation.

In a traditional cider-making operation where no yeast is apparently used, the inoculum resides on the press racks, the cloths, the vats, or even on the walls and ceiling. It persists from season to season but virtually none of it comes from the apples. Wild *Saccharomyces* yeasts are not very common, so this inoculum can take several years to build up but, once established, it can determine the 'house flavour' of

a particular product. It is largely a matter of luck whether this flavour is desirable or not. We return to the subject of yeasts in a later section.

Note: Virus-free cider trees and rootstocks are available from

Scotts Nurseries Ltd., Merriott, Crewkerne, Somerset TA16 5PL

Deacons Nursery, Godshill, Isle of Wight, PO38 3HW

THE SCIENCE OF CIDERMAKING

Part 3 - Juicing and Fermenting

In the last two articles we have considered the general principles of cidermaking and the cultivation of the fruit itself. In this part we look at how we can convert the fruit into a straightforward dry cider. Along the way we shall encounter a number of scientific concepts and some options to the process. Further variants will be described more fully in a later article.

Materials of construction

Before we go any further it is worth considering the equipment which will be used for milling, pressing and fermenting. I shan't repeat the description of the mills and presses themselves which was given in the first article, but it's worth stressing that only certain types of materials should be allowed to come into contact with juice and cider. Most metals should be avoided, with the noteable exception of food-grade stainless steel which is excellent but costly. Aluminium is permissible for short periods only. Iron and copper should never be in contact with cider or juice because they dissolve in the fruit acid to give strange colours and flavours. Lead is particularly

dangerous, because it dissolves to give a sweet compound which is potentially fatal. Indeed in the 18th century the so-called 'Devonshire colic' claimed a number of lives and this was eventually discovered to be caused by cider which became contaminated when standing in lead pipes overnight in pubs and inns. Similarly the old practice of lining juice tubs or press trays with lead sheeting is highly dangerous.

Wood is quite permissible and of course for many years was the only practicable material for fermentation and storage vats. It may be difficult to keep clean and free from bacteria but at least it will not poison anybody! Wood coated with modern polyurethane varnish (e.g. for press racks) is much easier to keep clean than is unsealed wood. For fermentation and storage tanks, food grade stainless steel, plastics, fibreglass and epoxy resins are generally preferable to wood, because they contain no pores where undesirable bacteria and moulds can lurk. Glass is also very satisfactory on a small-scale. If you particularly want to use wooden barrels, make sure that they are well scoured, bleached and rinsed or steamed beforehand. They should also be 'sweetened' with 5% sulphur dioxide solution (see Table) before a final rinse with clean water. It should go without saying that all equipment and containers in contact with juice or cider should be well cleaned (and well rinsed) beforehand. Modern non-foaming sterilising detergents such as 'Chempro' are most effective in this role, and should be used according to the instructions given on the packet.

Fruit and juice blending

Once the apples have been chosen, washed and milled to a pulp, they must be transported to the press in a suitable container - probably the ubiqitous plastic bucket! In the present article we shall assume that this is done almost immediately without 'cuvage' or 'maceration'. Even so, the juice and pulp will become quite brown in a matter of minutes and it is here that the natural colour of the product is determined. The press juice then needs to be collected in another container and at this point it is convenient to measure its sugar level, acidity and pH so that blending may be corrected with other batches of juice pressed on the same day. A fair amount of sugar still remains in the dry press-cake (or 'pomace') so by adding a litre or two of water to each 5 kg of broken-up pomace before re-pressing, a useful yield of slightly weaker juice may be obtained, which is usually added to the first pressing.

Previously we described the composition of the ideal cider fruit in terms of materials such as sugar, acid and tannin. Sugar levels are set largely by the weather - in a good summer we might expect them to be as high as 17%, but in a cool wet summer less than 10% might be achieved. The sugar levels can be measured directly on a drop of juice squeezed out from the fruit, using a hand held refractometer. This equipment is expensive (ca £70), but is often used by grape-growers, who need to measure sugar content daily as harvest approaches. For cider-making, the changes in sugar levels are not so critical and the fruit will usually have been stored for a while to convert all the starch into fermentable sugar anyway. So it is usual to measure the juice 'specific gravity' (S.G.) after pressing, using a hydrometer, which is much cheaper (ca £5) and available from 'Boots'. Roughly speaking, 15% sugar corresponds to an SG of 1.070 and a total potential alcohol of 8.5 %; 10% sugar is SG 1.045 and a potential alcohol of 6%. If the juice S.G. is less than 1.045 and you have no sweeter juice for blending, it should be brought up to this level by the addition of sugar or apple juice concentrate. Otherwise the resultant alcohol level may not be sufficient to protect the

final cider during storage. To raise the S.G. in 5ø steps, dissolve 12 - 15 grams of sugar in each litre of juice and re-test with the hydrometer until the desired level is reached.

Acidity and pH

The acidity is controlled more by the variety of fruit than the climate. Acidity has two aspects - total acid and pH - and both are useful to know. The total acid relates well to our perception of acid flavour, while the pH relates better to various aspects of fermentation biochemistry. These two are connected but not in a simple way, although the acidity always goes up as the pH goes down and vice-versa. In terms of total titratable acid (as malic), we should be looking for 0.3 - 0.5% in a cider juice. If the total acid is too low, the pH will be too high and the fermentation will be susceptible to bacterial infections. If the total acid is too high, the pH will be low enough to safeguard against infection but the final cider will be unacceptably sharp to the palate and may never be pleasant to drink. Acidity can be measured by titration - details will be found in any good wine-making book. Kits for measuring titratable acidity are available in the wine-making section of 'Boots'.

Measurement of pH has to be done by a dedicated 'pH meter'. These used to be very expensive, costing several hundred pounds, but modern 'chip technology' has now brought them down to the range of £30 or so. However, beware the very cheap pH meters which are sold in garden centres for soil testing - these are not accurate enough for cidermaking because we need to measure to at least the nearest 0.1 pH unit or it is not worth making the measurement at all! A desirable juice pH range for cider-making is say 3.2 - 3.8. At higher pH the fermentation will be subject to microbial infection and at pH 4.0 or above this can lead to serious flavour problems. Many traditional bittersweet cider apples tend to be high in pH which is why they need blending with more acid fruit, preferably before fermentation. That is one reason why bittersharp apples, such as 'Kingston Black', have been regarded as near perfection in terms of their composition for single-variety cider making.

If you cannot measure the acidity or the pH, taste the juice instead. Trying to ignore the sweetness and the tannin, judge whether the juice is insipid, balanced or sharp. If insipid, and you have no other juice for blending, malic acid may have to be added in steps of 1 gram per litre (0.1%) until the balance is improved. If the juice is too acid, and you cannot blend it out, you may have to encourage a malo-lactic fermentation to reduce it (see later), or you can add a little calcium carbonate to neutralise it, in 1 gram per litre steps. Malic acid and calcium carbonate (as 'precipitated chalk') are also available from 'Boots' (note that citric acid may lead to bacterial flavour defects in the final cider and should not be used unless malic acid is completely unavailable).

Other juice parameters, such as tannin, are difficult to measure, but only people using a high proportion of bittersweet fruit are likely to suffer from excessive tannin and this can usually be detected by taste although the juice sugar does tend to mask it. Deficiencies here can be corrected after fermentation, however. The purpose of blending before fermentation is to give a juice as close in composition to the 'ideal' which was described in the previous article. Although this may not always be possible, it is always worth the attempt at least in terms of sugar and acid levels.

Blending after fermentation is a worthy and useful art but it cannot correct a gross biochemical imbalance beforehand!

Juice preparation

Apart from the blending corrections described above, you can of course always add sugar, glucose syrup, synthetic malic acid and apple juice concentrate to any desired extent along with water. On a commercial scale there are considerable cost advantages to be be gained by doing so, since sugar and water are much cheaper than apple juice, but these have to be weighed up against the ultimate quality of the cider you wish to make. Excessive dilution will make the cider 'thinner' in its overall complexity of flavour and cannot be recommended for a high quality product.

The blended juice should now be strained through a coarse plastic mesh into a suitable clean vessel for fermentation, and at this point a number of other additions may be made. If it is important that the final cider should be sparklingly clear, a pectolytic enzyme may be added, which will help to ensure that all the pectin is broken down. Pectin is a sort of natural glue which sticks the apple cells together. Although it is water-soluble it is precipitated by alcohol, so it tends to lead to persistent hazes by the end of fermentation. Dessert fruit, or long-stored fruit, tends to suffer more from pectin release than does bittersweet fruit and will often give a very cloudy cider unless depectinised. Although there are natural enzymes in both apple and yeast which will break down the pectin during fermentation, these enzymes are often rather weak and require some assistance. The dosage rates for the commercial enzymes are given by the suppliers - small quantities are available from 'Boots' and larger quantities from specialist suppliers (see list at the end of this article).

The next addition is that of vitamins and yeast nutrient. These may be bought as such or may be added as thiamine and ammonium sulphate (or phosphate) respectively. The dosage rate is up to 0.2 milligrams per litre of thiamine and up to 300 milligrams per litre of ammonium salt. This is what was meant by 'amino nitrogen' in Table 1 of the previous article, and it is needed by the yeast to make protein and amino acids for its own growth. (This is not unlike human and animal nutrition - the yeast's carbohydrate or energy source is of course the apple sugar which is not in short supply!) Apple juices are generally very low in yeast nutrients (unlike beer worts or grape musts) and so your fermentation rate will probably be much improved if you add these. The fermentation is also much less likely to 'stick' or to grind to a halt before completion. The cider can therefore be racked and bottled sooner, reducing the chances of spoilage in store. On the other hand, it is undeniable that some of the finest ciders are fermented very slowly without the addition of nutrients, but the risks of failure are correspondingly greater. You pays your money and you takes your choice! Traditional cider-makers used to hang a leg of mutton or a side of beef in the fermenting vat to boost the nutrient levels. The meat broke down slowly in the acid juice, releasing soluble amino nitrogen which the yeast could use for growth. The supposed requirement of a few dead rats in every vat is a more colourful manifestation of the same idea!

Sulphur Dioxide

The next addition is that of metabisulphite, sulphur dioxide or SO2, which are all synonyms for the same thing. This topic always inflames great passions amongst the purist cidermaking lobby, who regard it as dancing with the devil - perhaps it is the connection with brimstone which worries them! However, it has a long and honourable history and the use of burning sulphur candles as a sterilant in wine-making is supposed to date back as far as Homer. Certainly it was in use for cider-making from Elizabethan times, and the controlled addition of metabisulphite is far more accurate than the haphazard application of sulphur candles could ever be.

In simple terms what happens is that the sulphur dioxide inhibits the growth of most spoilage yeasts and bacteria, while permitting the desirable fermenting yeasts (such as *Saccharomyces cerevisiae* or *uvarum*) to multiply and to dominate the conversion to alcohol. Only small amounts of sulphur dioxide are used, and its effectiveness depends on the pH of the juice. The Table shows the appropriate levels to use when a cultured yeast is being added for the fermentation. Lower levels are needed if a 'wild' *Saccharomyces* fermentation is required (see below), or there is a danger that all the wild yeast will be killed. In the absence of sulphur dioxide, the fermentation is much less likely to be 'clean' although with care it is possible to do without it. A great deal of the concern about sulphite derives from its excessive use at bottling not during fermentation, and from the fact that a very few people are hypersensitive to it in the free state. However, it must be stressed that no sulphur dioxide remains free by the end of fermentation, since it becomes bound to various intermediate chemicals (principally acetaldehyde) which the yeast produces on its route from sugar to alcohol. I would always advise the beginner to use sulphur dioxide to minimise the risk of taints and infection. Later on, the experienced cidermaker can omit it at his discretion and see what difference it makes.

Addition of Sulphur Dioxide

Juice pH	SO2 needed in parts per million (ppm)	Campden Tablets per gallon or ml. of 5% SO2 stock solution per litre
Above 3.8 (insipid)	.....Lower pH to 3.8 with addition of malic acid.....	
3.8 - 3.5	150	3
3.5 - 3.3 (balanced)	100	2
3.3 - 3.0	50	1
Below 3.0 (sharp)	None	None

Notes

1. If a pH meter is not available, use the taste of the juice as a guide

2. To make a 5% stock solution of sulphur dioxide, dissolve 8 grams of sodium metabisulphite in 100 ml of water. Then 1 ml of this per litre of juice (5 ml per gallon) corresponds to 50 ppm (parts per million) of SO2

3. Campden tablets are formulated with metabisulphite to give the equivalent of 50 ppm sulphur dioxide when each is dissolved in 1 gallon of liquid.

The Yeast

This brings us to the final addition, that of yeast. There are so many good dried wine-making yeasts on the market today that it is well worth considering their use. All of them will get a fermentation off to a good start within hours, by providing a massive inoculum of healthy yeast cells which will multiply quickly and swamp out anything undesirable. Some of these are more cold-tolerant than others and are capable of fermenting even down to 5ø C, which can be a great boon to a British cidermaker whose raw material may not be ready until early November. Some yeasts claim to confer specific flavours e.g 'Burgundy', 'Champagne' but these claims should be taken with a pinch of salt and in any case are probably not relevant to cidermaking. Stick to a good general purpose wine yeast - not a brewer's yeast and never a baker's yeast, since these have been selected to have other properties which we do not require. There is no need to select a yeast with a high alcohol tolerance since the natural sugar of apples will rarely produce more than 8% alcohol. If you fortify significantly with sugar and you want alcohol levels up to 12%, then you are making apple wine - not cider! Large commercial cidermakers do just that (known as 'chaptalisation') and then dilute the cider with water for retail sale, but this series is not concerned with that sort of business.

For small quantities of branded wine yeasts, 'Boots' is again a good bet (and, no, I don't have shares in the company!). On a larger scale, you can buy specific strains of *S. cerevisiae, bayanus* or *uvarum* which are mostly produced in Central Europe by firms such as Novo and Siha for the wine and fruit wine industry there. These are available through UK agents (see address list). Generally the yeast is grown up overnight as a 'starter' in sterile juice or sugar solution, and then pitched into the main bulk the next day. If sulphur dioxide is used, it is very important to wait overnight before adding the yeast culture. This is because the sulphur dioxide needs time to act against the wild organisms, and it will also inhibit the added yeast too strongly if they are all added together. By standing overnight, the free sulphur dioxide largely disappears once its work is done, giving the added yeast a chance to get away without significant inhibition.

Fermentation should commence within 48 hours if an active yeast culture is used. As an alternative, it is possible to rely on the few natural *Saccharomyces* yeasts which will be present in the juice after sulphiting, and allow them to multiply to sufficient levels to start the fermentation, but this may take up to a fortnight. If neither sulphite nor yeast are added, the juice will probably start to ferment within a day, but the wild yeasts which multiply under these conditions cannot be guaranteed to produce desirable flavours. In any case, they will begin to die after a few days as the alcohol level rises, leaving the fermentation at the mercy of any other dominant organism which has been able to establish itself. If you are lucky, this may be a useful *Saccharomyces* species - if you are unlucky, you have only yourself to blame!

In summary, therefore, I recommend the beginner to use a pectolytic enzyme, to use sulphur dioxide and to add a cultured wine yeast after standing overnight. You can perhaps skip the nutrients unless the fermentation begins to 'stick' or unless you know

that your fruit comes from big old trees with very low nutrient levels and you are not prepared to wait a few months. The progress of the fermentation should be monitored every few days with a hydrometer and the fall in S.G. plotted on a graph against time (a fall of one degree S.G. per day is pretty reasonable). This makes it much easier to see whether sticking is occurring, and the nutrient and vitamin can be added then if necessary.

Conduct of the fermentation

In the initial stages of fermentation, there is considerable frothing and evolution of carbon dioxide as the yeast multiplies and begins to break down the sugar into alcohol. There may be as many as 10 million yeast cells per single ml. of juice at this stage, so it is easy to understand that there is a lot of microbiological activity going on! A loose plug and the outpouring of gas will probably ensure that nothing undesirable can creep back into the fermentation vessel, be it a demijohn, a barrel or a 5,000 gallon stainless steel tank. When the initial frothing subsides, however, it will be worth topping up the vessel with a 10% sugar solution and fitting a fermentation lock to ensure that the flow of gas remains one-way. As you follow the drop in S.G. with time, it will begin to level off and you should consider the first racking of the cider from its yeast at an S.G. of 1.005. If it stops fermenting at an S.G. much higher than this, then it may be 'stuck', and nutrient addition together with twenty minutes vigorous aeration may help the yeast to grow again (the yeast does need some oxygen for growth). It may also stop if the temperature falls too low, but this should need no attention from the cidermaker. When the weather warms up again, the fermentation should re-commence. In fact, a cool fermentation (ca 15ø C) is generally preferred for cider and there is no need to keep the fermentation especially warm.

If the cider is particularly acid at this stage, the first racking may be delayed for a month or so to encourage the 'malo-lactic fermentation' which is described below. In general, however, it is bad practice to leave a fully fermented cider on its yeast lees for more than a few weeks.

The first racking should be into another clean vessel, trying to leave behind as much yeast as possible and with the minimum of aeration to the cider. This is generally done with a clean plastic syphon tube fixed to a wooden rod so it rests just above the yeast deposit or, on a larger scale, with a suitable pump. The transferred cider should be run gently into the bottom of the new vessel without splashing. Now that there is much less carbon dioxide to protect the cider, it is important to minimise the headspace and to prevent air contact as much as possible. This is partly to keep out any undesirable film yeasts or bacteria, and partly to prevent 'oxidation' which leads to flat dull flavours and a loss of freshness. This is why some people add 50 ppm of sulphur dioxide at every racking, although at the first racking this is probably unnecessary because of the remaining carbon dioxide. Sulphite added at this stage will almost certainly inhibit the malo-lactic fermentation, which may or may not be required (see below).

Maturation and Bottling

After the first racking the air-lock is re-fitted until it is clear that gas evolution has ceased, when the vessel should be topped up with water or cider and tightly closed. A

second crop of yeast will be thrown as the cider settles down. The cider may remain in this state for several weeks or months, before a final racking to a closed container for bulk storage or directly into bottle. It is important that it should not sit for long on a heavy crop of yeast, because the dead yeast will 'autolyse' which tends to give unpleasant flavours. However, a small amount of autolysis from the second crop may be helpful, because this releases nutrients which stimulate maturation through the so-called 'malo-lactic' fermentation. This phenomenon is due to a specialised group of bacteria (*Lactobacillus* or *Leuconostoc* species) which convert the malic acid of the apple to lactic acid, giving off more carbon dioxide in the process. Often, this happens in the spring when the trees are flowering, giving rise to the notion that somehow the trees and the cider are working in sympathy! Generally the malo-lactic fermentation is to be welcomed, since it lowers the acidity and gives additional rounder smoother flavours, although in very low acid ciders it can reduce the acidity too far. In bittersweet ciders it produces characteristic 'spicy' notes (often detectable in ciders from Normandy). It may be recognised by the evolution of gas without renewed turbidity (if a yeast re-ferments a sweet cider it becomes cloudy because the yeast cells are so large (typically 10 microns). Malo-lactic fermentations, unless very heavy, tend to remain clear because the bacteria are so small (typically 0.5 microns).

The malo-lactic fermentation is difficult to produce at will although some strains of lactic bacteria are now available commercially for use in the wine industry. It may definitely be prevented by the additional use of sulphur dioxide at racking. Sometimes it reduces the acidity too far and sometimes the 'wrong' organisms take hold, producing other defects such as 'ropiness' (which will be covered in a later article). But if the original juice pH was no higher than 3.8, the chances are that this fermentation will be beneficial if it happens at all. Even if it does not, the cider will mature for several months as its flavour balance stabilises and the harsher notes are smoothed out by slow chemical and biochemical reactions.

However, ciders do not generally profit by extended ageing and by late spring or early summer the cider will be ready for bottling and drinking, or for a second racking into bulk store. The golden rule at this stage is to minimise air contact whenever the cider is handled - it is a matter of preference whether you wish to add sulphur dioxide (ca 50 ppm) to help with this, but in any case you should not exceed a total addition of 200 ppm SO2 to any cider when all additions at fermentation and bottling are summed up. A dry cider with no added sugar and sufficient alcohol should be quite stable in clean, closed and well-filled bottles, and should stand a minimal risk of any unwanted conversion to vinegar!

We have now looked at the steps in producing a still, dry cider which is the easiest sort to make. In the next article we shall look at variations of this process to produce other types of cider.

Suppliers Names and Addresses

Mills, presses, tanks and fermentation sundries are available from

Vigo Limited, Station Road, Hemyock, Devon EX15 3SE

Specialised yeasts, enzymes and nutrients (in commercial quantities only) are available from

Three Choirs Vineyard, Newent, Gloucestershire (agents for Novo yeasts and enzymes)

Begerow Ltd., 15 High Street, Great Budworth, Northwich, Cheshire CW9 6HF (agents for Siha yeasts, pectinases and Beco filtration equipment)

The 'Gervin' range of winemaking yeasts are high quality European yeasts which have been repackaged especially for the amateur winemaker and are available from specialist 'home-brew' shops.

Larger branches of 'Boots' chemists carry a wide range of wine-making chemicals and sundries in domestic quantities.

Hand-held refractometers are available from

Bellingham and Stanley Ltd., Longfield Road, Tunbridge Wells, Kent, TN2 3EY

Low-cost pH meters are available from

Whatman Labsales Ltd., St. Leonard's Road, Maidstone, Kent ME16 OLS

Leading Edge Technology, 121 High St., Berkhamsted, Herts HP4 2DU

THE SCIENCE OF CIDERMAKING

Part 4 - Customising your cider

In the last article we looked at the production of a straightforward dry, still cider. In this part we shall look at the production of sparkling and sweetened versions, concluding with an outline of a traditional French and English technique which many regard as the pinnacle of the cidermaker's art.

Dry carbonated cider

To get some bubbles into our cider we need to incorporate excess carbon dioxide under pressure and to put the cider into bottles or into a keg which will withstand it. Then, when the pressure is released and the cider is dispensed, out come the bubbles! This is done commercially by chilling the cider and dissolving two or three volumes of carbon dioxide in the liquid using special equipment. Small scale commercial carbonation units can be bought or, on a domestic scale, a bottle or two can be carbonated using a soda-syphon and a 'Sparklets' bulb.

It is more satisfying, however, to allow the fermentation itself to generate the carbon dioxide by 'natural conditioning'. One way of doing this is by racking and bottling the fermentation early, say at a gravity of 1.010, and allowing the cider to finish fermenting and to mature in the bottle. The CO_2 produced will dissolve in the cider to produce bubbles when the bottle is opened. A drawback to this technique is that the yeast deposit in the bottle may be rather heavy and coarsely flavoured. An alternative is to rack the cider into bottles after fermentation to dryness, adding a small amount (10 g per litre) of priming sugar to each bottle, and allowing a secondary yeast fermentation of the added sugar to produce the gas. This can be very successful although the bottom of each bottle will inevitably be a little cloudy when poured, because there will always be some yeast deposit which will be roused up when the pressure is released. This problem can be lessened on a domestic scale by storing the conditioned cider in a pressurised keg or barrel similar to those used for home-made beer. In these devices the yeast drops to a below below the draw-off tap and a bulk, sparkling and clear cider is easily achieved. The ultimate way of avoiding the yeast problem is to produce a cider by the 'methode champenoise', in which the yeast is removed by inverting and turning the bottle in stages until it is all collected in the neck. This is then frozen in an ice-salt mixture, the bottle is opened, the frozen yeast plug is forced out by gas pressure, and the bottle is topped up and resealed before the majority of the gas can escape. The quality of such ciders is legendary, although for obvious reasons they have not been produced commercially in the U.K. for many years!

Any bottles used for carbonated ciders must be designed to withstand the pressure generated by the gas, or there is a serious risk of them bursting and causing injury (not to mention the mess!). Some years ago there used to be quart cider bottles with internal screw threads and special threaded stoppers, but these no longer exist. An alternative is to use glass beer bottles which are sealed with a crown cork - these and the capping tools are widely available from home-brewing suppliers. The industry has now gone over almost entirely to PET (polyethyleneterephthalate) bottles which are lightweight and hold a moderate pressure well. Also, if they do burst, there is no risk of injury from flying glass. If you are making a small amount of cider for home use, you can recover, rinse and re-use these bottles several times if they have previously contained other carbonated drinks. If you cannot scrounge sufficient secondhand bottles or you are working on a larger scale, you may have to buy new PET bottles

from a specialist supplier. Non-carbonated ciders can of course be bottled in wine bottles with regular corks if required, but the bottles must be stored on their sides to prevent the corks drying out and the air getting in (which will cause spoilage).

Sweet ciders

Even the 'dry' ciders described above will have a little residual sweetness, from the small amounts of non-fermentable sugars which exist in the original juice. However, many people prefer an overtly sweeter cider and so some way often has to be found of adding or retaining some sugar without running the risk of it re-fermenting. This is difficult if any yeast remains in the presence of an adequate supply of nutrients, because it will immediately get to work on the added sugar. Commercially, the problem is tackled by centrifugation and filtration of dry cider to remove most of the yeast, followed by pasteurisation to eliminate the remainder after the addition of sugar. This is not so easy to do on a small scale, although disposable-sheet filter units which can give near-sterile filtration (if properly operated) are available. These range from the types sold in 'Boots' up to small commercial types with stainless steel housings and fittings. The sweetened bottled cider can then be batch pasteurised in tanks of hot water e.g. at 68^{o} C for 20 minutes, although it is much more efficient to use a proper flow-through heat exchanger operating at 90^{o} C with a residence time of 30 seconds so that the pasteurised cider is filled directly into warmed bottles. Equipment of this sort does not come cheap and can usually only be justified in the context of a commercial operation.

Traditionally, naturally sweet ciders were made from slow fermentations which are poor in nutrients. Ciders which show an S.G. loss of less than one degree per day are suitable for this treatment. The cider is racked initially into a new clean tank at say S.G. 1.030, leaving most of the yeast behind. The fermentation will then become even slower, and the sweet cider is racked again (and preferably filtered) at S.G. 1.020 - 1.025. (Racking at S.G. 1.015 will give a medium sweet cider). After this racking it is worth waiting several weeks (under an air lock) to ensure that no further fermentation takes place, before sealing the vat tightly or bottling off.

It is best to choose days on which the barometric pressure is high for these operations, since this will help to keep suspended yeast to a minimum and will retain the maximum amount of dissolved carbon dioxide in the cider. The success of the whole process depends on reducing both yeast and nutrient levels to a minimum so that re-fermentation of the remaining sugar is unlikely to take place. Sweet ciders of this sort may have a slight 'prickle' to them, particularly in bottle, since a slow fermentation may continue to generate carbon dioxide. The procedure described is ideal for single-variety demonstration ciders or for those which need no further blending - the flavour tends to be 'fruitier' since the sweetness is derived from unfermented juice rather than from added sugar. The alcohol level in the cider is of course less than if it had been fermented to dryness because only a part of the sugar has been converted. Ciders which do need blending (see below) are best fermented all to dryness first, before blending and finally sweetening after a further period of storage.

If you want to sweeten dry ciders with added sugar (or with frozen or concentrated juice) but you do not want to pasteurise or filter them, it is important that they should be racked and stored for several months after fermentation is complete, to allow the

yeast to die out completely before the sugar is added. Otherwise the risk of re-fermentation is considerable. The chances of re-fermentation can be reduced by the addition of yeast inhibitors such as potassium sorbate and benzoate at levels up to 200 ppm. (Both these materials occur naturally in rowan berries and cranberries respectively). Potassium sorbate may be bought as 'wine stabiliser' from Boots or from other specialist suppliers. It is most effective if combined with say 50 ppm of SO_2 added at the same time. If the cider is to be sold, however, a total of 200 ppm for the sum of sulphite and sorbate must not be exceeded. Other additions, such as saccharin (which is of course not fermentable), may also be made to enhance the sweetness of the cider itself. Under present legislation, none of these additives need be declared on the label when added to ciders for sale. Although these materials are perfectly safe, they do have certain drawbacks - saccharin has a noticeable aftertaste and sorbate may lead to 'geranium-like' off-flavours in the presence of malo-lactic bacteria. Most small-scale cidermakers will probably wish to avoid them.

Blending

Blending of ciders, if required, should always be carried out well before the final racking for storage or bottling. This is because the changes in acidity, nutrients and yeast levels, which occur when different batches are mixed, may affect the stability of the bulked cider and allow it to ferment further, even if the individual ciders were stable before blending. Similarly, if clear ciders are blended together they are quite likely to throw down a new haze or deposit which may need time to settle down. The general principle of blending is to ensure a flavour balance which is unobtrusive, particularly in terms of its acidity and tannin. It is best to take small test quantities of the ciders to be blended, and sweeten these first to the S.G. which will be required for the final blend (1.025 for sweet, 1.015 for medium sweet). Then a measuring cylinder should be used to blend equal parts of those ciders which are highest and lowest in tannin. The proportions should be varied until acceptable tannin levels are achieved, and the operation repeated for any other ciders which are unbalanced in tannin composition. If the tannin levels are too low because no bittersweet fruit was used, it is possible to increase them by the addition of grape or other food grade tannin (in 0.1% steps) until a satisfactory level is achieved. Careful note should of course be taken of the volumes used for blending and the amount of any tannin added. If the tannin levels are too high because of a large proportion of bittersweets, then fining with gelatin can be considered. This is covered in the next article.

The trial blends which are now balanced for tannin can be blended for acidity following a similar routine. If the addition of acid is required, malic acid may be used in 0.1% steps. Removal of acid is difficult at this stage, but may be done if necessary by the addition of potassium carbonate - calcium carbonate used here tends to leave a residual chalky flavour in the cider. The trial blends now have the correct tannin and acid balance, and they can finally be corrected for other more subtle flavours and aromas by blending amongst each other. Finally, the main bulk of ciders can be blended according to the proportions determined by the trials but without the addition of the sugar at this stage. For reasons explained above, the ciders must be allowed to stabilise further in bulk store before correcting the sweetness (unless filtration and pasteurisation are used to prevent all possibility of re-fermentation).

French and English tradition

We have now seen how to ferment, blend and bottle a number of styles of cider. It is now worth looking at the production of high quality naturally sweet ciders by the best traditional French and English methods. The objective of these is to lower the nutrient status in various ways so that the fermentation remains slow and the natural sugar can be retained without fear of re-fermentation.

A blend of fully ripened sharp and bittersweet fruit is used for these ciders, taken from mature orchards which are naturally low in nutrients but fairly high in tannin. Dessert fruit is much less likely to be successful here, due to its generally low tannin and high nutrient levels. The sugar level should be at least 12% (SG 1.055). The fruit is stored until a cold day late in the year when the temperature is about 5^{o} C and expected to remain so for a week or more. The fruit is washed and milled in the normal way, but the pulp is then packed into barrels (or, better, plastic containers) to stand for up to 24 hours. This is the procedure of 'maceration' or 'cuvage', terms with no particular English equivalent. During this time, oxidation slowly proceeds which develops the juice colour, and pectin leaches out of the apple cells into the juice. The juice is then pressed out, rich in colour and thick in texture, and is run into clean tanks which are allowed to stand without sulphiting or the addition of yeast (author's note: If the pH is around 4, which it is likely to be, I do actually add 100 ppm sulphite at this stage to provide some inhibition of bacterial infection. The 'official' French recommendation is to burn 10 grams of sulphurated string in the barrel!!)

Since the temperature is low, no significant yeast fermentation takes place, but the natural pectic enzymes in apple juice slowly change the pectin to pectic acid. This forms a gel with the natural calcium in the juice and a 'brown head' (the 'chapeau brun') rises slowly to the surface. Some of the pectin also combines with juice protein and tannin and falls as a sediment to the bottom, leaving a clear juice between the two. To make this process more reliable, a mixture of calcium carbonate (3 g per 10 litres) and sodium chloride (4 g per 10 litres) is often added to the fresh-pressed juice - the calcium helps to form the gel, while the chloride helps to inhibit the growth of any yeast (author's note: I add 400 ppm (4 g per 10 litres) of calcium chloride which is a one-shot way of achieving the same thing). A specially prepared pectin methyl esterase enzyme (which is not the same as a regular pectinase and is available only in France as Klercidre) can also be added. This process is known in French as 'debourbage' or 'defecation' (for obvious reasons!) and in English as 'keeving', and generally takes about a week. If things go wrong, and a yeast fermentation starts too early, a 'white head' (the 'chapeau blanc') is formed. This means that the whole vat has become turbulent and the keeving has failed!

If the keeving has been successful, however, the clear juice between the top cap and the bottom sediment is very carefully pumped or syphoned into a fermentation vat. It is now allowed to ferment under an air-lock in the normal way (with its own yeast), but this fermentation will be very slow because most of the nutrients in the juice will have been left behind in the 'brown head' and in the sediment. In fact, scientific study has shown that the pectin and the amino nitrogen nutrients are reduced by at least 50% during keeving. With such a slow fermentation it should be no problem to make a naturally sweet cider, by racking at S.G. 1.030 and proceeding as described earlier. Preferably the ciders should be bottled in crown-cap beer bottles which are stored in a cool place for maturation -they CAN get quite fizzy if allowed to warm up too much during the summer!

The advantage of this process is that it can produce a naturally sweet and well-coloured cider, brilliantly clear due to the removal of pectin during keeving, and full of flavour because of the low nutrient levels during fermentation. The disadvantage is that a lot of it depends on luck - the correct fruit, cold weather, benevolent strains of wild yeast and freedom from bacterial infections! What actually happens is that the fermentation begins with so-called apiculate' yeasts from inside the apples predominanting - these then slowly die out as the alcohol level rises and the *Saccharomyces* (wine yeasts') slowly take over to complete the job. If you get the chance to look at the yeasts under the microscope, as I have done, you'll see all shapes and sizes of organisms imagineable. This is quite different from a fermentation with an added yeast, where all the cells are identical.

(Author's note: In my experience, the flavour immediately after even a well-conducted 'natural' fermentation is heavily dominated by ethyl acetate, and can be really quite unbalanced and unpleasant to drink. A few months storage in bottle, however, can work wonders in blending out these flavours to something really magnificent. Not everybody likes it, though - a friend of mine described my best quality cider as 'tasting like smoky bacon' (which is due to the natural tannins breaking down to give 'spicy' flavours)!!)

There is plenty of scope here for anyone who wishes to experiment with different parts of the process. For instance, the final colour and clarity of the cider is critically dependent on the length of 'cuvage', during which the oxidising enzymes produce colour from the tannin, and the pectin slowly migrates out of the fruit into the juice. If the pulp is held too long a time, the rich orange colour of the final juice will actually diminish and the flavour will become insipid due to excessive adsorption of oxidised tannin back onto the pulp. If the pulp is held too short a time, not enough pectin will migrate out into the juice to form a good 'head' during subsequent keeving and so, paradoxically, effective clarification and nutrient removal will not be achieved. If the pulp is tightly packed and too little air is present during 'cuvage', too little colour will be developed - but if the pulp is loosely packed and too much air is present, spoilage organisms (vinegar bacteria) will quickly take hold. If the weather is too cold, none of the desirable enzyme activity will take place - but if conditions are too warm, yeast fermentation will begin too early and the keeving will fail. If the pH of the fruit is too low (less than 3.6) the natural pectinase activity may be too slow to form a successful 'brown head' - but if the pH is too high (greater than 4) undesirable film yeasts will develop to the detriment of the required *Saccharomyces* species.

Balancing these factors (and many more) relies on judgement and experience and was part of the skill of the traditional cider maker, although he knew nothing of the biochemistry behind it. The new traditionalist should be able to build on this skill the better, if he only bears in mind the scientific principles of what he is trying to do!

So far we have considered cidermaking when everything goes according to plan. In the next part of the series we shall look at some of the more common things that may go wrong, and what we can do about them.

THE SCIENCE OF CIDERMAKING

Part 5 - When things go wrong

So far we have looked at cidermaking when everything goes according to plan. Inevitably, however, there will be occasions when things don't work out as expected, so in this section we shall look at various problems and some possibilities for their solution.

Slimy Pulp

If you are lucky enough to have genuine cider apples to use, and they're not stored for too long, you are unlikely to have problems with slimy pulp. True cider fruit has been selected over many generations to press cleanly and to leave a dry and handleable pomace (which is another good reason for using it if you possibly can). Remember, though, that the pulp should not be milled up too small, even with genuine cider apples - we are not aiming for apple-sauce! The ideal size for pressing is little nuggets of apple each about the size of a pea, which gives the best compromise between juice yield and ease of pressing.

With dessert apples, however, no matter how carefully you mill the fruit, there is always a tendency for pectin to leach out of the cells and to be partially broken down by the natural fruit enzymes while pressing. This is particularly true if the fruit has been stored for any length of time. The result of this is a 'cheese' of slimy pulp, which clogs up the press-cloths and makes it impossible to get a decent yield of juice. 'Golden Delicious' is especially bad in this respect. Under these circumstances you may find that light continued pressure over many hours gives you a better result than a hard quick squeeze. Even so you may have to resort to other measures. In the USA, 'press-aids' such as wood pulp or rice hulls are sometimes used, mixed with the apple pulp to provide better drainage pathways. An alternative is to press mixed loads of fruit if you can, the better with the poorer. If you can press a mixture of desserts and bittersweet, the tannin and the superior structure of the bittersweets will help to offset the poor characteristics of the dessert fruit.

The best solution is to apply a pectic enzyme to the pulp. In this case, you are aiming to complete the total breakdown of the pectin, to overcome its partial breakdown in the apple which is causing all the problem. You can use the same type of pectolytic enzyme which we described earlier for juice preparation, although the dosage rate will need to be about twice as high. The enzyme should be well-mixed with the pulp and allowed to stand, at 55øC for 2 hours or at room temperature for up to 24 hours. For most people, an overnight incubation in the cold will be the most practical solution. Next day, the pulp should press cleanly and easily, and you won't then need to add any more enzyme to the juice before you start to ferment. This technique is suitable

for mainstream cidermaking - it cannot of course be used if you are trying traditional 'keeving', because the pectin will be broken down too far and you will upset the natural balance of the juice. (In France, however, it is possible to buy special pectolytic enzymes which are suitable for keeving procedures).

Fermentation and storage problems

We have previously mentioned the effects of temperature, nutrients and so forth on fermentation, the possible use of sulphur dioxide, and the need to keep air out of the system. In a good and active fermentation, few problems should arise if these precautions are observed. In slower fermentations or in early storage, there are three classical microbiological problems which may crop up.

Film yeasts (generally of the genera *Candida*, *Pichia* or *Hansenula*) will readily contaminate a slow and unsulphited fermentation. The organisms are present on the fruit and thrive in aerobic conditions, so they sometimes appear on the top of slowly fermenting or stored ciders where they will start to break down the sugar or the alcohol. Their presence is often detected by a strong smell of ethyl and amyl acetates, reminiscent of the solvents used in nail-varnish remover. In small amounts these compounds are important contributors to the overall flavour of cider but as soon as they become obvious then you have a problem. Sometimes more unpleasant musty or oxidised flavours are formed instead. The yeasts themselves form a greasy/powdery film on the surface of the cider, breaking up into small white sheets and dropping to the bottom of the vessel when disturbed. Prevention is better than cure but, if film yeasts take a hold, keep the vessel well topped-up to exclude air and add 100 ppm SO2 to keep the organisms in check. The cider may still be usable if infection has not gone too far but extra care must be taken during handling to make the conditions for their growth as unfavourable as possible. Vessels where infection has occurred should of course be properly sterilised before re-use.

Acetic acid bacteria of the *Acetobacter* family are often confused with film yeast because they too tend to grow on the surface of poorly stored ciders. They oxidise the alcohol to acetic acid directly and so the cider smells and tastes of vinegar rather than of solvent. Acetobacter tend to form jelly-like sheets on the top of the cider - these do not break up when shaken but fall to the bottom all in one piece. They are aerobic organisms just like the film yeasts, however, so the same preventative and remedial measures should be effective. If the cider is too acetified for your taste, it can be neutralised by the careful addition of potassium carbonate. Alternatively the cider can be stored in a tightly sealed container until next season, when it can be blended back in with fresh pomace at the rate of 50 litres per 50 kg and re-fermented with a fresh yeast inoculum which may consume some of the acetic acid. The same technique may be worth trying for ciders affected by film yeast.

It has to be said that many so-called 'farmhouse' ciders are quite badly acetified, particularly the poorly-made 'scrumpies' which are sold to unsuspecting tourists in the West Country. There is probably some truth in the assertion that older generations of cider-drinkers became conditioned to these flavours since they were an integral part of the rough ciders which were then on offer. The same was probably true of wines until the widespread adoption of glass bottles and cork closures in the eighteenth century. Nowadays, however, most of us would regard acetified flavours as undesirable, and it

is certainly quite possible to make a fine and well-flavoured 'traditional' cider without them.

Cider 'sickness' is a disorder caused by bacteria of the genus *Zymomonas* (other types of which are utilised in the tropics for the production of palm wine). These organisms ferment sugars in the same way as yeasts, but they also produce large amounts of acetaldehyde which is said to give an odour of lemon or banana skins. In France, this disorder is known as 'framboise' since the odour is regarded as raspberry-like! The acetaldehyde also combines with the cider tannin to give a milky haze and the cider quickly becomes insipid and 'thin' in body. This problem only affects sweet ciders or those with residual sugar which are also low in acid (pH higher than 3.8), which is one good reason for fermenting and storing all ciders dry. Ciders which are naturally sweet and low in acid (e.g. French traditional) are obviously under greatest threat from this organism. Unfortunately it is totally resistant to SO2 so there is no easy control. The normal recommendation if ciders begin to become sick is to raise the acidity to 0.5% and to add an active fermenting yeast complete with nutrient. You will lose your sweet 'sick' cider but with a bit of luck you may end up with a much healthier dry one which will be some recompense! If the sick cider is already in active bacterial fermentation you will just have to let it take its course and then fine it and blend it off when all the sugar has gone. Once again, all equipment which has been in contact with cider 'sickness' should be well sterilised before re-use.

Other storage problems

Ropiness or oiliness is a curious condition which occurs sometimes in low acid ciders in bottle or in store. When the cider is poured, it assumes the consistency of a light oil or of a slimy ropy texture like raw egg-white, although the flavour is not much affected. This is due to the slow growth of certain forms of lactic-acid bacteria which produce polysaccharide gels (similar to those formed by related bacteria during yoghurt-making and which provide its texture). Ropiness does not generally occur where SO2 has been used. It can be ameliorated if the cider is transferred to an open vessel, well stirred to break the gel and treated with 100 ppm of SO2. Fining with bentonite and gelatin (see later) may also help to bring down the bacteria and the gel.

Mousiness is unmistakeable to those who have tasted it, although individual sensitivity varies widely from person to person. The flavour is best likened to that of a mouse-cage, although some people think it is closer to bread or freshly-baked biscuits. Strangely enough, the chemical compounds responsible for all these flavours are identical! This defect arises from a slow microbial action in storage, and although its chemistry is generally understood nobody knows why it happens in some ciders but not in others. Unfortunately there seems to be no reliable way of preventing its formation or of removing it once formed, although it is generally less common in ciders which have been sulphited, and access to oxygen appears to encourage it.

Discolouration of ciders (apart from the normal golden-orange colour of partly oxidised tannin) is nearly always caused by metals. Iron gives rise to blackening and copper gives greener hues, due to reactions between the metal, the tannin in the cider and the oxygen in the air. Often the colour does not develop until a bottle is opened and the air can get in - the colour then develops in minutes or hours. To confirm this, a pinch of citric acid may be added to a freshly-opened control sample. If this darkens

at a significantly slower rate than the problem bottle, then iron is the probable cause. There is not much that can be done to cure the problem although re-bottling in the presence of citric acid may be considered. A technique known as 'blue fining' can be used on a commercial scale to remove the metal but only in the hands of a trained chemist. Such problems will never arise if the proper sort of processing equipment is used so that free iron and copper cannot get into the cider.

Hazes and Deposits

Many people making a traditional product will be quite happy with a certain amount of haze in their cider. There are, however, degrees of acceptable cloudiness and if you have gone to a lot of trouble to make a sparklingly bright cider it is very annoying to have it develop a haze or a sediment later. There are a number of possible reasons for this.

Microbial hazes are caused by various spoilage yeasts or by heavy infestations of bacteria. Most of these have been covered above although there is one slow-growing yeast (*Saccharomycodes ludwigii*) which forms clumps at the bottom of the bottle in sweetened ciders without affecting flavour very much. Generally, microbial problems should be avoided by proper attention to cleanliness and hygiene. The only reliable way to tell whether a haze is microbial in origin is to look at it under a high-powered professional microscope (500x magnification). This is hardly practicable for the domestic cidermaker unless you have a friend or colleague with access to a laboratory. If you do, ask them to look for yeasts (about 10 microns in size) or for bacteria (about 0.5 microns in size but often in pairs or in chains).

Pectin hazes were described in an earlier section. If you want to be sure of preventing them, you must use a pectolytic enzyme which is added at the beginning of fermentation. If you think you have a pectin haze in the finished cider, add one part of cider to two or three parts of methylated spirit in a small glass and shake well. The pectin will form a gel or a clot, or possibly strings if there isn't much of it there. If pectin is confirmed, you can try adding some pectolytic enzyme to break it down although it won't be so effective in the presence of alcohol. Otherwise you must just live with it and remember to do better next time!

Tannin hazes are sometimes the most frustrating, because they may develop in store in ciders which may have been bottled completely clear. They occur particularly in ciders made with bittersweet fruit where the tannin levels are relatively high. Over time, these tannins polymerise together to generate large molecules which eventually become so big that they drop out of solution. Sometimes they form a haze, while sometimes they coalesce to a compact sediment. Often they cause a 'chill-haze', where the product becomes cloudy when put in a refrigerator for summer drinking but was quite stable at room temperature, or they may appear during winter storage if the cider was bottled before a snap of cold weather (a warming and cooling cycle is a good test to indicate potential tannin haze). The tannins are also responsible for much of the 'bite' of traditional bittersweet ciders so it seems a pity to remove them. Sometimes, however, bittersweet ciders may be so bitter or astringent that it is worth lowering the tannin levels for reasons of taste, as well as for haze stability. The 'fining' procedure below can be used for either. It can also be used for gross clarification before sheet

filtration or racking, or perhaps to remove 'ropiness' or 'sickness' bacteria. Do remember, though, that fining a low tannin cider will make it even more insipid.

Fining

There are many different ways of fining although the principles are the same for all. The tiny particles of beverage haze are electrically charged which is why they do not coalesce, because 'like charges' repel each other. If we add a material with an opposite charge we can neutralise the charges so the particles will then clump together and settle out. In ciders the tannin or other particles of debris tend to be negatively charged, and so we add a positively charged material which is usually a protein. Traditionally, egg white or fresh slaughterhouse blood was used - one egg will treat about 10 gallons of cider!. Nowadays we can go to 'Boots' and buy 'Wine Crystals 2' which is a special gelatin for fining purposes (this is much better than the sort of gelatin sold for cooking). If too much gelatin is added, the cider becomes 'overfined' and we get a gelatin haze instead, so it is wise to add some bentonite at the same time. Bentonite is a negatively charged clay which mops up any spare gelatin. An appropriate grade is also available from 'Boots' (as 'Wine Crystals 1') or from other specialist suppliers. There is also a much better material known as 'silica sol' (which is sold as 'Baykisol' or 'Syton') but this is not obtainable on a small scale in this country as far as I know.

Ideally it is best to run tests to find out how much gelatin and bentonite are required in a particular situation. For instance, a 1% stock solution of gelatin should be made up in warm (not boiling) water, and a 10% stock slurry of bentonite should be creamed up separately in warm water too. Then set up a series of six flasks each containing 200 ml of cider and an appropriate amount of bentonite as shown in the left hand columns of the Table. The appropriate volumes of gelatin solution are then added from a pipette or a small syringe as shown and the flasks are well shaken. After leaving for several hours, the flask which gives the greatest amount of clarification with the least amount of ingredients should be chosen for scale-up according to the right hand columns of the Table. For full scale fining, the bentonite should be creamed up in a small quantity of cider and then well distributed in the bulk. The appropriate amount of gelatin should be made up as a 5% solution in warm water and added to the bentonite-treated cider in a thin stream with constant stirring before being allowed to settle for several days. If the main purpose of the exercise is to reduce tannin levels, rather than to clarify the cider, the gelatin solution should be added first, allowed to stand for two hours after stirring and then followed by the bentonite.

After fining, a deposit will be thrown and a clear cider should remain above it. This can then be racked off, filtered and bottled accordingly. The handling involved during fining will obviously cause some aeration which should be kept to a minimum for all the reasons previously discussed. The addition of 50 ppm SO2 at this stage will also be helpful to prevent oxidation.

During this series we have looked at a number of ways to prepare, ferment and store good cider. There is of course no 'right' way of making cider - every product is different and this diversity should be welcomed. I hope that these articles have given potential or existing small-scale cidermakers some of the scientific background to

help them choose from the many different approaches to cidermaking which are possible. In the final article, we shall extend away from cider into the complementary activities of apple juice and vinegar making.

Cider Fining with Bentonite and Gelatin			
TEST (per 200 ml cider)		**FULL SCALE (per 100 l of cider)**	
Bentonite (ml of 10% suspension)	**Gelatin (ml of 1% solution)**	**Bentonite (grams)**	**Gelatin (grams)**
1	1	50	5
1	2	50	10
2	2	100	10
2	4	100	20
4	4	200	20
4	8	200	40

THE SCIENCE OF CIDERMAKING

Part 6 - Apple Juice and Cider Vinegar

In the first five parts of this series, we have looked at the making of cider. This final article looks instead at how we can stop the process one stage earlier to make apple juice, and how we can take it one stage further to turn our cider into vinegar.

Apple Juice

Apple juice is in some ways more difficult to make than cider, and indeed it can scarcely be regarded as a traditional product at all. Until the recognition late in the last century that fermentation was caused by yeast converting sugar into alcohol, the difference between juice and cider was somewhat obscure and of little practical importance in any case. Not until the invention of pasteurisation was there any practical way of preserving the juice with its full content of sugar. That is the fundamental process of juice-making - to preserve the sugar from the fruit without it turning into alcohol - and this can really only be done by heat treatment to kill the yeasts, or by deep-freezing or chemical additions to stop them growing. All these processes require a relatively sophisticated technology by traditional standards.

The milling and pressing requirements for juice making are no different from cider making, since both begin at the same point. The fruit requirements, however, are rather different. In cider we need high sugar to turn into alcohol, some acid to benefit the course of fermentation and some tannin to give body to the final blend. In juice the most important feature is the 'Brix/acid' ratio, which is the percentage sugar divided by the percentage acid. In the UK and the rest of Northern Europe, a ratio of 15 - 20 would be considered appropriate. In the USA, ratios as high as 30 are acceptable, but the juices would be considered very sweet to a British palate. Up to a point, the absolute values of sugar and acid do not matter so much as the ratio. Thus, a juice with 10% sugar and 0.5% acid would be equally as acceptable as a juice with 15% sugar and 0.75% acid, both having a ratio of 20. From this, it is easy to see that a Bramley juice with 10% sugar and 1% acid gives an unacceptably low ratio of 10, while a sweet cider cultivar with sugar of 15% and acid of 0.2% would have an unacceptably high ratio of 75. A bittersweet cider cultivar, with high tannin levels too, would also be quite inappropriate for juice making.

In practice, good juices can be made from a variety of dessert apples, and those which have interesting flavours in their own right (e.g. Cox or Russett) generally make interesting juices too. Apples which are delicate in flavour, such as Worcester Pearmain, make rather flavourless juices. Sweet apples can always be blended with Bramley to improve their acidity, while Bramley itself can always have some sugar added to improve its B/A ratio even though it will never make a first class juice. A good general starting point is three parts dessert apple to one part Bramley. Although the fruit must be clean and wholesome it can be small or misshapen. Indeed most commercial apple juice is made from such fruit which is cosmetically unsaleable on the retail market. But the fruit must be well-washed and **NONE OF IT MUST BE**

MOULDY! If you wouldn't be prepared to eat it as fresh fruit, then it's not fit for juice-making!!

Cloudy 'fresh' juice

One of the best juices to make, if we are going to the trouble of making apple juice at all, is the pale cloudy juice which has become very popular in the UK in recent years. (Curiously, the basic process was developed in the USA and Canada but it is scarcely used there at all at present). The fruit is chosen, washed, sorted, milled and quickly pressed - fruit blending has to take place before pressing. After screening through a coarse mesh, Vitamin C (ascorbic acid) is added directly to the juice at the rate of 500 parts per million (5 g per 10 litres of juice). Pure powdered ascorbic acid should be used for this - it will be much cheaper and more convenient as a winemaking sundry than as a formulated vitamin from the chemist shop. The ascorbic acid allows certain oxidation reactions to happen in the juice which develop its flavour, but it prevents the browning of the tannins which make it look unsightly and lead to sedimentation.

Now the juice must be preserved without delay. If you have room in your freezer, it can be poured into plastic containers, or into polythene bags packed into cardboard shells. Once frozen, the juice can be withdrawn from the cardboard and stored as frozen polythene bricks. The juice can be thawed for use as required, but it will not keep long after thawing, because the enzymes and yeasts that were present in the juice originally will still be active. Nor will the cloud be 'set' and it may settle out rapidly when thawed. However, freezing is very convenient if you have the space to cope with it.

Pasteurisation

The alternative is pasteurisation. For this, the juice must be run into Kilner jars or good quality glass bottles (not plastic!) which can be sterile sealed by heating. Crown capped beer bottles, available from home brewing suppliers, will do quite well, as will good quality screw-capped bottles. The bottles or jars are filled to within an inch of the top and placed in a large pan of water which is put on the stove and gently warmed. The bottles should be as far immersed in the water as possible. Using a thermometer, bring the water up to 77ø C and hold it at that temperature for 30 mins. Alternatively, place the thermometer in the centre bottle of the group and continue heating until the temperature of that juice itself reaches at least 74ø C. At this temperature, all the yeasts should be destroyed. Take the hot bottles out of the pan and cap them immediately. Do not stand the hot bottles on a cold metal surface or the cold shock may crack them. If using Kilner jars, follow the usual procedure to obtain a sterile vacuum seal. If using beer or screw-cap bottles, seal them tightly and then lay them on their sides to cool slowly, so that the hot juice can sterilise the inside of the cap. Do not hurry the cooling process. Next day, the bottles may be stored at room temperature indefinitely until required, although the juice itself always tastes best if chilled for a few hours before drinking.

Heat treatment of this sort is very satisfactory although the occasional broken bottle may result during pasteurisation. Mould growth very occasionally occurs in the bottles during storage because mould spores can be extremely heat resistant although yeasts are quite easily killed. An advantage of heat treatment is that it actually 'sets'

and stabilises most of the desirable apple juice cloud, which does not happen when the juices are frozen. On a large scale, purpose built pasteurisers may be purchased, or a handyman can convert a stainless steel sink with an immersion heater and a false bottom to maintain the correct temperature. Bulk pasteurisation of the juice itself in a tank or a saucepan is a poor alternative to in-bottle pasteurisation, because of the danger of overheating and excessive oxidation, and it is difficult to hot-fill the bottles aseptically on a small scale. Commercially, flow-through heat exchangers are used and the hot juice is filled straight into clean warm bottles.

Chemical preservation

It is also possible to preserve the juice by chemical means, by adding compounds which inhibit yeast growth. The only two practical materials are potassium sorbate or potassium benzoate, used at doses up to 200 parts per million (2 g per 10 litres). Potassium sorbate is less likely to give off-flavours and is fairly readily obtainable (as wine stabiliser) from 'Boots' although the dose rate needs to make allowance for the inert carrier which is also present. Sorbate is more effective if combined with SO2 and so two Campden tablets per 10 litres (50 ppm) may also be added. However, not everyone likes the taste of sulphite! The other drawback to chemical sterilisation is that it only inhibits yeasts, not enzymes and not certain bacteria, so the flavour and colour will still deteriorate after a few days in store. The opalescent cloud will probably sediment too. Generally, heat treatment is a much better bet than chemical sterilisation if long term storage is in view and, (*note added June 1997*) pasteurisation will of course protect against any risk of contamination by the lethal food poisoning organism E.coli 0157H, which chemicals won't!

Clear Juice

To make a clear golden juice it is necessary to destroy the pectin cloud and to allow a certain amount of oxidation for colour development. The most reliable way of doing this is to press out the juice as normal into a clean container, without the addition of any ascorbic acid. Add a pectolytic enzyme and keep the juice cool overnight to prevent yeast growth and fermentation. Next morning, the juice should be golden in colour and should have dropped bright, leaving a sediment at the bottom. If not, it may have to be fined with gelatin/bentonite (see Part 5) and left cool for a further day. Rack or strain the juice carefully into clean containers for preservation by freezing or by heat treatment as described in the previous section. Sometimes the colour becomes rather dark by this method, and a small amount of ascorbic acid (100 - 250 ppm) may therefore be added before enzyming to inhibit oxidation. In some cases the addition of pectic enzyme may be unnecessary since there may be sufficient enzyme and calcium present naturally in the juice for it to 'drop bright' by itself overnight in the cold - but you will not know this until you try it!.

WARNING

JUICES MUST NEVER BE BOTTLED (ESPECIALLY IN GLASS) WITHOUT EFFECTIVE PASTEURISATION OR PRESERVATION! *If all the juice sugar ferments inside a closed bottle, it can theoretically develop an internal pressure in excess of 400 p.s.i. (pounds per square inch). This is more than enough to cause serious damage or injury when the bottle eventually explodes (as it almost certainly*

will). Just for comparison, even a properly designed champagne bottle is only expected to hold a pressure of about 100 p.s.i.

Cider Vinegar

From a biochemical viewpoint, cider vinegar is the next step after cider itself on the road which converts sugar through to alcohol, thence to acetic acid and finally to carbon dioxide and water. At each step, the organisms involved gain energy - this, after all, is why they do what they do and their metabolism is very little different from our own in many respects. Animals, however, do not stop at the alcohol or acetic acid stage. Some micro-organisms do and we can take advantage of this to provide the products that we want. Vinegar is simply a dilute solution (about 5%) of acetic acid which has been converted from a corresponding quantity of alcohol.

To make cider vinegar we need to start with a fully fermented dry cider with a minimum 5% alcohol content. Sulphur dioxide should not have been added, because this will inhibit the conversion to acetic acid. Contrary to all good cidermaking practice, we then need to leave the cider in a vessel with plenty of access to air and to ensure that *Acetobacter* can get in. These organisms, fatal to good cider, are just what we need for vinegar. The traditional set-up for vinegar-making is known as the Orleans or barrel process and consists of a barrel laid on its side, three-quarters full of liquid with open access to air. The bung hole is lightly plugged or covered with gauze so that oxygen can get in but flies cannot! Alcohol converts to vinegar at the rate of roughly 1% per week so that a cider with an alcohol of 6% will give a vinegar of 6% acetic acid in a couple of months or so. Two-thirds of the barrel is then drawn off as vinegar, fresh cider is added, and the cycle is repeated. Modern vinegar factories do not use this method, because it is far too slow. They use big fermenters with forced aeration and a very high population of acetic acid bacteria, which can convert a wine or cider to a vinegar within a few hours. Efficient as the big fermenters may be, the advantage of the barrel process is that is has no moving parts and virtually nothing to go wrong. You just have to wait a bit longer!

Setting up the system is the hardest part. Whereas it is easy to go out and buy a good fermenting yeast, nobody to my knowledge will sell you a culture of Acetobacter over the counter although they are available to specialised microbiology laboratories. Traditionally, a vinegar barrel was always started by adding an inoculum of old vinegar from somewhere else. But it will be no good for you to buy a bottle of vinegar and hope to use it as a starter, since all modern commercial vinegars are pasteurised and the Acetobacter do not survive. If you wait long enough, though, wild acetic acid bacteria will almost certainly find their way in. Probably the best plan is to keep an open jar of cider, covered with a coarse mesh, in a warm dark place for as many weeks as it takes for a 'mother of vinegar' to form. It is wise to add about 25% of commercial cider or wine vinegar to the jar to inhibit other non-acetifying organisms. Make sure that the vinegar you add does not contain any SO2 or other preservative - this will be stated on the label.

The 'mother' is simply a floating mat of cellulose made by the *acetobacter* themselves to keep them close to the surface, since air is essential for their existence. Once you are sure you have a genuine gelatinous 'mother' and not a powdery film yeast, and you can really smell the vinegar, you can pitch it into your barrel with the required amount

of still dry cider and your Orleans process will be under way. Keep it warm, up to 30ø C if you can, for best results.

Another method for generating a vinegar starter is to make a heap of fresh apple pomace, keeping it moist and preferably warm for several weeks. During this time it will ferment its residual sugars and natural acetobacter should then proliferate. Once it smells quite vinegary, the pomace can be squeezed out through a muslin bag and the resultant liquor (rich in *acetobacter*) can be used as a starter which will eventually develop a 'mother'. Pieces of 'mother' can be purchased from home winemaking suppliers in the USA and in Germany, but nobody sells them in the UK, it seems. If you are really desperate you can get in touch with me and I may be able to get you a piece.

DO NOT, WHATEVER YOU DO, USE THE SAME EQUIPMENT AND VESSELS FOR VINEGAR MAKING AS FOR CIDER. The risk of cross-infection is just too great and it is not worth spoiling your good cider by trying to economise in this way. Keep both operations entirely separate! If you are making vinegar close to your cider, as you probably will be, it is doubly important that your cider-making kit be properly cleaned and sterilised anyway.

Once the vinegar is made it can simply be run into bottles for use. On a domestic scale there is no need for pasteurisation. Cider vinegar from the Orleans process is generally fairly clear but it may develop a further haze on storage in bottle. This is due partly to renewed growth of bacteria and partly to polymerisation of tannin. You can fine the vinegar with gelatin/bentonite if necessary to reduce an existing or a potential haze. If it is then important to prevent further clouding, SO2 at 50 ppm (i.e. 2 Campden tablets per 10 litres) may be added just before bottling, and this will inhibit both types of spoilage process.

Vinegar vats occasionally become infected with vinegar 'eels'. These are small and transparent nematode worms a few millimetres long, which live on the acetifying bacteria and which wriggle ceaselessly at the top of the vat. Although quite harmless they are generally unsightly and people do not like them. They may be destroyed by heating the vinegar to about 50ø C, followed by fining or filtration after cooling. Or you can just leave them as a talking point for your guests - they will liven up any salad dressing!

TAILPIECE

Well if you've got this far you MUST be interested! I hope you've enjoyed what you've been reading, and good luck with your cider, juice and vinegar making!!