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Barker, B. T. P. 1922. CP28 The microbiology of cider-making. *Journal Of The Institute Of Brewing.* 28 (7), pp. 517-534.

The publisher's version can be accessed at:

- https://dx.doi.org/10.1002/j.2050-0416.1922.tb06559.x

The output can be accessed at: https://repository.rothamsted.ac.uk/item/8w5wx/cp28-the-microbiology-of-cider-making.

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MEETING OF THE MIDLAND COUNTIES SECTION, HELD AT THE GRAND HOTEL, BIRMINGHAM, ON THURSDAY, FEBRUARY 23RD, 1922.

Professor A. R. LING, M.Sc., F.I.C., in the Chair.

The following paper was read and discussed:—

The Microbiology of Cider-making.

By B. T. P. BARKER, M.A.

The subject of this paper, although concerned with a beverage not very closely associated with the brewing industry in general, and perhaps on that account not of much concern to it, may nevertheless prove to be not entirely without significance to those who have to deal with the biological aspects of fermented liquors; and it may indeed be found that some of the results of investigations on the microbiology of cider may have some bearing on problems which occur in the course of work on the more important beverages. It is with that idea in mind that the subject selected is one which involves practically a brief review of the major part of the work which has been conducted at the National Fruit and Cider Institute, Long Ashton, on the biological side of cider-making rather than one limited to a single piece of research which, while probably being more complete, would be of relatively little interest to any one not directly concerned with the cider industry. The object is to present to those who are accustomed to deal with fermentations conducted with an initially sterile liquid, and controlled more or less from start to finish, a picture of the problems which arise in dealing with the fermentation of a liquid which by its very nature is charged at the outset with a multitude of organisms—some useful, some harmful, and some innocuous.

It is proposed to deal, in the first place, with the organisms found in apple juice as it comes from the press, to follow this with a survey of the various phases of fermentation, including references to some of the more important factors influencing the nature of the fermentation, and subsequently to review briefly the biological aspects of storage in cask and bottle. A short reference will be made to the more important disorders produced by micro-organisms to which cider is susceptible.

Beginning with the organisms which are found in the freshly

expressed juice, it is obvious that, while the main source from which they are derived is the fruit itself, there is another source far from being negligible. During the course of the active cider-making season throughout the autumn and early winter, while the mill, press, and accessory appliances are in constant and almost daily use, there is more than a chance of organisms being picked up from the plant in use, especially if the latter is not regularly cleansed and disinfected. There is, indeed, evidence available tending to show that every factory possesses, as it were, its own characteristic flora of micro-organisms, the combination and the nature of origin of which are due partly to fruit previously used and partly to a number of other factors which time will not permit of consideration here. It will be understood that, unless the plant is cleansed between each operation of milling and pressing—which rarely happens in practice—some of the organisms present in any given lot of juice will have been derived from previous pressings. Under some conditions, the factory flora is abundant enough to exercise a definite influence, possibly even a dominating one, on the character of the product; certainly in the average case it has to be taken into serious account. It is comprised of a mixture of yeasts, moulds, and bacteria, the various types of which do not differ materially from those which we shall in due course consider as characteristic of cider in general. As already stated, to a large degree their presence in the factory may be attributed to fruit previously used; so one may pass on at once to consider the flora of the fruit.

The classic researches of Hansen have shown the occurrence of yeasts in nature to be closely associated with fruit: hence the statement that the apple carries on the surface of its skin a by no means inconsiderable and mixed population of members of that family will not be novel. It may be of interest to record that their presence there has been traced back as far as the time of the opening of the blossom. Insect visitors to the nectaries of the flower, bees in particular, are certainly responsible for the general dispersion, and probably wind at the time the skin begins to get greasy at the approach of ripeness is another important factor of distribution. The consideration of the types which occur can be conveniently deferred until the nature of the flora in the juice is discussed. Various kinds of bacteria are also to be found on the surface of the ripe apple, especially certain of the acetic forms; it seems likely that all of the types producing the various bacterial disorders of cider also occur, with perhaps the exception of the forms causing ropiness.

The moulds present on the fruit in the orchard are for the most part

parasitic forms. Of these those of most common occurrence are the apple scab fungus, *Venturia inæqualis*, and the brown rot fungi, *Monilia fructigena* and *cinerea*.

In common practice the fruit is allowed to fall from the trees or is shaken off and may remain lying on the grass of the orchard for several days before being consigned to the cider house. This treatment is responsible for a marked increase in the number of kinds of organisms, and their multiplication is intensified by the subsequent conditions under which the fruit is kept. It may have to undergo a journey of some length by rail or road, either packed in sacks or lying loose in the trucks. When it reaches the factory the chances are that it lies about in large heaps for days before it is put through the cider mill. Bearing in mind the facts that it is, owing to the season of the year, almost invariably more or less wet and therefore very prone to "heat," and that during the course of gathering and storage it suffers considerable bruising and breaking of the skins, it is not surprising that fungoid rots develop freely and acetic bacteria multiply to an alarming extent unless great care is exercised. Many a brew of cider is irretrievably spoilt every year solely through inattention, unavoidable or careless, at this stage, which results in the fruit acquiring a taint in flavour, which is transmitted in turn to the cider. Most frequently it is a case of acetification, but some of the commoner fungus rots are often equally to be dreaded. Various species of *Penicillium*, *Mucor*, and *Monilia* are the most prevalent forms. Each produces a form of rot with a characteristic flavour of its own, which is subsequently ineradicable. They fructify freely and the spores are in due course carried with the juice into the fermentation vessels.

It will thus be gathered that the freshly expressed juice is invariably charged, more or less abundantly, not only with a variety of naturally occurring wild yeasts and torulæ, but a heterogeneous collection of undesirable fungi and bacteria. Fortunately, except on somewhat rare occasions, the fungi have little opportunity afterwards of doing serious damage. Those occasions arise when the onset of alcoholic fermentation is abnormally slow, giving time for appreciable mycelial growth before the production of carbon dioxide is sufficient to inhibit further development. Once that occurs, the fungi may probably, for practical purposes, be ruled out of account, for I have never met with a case where they have caused material trouble subsequently. The bacteria are incomparably more dangerous. Some acetification, for example, invariably occurs if alcoholic fermentation is slow in starting. Moreover, while bacterial activity is subdued once the yeasts become active,

it is not necessarily finally suppressed or eliminated as in the case of the fungi. Given conditions favourable to them later, several forms are capable of reviving again and causing serious complications in the finished product. For the time being, however, one can take leave of them while considering the stages of fermentation proper, and focus attention on the true yeasts and related forms.

There is no need to emphasize the point as to the varied collection of members of the *Saccharomyces* family which may be found in any sample of juice collected from the press. It represents a chance grouping, determined partly by the history of the fruit, and partly by the condition of the cider-house appliances. Some, as we shall presently see, play a very active part in the earlier stages of fermentation; others only become prominent later; and others, again, probably never need be seriously taken into reckoning. Obviously, however, the cider-maker who is content to rely on spontaneous fermentation to give him his product—and he is representative of the great majority of the industry—is, by doing so, deliberately accepting a result which is quite haphazard, and necessarily not infrequently inferior. It will naturally be asked why in these days, when pure culture methods are no longer novel, is so unscientific a method as natural fermentation still adhered to. Since the question has a very direct bearing on the remainder of the points which come up for consideration, some explanation may be conveniently given at this stage.

There are three possible general methods of fermenting the crude juice. Dealing with them in the order of simplicity of execution, the first is that of spontaneous fermentation, already mentioned. The second is that of dominant fermentation, to attain which the addition of a culture of selected yeast to the freshly expressed juice is required. The third is that of strictly pure fermentation, which involves not only the addition of a pure yeast culture to act as starter, but also preliminary sterilisation of the juice.

The case of spontaneous fermentation is to be considered in detail in due course, so one may pass on at once to the second method, that of dominant fermentation. This has been repeatedly tried, both on the laboratory and factory scale, and the results generally have been exceedingly variable. The reasons for this irregularity have been sought and discovered. It seems clear from their nature that, in spite of the favour with which the method has been regarded in some quarters, it must continue to fail to give uniform results under prevailing working conditions in cider factories. There are three outstanding difficulties which have to be faced. In the first place, it

has been found that dominance is not secured by the addition of a selected yeast, even when the quantity added is relatively large. Examination of the flora of the treated juice, when fermentation is in full swing, has shown that the tendency in the average case is for the selected yeast to suffer eclipse in its competition with the naturally occurring wild types. The relatively low temperature of the juice during the season of fermentation, which generally extends from mid-October until mid-winter, favours the growth of some of the more undesirable wild forms as compared with that of selected types, which are chosen primarily for features other than that of free growth at low temperatures. The obvious method of meeting this difficulty, viz., that of conducting the fermentation in a warmed building, is regarded as unsatisfactory for economic reasons, and because general experience is held to show that low temperature fermentation gives a superior product.

Even the conduct of fermentation at a higher temperature does not necessarily give an effective degree of dominance. This point raises the second main difficulty. Apple juice, like many other fruit juices, is none too well supplied with the nitrogenous constituents requisite for normal healthy yeast-growth. In the average juice the yeast cells are certainly suffering from nitrogen starvation to a greater or less degree, as the case may be. Some varieties of yeast appear to possess a lower nitrogen requirement than others, and in this respect some of the wild forms seem to hold a distinct advantage over cultivated types.

Equally vital is the third difficulty, for which the character of the present-day cider orchards is largely responsible. Instead of the cider manufacturer having a raw material of even only approximate uniform composition to deal with, he has to face a crude juice of different quality from practically every pressing of fruit milled, owing to the multiplicity of kinds of cider apples grown in the farm orchards of the West of England. It follows that the selection of any one type of yeast for purposes of dominant fermentation is accompanied by almost insuperable problems, for a type suited for one class of juice may be quite unsatisfactory for another class.

For these reasons, attention latterly has been rather diverted from the method of dominant fermentation as a means of control—from which, at one time, much was anticipated—to that of pure yeast fermentation, in the strict sense, in sterilised juice. Experimental work in this direction is now in progress at Long Ashton, and, at the moment, preliminary results only can be indicated.

Broadly speaking, two methods are under trial there. The first

involves the pasteurisation of the juice by heat. Since the flavour of apple juice is seriously affected by heating to a temperature high enough to secure absolute sterilisation, pasteurisation at a lower temperature has to suffice. In the average case it appears possible to raise the temperature to from 140° to 160° F., without imparting to the flavour a very definite permanent cooked character which will persist through the subsequent fermentation. The use of a suitable selected yeast for the latter has not so far been found to be accompanied by any very serious difficulties, no complications caused by the possible survival of spore-forming bacteria through the pasteurisation process having yet been experienced by us. The chief trouble is to keep down to the point of insignificance the flavour alteration due to heating. Juices of different chemical composition are not all equally affected, the more acid ones being the more susceptible to change. A varying standard of heating, adapted for the particular juice under treatment, may therefore have to be adopted. A few points of general interest arising from these experiments may be mentioned.

For example, the type of yeast used has been proved, as in other fermentation industries, to influence appreciably the flavour of the fermented liquor. This fact is not, however, in the case of cider of primary importance for this reason. The flavour of a cider is determined to a far greater degree by the kinds of apple used than by the character of the alcoholic fermentation. Until cider-makers can be supplied with but a few varieties of apples in bulk the question of yeast selection from the flavour point of view must remain a comparatively minor consideration.

The fact of the low nitrogen content of apple juice has illustrated the varying nitrogen requirements of different yeast types very clearly. Last season, working on a given pasteurised juice with several distinct forms of yeast, a marked variation in power of attenuation was observed. Each of the yeasts tested was capable of fermenting completely the quantity of sugar contained in the juice when supplied with sufficient nitrogen in suitable form: nevertheless in the cases referred to the specific gravities of the respective ciders 17 days (3 weeks) after making varied between the extreme limits of 1·018 (1·017) and 1·042 (1·035), a difference which, so far as is seen, can only be attributed to the varying effect of partial nitrogen starvation on the attenuation powers of the respective yeasts.

The second method of juice sterilisation, which is under trial this season, is based upon the fact that there is naturally present in apple juice a single substance or a group of related substances which, on

addition of formaldehyde to the juices slowly combine with that antiseptic in the cold to form an insoluble compound. Provided that a sufficient quantity is present to permit of the addition of enough formaldehyde to exercise a sterilising effect before the completion of the reaction, we have here an interesting case of sterilisation combined with the automatic removal of the sterilising agent after it has done its work, without any permanent effect on flavour or other feature open to objection from the consumer's point of view. There is some reason already to encourage hopes that the quantitative aspect will present no insuperable difficulty; but too little is yet known about the matter as a whole to warrant more than passing mention at this stage.

A method of partial sterilisation, somewhat analogous in character, was developed in France by Jacquemin some 20 years ago. This consisted in the addition to the freshly expressed juice of an amount of sulphur dioxide sufficient to prevent the growth of the naturally occurring organisms, fermentation being effected by the use of a culture of selected yeast which had been acclimatised to that strength of sulphur dioxide by repeated cultivation in gradually increasing concentrations. The weaknesses of the method in my own experience are, firstly, the persistence of the flavour of the preservative in the finished product, and, secondly, its failure to inhibit permanently the development of the bacillus responsible for the disorder known in this country as cider sickness. Thus, while the primary fermentation may be controlled satisfactorily, the mature cider is not safeguarded against outbreaks of one of its most serious disorders.

Experiments made at Long Ashton some years back on the effects of varying the amount of sulphur dioxide added may be of some interest in this connection. Samples of several different juices were allowed to ferment naturally, and the rate of fermentation, as indicated by the fall in specific gravity in a given time, determined in each case. They included examples of rapid, moderate, slow and extremely slow fermenting juices. To other samples of the same juices taken straight from the press were added varying amounts of sulphur dioxide. The effect of the sulphur dioxide was a delay in the onset of fermentation, the extent of which was determined by two factors, viz., the content of sulphurous acid and the natural rate of fermentation of the juice. The stronger the dose obviously the longer the dormant period; but the length of the latter for a given dose was not the same for all juices. The more rapid the natural rate of fermentation the quicker was the recovery from the action of the antiseptic. It was also demonstrated that the amount of sulphur dioxide required to prevent fermentation

in the first instance varied according to the natural rate of fermentation of the juice, rapidly fermenting juices requiring more than the slower types. The other feature of special interest was that, when fermentation did start, in all cases the subsequent rate was substantially the same as that of the untreated juice. The conclusion therefore is that, unless excessive quantities of sulphur dioxide are used, this antiseptic simply serves to defer fermentation; it does not materially alter its character or affect its normal rate.

Other methods of sterilisation have been proposed at various times such, for example, as treatment with ozone and with ultra-violet light rays. It has to be admitted that at the moment no method of full control of fermentation has established itself in practice to supersede the original system of natural fermentation. We may thus return to the review of the parts played by the wild yeasts and other organisms in the production of cider.

There are three well-defined phases in the natural fermentation of cider, which, mentioning them in order of occurrence, have been aptly described as the *apiculatus* yeast phase, the *ellipsoideus* yeast phase, and the acetic organism phase. Those terms indicate very fairly the predominance of the types of organisms at those periods.

The *apiculatus* phase may be regarded as extending approximately from the time the juice is expressed until fermentation reaches its most active point. It must not be understood that during that time *apiculatus* yeasts develop to the practical exclusion of other types or even that from the point of view of numbers alone they are in excess of some of the remaining species. What is actually the case is that during the period in question they constitute a well-marked feature of the micro-flora, while later they are swamped by other forms, and ultimately in the mature cider are only conspicuous by their absence. In one very extensive and complete investigation on the variation in the yeast flora during the course of manufacture of cider, during which samples of fifteen types of cider were subjected periodically to biological examination, on no single occasion was an *apiculatus* form isolated after the cider had reached bottling condition.

In addition to *apiculatus* types there may generally be found during the *apiculatus* phase from five to ten other types of yeast and *torulæ* in relative abundance. Some increase in number in proportion to the remaining forms as the second phase of fermentation is approached: others decrease. The individual forms present are found to vary in different juices, yeasts of the *cerevisiæ*, *pasteurianus* and *ellipsoideus* types being of common occurrence as well as *torulæ* of corresponding

cell form and film-forming species of the *Mycoderma* and *Willia* groups.

The *apiculatus* phase then is essentially one in which many competitors are striving for dominance. The next phase, the so-called *ellipsoideus* phase, is that of the main fermentation, in which certain races of yeast have definitely gained mastery. The description, ellipsoid, is perhaps not strictly accurate if it is interpreted as being indicative of the dominance of individual varieties belonging to the *ellipsoideus* group. Cases occur sometimes when the terms *cerevisiæ* or *pasteurianus* would more nearly describe the dominant features of the flora; but if the name be taken as indicative merely of a flora in which forms capable of conducting vigorous alcoholic fermentation are predominant, it is not then misleading. This phase lasts until active fermentation ceases, so long as the liquor is not subjected to any artificial process for arresting fermentation. In practice filtration or some other method is frequently utilised to restrain this fermentation before it comes to a natural end, and that introduces complications in the subsequent character of the flora. For the sake of simplicity I propose here only to consider the natural cycle of biological changes which take place when no attempt is made to interfere with the normal course of fermentation.

Active fermentation in cider comes to an end normally from one or other of two causes, the first being the exhaustion of the available supply of fermentable carbohydrates, and the second, starvation of the organisms owing to a deficient supply of assimilable nitrogen. In the former case a true "dry" cider is produced: in the latter one with more or less sweetness according to the extent of the nitrogen deficiency. In the former the organisms which will tend to persist are those with high attenuation power: in the latter those with the lower nitrogen requirement. It is evident therefore that, so far as organisms of the yeast group are concerned, the character of the flora in the concluding stages of cider production must be of a very variable nature.

It is, however, the cessation of active alcoholic fermentation which results in the marked change in the balance of the flora characteristic of the third phase. Up to that time organisms of the yeast group have been mainly in possession. From then onwards the tendency is for a change in the direction of bacterial domination, the acetic forms in particular coming into prominence. Hence the description of this stage as the "acetic" phase. It depends very largely upon storage conditions as to whether bacteria multiply to an extent

sufficient to affect materially the quality of the product. This really brings us to the final section of the subject, that of bacterial disorders, but, before entering on that, there are a few points which should receive brief notice before the subject of the primary fermentation is dismissed.

It will naturally be asked if, since individual ciders exhibit such varied floras, the particular combination of organisms in any given instance is the result of pure chance or associated in any way with some determining factor, such for example as the kind of apples used, the district in which the fruit was grown, or some other definite feature of the same order. The suggestions that individual varieties of apples either carry on their surface characteristic kinds of organisms living in a kind of symbiotic association or, alternatively, that their juice possesses qualities which encourage the development of special yeasts or bacteria at the expense of others, have, so far as my own observations go, no adequate foundation of fact. During the three or four years immediately preceding the war Mrs. Lessimore, of the Botanical Department of Bristol University, and myself made an investigation of the micro-flora of ciders manufactured from the Kingston Black apple alone, many samples of fruit of this variety grown in various districts throughout the West of England being secured for the purpose. The changes in the micro-flora of these ciders were followed in detail from the time the juice left the press until it was fit for consumption. The conclusion reached was that there was no single yeast or group of yeasts persisting through the course of fermentation which was common to all and, at the same time, distinct from those of other ciders made about the same date from other kinds of apples. As stated earlier, there could be no doubt that the distinguishing features of, for example, a Kingston Black cider are due to the qualities of that variety of apple and not to any determining degree to the micro-organisms. In the same kind of way the characteristics of the ciders made from fruit grown in certain districts and on particular kinds of soils are primarily due to qualities carried by the fruit and not by the organisms of fermentation.

It appears thus that, firstly, the main function which must be assigned to the latter in cider-making under present-day conditions is that of ensuring a type of fermentation which will suffice for the production of a sound alcoholic beverage and the suppression of undesirable activity on the part of injurious organisms; and, secondly, to secure this the cider-maker should for the time being concentrate his

attention rather on the prompt development of the middle or active phase of fermentation than on experiments with selected yeasts, the results of which must be erratic and futile until further research has overcome the difficulties which have been indicated.

The latter point requires special emphasis because of the numerous cases which occur where the cider acquires an ineradicable taint from bacterial activity owing to the slow development of this middle phase. Juices liable to this trouble are those with low nitrogen content. In them the more actively fermenting yeasts multiply relatively slowly, with the result that *apiculatus* types and bacteria have time in which to establish themselves and cause injury before the liquor is adequately charged with the amount of carbon dioxide necessary to restrain their growth. Hence, for example, in these cases appreciable acetification, detectable readily by the palate, frequently occurs in the earliest stages of manufacture. A less common case, but one with many interesting features, is associated with the production of a distinct aroma and flavour of aniseed. This arises from the activity of a special type of bacillus which forms a thick, milky-looking, slimy film on the surface of apple juices of low acidity and low nitrogen content. The aromatic substance is produced by its action on lævulose, none of the other sugars in the juice being affected in that way. As soon as alcoholic fermentation gets active this organism is suppressed and I have never isolated it from a mature cider. It is thus probably only a form to be feared in the pre-fermentation stage of manufacture.

Throughout the whole process of cider-making, then, it will be gathered from what has already been stated that there is a continuous struggle in progress between the yeasts capable of producing a sound type of alcoholic fermentation and undesirable yeasts, torulæ and bacteria. At no time is this struggle more pronounced or more vital than in the final stages when the liquor is ready for storage. The desirable yeasts are then getting exhausted owing to the chemical changes which they have produced and, because of the latter, are under conditions of malnutrition. Unless their vitality can be maintained to a sufficient degree deterioration in the cider is practically certain to follow. Experience has shown that provided there is just sufficient yeast activity to keep the liquor fairly well saturated with carbon dioxide the risks of serious deterioration from bacterial development are not great. Certain features have been noted which suggest that some other factor in addition to the carbon dioxide is involved in this preservative action of yeast, so far at least as some of

the bacterial disorders are concerned. The case of cider sickness may be quoted as an example.

Cider sickness is a disorder characteristic of ciders of the sweet type, which retain greater or less amounts of the original fermentable sugars of the juice, *i.e.*, those with a naturally slow rate of fermentation. The organism concerned is a bacillus which is probably present naturally in a large proportion of juices. No indications of its presence are shown until active fermentation has ceased, and even then the disorder rarely develops until summer temperatures are reached.

Sickness is characterised by a sudden violent decomposition of the residual sugar, alcohol being formed and large quantities of carbon dioxide being evolved. A peculiar aroma and flavour appear, due to the formation of relatively large quantities of aldehydes, formaldehyde and acetaldehyde being conspicuous. The organism rapidly dies, very probably being killed by the formaldehyde produced. The cider soon becomes thickly turbid, the turbidity being the result of the interaction of the aldehydes on certain constituents of the liquor. Experiments have shown that the development of this disorder in bottled sweet ciders is largely determined by the time of bottling. For instance, in one series a given cider, known by its general character to be likely to succumb to the disorder, was divided into a number of separate lots, which were bottled at monthly intervals from January to April. The April bottling turned sick within a few weeks of bottling, as soon as warm summer weather arrived; the March bottling succumbed shortly afterwards; the February bottling remained sound for a considerably longer time, but ultimately followed the example of the others; and the January bottling continued unaffected throughout the summer, and even in the second year showed no signs of the disorder. Now, so far as could be determined, the only difference in these cases prior to the onset of sickness was that more secondary yeast fermentation occurred in bottle the earlier the cider was bottled. Since the organism itself generates carbon dioxide and alcohol through its action on sugar, it can hardly be that the preservative action of the yeast fermentation proceeding after bottling was due to those products, and the conclusion that it is the result of the formation of some other volatile product of fermentation certainly seems tempting. The idea of its volatility is suggested because approximately the same amount of fermentation must have occurred in all the samples, and those which were bottled later must have lost this hypothetical substance in cask before being put into bottle.

There are only two other types of bacterial disorders of common

occurrence to which very brief reference will be made, viz., acetification and ropiness. My colleague, Mr. Otto Grove, has made a special study of both, and for details concerning them reference should be made to his papers in the Annual Reports of the Long Ashton Research Station.

As regards acetification, he has isolated from various ciders five different forms of acetic bacteria. The most common species is the well-known *Bacterium xylinum*. All of them are non-motile, asporogenous forms. Perhaps the most characteristic feature of difference between them is the nature of the film formed on the surface of the affected liquor. They develop readily in apple juice or cider at any stage of manufacture, provided that the liquid is exposed to access of air and carbon dioxide in adequate amount is not present.

Ropiness in cider is a disorder of fairly common occurrence, and has now been definitely proved to be caused by certain micro-organisms. Kayser, a few years back, described a number of species found in French ciders capable of inducing ropiness, and Grove has more recently isolated from a ropy sample of English-made cider a bacillus which possesses the same property. This is believed to be the first time a ropy bacillus has been successfully obtained from any English cider. The particular feature of interest in connection with ropiness for the present paper is the distribution of outbreaks. Although perhaps not an invariable rule, it is certainly remarkable how season after season the disorder appears in certain cider-making establishments and never in others. Our own case at Long Ashton may be quoted. From the time the work started there in 1904 until 1918 there was never a case of ropiness among the many hundreds of ciders made during that period. In the last-named year the methods had to be varied owing to war conditions, and for the first time cane sugar was added for sweetening purposes. Several of the ciders made that season turned ropy, and since then in other seasons there have been further examples of the disorder. I have met with a number of analogous cases and am disposed, therefore, to think that ropiness should be regarded as an introduced disorder in the case of cider, possibly in the first instance through the use of contaminated samples of cane sugar, and that ropy bacteria do not occur naturally in freshly expressed apple juice. It only remains to be added that this disorder, like the preceding, generally appears to give trouble in ciders in which normal yeast fermentation is completely exhausted.

In bringing this paper to a conclusion, it is obvious after what has been stated that cider making abounds in problems on the biological

side, and there is still far to go before cider makers can expect to control their fermentations with the desired degree of certainty.

DISCUSSION.

Mr. BUFTON enquired if Professor Barker, when using formaldehyde, had experienced any trouble in subsequent filtration. He (the speaker) had tried formaldehyde, and had to abandon it for the reason that, in each case, he got eventually what might be termed a winter haze, a very fine colloid haze, which refused to be filtered. Reference had been made to the difficulty of getting pasteurised juice to ferment, and he mentioned that last autumn he was doing some laboratory work on those lines, except that the juice he was trying to ferment had first been concentrated with the idea of preservation to a gravity of 1250°, and contained, roughly, 60 to 63 per cent. of sugar. Having concentrated it to that extent, he then took some of the juice and rediluted it back to its original gravity of 1050°, seeded it with a very active yeast, and kept it at a temperature of 60° F. No fermentation took place, but there had obviously been a precipitation of nitrogenous matter. He added more yeast and nothing happened for a month, and then, on adding a little ammonium tartrate, fermentation slowly occurred.

Mr. G. C. EVANS enquired if Professor Barker could name the bacterium which was the cause of cider sickness. From his own work upon the subject he concluded that it was probably *B. Fitzianus*, and found that it was resistant to acidities up to 0·4 and 0·5 per cent. He would like to know what remedy was suggested, and if it was not feasible to wash the apples upon the same principle as sugar beets with an antiseptic solution, and so start with a more or less sterile raw product.

Mr. PRICE said sugar refiners experienced trouble with cane sugar, due to *Leuconostoc mesenteroides*, and asked Professor Barker if he thought the addition of cane sugar to cider produced ropiness, as it did in sugar solutions.

Mr. J. W. ALCOCK enquired whether the author had advised apple growers to trim the trees so that the sun could get at the fruit and ripen it uniformly. At some markets, to-day, they would see apples which were turned out so that they were nothing but mould. It was only lack of air which had caused that condition. Nothing had been said in the paper about the grinding of the apples, or as to which produced the better juice, the old stone mills, or scratters, or the so-called pulpers. He contended that if they could only grind up the seeds of the apple they would be adding something which assisted the

fermentation, and tended to eradicate the objectionable acids. As to fermentation in the casks, there was no reason why, in a big factory, there should not be a flow of carbonic acid gas passed through the tops of the casks after they had subsided to some extent.

Mr. WALTER SCOTT said the present methods of cider making seemed to be rather primitive, and science, up to the present time, had not apparently been able to improve the conditions of manufacture, as, generally, spontaneous fermentation was relied upon still. He would like to know why cider was considered, in a hygienic sense, to be superior to beer, which had been sterile in one stage of its manufacture.

Mr. P. L. TALBOT said cider making perhaps was in the empirical position that they read of when the ancient Egyptians took barley that was sprouting on the ground and with it made beer. Professor Barker had spoken of pasteurisation and the consequent flavour imparted to cider. He (the speaker) could very well believe it because of the flavour of pasteurised beer. Unless the flavour was constant it was sure to offend the palate of the consumers. If it was constant they would get accustomed to it. In the brewery they always looked upon ropiness as due to dirt or contamination in the plant. Professor Barker had said that the condition followed the introduction of sugar, and the probability was that that sugar was not of a high grade, and that it carried in the contamination which brought the ropiness with it.

The CHAIRMAN said that they must all have admired the systematic way in which Professor Barker was carrying out his work. The industry was in a less advanced state than brewing, and they could now realise what they owed to the scientific men in the brewery. No doubt in the course of time the cider manufacturer would be in the same happy state. In the brewery they were dealing with a more limited flora than was the case in the cider industry. He supposed the organisms concerned with ropiness in cider were not the same as in the case of beer, but he would like to know whether it had been noticed that ciders low in acidity were more prone than others to the attack of the ropy organism, this being so in the case of beers.

Mr. HADLEY inquired how far they had got in the use of ultra-violet rays in the sterilisation of cider. He had tried it in regard to filtered beer, but he found that by no amount of exposure to the light could he get it to penetrate the cells which had escaped through the filters.

The CHAIRMAN mentioned that ultra-violet rays had been tried in many breweries, but as beer was opaque to ultra-violet rays the treatment was of no use. He alluded to the possibility in the not distant future of a special journey to Long Ashton, when he was sure

Professor Barker would allow them the privilege of seeing his work. He asked the members present to give Professor Barker a very cordial vote of thanks for his careful and able paper.

Professor BARKER, in reply, first referred to the point as to the difficulty of filtration of cider or apple-juice after treating with formaldehyde, remarking that, so far as their work at Long Ashton went, he did not feel that they had got far enough to say anything very definite on that matter. Attempts to filter had not been entirely satisfactory. Through a study of the malady of cider sickness they were brought into touch with the action of formaldehyde on certain constituents of the apple-juice, and throughout that work they were up against the difficulty of clearing the cider satisfactorily. With regard to concentrated juice and slow fermentation after dilution, that corresponded with their general experience at Long Ashton. One of the effects of heat on apple-juice was a tendency to a reduction of the natural rate of fermentation of that juice. *Apiculatus*, as a yeast type, might be quite useful for working with sterilised juices for specific purposes, provided that no objection was raised to the type of flavour that followed the use of it. He could say nothing as to the maximum amount of acetic acid which should be allowable. It would be a dangerous question to raise from the cider maker's point of view, because the cider maker was not entirely his own master in that matter. He had to take the fruit as it came to him from the grower. In the case of the large factories it was received largely by rail, and the fruit might be on the rail many days exposed to bad weather. There was frequently, therefore, appreciable acetification proceeding in the mass of fruit before it reached the cider factory. They were doing all they could to encourage the practice of washing the fruit prior to making, and he knew that those in charge of the larger cider factories were fully alive to the importance of that question. With regard to the identification of the cider sickness bacillus, he had for many years no opportunity of further studying that organism. When he ceased work upon it he had published a fairly full description of the character of the organism, but had not then succeeded in identifying it with any other described form. As regarded the control of sickness, if a maker set out to produce a dry cider the disorder was not going to be a serious trouble to him. It was only in cases where there were appreciable amounts of residual sugar in the cider that the major difficulties of cider sickness occurred. With a sweet cider, requiring a sufficient degree of natural acidity to counteract the sweetness and to give the cider a naturally brisk flavour, they found that they could go

up to somewhere between ½ per cent. and ¾ per cent. of malic acid in the product, and that amount of acidity materially restrained the activity of the sickness bacillus. Last year and the year before, however, at Long Ashton, they were seriously disturbed, owing to the fact that they had a number of ciders turning sick in which by blending suitably they had brought up the acidity to nearly ¾ per cent. of malic acid. Further examination showed that there were at work acid-reducing bacteria, as a result of which the acidity was reduced to a point when the sickness bacillus could come into play. That was a further illustration of one of the difficulties which the cider industry was up against in the micro-biological direction. As to the washing of apples in order to get as sterile a juice as possible, he said that by the use of a dilute solution of formaldehyde they could undoubtedly destroy a large percentage of the organisms present on the fruit, and delay the onset of fermentation. At the moment it did not seem that, working under ordinary practical conditions with fruit in the various states in which it arrived, they could sufficiently get at the organisms which occurred in the bruised and broken tissues of some of the apples. Many apples had the skins damaged, and organisms penetrated into the inner tissues. Washing with formaldehyde did not appear to reach all of these. He had not met with the organism introduced by cane sugar referred to by one of the speakers. One questioner expressed the opinion that by grinding up the seeds they got a better type of cider. They certainly got a different type of cider, and he thought the reason was that in crushing the seeds they tended to extract a certain amount of nitrogenous matter in which the seed was rich, and therefore a higher rate of fermentation in the juice and its resultant effects were obtained. Dealing with the question of cider being a hygienic drink, he said that many people not accustomed to drink cider and ordered to do so under medical orders undoubtedly did really derive material benefit by drinking a good brand of cider. Possibly it was due to some of the natural constituents of the apple present, or possibly it might be due to the presence of vitamins. During the war they were experimenting with a form of apple jelly made from concentrated apple juice, and that jelly months after it was made contained appreciable quantities of vitamins. In the matter of dilution with water the cider industry itself was not at one on the point. In some districts the addition of water to cider was regarded as a heresy. In other districts it had been the practice as far back as they knew the history of cider in those districts, and he did not think under

conditions like that that one could lay down any hard and fast rule. The main thing was to have a product of marketable value, and whether or not water was added to the juice seemed to him relatively immaterial, so long as the product in the end was wholesome and palatable. Their work at Long Ashton on the effect of the addition of water had shown that in certain cases it was possible to make a better and sweeter cider after addition of water than by using pure juice. It sounded rather a paradox that diluted juice could make a sweeter cider. It came about in this way. If water was added, the percentage of nitrogen available for yeast in the mixture was lowered. The result was a slower fermentation and a higher residual amount of sugar. Dealing with the point regarding the possible standardisation of flavour after pasteurisation, he appreciated its force and had been very much struck with some recent samples made under pasteurised conditions. He had not found it easy to detect which samples had been pasteurised and which not, when the juice was pasteurised before fermentation; but there were at times cases where the difference could be readily detected. He felt satisfied that, if the cider manufacturer could be supplied with only a few sorts of apples with which to make cider so that he would be able to get a standard juice to work on, it might then be possible to adopt a standard system of pasteurisation and to produce, by pure yeast fermentation subsequently, a cider which would not reveal to the consumer any marked traces of the pasteurisation treatment. He agreed that ciders of low acidity were more susceptible to ropiness than those with a higher acid content. He was very glad to hear the Chairman's reference to the debt which they owed to science. They had a very good illustration of the truth of that observation in the brewery, where they saw the fruits of the introduction of scientific methods and of scientific research. He hoped they might be able to use that as an illustration in obtaining increased financial support for research work in the cider industry. He had not been able to do anything at Long Ashton in the way of investigation into the use of ultra-violet rays. Most of that work had been done in France, and he believed the conclusion arrived at there was that cider was not a very satisfactory beverage to treat by that method.

In acknowledging the vote of thanks, Professor Barker said he would be very pleased to welcome the members of the branch at Long Ashton at any time, and he hoped they would see their way clear to organise the visit of a party.