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MEETING HELD AT THE CRITERION RESTAURANT, PICCADILLY, ON MONDAY, APRIL 10TH, 1911.

Mr. S. O. NEVILE in the Chair.

The following paper was read and discussed:—

The Principles and Practice of Cider Making.

By B. T. P. BARKER, M.A. (Director, National Fruit and Cider Institute).

IT is impossible within the limits of a single paper to deal adequately with all the various phases of cider making, and it is proposed, therefore, not to attempt more than a general sketch of the main outlines of the subject. The importance of the industry in the cider producing districts is shown by the fact that there are at least 75,000 acres devoted to the culture of cider and perry fruit, and that there are from 50,000,000 to 100,000,000 gallons of cider made every year,

which at a price of 6*d.* per gallon and upwards would amount to considerably more than £1,250,000 in value.

Typical cider orchards are attached to most farms in the West of England. The cider-maker at the outset is in a position of considerable difficulty on account of the extremely miscellaneous character of the cider fruit grown. It is comparatively rarely that many trees of the same kind are to be found in one orchard; and, taking the cider counties throughout, there is practically only one apple, Kingston Black, which is grown at all generally. In orchards about 5 acres in extent there are usually to be found as many as from 100 to 200 different sorts of apples. These, for the most part, are peculiar to the parish or district, and in adjoining parishes apples of an entirely different character may be found. The cider merchant who has to rely mainly upon purchased fruit is, therefore, at a disadvantage, because the nature of his raw material is constantly varying unless he is able to procure fruit regularly from the same orchards season after season.

As an illustration of the variations in character and quality of individual varieties analyses of the fresh juices of some typical cider apples are given in Table I.

Vintage apples may be classified into three main groups. The first is the sharp or sour class (represented in Table I by the first four varieties), in which the amount of malic acid is above 0·45 per cent. The tannin varies considerably in apples of this class; but all show a comparatively large amount of malic acid, although even that varies very widely in different varieties. In referring to the question of tannin in apple juice, it should be mentioned that the usual method of analysis for tannin which has been hitherto used in cider work in this country, and which I have adopted simply to get continuity of results, consists in the estimation of the reducing power of the juice or cider on potassium permanganate, indigo carmine being used as an indicator; and the result therefore includes not merely tannin itself, but also small quantities of certain other substances. The figures given for tannin, however, represent fairly accurately the relative degrees of astringency and bitterness of the respective juices. The second class of apples is termed the sweet class, and its members (represented in Table I by Sweet Alford and Morgan Sweet) are characterised by the low percentage of acid and also of tannin in their juice. The percentage of acid is normally below 0·45, and that of the tannin below

0·2. The remaining varieties in the first part of the table belong to the third class and are termed "bitter-sweets." In this class the malic acid lies normally below 0·45 per cent.; but the amount of tannin is invariably—except in abnormal seasons—above 0·2 per cent.

TABLE I.—*Giving Particulars of the Juices of Typical Vintage and Market Varieties.*

Name of Variety.	Specific gravity.	Malic acid, per cent.	Tannin, per cent.	Rate of fermentation.
Vintage Apples.				
Foxwhelp	1048	1·30	0·308	1·5
No. 182	1068	1·08	0·152	10·0
Kingston Black	1070	0·56	0·192	1·5
Dymock Red	1056	0·48	0·252	3·4
Sweet Alford	1053	0·20	0·150	2·5
Morgan Sweet	1055	0·11	0·138	11·2
Royal Wilding	1064	0·24	0·322	3·2
Medaille d'Or	1071	0·27	0·730	6·5
Market Apples.				
Allington Pippin	1047	0·77	0·042	14·0
Blenheim Orange	1048	0·65	0·088	10·8
Bramley's Seedling	1047	0·87	0·080	7·8
Cox's Orange Pippin	1057	0·60	0·042	14·2
Ecklinville	1034	0·83	0·042	7·2
King of the Pippins	1041	0·51	0·026	11·7
Lane's Prince Albert	1045	0·84	0·092	10·0
Newton Wonder	1044	0·65	0·084	10·8
Stirling Castle	1030	0·64	0·016	9·3
Wellington	1043	0·86	0·060	14·3

Table I also illustrates the variations in the specific gravity of the juices of different varieties, the range being from 1071 to 1048 in the instances quoted. The average specific gravity of the juice of vintage apples is about 1055, but in exceptional cases it may exceed 1090 or fall below 1035. In dealing with juices obtained from mixed fruit, which is the typical kind of juice the cider-maker has to handle, a gravity higher than 1060 is rarely obtained, and it frequently falls below 1050. In exceptional cases it may even fall below 1040. The final column of the table shows the rate of fermentation. It will be noticed that there is considerable variation in this respect between the

different kinds, ranging from 11·2 down to 1·5. The numbers represent the average rate of fall per day in the specific gravity of these juices, fermented at a temperature of 28° C.

Table I also contains analyses of the juices of typical market varieties of apples, as distinct from those regarded as true cider varieties; and it indicates the reasons why these are not so well suited for the production of cider. The specific gravities range very low as compared with that of the average vintage variety. The acidity is comparatively high in each case, and each of the apples mentioned would have to be placed in the sharp class if considered from the vintage point of view. The tannin is extremely low and the rate of fermentation very high as compared with the best vintage varieties. As a result, if the market apples alone are used for cider making, the type of drink which is produced when the cider is completely fermented is a thin, sharp drink, lacking in body, and generally, owing to the high rate of fermentation, of a comparatively coarse flavour.

Owing to the multiplicity of varieties it is evident that the first step in the direction of progress in cider making must be to make a limited selection of the best of the existing kinds and to propagate those exclusively, in order that there may be reasonable uniformity in the raw material available and the requisite knowledge of its vintage qualities.

There has been in the course of the work at the Cider Institute a considerable amount of difficulty in estimating the value of different cider apples for the purpose of making such a selection, not merely because of the number of varieties used for vintage purposes but also because so little has been known hitherto about the relative value of the individual varieties when grown under corresponding conditions. We have attempted to make a study of the comparative merits of the varieties which have hitherto been regarded—frequently on insufficient grounds—as the best standard varieties in the trial orchard at the Institute, which has been planted with a number of trees of each of these sorts, so that all may be tested under similar conditions. Obviously it is not sufficient merely to take into consideration the suitability of the juice from the chemical point of view. Factors such as the yield of juice from different varieties, the size of the crop, and the vigour of growth of the trees must also be estimated, and it is therefore essential that in an endeavour to put the culture of cider

fruit on a sound basis work of that character in the orchard must be carried on.

Table II illustrates the very considerable variation in quality which is found in the juices of the same kind of apple grown in different localities and on different soils. These analyses have been made from fresh juices from the same kind of apple, Kingston Black, the respective samples of which were obtained in 1908 from the localities mentioned in the first column. There is a considerable range in the specific gravity, varying from 1075 to 1050. The malic acid does not show such great variation, there being only one case in which it falls below 0·4 per cent., while in no case does it rise above 0·8. The tannin shows rather wide variations, considering the comparatively limited amount present in the juice. The investigations at present in progress to determine the effect of the soil on the quality of the cider indicate that the soil most suited for the culture of cider fruit and for the production of cider of good quality and full body is a fairly heavy clay loam with a stiff clay subsoil. It is from this type of soil that most of the prize-winning ciders are produced. They are distinguished mainly from those off lighter types of soil by a greater amount of body and the well-marked fruity aroma and flavour.

TABLE II.—*Analyses of Kingston Black Juices*, 1908, *showing Variations due mainly to Soil Influence.*

Locality where grown.	Specific gravity.	Malic acid, per cent.	Tannin, per cent.
Long Ashton, Somerset	1062	0·76	0·272
Berkeley, Gloucester	1066	0·39	0·172
Easton-in-Gordano, Somerset	1050	0·44	0·152
Ash, Devon	1068	0·44	0·242
Martock, Somerset	1071	0·67	0·192
Newnham, Worcester	1058	0·53	0·186
Budlake, Devon	1056	0·46	0·116

As might be expected, the quality of the juice varies very considerably not only off different soils but also in different seasons. Table III indicates the variations of the juice in different seasons, the apples in the case of each variety being taken from the same tree.

The results for four seasons are shown for the Kingston Black apple,

TABLE III.—*Showing the Variations of Juices as a Result of Seasonal Influence.*

Name of Variety.	Year.	Specific gravity.	Malic acid, per cent.	Tannin, per cent.
Kingston Black	1904	1054	0·47	0·178
,, ...	1906	1064	0·70	0·164
,, ...	1908	1062	0·76	0·272
,, ...	1909	1048	0·60	0·148
Butleigh No. 14	1904	1089	0·19	0·316
,, ...	1906	1092	0·20	0·432
,, ...	1907	1086	0·16	0·324
,, ...	1908	1098	0·10	0·420
,, ...	1909	1058	0·34	0·108
Chisel Jersey	1907	1086	0·23	0·544
,, ...	1908	1070	0·27	0·540
,, ...	1909	1052	0·24	0·126

the fruit being taken from a tree grown in the old orchard at the Institute. It will be observed that there is an appreciable range in the specific gravity and also a considerable variation in the amounts of malic acid and tannin. One of the other apples mentioned, known as Butleigh No. 14, is particularly interesting, since it contains in a normal season much more sugar than any other English variety thus far examined. It is comparatively rare for the specific gravity of its juice to fall below 1080. It was in the abnormal season of 1909 that a result was noted which at all approached the average of other kinds. It is not perhaps surprising to find that apples of this type, which are extremely rich in sugar, are very poor as regards yield of juice. The quantity of juice obtainable from a Butleigh No. 14 apple is very small in comparison with most varieties of lower gravity.

There is still another factor to be taken into account in connection with the variation of quality of the juice under different conditions which may be referred to here, that being the influence of the kind of stock upon which the apple is grafted or budded. In one of the trial plantations at the Cider Institute a number of the best cider apples have been propagated on different types of stock; and it is hoped that it may be possible to arrive at some idea as to the influence of the stock upon the quality of the juice produced.

In addition to the attempt to select the best native cider apples by trial under uniform conditions at the Institute, this line of

work has been supplemented by the planting of similar trial orchards in different districts of the cider-producing counties, so that the varieties may be tested on distinct types of soils and under different conditions. There are now more than 50 such orchards in the West of England; and in the course of a few years it is hoped that they will yield results of considerable value. Attempts are also being made to improve the quality of cider fruit by raising new varieties containing suitable combinations of desired characters. This work is being conducted on Mendelian lines, and will necessarily be slow in yielding results; but there appears to be no reason why, if apples follow the laws which have been found to hold in the case of other plants, it should not be possible to breed into a given variety the qualities particularly desired. Those qualities are, from the cider-maker's point of view, not only richness in sugar and suitable amounts of malic acid and tannin, so that the liquor may have a well-balanced flavour, but also good cropping qualities, vigour of growth, disease-resisting qualities, and a good yield of juice. Perhaps the most important of all is a comparatively slow rate of fermentation of the juice. It is found by experience that, other things being equal, the slower the rate of fermentation the better is the quality of the cider produced: and thus the aim of the cider-maker is to work as far as possible with varieties which ferment at a comparatively slow rate. I shall have occasion to refer to this question later on.

Having thus considered briefly some of the more important points in connection with the nature and quality of the raw material, the actual operations directly connected with cider making and the questions arising therefrom may now be described. The first essential is to get the fruit harvested and stored in a satisfactory manner; and it is not going too far to say that undoubtedly at the present time more cider is spoilt owing to want of care in these matters than from any other cause. Unfortunately, it is far too common to find that the fruit is gathered and stored without any trouble at all being taken; and the result is that the fruit during the period of storage keeps badly and rots very rapidly, and is in the end milled and pressed in a thoroughly unsatisfactory and uncleanly condition. It is not necessary here to go into details with regard to the methods of gathering the fruit; but the question of storage deserves a brief mention. A number of experiments have been made to determine whether it is better to store the

fruit under cover or out of doors in the open. The general plan is to store it in heaps on the grass in the orchard; but that is not entirely satisfactory, since in wet seasons the lower layers of fruit are apt to acquire a marked earthy taint in flavour. Hurdle stores are frequently used now to prevent the fruit resting directly on the grass; and these may be recommended as being thoroughly satisfactory for general purposes provided that the weather conditions are not too unfavourable. If the weather conditions are reasonably favourable, the quality of the cider made from fruit stored out of doors without cover is practically equal to that stored under cover in an apple loft; but where excessive rain or frost is to be feared, it is certainly the wisest plan to store the fruit under cover. In either case it is essential that the heap of apples should not be too deep. A depth of about 2 feet is quite enough, since, if it is much more, there is considerable danger of the fruit heating and acetifying, and of rot spreading very quickly. It is very desirable, also, from the point of view of the keeping quality of the fruit, that it should be gathered in as dry a condition as possible before storage, so that it may be stored for the necessary period of time without serious danger of deterioration in quality.

The changes which take place in the fruit during the course of ripening have been investigated by Behrend, Kulisch, and others, and it was demonstrated that during the period of storage the percentage of sugar increases considerably and that the acidity decreases. The fruit also, during the period of storage, loses water by transpiration, so that in that way a concentration of the juice occurs. Changes also occur in other constituents of the fruit. From the chemical point of view, therefore, the period of storage is a critical one. Not only is it important from that point of view, but also because the state of ripeness of the fruit at the time it is milled determines very largely the subsequent rate of fermentation.

In Table IV are given results which indicate the changes which take place in the rate of fermentation of the juice as the fruit ripens. The Early Red Jersey apple is a comparatively early ripening one, and the fruit is, in a normal season, at the best condition of ripeness for vintage purposes during the early weeks of October. The analyses of the juices of fruit taken from the same heap and gathered from the same tree, pressed in consecutive weeks, show that the specific gravity gradually rises during the course of storage within the period over

TABLE IV.—*Showing Variations in Quality of Early Red Jersey Juices due to the Condition of Ripeness of the Fruit.*

Date of pressing.	Specific gravity of juice.	Rate of fermentation.
Apple.—Early Red Jersey.		
September 29th	1047	2·6
October 6th	1052	2·0
„ 14th	1051	1·3
„ 21st	1055	2·2
November 7th	1053	3·2

which the tests extended; but the rate of fermentation does not present a similar regular type of variation. The comparatively unripe fruit possesses a relatively high rate of fermentation. The rate of fermentation becomes gradually less as the fruit gets riper, until it attains what may be termed the optimum point of ripeness, when the rate of fermentation reaches the lowest point. After that it begins to increase again, and by November 7th the highest point was reached in the series of trials referred to. If the experiment had been continued further, there would probably have been, judging from other results, a very considerable increase in the rate of fermentation subsequently.

It is not an easy matter to determine, when dealing with a heap of fruit, exactly at what time it is in the best condition to bring to the mill. There is, unavoidably, considerable variation in the degree of ripeness of individual apples in the heap, so that the state of the heap as a whole must be taken as a criterion. There is no satisfactory test known at present which will enable the maker to determine easily whether the fruit is at its optimum point of ripeness or not. The usual plan is to examine a number of apples in the heap by lightly pressing them between the thumb and forefinger. The cider-maker knows by experience, by the "feel" of the flesh under his thumb, whether the fruit is in good condition for cider making or not; but the result certainly depends on the individual experience of the maker.

The types of mill which have been used for grinding the fruit have varied very much from time to time. The primitive form of mill consisted of a circular stone trough in which the apples were placed, and in this trough two large stone rollers were made to revolve,

usually by means of horse power. The method of milling with such a machine is a very tedious and costly one, but occasionally they may still be found in use. They have given place in commercial work to a speedier type of mill, since obviously they were of little value for such purposes. At the same time there were, undoubtedly, many good points in connection with the old stone roller mills. The fruit was well broken up, all the particles of the flesh and the peel were thoroughly crushed, and the juice obtained after crushing with a mill of that type probably possessed more of the fruity character of the apple than that yielded by any of the more modern types of mill. In the modern types of "crusher" mill the apples are first roughly broken into coarse pieces by revolving iron arms which force them through a grating, and these are made to pass between two revolving stone rollers, which are generally grooved. In that manner the fruit is broken up into a comparatively fine pulp. There is a certain amount of crushing action in this type of mill, but not to the same extent as with the old stone roller mill. The most modern form, which is being largely used now, does its work without any crushing. It consists of a steel drum, made to revolve at a speed of about 2000 revolutions per minute, on the surface of which are arranged a number of toothed knives which project about one sixteenth of an inch above the surface. The fruit is put into a hopper and brought into contact with the revolving drum, which rapidly grates it into an extremely fine pulp, which comes from the mill in a state resembling apple sauce. The "grater" type of mill is most useful for commercial purposes, and it does its work with extreme rapidity; while owing to the very fine condition of the fruit pulp the yield of juice is extraordinarily high. From a modern mill of the "crusher" type little more than 70 per cent. of the weight of the fruit as juice can be expected; but with the "grater" type of mill it is by no means uncommon to exceed 80 per cent. of the original weight of the fruit. It has on occasion even approached 90 per cent. The difference between the "grater" and "crusher" types from the commercial point of view is thus very considerable. At the same time it is almost certainly the case that the quality of the juice, as far as body and fullness of flavour are concerned, is not so good from the "grater" as from the "crusher" type.

The apple pulp, or "pomace" as it is generally termed, after passing

from the mill is built up into a series of layers, about 4 inches in depth, each enclosed in a strong net-like cloth made of cotton or other fibre, and separated from one another by suitably constructed wooden racks on the bed of the press to form the "cheese." The latter is then subjected to steady pressure until the edges of the racks practically meet. With a suitable machine of moderate size it is possible to mill half a ton of fruit, build up the cheese, and express the juice within the space of half-an-hour. With an efficient press the yield of juice should average about 80 per cent. of the original weight of fruit. The pomace after pressing contains from 60 to 70 per cent. of juice which it is not possible to express conveniently by any ordinary process now in use. Sometimes the pressed "cheese" is broken up and re-pressed; but that procedure, as a rule, gives barely sufficient additional juice to make it profitable.

There has been considerable controversy as to whether it is advisable to allow the pomace, after being milled, to stand and macerate for a time before pressing. Some makers are firm believers in the value of the process, and others are equally convinced that the best results are to be obtained by pressing the pomace immediately.

TABLE V.—*Showing the Results of Maceration as compared with those of Immediate Pressing after Milling.*

Apple.—Cherry Norman.	Pomace pressed immediately.	Pomace macerated 24 hours.
Weight of pomace	1275 lbs.	1300 lbs.
„ juice after 1st pressing	857 „	970 „
„ „ 2nd „	94 „	91 „
Specific gravity of juice	1055	1056
Percentage composition of juice { malic acid	0·14	0·14
Percentage composition of juice { tannin	0·352	0·316

Table V gives the results obtained in one of a series of trials, and it shows approximately the effect of maceration. There was a considerable increase in the total quantity of juice expressed during the first pressing. The results for the second pressing are approximately equal; but these are determined by the kind of pressing first given. The specific gravity of the juice varies comparatively little, and there is no variation in the percentage of malic acid. On the other hand,

the tannin shows a slight reduction in the juice from the macerated pomace. There are, however, other changes which are important but not shown in the table. They have mainly to do with the mucilaginous bodies in the juice and are of importance in the later stages of manufacture, since they have a considerable bearing upon the ease with which the juice will naturally clear itself. Juice from pomace which has been allowed to stand 24 hours before pressing will generally fine down naturally and more easily than juice from pomace which is pressed immediately after milling.

Passing on to the question of the fermentation of the juice, it is the practice of many makers to "keeve" the juice before it is placed in the fermenting cask. The process of keeving consists in exposing the juice in a large open vat for several days, so as to give the solid matter suspended in the juice a chance of rising and forming a head. This can then be skimmed off from time to time, so that when the juice is eventually racked into the fermenting cask it is comparatively free from solid matter. There is considerable value in the method when the juice contains large quantities of suspended material; but with the modern types of cloths and mills there is generally very little present in the juice, and keeving may be omitted without any serious disadvantage.

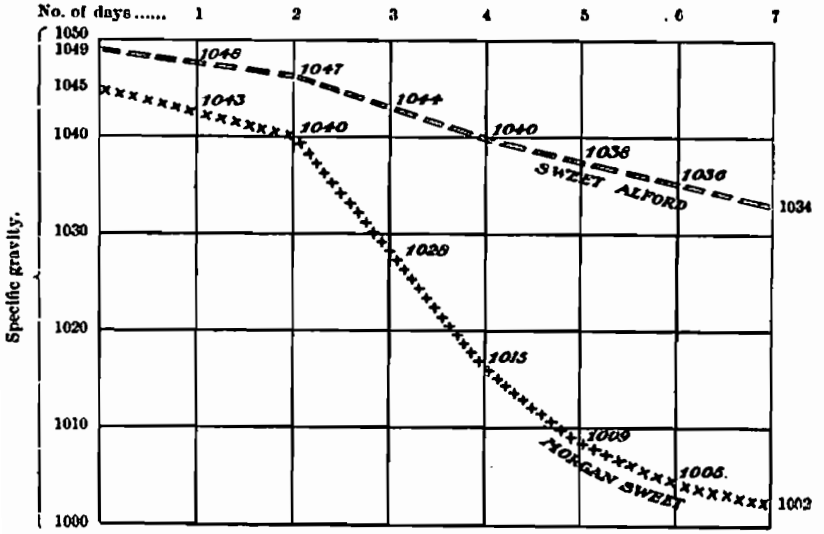
The fermentation is generally allowed to develop naturally. A spontaneous fermentation sets up in the juice within a few days after pressing, the time of its first appearance depending very largely on the temperature. Normally, the juice is in full fermentation within a fortnight or three weeks after the date of pressing. Many experiments have been made on the use of selected yeasts, so as to get a more regular type of fermentation, but the results from these are, on the whole, rather disappointing. There is considerable irregularity in the results, which is not surprising considering how the quality of the different juices varies owing to the miscellaneous character of the raw material which is used. It is quite possible, if a more or less standard quality of juice could always be used, that it would be found that fermentation by the aid of pure cultures would give more satisfactory results than natural fermentation; but, taking the conditions as they stand at present, it cannot be said that fermentation by means of selected yeasts has regularly given appreciably better results than natural fermentation. There is, however, room for a great deal

more work on the point, and experiments are still in progress. The matter cannot be considered as finally settled by any means.

The yeasts which are naturally present in the juice vary very much in character. There are usually from half-a-dozen to a dozen different kinds present. Some are not numerous, and are very soon crowded out by the more strongly growing forms. There seems to be a series of well-marked phases in the domination of certain types. During the earlier stages, yeasts of the *apiculatus* type appear to be most numerous; later, yeasts of the *ellipsoideus* class form the majority; and, finally, when the cider has finished active fermentation and has had time to mature somewhat, a number of minute torula-like yeasts, which have not been fully investigated yet, become conspicuous. They probably have a considerable bearing on the elaboration of the flavour which develops in the course of the ripening of the cider.

With regard to the course of the fermentation and its degree of rapidity, the accompanying chart illustrates the variations obtained with juices from different kinds of apples.

CHART I.—*Showing the Typical Course of the Normal Alcoholic Primary Fermentation of Sweet Alford and Morgan Sweet Ciders.*



The two varieties shown, Sweet Alford and Morgan Sweet, very nearly agree as far as chemical composition in respect of sugar, malic

acid, and tannin, is concerned; but it will be noticed that there is, nevertheless, a considerable difference in the character of the curve of fermentation. The Morgan Sweet juice ferments very rapidly, while that of Sweet Alford moves at an extremely slow rate; and if the chart were continued to a later stage, it would be found that fermentation in the latter case came practically to a standstill above 1·030. These are, however, only results for two particular juices. The juices from the same kind of apple taken from different soils or in different seasons will vary to a certain extent; but the contrast of character between rapid and slow fermentation holds good fairly well for individual varieties. Certain varieties normally ferment rapidly, and others slowly.

Fermentation is allowed to proceed in the fermenting cask until the specific gravity has approximately reached the point at which the maker desires to maintain it. There is a much greater demand in the market for sweet than for dry ciders; and, consequently, the aim of most makers is to retain a fair proportion of sugar. In order to accomplish this, it is generally necessary to check the fermentation by some more or less artificial means. A number of methods have been tried, and the most successful and least objectionable is filtration.

Finings are used occasionally, but the results are not usually so satisfactory as with filtration. There are certain very interesting cases, which occur unfortunately comparatively rarely, when the juice will naturally clear itself at a comparatively early stage of the fermentation. This result is brought about by the clotting of the pectic constituents present in the juice, whereby the organisms become entangled in the clot; and, as the clot condenses and separates itself from the liquor in the fermenting cask, brilliantly clear cider can be racked off into another cask. Comparatively little fermentation sets in afterwards in such cases. Cider which "drops bright," or fines itself naturally in that manner, undoubtedly is of superior quality, as a rule, to cider in which fermentation is checked by any other means.

If dry cider is required, fermentation is allowed to proceed until the specific gravity reaches a suitably low point, when, by means of racking or filtration, it is fined.

After fermentation has been more or less completely checked, the cider is transferred to storage casks and allowed to mature. It is

at this period that particular care is required. In the fresh juice acetic bacteria are invariably present. Consequently, when the normal alcoholic fermentation has subsided, if air gains access to the cider, acetification will very rapidly take place owing to the low alcoholic strength of the cider. Acetification is one of the greatest troubles with which the cider-maker has to contend. In warm weather acetification occurs, to some extent, in cider in cask, unless special care is taken.

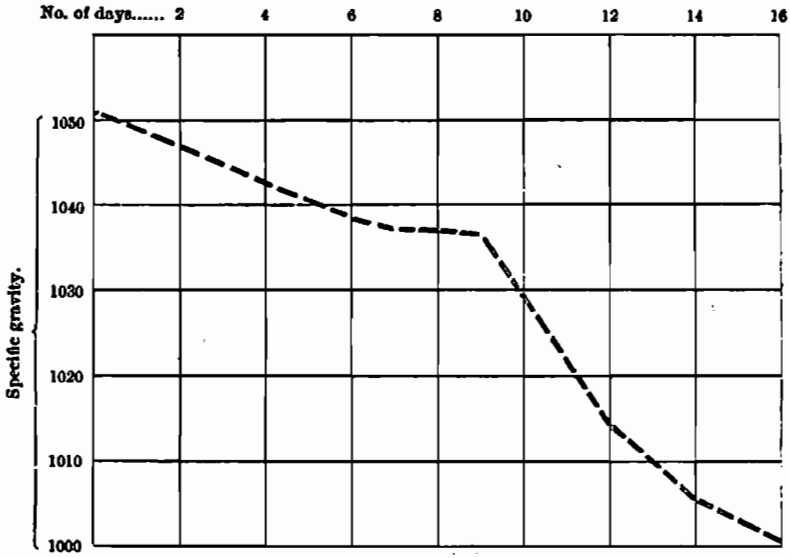
The period which must elapse after fermentation is checked, before the cider is in a fit state for consumption, varies very much according to the type, but the average cider is generally fit for consumption within a month after the cessation of fermentation. As a general rule, cider is probably at its best during the first year after making. There are a few types which improve in bottle for a number of seasons; but these appear to be exceptional cases rather than the rule.

Reference has been made to acetification as one of the most troublesome disorders to which cider is liable. Ropiness is another disorder of common occurrence; but the most characteristic of cider disorders is that known as "sickness." It generally attacks ciders of the best quality—those which contain a considerable amount of sugar, and which possess a full, rich, fruity flavour. The following chart illustrates the course of fermentation in a typical instance before and after sickness sets in, the cider being kept throughout at a temperature of 28° C.

The Horner juice is normally one with a slow rate of fermentation, and is capable of giving cider of the best type if suitably blended. There is a gradual drop in the gravity until, at a point just below 1040, the primary alcoholic fermentation has practically come to a standstill. Suddenly, after a day's pause at 1037, the rate begins to increase, and continues at a much more rapid rate than the original, until, finally, practically the whole of the sugar is destroyed in a very short space of time. If sickness had not set in, the gravity would have been maintained indefinitely above 1030.

Normally, in the cellar, there is no indication of sickness showing itself until the warm weather sets in, but during May and June it is extremely liable to make its appearance in ciders of a sweet type. At present, there is no satisfactory method of preventing the disorder in cask. There appear, however, to be two or three promising lines of attacking the problem. For instance, by blending juices of this type

CHART II.—*Showing the Course of Fermentation of Horner Cider previous to and during "Sickness."*



with juices fermenting normally more rapidly, so as to increase the rate of fermentation of the mixture, normal alcoholic fermentation proceeds more rapidly and leads to a greater attenuation, and the cider is less liable to sickness on that account. Another means is by utilising a comparatively large proportion of apples of the sharp class in the blend. The bacillus responsible for cider sickness is one which will not flourish in the presence of a considerable amount of malic acid, so that, as far as flavour will allow, an increase of acidity is desirable. The third method is, when dealing with such ciders as are liable to sickness for bottling purposes, to bottle at a very much earlier date than usual. Cider is usually considered best for bottling during the month of April. Ciders liable to sickness can, however, be bottled successfully as early as late January or early February; and in the most recent experiments it has been found that such early bottled ciders have not turned sick, whilst the same cider bottled in March, April, and May, has turned sick regularly when kept under ordinary conditions. There is promise, thus, after further experiment, of being able to deal with this troublesome disorder.

Such, then, is a brief outline of some of the principal features of

cider making. In a general paper of this character it is not possible to go into much detail on particular points, but enough has been said to indicate some of the problems under investigation, and to show how wide is the field for further research. Cider has recently come rapidly to the front as a beverage. Its sale is increasing season by season, and there is no doubt that, when it is well made, it is one of the most wholesome and palatable beverages we have, and should have a promising future before it.

DISCUSSION.

The CHAIRMAN said that they had all listened to this paper on a kindred fermentation industry with great interest, and it was interesting to some of them to find that the manufacture of cider progressed in many ways on parallel lines to the manufacture of beer. It was interesting to hear that the original gravity of cider so nearly approximated to that of beer, also that the difficulties which faced the cider manufacturer were similar to some of those which faced those engaged in brewing. They were very fortunate in having this paper on an industry which so much resembled their own, and to which the progress of scientific research was now being applied.

Mr. A. CHASTON CHAPMAN, having expressed his appreciation of the paper, said that there was probably no one who knew more about the chemistry and the technology of cider than Mr. Barker, and they were fortunate in inducing him to address them. It was a very fascinating subject, because they saw here taking place under their very eyes the emergence of an ancient industry from the state of pure empiricism or rule of thumb into the condition of a scientifically controlled industry. No one present was old enough to remember the same phenomenon in connection with brewing, but in this case they actually saw a beverage which had been made for probably several thousands of years, being for the first time studied scientifically, and he had not the least doubt that, with the work of men like Mr. Barker and his colleagues, this industry would before long be placed on a foundation as satisfactory as that on which brewing rested. He was certain that Mr. Barker would be the first to admit there was a great deal yet to be done; he and his friends had been working only a few years, whereas the pioneers of brewing

science commenced their work 70 or 80 years ago, and even now that work was a very long way from being complete. It was clearly not within the scope of the paper to deal minutely with the changes which took place in the raw material in the earlier stages, or during the process of fermentation, but there were a few questions that he would like to ask, and, if there should not be time to answer them, possibly Mr. Barker might deal with them when the paper was published. He noticed that there were some very remarkable results in connection with the rate of fermentation, and he would ask how far the author thought that the rate was dependent on the chemical properties of the juice, and how far it might be a function of the particular yeasts which happened to be active in any particular case. They were obviously not dealing with the same yeasts in all cases, and consequently the results were not strictly comparable. Under these circumstances it might be that those rates of fermentation had not quite the degree of importance which appeared to be attached to them. Another thing exceedingly interesting was the curious change which apparently took place when the apples were allowed to ripen in the store. There they saw that the rate of fermentation of the resulting juice diminished during the first period of storage, reached a minimum, and then increased again. He should like to ask whether experiments had been made to ascertain what this was due to, because at first sight it seemed almost inexplicable. Could it be that the amount of the sugar diminished during the first period of storage, and then, for some extraordinary reason, increased? Another point was in connection with the actual fermentation itself; Mr. Barker said that the organism which appeared to dominate during the earlier period was the apiculatus, which was what one might expect, as it was one which could only ferment very readily fermentable sugar, and therefore one might expect it to function first. Then yeasts like the ellipsoideus began to appear, and lastly came the torulæ. This was interesting, since in the case of beer the secondary fermentation or conditioning was, to some extent, brought about, not by yeast at all, but by torulæ. Putting his questions into a compact form, he asked whether any detailed investigation had been made with regard to the actual constitution of the apple juice at different periods of ripening, etc., not only with respect to tannin and acidity, but with respect to sugar, nitrogenous substances, and various other

constituents, which must have a most important influence upon the nature of the fermentation change and upon the character of the *finished* product. It seemed, from the results given, that importance was attached very largely at the present time to the determination of the acidity and the tannin, but he presumed that other estimations had been made and were on record in considerable numbers. With regard to the tannin, he would suggest that it would be an advantage to substitute for the permanganate method, which was exceedingly unreliable, a method which was more exact. Some time ago he had devised a process in which the tannin was precipitated by means of cinchonine. A precipitate of definite composition was obtained which could be weighed. This method was specially devised for the analysis of hops, but, doubtless, it could be applied to cider. For the sake of the continuity of results, there was no objection to expressing the percentages of tannin by both methods for a time, but he thought the cinchonine method would probably be preferable. If the tannin percentage really had any technological meaning, it would be an advantage to have numbers which should be more exact than those obtained by the process now used by the author and his colleagues. There were many other points he would like to have alluded to had time allowed, but possibly some of them would be dealt with by the author when the paper was published.

Mr. WALTER F. REID said that he felt that he could not add much to the highly interesting information which had been given; but he congratulated Mr. Barker on the scientific manner in which he was dealing with the problem before him. It seemed to be almost an impossible task to put a whole industry in order where everything seemed to be in such utter disorder; and when one began with a material which was practically different in every orchard, and where the quality varied so considerably from year to year, for climatic and many other reasons, it seemed almost a hopeless thing to bring order into such an industry; but Mr. Barker had tackled the question in a way which he felt sure would lead to very valuable results. He was glad indeed to see that, in spite of the long period which was necessary to obtain any results, he was beginning from the very beginning, and was trying to obtain varieties of apples which would give certain definite results. Many years ago he started on a similar experiment himself, not with the object

of making cider, but with the object of obtaining eating apples; and he had had those experiments going on for some 25 years. He had some 200 or 300 varieties of apples which he grew from seed that resulted from crossing various kinds of apples; and he hoped he would not discourage Mr. Barker if he said that out of all those seedlings he had obtained within the 25 years only four different varieties that he could successfully test; three of those he cut down and grafted with other varieties, because they were of no use, and the fourth was a very nice kind of apple, of which he was very proud. That showed the great variety of experiment which was required before one could place an industry of this kind on a satisfactory basis. With regard to the fermentation itself, he had always regarded it as somewhat of a toss-up what you were to get with cider in the ordinary way. He himself made a cask or two every year, and he had perhaps some little right to speak from the rule-of-thumb point of view. He had not treated the problem in a scientific way, isolating the different ferments. He took it that the only way to get a definite fermentation would be to sterilise the cider juice first, and if you did that you would at once destroy some of its characteristics, especially the delicate flavour which good cider had; and you were almost bound, if you took cider in the ordinarily accepted sense, to take the fermentation organisms or germs which you found on the apple itself. With regard to the quality of different apples for producing a palatable cider, first of all, he thought they ought to decide what was to be the character of the drink which was to be sold generally as cider. He did not refer to the chemical question so much as to the question of flavour. Some people insisted on having acid cider; whilst others said they could not drink it. What was to be the standard of cider? Their neighbours on the other side of the Channel were quarrelling amongst themselves about champagne. After making champagne for centuries they themselves did not know what champagne was. But when we started on English cider—which he had no doubt would in time become a national drink of very great importance—we ought to decide on how we were to improve it—whether we should improve it as a drink which should be decidedly acid in flavour, or whether we should improve it by a sweeter and milder taste. As Mr. Barker knew, we could get either; and he should like to ask in which

direction Mr. Barker was aiming to work in the selection of the apples he was growing and testing? That was a point which had to be settled by general consent. Or was he going to develop, say, half a dozen different types of cider? If so, it would take several lifetimes to develop the whole industry on the very scientific grounds he was now pursuing. He heartily congratulated Mr. Barker on the success he had already obtained, and he thought that with the large number of experimental orchards which he had spread through the country he was holding out great hopes to agriculturists that they would be able to utilise their land even better than by afforestation.

Mr. JULIAN L. BAKER said that the Chairman had alluded to the similarity which existed between the brewing industry and cider making. Worts were boiled with hops largely for preservative purposes, and in this connection he should like to know if Mr. Barker attached much preservative value to the tannin in the apple-juice. He was at present investigating organisms which caused ropiness in beer, and it was interesting to know that ropiness in beer could be overcome by proper adjustment of the hop rate and the quality of the hops. Since hops contained tannin there might possibly be some connection between the tannin contained in the apple-juice and the tendency to ropiness in the finished cider.

Mr. W. A. RILEY wrote that he would like to ask Mr. Barker how he prepared his nutritive liquids for the cultivation of cider yeast. Was the apple juice, as taken from the press, filtered or unfiltered, and how long was it sterilised? He had found that grape must was not altogether satisfactory. In producing a dominant fermentation with a selected yeast, had it been found an advantage to use the juice of one variety of apple, and at what period after pressing should yeast be added, would 3 hours be too long? Had it yet been settled that one part of juice (sterilised) fermented with a pure yeast was sufficient to start about 350 parts of juice, or must this be determined by local conditions? In Germany, he believed most of the yeasts used had originated from wines. Which was the best to use, a cider or wine yeast? He knew that a wine yeast produced a cider with a drier palate, and perhaps the cider produced would not be suitable for our English tastes. Would it be possible in a good and plentiful apple year to express the juice, filter, sterilise and evaporate to a syrup *in vacuo*, and then at some convenient period, break this down with juice, such as was made for "small cider,"

and ferment the mixture with a pure yeast. With regard to the cause of "sick cider," was it true that juice from Herefordshire apples was more prone to this trouble? He believed that, in some cases, samples of the juice were taken at keeving period and placed on a forcing tray, as a high temperature was favourable, so that an early warning might be given of their stability. Had Mr. Barker yet isolated any organism that gave rise to this trouble, or was it due to some chemical change in the apple itself? With regard to the utilisation of the pomace, he had dried some tons of pomace this last season through an ordinary brewer's dry grains machine, and found that he obtained about 25 to 27 per cent. of dried pomace, having an average of 4·75 per cent. of oil, 6·12 per cent. of albuminoids, 52·87 per cent. of carbohydrates, 33·56 per cent. of woody fibre, etc., and 2·70 per cent. of ash. This was mixed up with cut hay, treacle, and linseed cake, and given to cattle, but the cost was somewhat prohibitive, being as near as he could calculate about 25*s.* per ton dried, not including cartage. It took some 30 hours to make 5 cwt. in one cylinder from a ton, wet. A great difficulty was found in preventing the chads becoming mouldy, and unlike brewers' grains it was noticeable in the dried stuff. He found that if the pomace was taken direct from the press and spread out in the open it delayed the formation of mould. He would like to hear Mr. Barker's opinion as to the utilisation of the chads, and he might add that the cattle did well on it. He did not yet know the final results, as they had not yet been killed.

Mr. H. F. E. HULTON asked if in the case where pure yeast was tried the amount used was sufficient to swamp the yeasts already present in the juice. He understood that the flavour was spoilt if the juice was sterilised by boiling, so that, unless a large excess of the selected yeast were present a mixed fermentation would result.

Mr. B. T. P. BARKER, in reply, said that with regard to the cause of the differences in the rate of fermentation of individual ciders, to which Mr. Chapman referred, so far as he was able to determine, he thought the work had been perfectly sound. It was not a question of the kind of yeast to any serious extent; the variations in the rates were primarily due to differences in the amounts of nitrogenous substances available for yeast nutrition in the juices of the respective apples. The total amount of those substances was extremely small. During the course of the ripening of the fruit, those nitrogenous constituents, in

common with other elements, underwent changes, and for that reason the changes in the rate of fermentation during ripening might be *understood*. Going back to the question of yeast effect, the rate of fermentation of the juice, after the addition of a relatively large quantity of a strong culture of pure yeast, did not differ seriously from the rate resulting from natural fermentation. Therefore it hardly seemed as if it were a question of the kind of yeast so much as that of the nutrition of the organisms of fermentation. With respect to the chemical determination of the changes which occur during the course of the ripening, as far as he was concerned he had done practically nothing in that respect, as his time had been occupied with other branches of the work; and it was also for that reason that he was adhering to the original method of tannin determination. He quite realised that it was extremely unsatisfactory, but he had not had time to adapt one of the better methods to cider work. During the course of the cider-making season he had 500 or 600 different juices through his hands for analysis, and in addition attention to the general experimental work was necessary, so that there was little opportunity to devote attention to points of that kind.

Mr. CHAPMAN asked if cider makers attached any importance to the amount of tannin, if they knew it beforehand. Given certain analytical knowledge, could they predict that those apples would yield cider of one kind or another; or, would other apples, which yielded another certain proportion of tannin, yield better cider? Was it really an important estimation as a guide?

Mr. BARKER said that he certainly considered it a useful estimation as a guide, because the amount of tannin was important in connection with blending. In blending, the amounts of malic acid and tannin should be so adjusted as to get a well-balanced cider in flavour. The percentages of malic acid and tannin which were considered about the most satisfactory for general purposes were between 0·35 and 0·7 of malic acid, and between 0·15 and 0·25 of tannin. On a large scale, commercially, it was extremely difficult to do anything very satisfactory in the way of blending to a uniform standard; practically all the fruit was sent in in a mixed condition, and therefore suitable quantities of juices of different types to blend so as to give the desired standard were not always available. With regard to the question of the type of cider the maker should aim

at producing, what he had just said respecting the standards of malic acid and tannin for blending would furnish some clue. The most popular cider was one not too sharp, nor too sweet, nor too bitter, but yet with sufficient acidity and bitterness to give it a definite character, and enough sweetness to mask natural roughness. The best way of getting over difficulties with regard to type was to grow a sufficient quantity of apples of the pure sweet class, because then it was possible by blending to tone down any excess of acid or tannin. In the trial orchards which were now being planted, they were selecting varieties representing the three classes of cider fruit, and the proper quantities of each, with a view of making such orchards produce a good blend. There must be always some elasticity in the type of cider produced to suit the variations in the public taste. These were rather wide variations; but he saw no reason why, by growing apples of the three classes in suitable proportions, all tastes should not be quite easily met. The preservative value of tannin was a matter he could say very little about with respect to cider. He had paid some attention to that subject in connection with the development of various disorders, not so much in connection with ropiness as with sickness. He found that ciders containing large amounts of tannin would apparently turn sick quite as easily as the ciders made from apples of the pure sweet type with a very small amount of tannin. The feeling he had was that in cider work the importance of tannin as a preservative had been rather over-estimated. As far as his own experience went, he preferred to rely on the malic acid rather than on the tannin to check disorders. Another point which had been raised was concerned with the utilisation of the pomace after it had been pressed. It was largely used for cattle feeding. Cows liked it, and they would consume large quantities of it; but there were certain necessary precautions to be taken. If they were fed too largely with it, the milk was quickly tainted; and if the pomace was not used in a perfectly fresh condition, it was bad for the cows, because acetification took place rapidly. It was also used in a dry state mixed with other foodstuffs for cattle. That method had been developed during the last season or two; and, though he did not know much about it, there seemed some possibility of its being usefully applied in that direction, in spite of certain practical difficulties in the desiccation of the material. They had also been making some experiments in using it to freshen up old cider—

cider which had become flat, or so badly acetified as to be no longer saleable. By breaking up the pressed pomace, soaking the old cider *in it* for 24 hours and then re-pressing it, a considerable amount of the old cider was replaced by the juice of the pomace which it was impossible to express by means of the ordinary press, and a very drinkable cider could be made in that way. Of course, it was not of the highest type, but it had some commercial value, and cider which was at present discarded might be thus utilised. In connection with the use of pure yeast for cider work, the quantity they had used had been proved to be sufficient to swamp the natural yeasts occurring in the juice, because they had made series of plate cultures from time to time during the course of fermentation, and had been able thus to check the relative proportions of the naturally occurring yeasts and those which were added. He was not in a position to give any definite statistics as to what quantity of selected yeast was necessary, but he always erred rather on the overside than on the underside in experimenting in that respect. Professor Allwood, who had been carrying on experiments on cider making in connection with the United States Department of Agriculture, had given a number of statistics on that point, which he claimed to be thoroughly satisfactory, and his work had been published by the United States Department of Agriculture. Dealing with individual points raised by Mr. Riley, the following procedure was adopted for the preparation of active cultures of cider yeasts for use in cider making:—An actively fermenting culture of the yeast in about 250 c.c. of sterilised beer wort was first prepared, and then used for the inoculation of 2 litres of sterilised apple-juice, which was taken in an unfiltered condition direct from the press and must be of a rapid fermenting type. After two or three days at 25° C., it should be actively fermenting, and then fit to be used to produce dominant fermentation, the total quantity being sufficient for 100 gallons of freshly pressed apple-juice. At the usual autumn and winter cellar temperatures, a delay of three hours after pressing, before the addition of the yeast culture to the juice required to be treated, was of no serious consequence. At the same time, it was generally advisable to add it as soon as possible after pressing. The comparative results of dominant fermentation with a number of yeasts differed to an appreciable extent, according to the types of juices for which they were utilised. A yeast which was well suited

for a juice of comparatively high acidity was not necessarily adapted for a juice of low acidity or somewhat marked astringency. Consequently, it was an advantage when working with a selected yeast to use juices of as nearly as possible the same type, if not actually of the same variety. The question as to the correct quantity of the active culture of yeast to use for producing dominant fermentation in a given volume of freshly pressed juice could not be considered definitely settled. Much depended upon the type of juice and upon local conditions. A similar answer held good for the enquiry as to the relative values of wine and cider yeasts. In fact, the use of selected yeasts for cider fermentation was at present in its infancy, and few general conclusions were yet justified. The principal objection to the suggestion of concentrating juices in a plentiful apple year, to be broken down afterwards, and then fermented, appeared to be that it was doubtful whether the fresh, fruity, apple flavour characteristic of well-made ciders could be conserved by such a process. Considerations of expense would probably also put such treatment out of court. However, little information appeared to be available in this connection. Ciders made from Herefordshire apples could not be considered more prone to "cider sickness" than those made from the produce of other counties. Since sickness most easily developed in ciders low in natural acidity, it followed that those produced mainly from sweet and bitter-sweet apples were most subject to the disorder. Such types predominated in Somerset and Devon, while in Hereford a sharper type of fruit was more common, and therefore, on the whole, Hereford ciders probably suffered less from sickness than those made in the more southern counties. The fruit of certain districts was peculiarly prone to produce sick cider, mainly on account of the very slow natural rates of fermentation of the juices of those districts, due probably to soil influence. It was possible by forcing at 28° C. to obtain an early warning of liability to sickness, and such information was of service to the maker, since he might then blend those juices with others possessing a more rapid rate of fermentation and of a more acid character, and thus, in conjunction with bottling at an early date, reduce the risk of the development of sickness. Mr. Hillier, of Bristol University, and he (Mr. Barker) had isolated the bacillus which caused sickness, and were now engaged upon a study of its characters. All the characteristics of sickness were

produced in sterilised ciders infected with this organism. At the same time, the peculiar flavour and aroma of "sick" cider had been noted by him in the fruit itself in one or two rare instances, and these might perhaps be explained by the assumption that, owing to abnormal conditions, chemical changes had taken place in the fruit naturally corresponding to those produced in the fermented cider by the sickness bacillus. With regard to the utilisation of the pressed apple pomace, it was undoubtedly useful as a cattle food if used in a perfectly fresh condition and not in excess. During the past year, at least, it had been used as a constituent of certain cattle foods after desiccation, but he was not in a position to express a definite opinion of its merits in that form.

The CHAIRMAN said it only remained for him to propose a very hearty vote of thanks to Mr. Barker. They would all agree that the paper had been exceedingly interesting, and the older members of the Institute would feel considerable sympathy with him in his work, because it was in many respects parallel with the work which the earlier members of the Institute were doing many years ago. As the paper had been general in its scope, he hoped that was not the last they would hear on the subject, but that as time went on, and the work Mr. Barker was doing progressed, he would some day come again and give them a paper on the ferments of cider, and other questions which were at present shrouded in mystery, but which were of peculiar interest to all engaged in the fermentation industries.

Mr. BARKER, in response, said that if on any future occasion they cared to hear about the progress of the work on any specific points, he should be pleased to come and give some account of the results.