# THE ART OF BREWING.

BY

F. FAULKNER

with Appendix.

SECOND EDITION.

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*PRACTICAL AND THEORETICAL.*

BY

FRANK FAULKNER.

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# PREFACE.

To My Readers—

Years ago, as the pupil of a very eminent scientific Brewer, the late Mr. James Young, I had opportunities of gleaning and working out much theoretical knowledge, that does not perhaps come under the observation of ordinary Brewers.

It has been the task of my leisure to collect some of the more interesting and important features of this knowledge and present it in simple form to the many readers of *The Brewers' Journal.*

The reception the essays met with has warranted their revision and collection in a separate volume, as also a proposal for the continuation of them in more detailed and practical shape.

Whether this takes place or no, let me hope that the present collection will tend to raise the Art of Brewing in the estimation of my readers, and to clear away some of the prejudices and partialities that have so long surrounded it.

Faithfully yours,

FRANK FAULKNER.

St. Helens, Lancashire.
*June*, 1876.

# CONTENTS.

ESSAY VII.



ESSAY VIII.



ESSAY IX.



ESSAY X.



ESSAY XI.



ESSAY XII.

# PRACTICAL AND THEORETICAL ESSAYS ON THE ART OF BREWING.

IN commencing a series of papers on this complex subject, it will be well in the introductory essay to mark out a line of arrangement, and to explain in what measure the arguments will be theoretical, and to what extent practical. First of all, I do not intend to occupy one line of space by dilating on the threadbare subject, "Origin of Beer." Such knowledge is easily obtained from any Encyclopædia or work on brewing; but, on the contrary, I propose to embark at once into a brief explanation of some of the modern theories respecting the brewing process, step by step, from a consideration of the materials in use, to a final review of the essential characteristics of a finished beer; and while mentioning theories, although in the limited space at my command, I cannot attempt to enter into minute argument or detail, I still hope to so place them before my readers as to interest all classes to such an extent as to enable them to work more perfectly in practice, in seeing that theory and practice, instead of being rivals, are in reality of mutual aid to each other.

Then again, in regard to practical information, although I cannot pretend to unravel all the mysteries of brewing, I do hope to make clear many complex practical operations, so that my essays shall be of some advantage, and thus in blending the two distinct kinds of teaching, hope to interest the mere theoretical chemist, as well as the practical brewer.

I purpose arranging my subjects in the following order :—

I.—Water.

II.—The materials used in the production of beer; malt and its substitutes; hops and hop supplements.

III.—The chemicals used in brewing, their principles and uses.

IV.—The construction of brewing vessels, and the means of cleansing them.

V.—The arrangement of brewery buildings with reference to different systems and trade requirements.

VI.—Electricity in reference to beer and brewing.

VII.—The mashing process.

VIII.—Boiling and cooling.

IX.—Vinous fermentation.

X.—Cleansing and yeast management.

XI.—Racking, fining, and the storage of beer.

XII.—Recapitulation and general summary.

# ESSAY I.

## Water.

THIS is a subject that has never received any great amount of attention, and yet in its bearing and influence on the production of a characteristic beer, its importance is great. So far as brewing is concerned there may be said to be simply two kinds, hard water and soft water, for that perfectly free from salts, is not fitted for the production of beer of striking qualities. The first named is a water containing in solution certain salts of lime and other bases; some hard waters softening more or less by boiling, and some undergoing no chemical purification. While, secondly, soft waters are such as either contain no salts in excess, or only those of soda which communicate no indication of hardness.

Now, I think, it may be stated that much misunderstanding, in reference to water, is prevalent among brewers; for it has long been imagined that Burton water is the only one which can be used with any striking advantage. Let us see, first of all, what the influences of hard and soft waters really are, mentioning, to begin with, that a water to be fit for brewing purposes must be free from vegetable or animal contaminations *in any quantity*. I say "any quantity," because all natural waters contain some slight amount (although those at Burton certainly are remarkably free), so we cannot expect to find a perfectly pure water in this respect; yet, nevertheless, the quantity of vegetable matter present ought not, I should say, to exceed one or two grains in a gallon, for, if it does, you may be sure that surface water is finding its way into your well, and thereby unfitting the water for use, since with animal or vegetable matter in solution you obtain in your produce a class of ferments or organisms which are quite inconsistent with soundness or long keeping qualities; and although chemical agents are known which tend, when properly used, to destroy the harmful organisms referred to, such a great amount of theoretical knowledge is required to arrange the practical and advantageous use of them, that in this essay further explanation is unnecessary. Now the influence of hard waters may be explained by the fact, that as they hold generally in solution two salts named calcic sulphate and sodic chloride, and as these salts are known to possess in very marked degree the property of modifying the solution of albuminous principles from malt, the influence of a hard water is such, that you obtain a wort much less contaminated with nitrogenous matters than would otherwise be the case, and we shall see the great importance of this in future essays. Secondly, the tendency of a soft water is just the reverse: it has great solvent and extractive power, not only on account of not containing in solution the salts named above, but through holding dissolved in many cases the sodic carbonate, a salt very frequently used for inducing extraction of organic matters from vegetables. Now, in practice, what do we find as a result of these two distinct and characteristic influences? At Burton, where they have water containing immense quantities of calcic sulphate, they obtain from their malt very pure worts, comparatively free from excessive quantity of albuminous principles, and for reasons we shall see hereafter, their beer, on this account, possesses marked keeping qualities without low attenuation being necessary; and, as a secondary result, ready spontaneous clarification. Such a water is admirably adapted for pale ale brewing; but is not naturally fitted for obtaining the full round flavour we desire to find in stouts; and thus London porters have long been noted, not on account of any superior skill in arrangement of grist proportions, or conduct of the brewing operations, but bocause the soft London waters (taken in connection with the fact that sodic carbonate is present in them) tend to dissolve much more from malt than a hard water is capable of doing, of the different matters that, while militating against long keeping qualities, constitute the fulness or roundness on palate so necessary for certain beers; and so wo begin to see, I trust, why London is a great brewing centre for porters, and Burton for pale ales; for it is almost needless to point out why pale beors are so rare in London, when you consider the extractive properties of sodic carbonate oxisting in watery solution. Now, from all this it may be imagined that you are bound to pick your water for different classes of beer; but such is not the case, and I hope to unfold, as I go on, different methods for overcoming defects in the chemical properties of the brewing water; and I am quite certain, that if a water be free from excess of organic impurities, no matter whether hard or soft, you can produce beers quite equal to Burton or London brands, if you only once learn the chemical principles of brewing itself, and follow out its teaching in practice; but, at the same time, if you have naturally a good brewing water, the use of it considerably simplifies the after processes of mashing and fermentation. Space will not permit of my branching out into tho ramifications of this subject, but I shall briefly refer to the question of artificially hardening or softening waters in Essay III. simply remarking here that I do not hold with the practice, but prefer to work out improvements in produce by a different method. Thus, finally, a brewer does not care to use a chemically pure water, one free from salts and organic matter altogether; but a water, if possible free from the latter impurities, while containing in solution such soda and lime salts as are known to be of actual service in giving to the beer distinctive properties: while it is well to bear in mind, even at this primary stage, that to a certain extent you can atone for differences in the hardness or softness of water, by a proper alteration in your mashing and fermentation systems, and, therefore, if the brewing water in use is only pure, so far as vegetable contaminations are concerned, there is no necessity to pin such a great amount of faith on its mere hard or soft properties, which, although very important features, are not so, to the extent popularly imagined by brewers.

## ESSAY II.

### The Materials used in Brewing—Malt and its Substitutes—Hops and Hop Supplements.

Before I embark into a detailed consideration of this subject, I must enter for a few moments into a theoretical explanation which will be of service in explaining, in great measure, some of the difficulties we shall have to deal with. I hope I shall not be misunderstood when I say that albuminous principles, existing as they always do in beer, require very careful management to prevent their evil action coming into full play. In the proper place, and under certain circumstances, they are of the utmost value, but otherwise their presence is a danger we cannot over-estimate, and it is the great aim of a brewer to so regulate his processes that dissolving, as he always does, far more nitrogenous matter than he requires (this quantity depending, as I indicated in my first essay, a great deal on the character of the brewing water), he may free his produce from excess of it before that produce passes beyond his control. I have said this much of albuminous principles because, as they exist in different cereals in varying proportions, the percentage of this organic material present, affords an index to brewers of a very important character, namely, as to what cereals are fitted for malting and what are not; and although, as we shall see presently, the use of a pure saccharine enables us, to some extent, to balance, as it were, a highly nitrogenous cereal against one more rich in useful constituents, you cannot overlook the fact that such cereals as are rich to excess in albuminous matters, are not fitted for brewing purposes.

Then, again, we naturally desire to select a cereal very rich in starchy matter, for on this crude starch we depend for our supply of dextrine and sugar to allow of the formation of the alcohol, ethers, and the other wonderful products of vinous fermentation. Thus, no grain is so suited for malting purposes as barley, not only in reference to its comparative freedom from excess of albuminous matter, but also in reference to the quantity of starch present, and the proportion of husk to kernel; and this latter consideration is no small feature in practical malting; for if husk be too thin the acrospire bursts through, and the chemical modification becomes less perfect, while soluble matter becomes dissolved in the sprinkling water; while, on the other hand, if husk be in large proportion the value of the grain is lowered, since no useful constituents are contained therein. Thus the husk proportion even has to be considered: for existing in moderation, it performs the office of regulating course of acrospire, and when the grain is mashed it facilitates filtration, aiding thereby the full flow of a brilliant wort. We may take it, therefore, that the three controlling influences (putting out of sight for a moment any Excise restrictions that may exist) are, percentage of starchy matter, proportion of albuminous principles, and percentage relation of husk to kernel.

Of late years wheat, oats, and Indian corn have been experimented upon with average results, and if Excise laws were a little less severe, we should see great steps taken in the direction of finding good substitutes for barley malt; but at the present time I can fairly say that nothing answers so well as barley for malting purposes.

One word as to the malt duty. Farmers seem to think that if this were abolished there would be a greatly increased demand for barley; but would it be so? The duty at an end, brewers would be under no restrictions of any kind, and would use raw grain, specially prepared, with an admixture of saccharine, and this raw grain would not, I fancy, be of English growth. This is simply an idea of mine which I commend to the consideration of those who so strongly urge the different governments to establish the principle of free trade in malt.

Now, if we fairly understand the principles on which a grain is selected for malting purposes, the next point to consider is, what the effect of malting is, bearing in mind, that as a process it is enforced by Excise laws, but beyond that can hardly be said to be actually necessary. Now, in malting we imitate Nature, and Nature ordains that, in order to sustain the young leaflet as it shoots forth from the grain, the contents of this grain of corn shall be in a soluble state. The chemical fact is, that during malting a portion of the albuminous matter of the barley, wheat, Indian corn, or oats becomes altered into a principle called "diastase," which is known to possess the very wonderful property of inducing, under certain conditions of temperature and fluidity, the changes of starch into dextrine and sugar. Now, the old idea respecting malting was (and I am not sure that it is not generally believed now) that by the process we created or formed the sugar which we afterwards dissolved in the mash tun; while few practical brewers are aware that, while a considerable modification takes place on the malting floors, the enormous chemical action occurs during mashing and standing; and that on the success of this process depends the future quality of the beer.

Now, as we know in nature the constituents of the grain become more or less soluble or changed, as the future leaflet progresses under the husk to make its exit at last at the opposite end to the rootlet, so do we know that in practical malting we try to arrange that this acrospire, as it is technically called, shall progress and lengthen out till the time when we expect that the whole of the constituents of the grain of corn are so modified—not under its influence, mind, but as a necessary and natural result of its growth—that under proper management in the mash tun they become capable of acting and re-acting one on the other, and result in such very different materials to be taken into solution, and thereby form a perfect beer, that, looking at the common process of malting, one feels almost ashamed that greater attention and consideration have not been paid to the theoretical principles so beautiful in their very complexity, which explain the possibility of obtaining a saccharine fluid from material so different in properties to sugar. I said just now that malting could hardly be considered theoretically necessary; and all I mean by that is that under proper conditions you can effect in a mere artificial way in your mash tuns what you carry out naturally on the malting floors; but, in spite of this, there is no doubt that by a correct system of malting you do so modify the original starch, and create or bring into action as diastase a portion of the previously dormant albumen, that a beer produced from malted grain will at all times be superior in brightness and stability to a beer from raw grain, however carefully dealt with. Now there are a great number of malting systems, and, as may be expected, you get very variable results; and thus it is not difficult to understand why the beers at a single brewery vary so, when different malts are experimented with; for, of course a different mashing temperature, time of standing, &c., are necessary, according to the fact whether the malt in use happen to be well or badly made, friable or steely; and yet how seldom do we see this difference made in practice; on the contrary, the same system of mash appears to be considered equally suitable for all sorts and kinds of malt. I must now for a moment refer to albumen once more, as an agent capable of effecting under different limits of temperature and fluidity a variety of rosults; and thus, in the case of growing corn, it seems to have the power of inducing the formation of lactic acid, from the small quantity of sugar formed during the germination process or originally existing in the cereal, and thus it comes about that your steep water is sour, and your vegetating corn smells sour, and, as a necessary consequence, you find acidity in your worts from the mash tuns, and if you take the trouble to examine you will find your worts far more acid at first "setting tap" than they are nearer the end of your process, when the acidity, with a successful system, is *nil;* and thus you will understand that the normal acidity of beer refers to the acidity you unavoidably extract from your malt; and so it ought to be the aim of every maltster to reduce any excessive percentage of acidity by constant change of steep-liquor and a slow and gradual germination on the floors at a low temperature. This mere normal acidity of malt is of no disadvantage, so long as you do not overstep the limit of safety; for it tends to give to your beer a peculiar and yet very pleasant taste, quite different to the real acidity which arises in the final processes, and due, of course, to acetic acid. Thus, as a result of malting, you modify the starchy constituents, and you generate a principle (diastase) capable of effecting further modification, under certain conditions of temperature and fluidity; you get rid of a great deal of nitrogenous matter, in the form of the rootlet, and you produce that lactic acid, against your will, perhaps, which becomes the normal acidity of the soundest beer. All I have to say about the practical part is, that with lengthy steep, low heats, gradual growth, not carried to excess, and slow drying, you effect modifications in a regular and complete manner, without allowing of excessive formation of acid.

Do not let the fact escape your mind that very little sugar is found during malting; a good system means that you so modify the constituents of the grain that they are easy of conversion and extraction in your mash tuns; and that when, as a result, you have steely malt to deal with, the mashing process must do a great deal of the work that might have been done naturally; and there can be no two opinions as to which form of procedure is the best. Well, then, as malt is rich in modified starchy matter (the modification of course varying with the system in practice) contains a little sugar, and abundance of albuminous principles, and other matters I need not refer to here, it remains for the brewer to so manage his mashing process that he alters the one—not all into sugar, mind, but into sugar and an intermediate principle, dextrine; prevents, as far as possible, at the same time tho solution of matters which can injure his product; and that he takes care that, if extracted in spite of his usual precautions, he rids his beer of them before their known tendency can exert harmful influences. Just in the same way as lactic acid is formed in the germinating grain, so will its formation continue, if ignorance or neglect is displayed in somo of the primary or after processes; and I trust I have said enough on this subject to make clear that albumen is a substance so powerful in its effects, when held in solution in an organic fluid, that the aim of the maltster should be first to malt a grain not over rich in this substance, and that when germination is taking place, to prevent too much of its harmful influences coming into play. This formation of lactic acid makes it clear why unsound beer is generally produced from slack malt; the malt absorbs moisture, the albumen is thus enabled to induce formation of lactic acid, and besides being slack your malt becomes excessively acid. Some writers advocate redrying it, and suppose by so doing that they restore it to its original value, in the same way that some practical men think they restore acid beer to its original worth by neutralizing the acid, but it is not so; yet I have only space here to say that the re-drying simply enables you to get a better grist through your mill, and obtain a brighter wort, but it does not rid the malt of acidity, but, on the contrary, actually tends to increase its amount.

For a few lines we now come to a consideration of substitutes for malt, and of course I refer to sugars and saccharines; and there is very general misunderstanding on this subject, for brewers often forget that one of the most essential principles in beer is dextrine, or gum, obtained from the starch of the original barley, and that in attempting to brew with sugar you fail to have present in your beer this principle so necessary to soundness and condition, so I wish to point out that in using sugar or saccharino you replace the sugar obtained from malt, but not the dextrine—which I shall be enabled in future essays to explain, is a substance equal in all important bearings to sugar itself, and for some beers even more important. Now there are several kinds of substitutes: the ordinary cane sugars which, containing as they do, much albuminous and other impurities, need great care in use and a knowledge of chemical principles; and the saccharines or starch sugars, which are now manufactured by acting on starchy matters, and cane sugar with weak acid. Now this artificial action, so good and perfect an imitation of the natural conversion in cereals, is so important in reference to one intricato subject in browing, that I shall in my essay on vinous fermentation again refer to it, but I may remark now that the kind of sugar you obtain varies with the material acted upon; thus, Hill & Co.'s saccharine, made by acting upon cane sugar with sulphuric acid, is very different in appearance, sweetness, and other important properties to the saccharine made from maize, rice, or other starch-yielding substances. I have often wondered why saccharine makers do not prepare a mixture of saccharine and dextrine, for I am certain you might then employ with advantage a much larger proportion of malt substitutes than you do now; but before we finish with theoretical observations in respect to sugar use, let us see what effect its excessive employment is likely to have on yeast supply. We shall note in future essays that the basis of ferment is albumen (which is a very general kind of term), and by substituting saccharines for malt in large excess, we so reduce the quantity of albumen present in the worts, that we find our yeast supply deficient in quantity and not sufficient to prevent, when rising to the surface, the fermenting body of wort from coming in contact with the atmosphere. The same argument does not hold good in full force to cane sugars, which contain albuminous principles, and are, therefore, considered impure from a brewer's point of view; but as a practical fact it seems, in introducing sugar albumen into worts, we do not either introduce the most suitable kind of ferments, or, adopting for a moment the more recent theory, the most suitable food for healthy germs; but in winter, perhaps, some advantage is derived, if this kind of sugar be used in mash tuns or copper, by giving a slight change to the ordinary character of fermentation in progress. Finally, in reference to malt and its substitutes, I come to a somewhat important question—Does it pay to use sugar in brewing? If you employ cane sugar and can still keep up the quality of your produce, which is a difficult matter, it certainly does; but not so with patent saccharines, unless you adopt the idea that in substituting the sugar for malt, you need not do so in reference to the actual weight equivalent to tho total malt extract, but only to the extent of the equivalent to the spirit yielding principle you extract from the malt. Now, a great many brewers depend upon albumen as a palate fulness constituent, in spite of its evil action in finished beers, so that they could not well adopt the theory of the saccharine makers, while I myself depend on dextrine, and am inclined to think you want something else in beers besides sugar and spirit; you require softness and fulness as a first characteristic, and it would be impossible to have these striking qualities in perfection, if we used a great excess of saccharine, and used it on the assumption that, as it was all pure or spirit-yielding, a lesser quantity would suffice than the true equivalent weight of the malt displaced. This causes the wonder in my mind, that a saccharine consisting of dextrine and grape sugar in proper proportions is not prepared; for then you might, with advantage, substitute it for malt to a great extent. Used in moderate quantity—say, one fourth—it tends to purify your worts by reducing the percentage of albuminous impurities present, and so far its use is of service; but I do not think you can carry out the system of excessive sugar substitution until the composition of the saccharines is altered as proposed. The actual equivalent of saccharine for malt extract is easily ascertained.

One quarter of malt yields, say, eighty-four pounds per quarter saccharometer extract, equalling a real yield of 224 pounds. Now 2 cwt. of sugar, if quite free from moisture—which no saccharines are—would yield in solution the same saccharometer extract of eighty-four. If to the cost of this you add Excise duty, 11s. 6d. per cwt., carriage, and loss of grains by substituting sugar for malt, you will see that saccharines, when used on this principle of full equivalent allowance, cost more than the usual material; but to the extent that by their substitution for malt, you can purify the worts extracted from excess of hurtful principles, saccharines are useful in brewing, although we must not forget that the foregoing argument applies simply to pure glucose or saccharine, ordinary cane sugars being even richer in impurities than malt. In reference to its bearing on fermentation, some detailed remarks will be made in due course.

### Hops and their Substitutes.

There is not space to enter into a lengthy essay on this subject; we all know what a very useful purpose they fulfil in brewing, and yet I would wish to give a few fresh hints concerning their use. Hops not only yield us a bitter principle, medicinally preferable to any other, a narcotic oil and resins, but they also yield, what is of the greatest importance, a certain amount of tannic acid, which enables us to utilize gelatine as a fining agent, while beyond this, in a practical way, the hop flowers act in the hop back as a perfect filtration material. Now the bitter principle is a most essential constituent, and upon it we depend for our different tonic flavours, while the resins, no doubt, assist spontaneous clarification of the beers, but I am afraid popular error exists, as respecting the hop oil, and popular ignorance in reference to the tannic acid. First of all, the hop oil to a great extent is lost during boiling: another portion of it is seen floating about on the surface of the cooling worts, while the remainder, carried into the fermenting tuns, gradually gets dissolved in the alcohol and ether formed there, and until this solution does take place you cannot expect to have a brilliant beer. It may give some useful and pleasant qualities to beer, but still its effects are not of sufficient importance to justify the very expensive methods which some brewers have adopted to retain it in the worts while boiling.

Of far more interest is the tannic acid, a very astringent principle, which effects the coagulation of animal gelatine, enabling us, as I have said, to employ isinglass as a fining agent. This agency has been sadly overlooked, and we have seen hop substitutes prepared, which, containing no tannic acid, have given to tho beer no power of so coagulating the fining material as to enable it to act in its peculiar way. It is not wonderful that with the variable English climate wo find hop culture a very difficult subject to deal with; and when we think what a delicate plant the hop grower has to cultivate, and how much the price nccessarily varies according to the character of the season, it is not strange that substitutes have been prepared and are now offered openly for sale under Excise restrictions. Putting asido the question whether the substitute bitters are equally as good as that derived from the hop flower, there is one obvious objection generally urged against the use of them, and that is, that no information is given as to the composition of the substitutes, and there will be at all times, no doubt, a widesprcad dislike to tho use of secret powders in place of the hop-flower. But surely we cannot expect the makers of those condiments to publish their method of mixing and the namcs and porcentagos of constituents, since thoy can hardly registor or protect by patcnt such information;

and, fairly speaking, so long as the substitutes really do fulfil the essential principles of a hop replacement, I do not see any disadvantage or fault in the use of them. Nevertheless, I do think that every brewer ought to satisfy himself of their perfect harmlessness before he employs them as trade materials; and, besides this, he must take care that they contain a bitter principle equivalent in value to that of hops, that they contain also the resins, and, above all, that necessary proportion of tannic acid, so essential to the success of his clarification process. On this subject I will give a practical hint to enable any of my readers to detect whether the substitute he employs, or has submitted to him, contains this necessary astringent principle. Dissolve a little of the hop supplement in an excess of water, and then add a few drops of ordinary finings, well mix, and observe the result: if the fining agent cuts or coagulates, and rises to the surface in a cloudy form, he may feel sure that the necessary coagulating principle is present; but my readers must not run away with the idea that the presence of tannic acid in beer ensures its perfect brilliancy, and that its rough unskilful use, when not present originally in the brewing materials, would be of service. It is a substance with great coagulating and precipitating power on organic matter, and, fortunately, its presence in hops seems to be to the extent just suited to the necessary clarification of worts and beers; so where foreign bitter matters are substituted for the hop-flower and its numerous useful constituents, it surely behoves all brewers to see that besides being pure, they also contain the essential matters necessary to the brewer's purpose in proper proportions; for I am sorry to say that several of these hop substitutes contain no tannic acid whatever—the most fatal defect; although one, which I will not further specify, contains not only the necessary percentage of tannine, but also a due proportion of the other hop principles; but in saying all this in connection with tannic acid, I must warn brewers against employment of this substance in any shape or form unless a true knowledge is possessed of its active properties, for much harm would, of a necessity, result by its careless use: and all will be ready to admit how difficult it must be to arrange an artificial material on the exact basis of a natural flower, possessing at the same time equal powers and effects. And from this we may learn that great discrimination ought to be exercised in the use of these substitutes, which are naturally considered objectionable by our hop growers, but are not therefore of necessity either practically or theoretically useless.

## ESSAY III.

### Chemicals used in Brewing: their Principles and Uses.

In coming to a consideration of this subject, I must explain that we shall have to anticipate a great deal of the theoretical knowledge that will be explained in future essays, in order to allow of a proper explanation respecting the uses of these chemicals; and I do not know that this will be a positive defect in the arrangement of the papers, since the theories in question will easily bear more than one repetition, and the advantage gained will be that in describing theoretically and practically the operations of mashing, boiling, and fermentation, I shall be able to refer to these chemical substances, and point out their advantageous use under different circumstances, with the knowledge that my readers will be able to follow my meaning, through having in this early paper gained a theoretical knowledge of their characteristic actions.

I hope it is not idle to protest against the wide-spread objection to the use of any chemical substance in a brewery, which has about as much reason or sense in it as the old petition against the use of hops when they were first used in beer; and since brewing has derived great advantage from the explanations given by chemists of its various processes, I cannot imagine why scientific brewers should not try to improve beer, or aid its keeping quality, by the use of such chemicals as are known to be of actual service without the cry of adulteration being raised, with the same measure of justice as if the same term were applied to the salting of meats. The action of each chemical is based on true theoretical considerations, and when my readers come to understand some of the complex ways in which these useful materials act, I think they will agree with me that such brewers as are skilful enough to use them properly are likely to have great trade advantages. First of all, we have the salts that are supplied to brewers for the purpose of so hardening their brewing water that it resembles, in saline contents at least, the Burton type. Now the keeping qualities of Burton beers have been so very extraordinary, when we consider the faults of their fermentation system, that thinking men began to look into the matter, and discovering that the Burton well-water was rich in one particular salt, worked out the fact that this salt was capable of influencing this keeping characteristic in no small degree, by diminishing the quantity of albuminous matter withdrawn from the malt. Of course there is more than one argument respecting its action:

some thinking that its influence is actually direct, while others suppose that by the mutual action of this calcic sulphate on the salts naturally contained in the cereals used for brewing purposes, fresh combinations arise which then exert this purifying action ascribed by the former to the lime salt alone. Be this as it may, there is no doubt that waters containing much of this lime salt are most useful for brewing purposes, but of late years two other chemical combinations have come to be regarded as agents acting in the same way. I refer to the sodic chloride or common salt and the calcic bisulphite, which latter is of service in another way, which I shall presently refer to. Now if your water contains no calcic sulphate you can add it, but you must remember that it is a very insoluble lime salt, and practically requires a lengthy period for the solution of lesser quantities than we find naturally in waters; and this fact that waters take up in the cold, under the influences, may be, of such a gas as carbonic acid, salts which are otherwise only slightly soluble, is a wonder to the ordinary mind, and is, above this, one of the beautiful laws of nature. Then, again, brewers are not allowed to use much salt or sodic chloride, and very properly too, when we consider the temptation that occurs to some men to use it for an unworthy purpose; and as regards the bisulphite, although it is powerful in this agency that we are speaking of, its smell is a disadvantage which almost unfits it for use in the mashing liquor; nevertheless it is a substance of eminent service in other stages of the process. Thus the three chemicals used by some brewers as preservative agents, preservative, mind, by preventing undue solution of the active principle albumen, are—the calcic sulphate, the sodic chloride, and the bisulphite of lime; and to the more extent of practically hardening a soft, pure water, and thereby fitting it for the more easy production of some varieties of beer they are of some service, but no natural presence or artificial addition of one or other of these substances will render a contaminated water good. To be a good brewing water, absolute freedom from organic matter is a necessity, and my readers must not imagine that by adding these chemicals they get over the organic contamination defect, although, to a certain extent, the two latter named compounds would nullify the primary effects of organic impurity. Thus, as I before explained, brewers at Burton not only depend upon the presence of a most useful salt in the water, but on the fact that it is free from organic impurity; once let this advantage disappear, and in order to produce the same keeping beer the system of brewing would have to undergo alteration. Now before I go on with the other preservative agents, it will be necessary to ask ourselves—What is the basis of preservative action? Well, in a brief sentence, you must either prevent the agent of change being present in your product, or, if there, you must arrange that it shall be incapable of modification. We have studied the first class of preservatives, and in relation to the second it is well to understand that, before this albumen can undergo any change itself and so become the active agent of alteration, or simplification of organic compounds in contact with it, it must absorb a quantity of oxygen (which is, as we all know, one of the atmospheric constituents), and so become oxidized, as it is called, this oxidation conferring upon it the power of acting as a ferment. Thus the idea of the second class of preservative agents is to put in your brewing water, your boiling worts, or your finished beer, a chemical substance capable of absorbing oxygen to a greater extent, or in more refined chemical language, having a greater affinity for oxygen than the albuminous matter. Such agents are ordinary sulphurous acid, and its combinations, the mono-sulphite of lime or magnesia, and the bisulphite. These three chemicals have a marked affinity for oxygen, and while they exist in their normal state in wort no oxidation of the albumen can take place, and, as a consequence, no formation of acidity will result. This, mind, is one of the ideas of chemistry; and yet brewing is said to owe nothing to chemical knowledge, nevertheless one might look around a long time before finding any subject worked out with more refinement of theory than this action of preservative agents. When you smell how sour your grains are a few hours after being thrown from the mash tun, you will understand what a powerful agent of change exists in the original malt, and how soon its powers are brought into play, when absorption of oxygen and lowering of temperature of mash are allowed. The least neglect in mashing, the exposure of the worts to cooling influences allows of this acid formation increasing to an enormous extent, and thus these chemicals are of use, more especially in smaller breweries where the same appliances for systematic work are not at hand. Now, it will be observed, that these preservatives are generally compounds of lime or magnesia, and this is arranged, as might be supposed, for a purpose. The sulphurous acid of the mono or bisulphite, in acting as a preservative, absorbs oxygen, and in doing so becomes a stronger acid, the sulphuric; then the lime or magnesia becomes useful, for we get the sulphate of lime or magnesia (so highly prized by some brewers), by a combination of the acid and the base. There is one objection, perhaps, to the bisulphite or sulphurous acid which does not apply to the mono salt, and that is the powerful smell of the two former compounds; but this smell in the primary stages is of no importance, since it passes away at the same time that the substance is acting as a preservative; that is, the sulphurous salts of lime are of unpleasant smell, but the sulphuric salts are without odour, and thus the defect of original smell vanishes so soon as the substance is doing a service. I have tried to make this explanation as simple as possible, because it is of much importance to understand exactly how these agents act, so that when we come to the stages of brewing where they are more generally employed we shall better understand their influences. We next come to the salts employed to restore beer, as it is called, although, as I shall have to point out presently, no restoration really takes place except in the sense that you neutralize the acid which has been formed from your alcohol. Many substances have been employed for this purpose, but it unfortunately happens that most of the salts of lactic and acetic acid have a nauseous taste on the palate; but perhaps the three most suitable are—Lime, Soda, and Ammonia, in a pure and suitable chemical state.

I do not know whether this restorative process is carried on in many breweries, but there is one hint on the subject of some value. We have seen what normal acidity means, and how this slight amount constitutes one of the characteristic palate flavours of all beer; the necessity arises then to obviate, while actually neutralizing beer, the absolute neutralization of the whole of the acidity. Now this normal acidity which you want all beer to possess, and which the soundest beer does possess, is at the rate of decimal one per cent., but in these papers I cannot go into a detailed explanation of the process for ascertaining this percentage; suffice it to say that if you keep adding alkalies till the point of absolute neutral reaction is arrived at, your beer will be rid of one of these palate characteristics I have spoken of. This process is at all times a very sorry one, for the agents employed are not in any way preservative, and beer so cured of acidity would probably soon acidify again; and it is apparent that as the salts formed are so harsh and unpleasant, it is not possible to neutralize with success a very acid beer, since the result, free from acid, would nevertheless be unfit for drinking purposes, not only on account of excess of lime or soda salts present, but because the greater part of the original spirit would have disappeared in the form of acid. It is better by far to improve your process and use chemical agents in the primary stages than to fall back upon the correctives of bad work in the final product, the more especially as these substances have no restorative power in the true sense of the word. There is one chemical now used for the purpose of softening gelatine for fining purposes, and that is sulphurous acid. Its power of softening isinglass when in a moderate state of concentrated solution, say about 12 lbs. per barrel saccharometer gravity, is extraordinary; you would not care to use acid of greater strength, for I am told if the gas is forced into solution under pressure to a greater extent than the gravity indicated above (some 1032), the excess has a tendency to escape very quickly when the liquid comes to be exposed to the air; and not only this, shows too great an inclination to absorb oxygen and become sulphuric acid, and you do not want this result to take place till you get it in your beer. Now the beauty of using this acid in place of your acid beer is more complex than some people suppose. First of all, it is no acid in a brewing sense, that is, its presence in beer causes no taste of acidity, so your "finings," prepared by its agency, are called "non-acid;" again, this sulphurous acid is a powerful absorbent of oxygen, and so prevents decomposition of the animal matter, gelatine, or the formation of mould; and, thirdly, when your finings are added to beer, they, through the agency of the acid employed in their preparation, become actually preservative, so far as this liquid portion is concerned, instead of being the direct cause of acidity as in the case when sour beer is employed. Lastly, in reference to chemicals, I must refer to calcic phosphate which is used as a means of improving the quality of the beer, so far as its animal strengthening properties are in question. I do not know that it is ever used in its separate form, but it is contained in one of the materials sold for use in breweries. Now we know how this calcic phosphate is necessary to bone formation, and with this in view there is no objection to its use in definite quantity, the more especially as a phosphoric acid salt exists in all beers, being obtained in a natural way from the cereals employed in the production of them. I believe that all these chemicals are mixed and prepared on the same theoretical principles; but some makers combine the two ideas of preservation and neutralization in the same material, and I must say with great success. Taking it as a fact that a few years ago no employment of chemicals was understood or thought of, it is necessary to remark that brewing has much altered and competition has necessitated low gravities, or, in other words, large extracts, which means the extraction of matter from malt serving no useful purpose, theoretically speaking. Thus greater skill is necessary to counterbalance the known effects of these matters, and where this skill is wanting men must fall back upon these corrective agents to annul faults in the system, or disadvantages connected with the description of water or materials employed, taken in connection with the excessive solution process carried on, for, while there is a natural means, no doubt, of overcoming the disadvantages in question, it is perhaps so expensive when worked out in practice as to render it unfit for general adoption. Taking a glance at the whole subject, a brewer ought to be something of a chemist too, before he employs agents of such momentous influences, either for the purpose of neutralization or preservation; but as I shall have to speak of their action in detail, when treating of the different brewing operations wherein their employment is advocated, I think this brief outline of their more apparent properties will suffice. I have made no mention of firms, since my doing so would be quite unfair, and I have tried to avoid making any remarks which could be considered one-sided, or forcing my own especial views; nevertheless, I hope it will be clear to all who read these papers, that this subject of all others is well worthy of study, for when we think of the rapid strides recently made in the use of chemicals in brewing operations, we must believe not only that great advantage has resulted from their use, but that with a little more care and knowledge being exercised in their preparation, so far as percentage of constituents is concerned, they will come to be regarded in the future—when under more liberal Excise regulations brewers will be enabled to employ a greater variety of grains, either raw or malted—as necessary materials, and not, as appears to be the idea now, the secret aids to inferior systems.

## ESSAY IV.

### The Materials used in the Construction of Brewing Vessels, and the Means of Cleansing them.

This essay ought to be considered jointly with the previous paper, because I shall have soon to speak of other chemicals which I omitted to mention before, as I thought it best to confine my remarks to such combinations as were used for the preservation of beers; while the agents I shall have to mention in this paper are those which are used simply for the cleaning or preservation of the materials used in the construction of brewing vessels. Now, in reference to metals, we are all aware that a great many of them oxidize, or tarnish by exposure to air, and, chemically speaking, this oxidation process is all that is required to render such metals soluble, some of them in mere water, others in weak acid solution, and this simple fact really guides us in the selection of metals for use in a brewery.

I have tried to make it plain how it comes about that acidity is formed in the primary stages of malting, the practical result being, that however skilful our process may be, our soundest worts contain sufficient lactic acid to render such worts very distinctly acid to test paper.

This fact has a great bearing upon the question of conjunction of dissimilar metals in brewing vessels, a subject I shall refer to in detail in Essay V.

Now I dare say most of my readers will have noticed how a copper tarnishes when liquor is boiled in it, or even when simply exposed to the air, and how bright it looks after a wort has been heated in it afterwards; first of all, an oxide of the copper has been formed, and the free acid of your wort aided in a measure by the saccharine is just sufficiently strong to dissolve this oxide off. I have known beer to be contaminated with copper from this very cause; and thus we see a necessity for keeping vessels composed of this metal clean and bright. Again, we must understand that this property of metals to oxidize varies in intensity, some metals being more stubborn in this respect than others, and so it comes about that copper has been selected as a metal suitable for use. Of course it is not perfect, for, as we have noted, it does tarnish and oxidize, and become soluble in your worts, but it is far preferable to such weak and easily soluble metals as zinc or lead, even if they could be used where great exposure to heat was necessary. Tin is a most useful metal, so far as not having any tendency to oxidize is concerned, but it is not adapted to any purpose in a brewery, except as a means of coating other metals not so stable as itself.

Iron has some very peculiar properties of its own, which unfit it for use in a brewery after a certain stage of the process. One old idea was (and this idea still continues to a certain extent) that it had the power of precipitating organic impurity from water, by absorbing oxygen from the atmosphere, and then passing this oxygen on to the impurity, so rendering it insoluble. Be this correct or no, I believe that iron is supposed to have such a powerful affinity for oxygen as to be capable, under certain circumstances, of decomposing water in the cold even, absorbing oxygen and setting free the other element of the water—hydrogen. This sort of agency is more intense when the liquid contains much free acid, as in fermenting wort, when elements are more or less in a loose state of combination. I well remember the case of some distillers, who could not discover for a long time the cause of a certain unpleasant smell connected with their raw spirit, which was at last traced to the fact that their fermenting vessels were composed of iron, the result being that through the agency of this metal hydrogen was liberated from the water of the wash, and went to form evil smelling compounds, damaging to the good name of their produce. While the wort is hot, and before the fermentation stage, no evil action arises, and thus this metal I refer to is well adapted for the construction of tanks for water storage, under backs, hop backs, and coolers, but not beyond this point if you wish to avoid its dangerous influences.

Brass, as a compound metal, is very serviceable for certain uses, but its price is an objection, when taken in connection with its other defects; although it must be understood that it is a most stable metal, resisting chemical action in a marked degree. Thus brewers use iron in certain positions, tin as a coating metal, brass for some secondary purposes, and copper as a material for boiling pans; but I ask all to beware of lead and zinc, for which many small brewers seem to have an especial liking. I go into breweries, and see lead used for wort mains, and more constantly for patches on coolers and in working squares, and zinc, too, for certain purposes. Now, when I say that both these metals oxidize easily, become thereby soluble—the lead more especially, when carbonic acid is present in solution—and form poisonous salts, it will be seen that there is good cause for prohibiting their use; and when I add that in the case of lead or zinc patches on wooden vessels, actually fastened down with copper or other nails, you form a perfect little electrical battery, or a series of such batteries, in your cooling or fermenting vessels, it seems wonderful that more unsound beer is not produced, when you think of the number of cases in which this fatal combination of metals is allowed. I will refer again here to iron and copper more in detail, as brewers naturally select these two metals for the construction of some of their brewing vessels, having regard to their known characteristics. Thus we select iron for tanks, mash tuns, hop backs, and coolers, because it is a metal economical in all ways, and when used alone for such vessels as I have named exhibiting no hurtful action. It is, however, said to induce coloration of worts, probably effecting this by acting as a carrier of oxygen, as you may term it, just in the way that it behaves when precipitating organic matter from water. Thus it absorbs oxygen from the atmosphere, and induces in turn the oxidation of the colouring matter of the wort, the effect in this respect being more marked when you allow a film of rust to gather on the surface of the metal; for this rust, or oxide of iron, will very readily dissolve in the acid of your wort, communicating thereby a reddish tint. Then again, in using iron we must remember that it radiates heat very quickly; so that iron mash tuns ought to be surrounded by a wooden casing, the space between being filled up with some non-heat-conducting material. We select copper for our boiling pans, since it has not the defect pertaining to iron, in respect to coloration, is a very good conductor of heat, of great fire-resisting capacity, and suitable, for this purpose more especially, in numerous other ways. So long as you keep it clean, no harmful effects from solution of copper itself in your worts need be apprehended, and, economically speaking, I do not know of any other metal that would answer our purpose so well. No chemical agents of any kind are required to cleanse those metals, the mechanical friction of some rough material, such as iron filings or ashes, being quite sufficient. In considering wood as a substance for the construction of brewing vessels, it will be well, first of all, to understand how it comes about that it so rapidly decays, more especially in a brewery. Wood, as we know, is full of minute pores, and these pores are charged with albuminous sap, which, under certain circumstances, so soon as vitality is ended, works the absolute decay of the woody fibre. The circumstances I refer to are the presence of air and water, and thus, in a brewery where the vessels are so constantly exposed to the influences of steam and hot air combined, we find that wood very rapidly decays, so much so, indeed, that other materials are now very generally superseding it. In view of this speedy alteration in woody fibre, means have been taken for some years to prevent this change being so rapid, or even taking place at all. Two distinct systems are adopted: you either displace the albuminous matter from the pores of the wood, get rid of the ferment in fact, or else you first drive out the moisture, and then prevent either air or moisture coming in contact with the albuminous matter, so rendering it capable of acting as a ferment, by coating the wood with some material capable of resisting their action. Well, in the first instance, paraffin may be used with great advantage; and an example of the working of the second principle is seen in the application of enamels to wood surfaces. I simply give two examples, since in order to preserve wood you must, whatever your system be, carry out one of the two principles explained above; you adopt just the same measures, in fact, as you do when attempting the preservation of beer, and you will find presently that just as albuminous matters in the pores of wood work the destruction of woody fibre, just so does the excess of albuminous matter in a finished beer work the destruction of the alcohol. Understanding theory thus far, is it not apparent to us why wooden vessels so rapidly decay? why floors and beams so soon rot in a brewery? when you think of the endless succession of heat and cold, moisture and dryness; and would it not be well in all cases to prevent this action by adopting one or other of the two systems of preservation, even if not to get rid of wood as a constructing material altogether? Now the porous nature of wood is unfortunate in another respect, for the pores, in acting as the containing passages for the necessary sap during growth, act as the recipients of all sorts of impurities, when that albuminous matter has been by one means or another removed—of course I refer now to wood in its natural state. Thus, the albuminous matter gets gradually drawn out by the solvent power of water and wort, or the attrition of mechanical cleansing, and your woody surface soon loses its smooth appearance and becomes a very sponge in action; impurities from the worts settle in these pores day after day, and soon act as ferments, and incipient action on the coolers has been very frequently the result. This is more often the case where hot liquor is employed for cleansing purposes, before these impurities have been first washed out by cold. The effect of this hot liquor is to close the pores, shutting in the impurities, and afterwards, when your boiling hot wort becomes sufficiently cool, the pores gradually open again, and the contents once more set free, work their insidious action in your saccharine fluid, aided by the favourable temperature; so, I trust, you will see why it is advisable to use cold water for cleaning, and hot liquor for finishing off with, that is if you are in favour of a dry surface. Some writers on brewing advocate the principle of leaving coolers and other vessels wet in order to prevent loss of wort by absorption, but it is an unfortunate fact, in reference to the above idea, that where you have some slight portion of saccharine matter in contact with albuminous impurity, this film of moisture is the very condition necessary for the formation of acid; so I am in favour of scalding all wooden vessels after they have been freed from apparent impurities. Thus we see that even the selection of a material for brewing vessels is an important matter; putting on one side the question of primary cost, and consequently very hard woods, such as oak, are picked in preference to softer and more porous qualities, and the necessity arises that, if means have not been taken to prevent the action of decay in the wood itself, some knowledge should be gained of the way in which this action can be prevented, bearing even in an indirect way on the future qualities of the beers brewed or fermented in wooden vessels. Now ordinary lime, or a mixture of that with quicklime, answers well in practice, for lime is not only a neutralizer of acidity, but is also an agent of attrition, that is, a good scouring material, and you cannot well use too much of it, although I am afraid it has rather an injurious effect upon the wood itself; neverthe less it tends to keep vessels perfectly sweet, and in this respect, knowing how prone wood is to acidify when it once becomes soaked, as it were, with saccharine matter, the benefit derived from the use of lime cannot be overestimated. But you require sometimes something stronger than lime to act in a different direction; you want a substance capable of penetrating into the pores of the wood to dissolve therefrom the albuminous impurities; such an agent is potash, and although it has a peculiar and destructive action on woody fibre when used in a too concentrated solution, it does tend in marked manner to rid the pores of all impurities. Salt, again, is universally used for withdrawing the sap from new wood, although, perhaps, there is one disadvantage connected with its use, that is, the pores getting full of saline matter it remains there attracting moisture, one of the very essentials, as we noted, to the formation of acid; thus, after salting the cask or other vessel, it should be filled with cold water until every trace of saline matter is removed. We now come to the agents that act in a different way to those I have already mentioned, and which are used for the purpose of actually destroying the impurities existing in the pores of the wood; such are chloride of lime and ordinary sulphuric acid. This latter does not commend itself, since it has a most destructive action, not only on the impurities, but upon the woody fibre itself. There is more to say of calcic chloride, which is a powerful and harmless oxidizing agent. When this is used, it acts chemically by oxidizing the organic impurities existing in the pores of the wood; but I need not go more deeply into the chemistry of this action than to say that, in order to destroy an organic impurity, you must either oxidize it, or withdraw from it some of its essential elements; chloride of lime works in the first way, while sulphuric acid induces decomposition by the second. The only objection to the use of this lime-salt is due to its very powerful and overpowering smell, the gas given off having a strong tarnishing effect upon all metals within reach. Nevertheless, it may be employed sometimes with great advantage, more especially where ill success has attended the brewing operations. It is used in practice in watery solution, and any excess of it may be removed by washing the vessels after the chloride process with a weak solution of calcic bisulphite, a mutual reaction taking place, giving as result harmless and tasteless salts. Again, bisulphite acts as a cleansing agent by withdrawing oxygen preventing formation of mould or oxidation of nitrogenous matter. It will thus be seen that our chemical cleansing agents are somewhat important and diverse in action ; the simple lime neutralizes acidity, and is a good scouring agent, but has no penetrative power. The common salt and potash extract the albuminous matters from the pores of wood, while the sulphuric acid, the calcic chloride, and the bisulphite of lime, tend to destroy or render inactive all the impurities that they may meet with. Where the skill to employ these more complicated chemicals does not exist, there is no substance so useful as lime, slaked down in boiling water, and used in just the same manner as soap or any other cleansing material. Now considering the great tendency that exists for all kinds of wood to decay, for its pores to retain impurities which, in contact with saccharine matter, soon give rise to formation of acid, it is not strange that other materials are now advocated as being more suitable for brewery use. Stone, slate, and glass are now coming into very general demand, while you see some vessels constructed of concrete, lined with glazed tiles, the idea in all cases being to substitute some lasting material for wood, and, at the same time to obviate as far as possible the exposure of beer to metallic influences ; thus, in giving up wood, you substitute some inactive non-metallic material. These hard non-porous materials are well suited for brewery use in a variety of ways, but you have to guard against any sudden changes of temperature when cleansing them. Slate being a very good radiator of heat is not quite suited for the construction of cleansing vessels, in which you wish no sudden reduction of temperature to occur, the result of such reduction in a generality of cases being to increase the difficulty of spontaneous clarification; but settling-tanks of this material are so sweet and clean, so cold where you require cooling influences, that I cannot say too much in its favour when used for such a purpose. These kinds of vessels are always of necessity free from acid, do not require the use of any cleansing agent, and of course do not need scalding; in fact it is far safer not to scald them, as the material is not a good conductor of heat, and a crack or split would result on the application of any liquor at an elevated temperature. With respect to shipping away casks, I shall not be far wrong in saying that much unsound beer is produced by putting a perfectly mild ale in a cask that is more or less acid. If this acidity of casks were simply surface acidity, I do not imagine it would greatly increase the normal acidity of your beer; but the surface acidity is simply an indication that you have allowed impurity to accumulate in the pores of the wood, and this impurity, as I pointed out before, whether existing there naturally as albuminous matter, or allowed to remain there through carelessness in cleansing, is capable of inducing formation of either lactic or acetic acid, the former from sugar, tho latter from alcohol, and in this case you know it exists in a state capable of inducing tho acetous change, since you have the sharp stinging smell to show that such action has already taken place. This fact is a great trouble to brewers, and those who neglect to guard against its influence suffer heavy losses by returns; for a beer may be brewed on a correct system and be perfectly sound when racked, and yet it will not long resist this influence that I am now speaking of.

Now, preservatives of the sulphurous acid type do not answer every purpose in such a case, for, as we saw, they tend to prevent albuminous principles from absorbing oxygen, and so become ferments, or adopting the more modern theory, prevent the germs of Pasteur from springing into life; not that we need pay much attention to Pasteur's theory here, since he does not deny the power of albumen to induce acetous change. But in the case we are considering, the albuminous principles are already in a state of oxidation, and it is now too late to prevent their action by cutting off the supply of oxygen. We must therefore fall back on a class of preservative agents, containing a strong neutralizing alkali as well as a preventive of further oxidation; such agents—and I may mention the calcic monosulphite as an example—are prepared and used with very great success—a success which is very evident in such breweries as do a large export business, or where casks are exposed to weather influences for a lengthy period, and where surface acidity may be fairly considered unpreventable, unless means are adopted of preventing the fluid contents from coming in contact with the woody material or the impurities contained in its pores. To this end we find many eminent brewers coating their casks internally with a patent enamel, in imitation of the old Bavarian method, while others use wood for the construction of casks which has been freed from pore impurity, and the vacuities filled up with some harmless substance, insoluble in water or spirit.

Before I close this paper, I must in a few brief sentences refer to the steaming of casks, and express my opinion that the process is worse than useless; it may tend to drive off evil smells, but it does not destroy your active agents of organic change; the heat closes the pores of the wood, locking up therein moisture; and that this is a fact only observe a steamed cask, quite dry, a few moments after the operation, and yet with a damp surface at the end of a few hours. And why is this so? The moisture locked up appears again so soon as woody material cools sufficiently to allow of its pores opening once more, and nothing causes so speedy a generation of surface acidity as this film of moisture; and yet if a steam process is adopted, I do not see how it can be avoided, except by artificial drying by means of hot air. Casks can be prepared for use quite free from moisture by the use of hot liquor in sufficient quantity, the advantage being that no reappearance of moisture occurs. Such, then, are some of the theoretical and practical considerations which have direct reference to the subject of my fourth paper.

## ESSAYS V. AND VI.

**The Arrangement of Brewery Buildings in reference to Different Systems and Trade Requirements, and Electricity in reference to Beer and Brewing.**

It is my intention to combine these two essays in one paper, giving a short time to the latter first of all, since it has some influence and bearing upon the subject matter of the former essay, and yet is not alone of sufficient interest to general readers of articles on brewing, to make it expedient that I should devote the whole of a paper to its consideration. Brewers have long been aware of the fact that it is most difficult to protect worts from injury during the summer months, but more especially when the weather is close, and the atmosphere charged, as they term it, with thunder. Now we are quite aware that there are several reasons which tend in effect to militate against the soundness of summer brewed beer, and we must take it that the excessive electrical tension of the warmer months either directly or indirectly makes successful brewing a very difficult operation at such times. Let us see if we can understand a little better what forms of electrical force a brewer has to deal with; and then, in the afterpart of the present paper, we shall better understand how to contend, more or less successfully, with this atmospheric power by a proper construction of our brewery buildings and a skilful arrangement of plant.

First of all, we may take it that we have little to fear from thunder itself, which is simply the manifestation of intensity of electrical tension; but when thunder comes, we may know that the atmosphere is so highly charged with electricity that it may or may not induce unhealthy action in our fermenting or quiescent beer, yet cannot fail to exert some influence upon it; and I need hardly say that such beer as contains the most stable constituents and has been properly produced will resist the hidden influences of electrical force much longer and better than those beers which, through some fault in production, need but the slightest disturbance to bring about their complete deterioration. This atmospheric electricity is, one will suppose, mostly frictional, and yet it is more in accordance with modern knowledgo to say that every chomical change progressing in nature helps to increase tho store of electrical force in the earth and in the atmosphere above; nevertheless, it will be better to consider atmospheric electricity as frictional in its origin, to distinguish it as such from the other electrical forces that more especially effect the brewer.

Shall I be wrong in styling the second electricity as chemical in origin? that is, if two dissimilar metals *are placed in contact* in a liquid capable by its acidity of acting upon one of them, an electrical current is set up which possesses equal powors with frictional electricity of affording manifestations of light and heat, and bringing about decomposition of compound chemical substances. Thus its origin is chemical action, the solvont power of the acid upon the weaker metal.

Again, if two or more metals not homogeneous in mechanical structure are jointed together and exposed to heat, another kind of electrical power is generated, and thus I had some ground for saying that eloctricity is set free by a variety of processes, and it more ospecially concerns the brewer to be aware of this fact.

We cannot certainly stop or diminish electrical forces, or check electrical tension, in tho atmosphere, but by a proper arrangement of buildings, by insulating vessels and pipes, and by employing no conjunction of dissimilar metals, we can in great measure prevent the atmospheric electricity exerting baneful influence on our produce, and retard the generation of chemical electricity in our working vessels. The oarth itself being fully charged surely it is right to keep your casks and different vessels off the ground; and if a great amount of metal is used in the form of pillars and girders (metal being a conductor of electrical currents), is it not wise to insulate your vessels when placing them on metallic supports, and knowing as we do that the air is the carrier of electrical waves, surely it is advisable to prevent draughts of air passing through your fermenting and store rooms; and since we have the knowledge that this state of high electrical tension is most energetic in causing change in such organic solutions as are themselves prone to alter under internal influences, surely it is wise to remove worts from coolers with as little delay as possible at such times as we know that the atmosphere is fully charged with this highly important and active agency. Then, again, with the knowledge before us that worts are more or less acid, and that this acidity is capable of acting on metallic substances, dissolving them when separate, and actually setting up electrical currents when any conjunction between dissimilar metals is allowed, it is unguarded and ruinous to allow of any contact of metals in our fermenting fluid, or in the beer at any stage of the process, since the normal acidity of all beer fulfils every necessary condition when in contact with the dissimilar metals for generating electrical force. Again, since we have seen that metals non-homogeneous in structure when heated together afford slight indications of passage of electrical currents, it is hardly prudent, I think, to employ such refrigerators as are composed of long series of pipes, themselves composed of three or four distinct metallic constituents. Now, although it is a question for consideration and debate, whether such minute currents of electricity as may fairly be said to arise from the conjunction of metals in worts or beers really have the power of effecting its decomposition, we may be quite certain that they have a marked agency in effecting palate flavour, and keeping quality. Thus, it is highly necessary for every brewer to be wary respecting the use of metals, or, when in use, to prevent their acting as conductors of electricity, or by actual contact with dissimilar metals, giving rise to electrical forces capable of aiding, if not actually bringing about, destructive changes in the beers. The importance of this latter kind of electrical force being known to every brewer cannot be over estimated: for if we could trace the cause of much unsound, unpalatable beer that is brewed, we should often find it due to the silent agency which is continually at work in the brewery, if we neglect the teachings of science and ignore its most palpable facts. It is not necessary that I should go more into detail to explain fully the influences of electrical forces on the produce of a brewery, since it is not requisite for ordinary brewers to understand every theoretical doctrine, but rather to gain just sufficient practical knowledge as will enable them to check these hidden influences by careful attention to the very simple, theoretical laws I have tried to explain.

Thus in the construction of brewing vessels and brewing buildings we ought always to keep in view the question of electrical force, and, as we progress with a consideration of this paper, we shall see in what ways we can carry out in practice the few theoretical laws that I have mentioned.

Now in commencing to write upon the subject matter of Essay V., "The arrangements of brewery buildings in reference to different systems and trade requirements," we must, as a starting point, take it for granted that different systems involving the divers construction of brewery plant, are necessitated not only by differences in public taste, but also by differences in the chemical constitution of the materials we have to deal with. Thus it is difficult to lay down hard and fast rules on this subject, but whatever the special requirements may be, there are some general factors which we may consider as having a very important bearing upon the question of site selection and construction of brewery buildings.

First of all, good drainage is an essential point, for no compounds so quickly decompose and emit offensive gases as the bye products of the brewery; and since a great deal of this matter is more or less insoluble, requiring to be washed away in the solid form, the necessity arises that the drainage system should be perfect.

The next point is the water supply in reference to the drainage question, since we find brewery well waters frequently contaminated with organic matter derived from the brewery refuse imperfectly carried off by the drains. For instance, the well is shallow, with no protecting layer of clay existing, as it does naturally in the London districts, and as a result you find surface water containing immense quantities of impure matter, in many cases derived from a drainage source, percolating into your well, and so rendering the contents unfit for brewing purposes. Now, nothing is so important as a good water supply, pure so far as its freedom from organic matter is concerned; so brewers ought first of all to place their brewery buildings in such position as will allow of a pure supply being obtained, and then to take care that their drainage arrangements are so perfect that no possible contamination of this supply can take place. This sometimes is a very difficult matter, and I was once told that so sure as Burton became a large manufacturing town, with a gigantic drainage system, the superiority of the beers produced there would gradually vanish, since it is almost a matter of impossibility in many districts to avoid drainage matter percolating into the local water-bearing strata. Nevertheless, town waters are generally pretty pure, since there is not the same danger of contamination, coming as they do from a distant source, as in the case of springs which are situate on the brewery site. We must believe, then, that a browery first of all ought to be built in somo spot where you can depend upon a safe drainage system in reference to purity of water supply; not that I care in the least whether a wator be hard or soft, but only wish for one pure in other respects; for I know of nothing that will counterbalance in a practical and economical way the presence of organic impurities.

There are now a few remarks to make about the question of malt and hop storage. The first most certainly does improve very fast when kept in large bulk; so the custom is to erect very large bins on the brewory premises, into which all malt is shot directly it is received, to mature and improve under the influences of age and bulk. Such bins ought to be composed of some non-porous material, or lined with such things as tiles or galvanized sheet-iron, since malt ought not to come in contact with brick walls, and wood does not answer so well as a covering material, since it allows of the weevil (a small insect very destructive to malt) finding a suitable harbouring place. Then, hops should be stored in dark dry rooms, kept as free from currents of air as possible, for we know they rapidly colour when exposed to the influence of light, and when currents of air pass the volatile oil is quickly carried away These two departments of a brewery should be distinct if possible, and yet in connection with the grinding loft and copper stage. The next point is cellarage, and these ought to be lofty, and so constructed as to be free from air currents, for the reason that draughts may be said to be carriers of electrical waves. If they are under ground you get a more equal temperature, and yet there is the disadvantage that you have to rely on artificial light—a most decided evil, since it causes elevated temperature, or, more strictly speaking, unequal temperature. Then on the basement in connection with your stores you have your tun room, directly below fermenting room, fitted up with pontoes, unions, or travelling yeast backs, according to the system in practice, and this floor of all others should be well drained. The ventilation of each department should be arranged so as to enable steam and hot air to pass away easily without the aid of strong draughts. The upper parts of your buildings are arranged in great measure in reference to the question whether your system be slow or fast; for if the former is adopted, much more room is required in the way of fermenting tuns, settling tanks, and yeast backs; but in this upper portion of the brewery you need to be very careful in respect to levels, for the less pumping you have to do the better, and very frequently you find extra pumping necessary to overcome some original fault in arranging levels. Now we know what a gravitating brewery is where you have a natural flow from the mash tuns to the cellars without the aid of any pumping power, and all brewers would do well to approach as near as possible to perfection in this respect; but it is not always possible to arrange buildings of such great height, but, nevertheless, it is well to remember that pumping is a disadvantage, especially with boiled worts, for after ebullition the wort is free from air, while pumping tends to recharge it again—a grave fault in some districts where air is impure and charged with animal life. It is almost impossible to keep long series of pipes free from contamination, and there is no doubt that when worts come in contact over and over again with metallic surfaces they do more or less become tainted by a minute solution of metal; so it is well to remember that if levels are arranged in a systematic manner, very little pumping and consequent passage through long series of pipes will be required. But this question of levels is important in more ways than this, for if any defect in their arrangement escapes notice, it is wonderful what a complexity of work it entails, and how repeated pumping becomes necessary. Then we have to decide the question of steam *versus* fire boiling—which is preferable? One would imagine that, chemically speaking, there would be but little difference between a temperature of 212° or so, obtained by steam heating or derived from fire; but, at any rate, the latter seems more penetrating, or, in other words, it seems to effect more changes in the wort, and, as we shall see when speaking of boiling, these changes are strictly chemical in their nature, and of some moment. We have read enough of metals to enable us to see that brewers ought to be careful in making a selection for use in their brewing vessels, but, at the same time, we may as well bear in mind that so long as wort is hot little danger arises from the use of those I have specified, but after the wort is cold it ought only to come in contact with tin, and thus, in most modern well-constructed breweries, one notices that the mains are all composed of copper coated with this metal; and if we remember the subject matter of the paper on electricity, we shall see that it is important that this tin surface be kept perfect, not allowed to wear off without replacement, for if it does you are permitting the contact of dissimilar metals in an acid fluid, although, so long as tin surface is perfect, this is not the case. Thus, while the use of metals generally is a disadvantage which we try to diminish by selecting such as are most stable, the habit of allowing any combination of metals is fatal to the production of sound produce; so much so indeed that in arranging brewery plant one must insist upon only a single metal being employed, after the mashing stage of the process, the most suitable being copper, this copper being coated with tin for all purposes after wort has passed from coolers; again, I repeat, that it is important to remember how no objection exists to the use of this combination so long as the fluid simply touches the exterior coating, for to allow of injurious effects arising, both metals must be in contact with each other and the fluid at the same time. Then, again, when we remember the conducting property of metals, the electricity contained in the earth, and the influence of currents of this force upon our organic fluid, we ought to see that our attemperators are not in metallic connection with the ground, and it is easy to insulate them by inserting a length of some non-conducting material, such as india-rubber, while the vessels themselves should not rest upon metallic supports but on some non-conductor of electrical currents, such as glass, wood, slate, or porcelain. To prevent rise of heat in some stages of the brewing process, to retard fall of temperature in others, the use of attemperating piping and steam heating coils is now universal; so I advise every one to see that this piping, after the boiling stage, is coated with the metal I have mentioned, as capable of resisting all ordinary chemical action, for in fixing metal piping it is expedient to bear in mind the laws of electricity, while remembering the more practical influence of the chemistry of metals. The whole brewery itself is so arranged that each department is distinct and separate, and yet in immediate connection with the next in natural sequence. Your mill room and grist bin stage should command your mash tuns, which themselves should be sufficiently elevated to command grain tank, which in its turn should be situate at such a height as to involve the minimum of labour in loading trucks or carts, while the fermenting room should be in close proximity to the refrigerating stage, and yet the one should be so cut off from the other by thick walls and doors that one should not suffer from the heating influence of the other. The coolers should be well ventilated to allow of free escape of steam, and yet this ventilation should not allow of excessive admittance of light, for the general light in a brewery should be diffused, being thus capable of effecting less chemical change than actual sunlight is credited with, and this observation applies in full force to the fermenting room arrangements; and yet how frequently you see the working beer exposed to atmospheric glare. Then, again, the cooling-room should be in direct connection with the hop backs, and these with coppers, although all such departments should be separated from each other by party-walls and doors, to prevent the hot air, the dust and dirt of one department drifting into the other to contaminate the worts exposed on the cooling-floors. I may make here with advantage one or two remarks concerning the different methods of preventing external heat influences. Theoretically speaking, there is a vast difference between the effects of a summer heat and the heat caused by the steam atmosphere of a brewery; in both cases you get the same result so far as change in temperature of cooling, fermenting, or quiescent beer is concerned; but in the case of summer heat you have to contend against the fact that at such times the hot atmosphere is highly charged with vital impurities, so it is not so much the mere heat of the summer months that prevents the brewing of keeping beers while that heat lasts, but rather that at the times of such heat the atmosphere is antagonistic altogether to the long continued soundness of such a fluid as beer, containing, as it does, the necessary food for the atmospheric contaminations. Now you prevent internal heat influences by building up distinct departments separated by thick walls, so as to prevent, for example, the steam of mash tun room, tun room, and cooler room drifting into departments where this heat and moisture would be disadvantageous; again, as regards external heat, you can try to diminish its mere heating agency by having thick outside walls, double cased windows, or simple ones protected by sun-screens; while the roofing of such of the departments as you require cool may, with advantage, be covered with a coat of whitewash in order to reflect the heat-rays, instead of allowing them to be absorbed by the ordinary dark-coloured roof materials. Another useful method is to keep the roof, windows, floors, and outside walls wet, a mere film of moisture on windows being sufficient to prevent passage of heat-rays, while the evaporation of moisture from walls and floors tends to produce a chilling effect. Then you must guard against the chemical agency of summer heat by not exposing your worts a moment longer than necessary at a dangerous temperature, and after passing from cooler, arrangement of cooling power is wanted to restrain the rising temperature within limits, and so keep your fermentations as healthy as is consistent with the actual state of the atmosphere. We ought to restrain, not only the rising temperature of the beer, *but also of the yeasty head above;* a point, which is too frequently neglected. The tun room, racking and storage departments are all arranged on the same systematic plan, and we may sum up the most palpable features of brewery arrangements thus :—

Necessity of good drainage in reference to the contamination of water supply, the connection of various departments, and the desirability of separating them by thick party walls.

The necessity of keeping malt and hop stores free from damp, excessive light, and currents of air.

The absolute necessity for great care being exercised in the arrangement of LEVELS, having regard to the objections to the use of excessive quantities of metallic piping, and the dangers of too frequent pumping.

The desirability of insulating all vessels and pipes, so as to prevent easy passage of electrical currents.

The necessity of avoiding contact of dissimilar metals in wort or beer; and, finally,

The wisdom of protecting certain departments of the brewery from internal and external heat influences.

We will now come to a consideration of the internal arrangements of a brewery in reference to different systems, which differences are necessitated, in great measure, by dictation of public taste.

If you require a very pale beer, for instance, it is essential not only to use pale malt, but also to avoid the use of iron, which, as I said, is apt to cause coloration. Then, again, you must not have boiling vessels too deep, for according to depth so is pressure, and according to pressure so is coloration while boiling is going on by fire heat. It is necessary, also, to avoid the practice of having closed coppers, which were originally employed, I believe, to prevent the loss of hop oil, which passes off with the steam. The fact is, they did not really effect this object, and the only advantage you derive from their use is extra temperature, more penetrating, perhaps, than the ordinary boiling temperature of wort, but you may be sure that you do not employ this increase of temperature by preventing free escape of vapour without coloration of your worts taking place through the caramelization of the saccharine, while it is worthy of a remark that this caramel formed is incapable of undergoing vinous fermentation. Thus you see that increase of pressure, and consequent increase of temperature and coloration, is arrived at by greater depth of boiling wort, and also by preventing free evaporation; so that at Burton, where pale beers are an essential characteristic, the brewers are well aware of these effects of pressure; and the depth of their coppers is arranged accordingly, that is, the depth is little as compared with the diameter, and thus the evaporating surface is great. It is a principle well worth remembering in the arrangement of a brewery that pressure is directly as perpendicular height, and as another example of its bearing, I may say that if your coppers are very elevated, and your mash tuns very near the basement, it is almost impossible to get a steady mash through the ordinary mixing machines, unless you get your water pressure diminished by flowing into an intermediate jack-back, not situate too high above the mashing machines. Again, the question of pressure regulates the construction of vats and working rounds, and militates against the adoption of an excessively deep vessel either for boiling or fermenting in, for in the case of fermenting tuns of great depth the pressure on the lower portions of wort would be sufficient to retard the attenuation in marked degree. Then, again, when public taste demands a heavy full-palated beer, you want to arrange your plant so that dextrine in excessive quantity can be obtained in your worts, that no delay in raising this dextrine wort to the boiling point be allowed, and this may be done by having sufficient copper room and powerful furnaces. Then, once more, if you require a saccharine beer, one that will come to maturity in a short time, you so arrange your mashing system and plant (unless it is in your power to so regulate the malting of the original grain that any special mashing system is unnecessary) that you may, by its proper working, procure this characteristic beer. You want internal mashing machinery and lengthy time of mixing and standing, with a double flow of liquor at different heats, so as to arrive at a perfect saccharization of the starchy matter of your malt; and concerning this important subject I shall have many remarks to make in my next essay. But brewers have another way of obtaining a saccharine beer, and that is by the use of sugar or glucose; and here, again, we have to make such arrangements in plant as will allow of the easy solution of matter which is not after all so very soluble, in the cold at any rate, for one constantly hears complaints from brewers respecting this difficulty.

Now, to begin with, grape sugar is not nearly so soluble as cane, while the glucoses are delivered in all sorts of conditions, some in boxes or large square blocks, others in small lumps and powder, and others in a semi-solid condition in casks. Now it is highly dangerous to throw any quantity of sugar or saccharine in your copper, but I may incidentally remark that so long as rapid ebullition is taking place the danger is much reduced. It is far better to have a wooden tank, commanding your coppers, fitted with a false bottom (a diminutive hop back, in fact), with a steam coil below; you then cover the false bottom with liquor, put steam on, and so soon as liquor is actually boiling tip the required quantity of sugar in. You do not require a very concentrated solution, and an allowance of 5 cwt. to a barrel of liquor, which is equivalent, in the case of a simple saccharine, to a saccharometer gravity of 95 per barrel, is quite sufficient. It is really wonderful how rapidly you can dissolve these lumps of saccharine in liquor *actually boiling*, when you compare the fact with the state of things when your solvent is but hot and not actually boiling. In case you cannot arrange your plant in such a way, there is a simple way of dissolving the semi-solid saccharines supplied in casks; you suspend the cask over your copper with the shive knocked out, you then insert a steam jet at the cork hole, and the semi-solid mass is soon dissolved out, passing through bung hole to copper below. In small breweries, where consumption of such materials is not large, it is advisable to use the dry kinds contained in bags, since it is difficult and wasteful to divide a cask of semi-solid glucose. Then, if to satisfy certain trade requirements, you require a slow fermentation system, and if rousing machinery is employed, or may ever be required to supersede manual power, it is well to arrange your tuns in parallel lines, so as to suit the mechanical arrangement of machinery. Then, again, you require greater capacity for yeast thrown up during the slow progress of the attenuation, much greater quantities of albuminous matter being eliminated as yeast by this system in the fermenting tuns than by any other process at the present time employed; in fact, with our present knowledge of fermentation, the tuns do better closed in altogether, and a certain refinement in process would be arrived at if, when fitting up plant, we arranged for not only restraining rise of temperature of fermenting wort, but also of the yeasty head above. This is done in perfection by the use of double stone squares, as they are called in Yorkshire, or by double squares or rounds fitted with attemperating coils, these squares being placed in connection one above the other, the upper one being the recipient of the yeasty matter during fermentation; or else, as in some breweries where a pumping system of rousing is in practice, the alternate vessel into which the fermenting wort is pumped, flowing therefrom to the lower vessel in due course, and finally the vessel into which the yeast forces itself when attenuation is advanced and pumping discontinued. This cooling of yeasty heads may be effected also by a totally different plant arrangement, air being cooled by means of ether machines and then forced as a cold blast upon the surface of the yeasty heads in fermenting tuns.

I would direct especial attention to this point, since yeasty floating heads are many degrees warmer than the fermenting wort below, the difference depending upon many influences; now nothing, perhaps, is more important than soundness of store, and I need hardly say that high temperature militates against this soundness, and yet in the generality of breweries we see no arrangement of plant made to restrain this rise of heat in yeasty matter, while the greatest effort is made to keep the *wort* within safe limits of temperature. In arranging a brewery for a skimming or other cleansing system, it is well to remark that better export and bottling beer is brewed by a skimming system than by any other, as you are able to free your beers better from suspended impurities and excess of gas in these shallow settling tanks to which your skimmed beer is conveyed from rounds, than in any other kind of vessel that I know of, especially when they are of considerable depth or constructed of some unsuitable material; but for fresh beers, generally, such as stouts and mild running beers, both unions and pontoes answer very well, so long as a slow system of fermentation is in progress. I say this since with a fast system you lose to a great extent all control over your vinous fermentation when the beer passes from rounds to unions and other working casks. With a slow system you can attain such brilliancy of produce in these vessels that the use of no intermediate racking tank is required, while by a proper arrangement of the metallic connections the racking may take place direct. There is no doubt that a skimming system involves less waste, is economical in time and space required for vessels, in labour, and hot liquor or steam use. If you have it in practice, yeast backs of great capacity, and yeast presses, are a necessity; balance disadvantages, few as they are against the benefits of such a system, and the doom of unions and pontoes as cleansing vessels of the future is sealed. Let every part of the plant be so arranged that no delay occurs in the process of brewing; let your stock of shipment casks be in excess, to give time for their complete cleansing, much damage being done when beers are placed in casks either warm or damp. Let the mechanical motive power be arranged to so avoid complexity in this part of the plant arrangement, and make every provision for supply of hot liquor and steam for cleansing purposes. Whatever the plant may be, make every arrangement for keeping vessels, pipes, and pumps free from all hurtful matter, and so place them that thoy can be readily examined and cleaned. Nothing is more important than cleanliness; guard against any acidity or cause of it, and do not stint the use of such a useful agent as lime, and remember that within certain limits, which we shall study by-and-bye, we can so alter the taste and general characteristics of our beer by the aid of chemical knowledge, of grain constituents, and method of extraction, that by a proper working of the plant we may gratify a variety of tastes, and produce a stout and a pale ale of good keeping quality by the use of water theoretically too hard for one and too soft for the other.

Such, then, are some of the essential principles to guide us in constructing a brewery, and adapting it for special kinds of productions by differences in plant arrangement. They may be called by some the refinements of theory, but they are, nevertheless, the essential accompaniments of a successful practice.

I have no greater space at my command to explain in a detailed manner the more difficult problems of plant arrangements, but I have tried to run through some of the more important matters with the intention of describing any special plant adjustment as we progress in future essays, with a consideration of the different brewing operations.

## ESSAY VII.

### Mashing.

Before I proceed to explain this important process it will be well to say a few words respecting the preparation of the grain—I mean so far as grinding is concerned. It has been said by a very eminent chemist, that because in a laboratory we pound matters up before attempting their solution, we ought, therefore, having the same object in view, to crush malt up much finer than we are in the habit of doing. Now it is very evident that we depend upon the husk of malt acting as a filtration medium, and if we cut this husk up into minute fragments our goods will brew "*dead*," as it is technically called, and we shall lose time and extract too.

There is nothing so necessary in this mashing process as to have a grist which, when mashed, will brew well; and it is right for a brewer to select malt which has been well germinated—and so rendered specifically lighter than the original grain—and then, in grinding it, to so arrange that its internal particles shall be in contact with the solvent, and yet not brought to such a state of division that any difficulty is likely to occur when drawing off the saccharine fluid.

In practice we often see this "*deadness*" of the mashed grist, and when you think what a mass of heavy pasty matter you have to deal with, it is evident that unless we have the husk in partial entirety, to act as a buoyant filtration medium, we are unlikely to extract our wort in a satisfactory manner. The difficulty of mashing raw grain arises from the fact that the contents of the grain are neither so soluble nor so specifically light as the constituents of malted grain, and consequently there is no apparent lightness about such a grain when mashed; so distillers, who alone are allowed to use raw grain admixtures, have to adopt various expedients for overcoming this disadvantage, and obtaining the worts in a reasonable time and a satisfactory condition. Practically the subject is of much importance, and I would say, avoid low grinding without going to the other extreme of coarseness; you can always hit upon the medium condition, that while making sure of fulfilling the object of grinding in reference to every single grain of corn, you are yet leaving the husk in such a state of entirety that you may be certain of satisfactory mash tun indications. The best extracts are obtained from a grist of medium grinding condition, for in taking it too coarse you lose extract through much of the thin corn escaping crushing; while you lose extract by taking a very fine grist through the great difficulty experienced in extracting from the pasty goods, the results of your mashing and sparging processes.

Thus we see that methods that answer admirably on the small scale with all the appliances of a laboratory, cannot be carried out in all cases in a brewery, where celerity of process is of the first consideration. Brewers, especially those in a large way of business, are, as a rule, too fond of obtaining extraordinary extracts from malt, the unfortunate part of the affair being that much of the matter they extract is worthless, and only tends to deteriorate the keeping quality of their produce; and if character of beer is viewed as of greater importance than mere extract obtained "per quarter," it is safer to err on the side of taking a somewhat coarse grist than to fall into the difficulties and delays resulting from the employment of a fine one. There is one more point to mention in reference to grinding, and that is the necessity of arranging for this operation taking place some twelve hours, at least, before mashing time. Much heat is generated by the friction of the grain against the rollers of your mills, and it is highly impolitic to mash this grist until the heat has been dissipated, since under such circumstances it would be impossiblo to regulate, with any degree of certainty, the temperature of liquor required to arrive at a stated initial heat; while I am inclined to the belief that the grist mellows, and becomes more suited for undergoing satisfactory changes in the mash tun, under the lengthened influenco of this increase of temperature in grist bins.

Now, in coming to a consideration of the mashing process, I will first of all endeavour to make plain the theoretical principles involved, and then briefly refer to the manner in which these considorations are carried out in practice.

In malting we have seen how the selected grain has been fitted for the brewers' use, how the starch has been partly altered into sugar, and how much of the remainder has been modified under the influence of germination; but, above all, we have noted how a portion of the albumen has been changed into a most active principle, which chemists have named "*diastase*," and how another portion has disappeared in the form of rootlet; and then, when these changes have taken place in perfection, we understand how, by means of drying, the grain is deprived of its moisture and vitality at the same time, and rendered fit for storage.

Excise laws, severe as they aro, tend to prevent improvements in the process, and actually place a premium on inferior manufacturo; nevertheless, if skill is shown in working under present conditions, a satisfactory result may always be arrived at. I have said that there are many different systems, and, as a result, you find malts vary, in the respect that some are so perfectly vegetated that the after process in mashing is simple and easy for certain beers; while other samples, *apparently of perfect growth*, have been vegetated under such a faulty system that excessive acidity, unmodified condition of contents, and necessary hardness of kernel, are constant characteristics. Now the art of mashing consists in so working out practically theoretical laws that we obtain in our worts, in definite and distinct proportions, such matter as we know is necessary for the after formation of spirit, fulness on palate, and keeping quality, and this latter property depends nearly altogether on the proportions of constituents extracted in the mashing process, and afterwards modified under the influence of vinous fermentation. Now in malt we have large quantities of starch present, and such a quantity of diastase as is capable of effecting, under proper conditions of heat and fluidity, far more modification than we ever call upon it to induce, unless we mix crude starch or raw grain with our malt, and so practically diminish the proportion of diastase present. Besides these two constituents we have much unmodified albumen present, too much in fact; and since waters vary in their extractive powers, many brewers find, or would find if they looked into the matter, that the cause of the unsoundness of their produce is due to the fact of excessive solution of this albumen, on account of peculiarity of solvent, without any means being adopted of overcoming this disadvantage in the after stages of the process. To compensate for this excessive solvent power of soft waters on account of freedom from certain salts of soda and lime, some brewers are in the habit of using such preparations as mono- or bi-sulphite of lime, which act, as I have before explained, in much the same way as calcic sulphate in preventing undue solution of albumen.

Now the principle of mashing is that when you bring this active principle, diastase (modified albumen), in contact with starchy matters at a certain temperature and fluidity, this extraordinary principle has the power of inducing the change of the whole of the modified starch into sugar, and an intermediate compound called dextrine or gum, and the better the malting system has been the more perfect and speedy this chemical action in the mash tun. Chemists have been able to imitate this action in the laboratory by the use of acid, and, in a practical way the saccharines we employ as substitutes for malt are made from starch-yielding cereals, through the agency of very dilute sulphuric acid at a high temperature. Any one, whether he has a knowledge of chemistry or no, can test this fact for himself by the use of iodine. When iodine solution comes in contact with starch an intense blue coloration is the result, and if you take a little mash and squeeze out some of the liquid and test it with iodine you will see that starch is present, but if your mash system has been successful you will find that this starchy matter very rapidly disappears, your wort, in fact, is quite free from it, while sugar and dextrine are found in its place. Now upon the dextrine and sugar extracted depends, in great measure, every future characteristic of your beer, but you must not forget the albuminous principles which are dissolved while this chemical action is proceeding; and, above all, you must not forget the *proportions* of these three constituents, for on the proportions very much hangs.

Let us examine this matter closely, for its importance cannot be over estimated. During the chemical action that takes place from the first moment of your hot liquor touching your crushed malt, starch gradually alters, first into dextrine, and this partly into grape sugar. Now it fortunately happens that by a correct knowledge of the effects of different heats, varying lengths of process, and so forth, we can control this wonderful action, not altogether, mind, but to such an extent as enables us to produce beers containing very different proportional quantities of dextrine and sugar. The benefit of this fact is that in a small brewery where bulks are but small, and where cooling influences in the winter months are in full force, we, by a simple change in process, are enabled to get a wort fully charged with sugar which undergoes easy decomposition in the fermenting tun; and again, when you wish a beer to attain early brilliancy and condition, and may be the taste of age, you proceed in the same way to obtain a saccharine wort, but for beers which require much palate fulness, or are intended for export—for stouts, and such like—you try and obtain a larger percentage of dextrine, which is capable of resisting the decomposing effect longer, and which being present in a finished beer, does not allow of a wild decomposition in cask, but a slow and gradual change, enabling you to retain constant condition for a lengthy period. Then again, bearing in mind the evil effects of excessive solution of albumen, and that the quantity extracted depends in great measure on the character of the grain malted, and the solvent properties of water used, it must be our aim to select a suitable grain, and then to use such a water, either naturally or artificially rich in certain saline contents, and such a temperature of liquor as will tend to prevent undue solution, without being contrary to theoretical laws. Now with imperfect malt it is by no means so easy to arrange the proportion of dextrine, sugar, and albumen extracted, as your idea in this case must be to change as much of the starchy matter as possible into sugar, or at any rate to leave no starch unaltered, for it happens that starch is soluble in very hot liquor, and our mash as we know gets warmer and warmer as the sparge process is carried on, and unless the starch has been altered in the primary mashing operation, it will be dissolved when the liquor gets sufficiently warm, and when this crude starch is in solution you may as well give up all faith in the keeping quality of your beer. We know that the temperature of mashing liquor is kept within two limits; it must not be too high or your starch would come into a gelatinous state and resist the action of the diastase, and you cannot get below a certain limit, for if you did the diastase would refuse to act, while ordinary albumen would rapidly break up the sugar of the original grain into lactic acid. Now, as a general rule, I may say that the mean mashing heat in England is about 170° Fahr., and you will find that when liquor is mixed with ordinary malt at the rate of two barrels for every quarter, at the temperature named, the resulting "initial temperature," as it is called at the moment of mixture, will be some 150° Fahr.

Of course outside cooling influences are at work; some mash rooms are cold and exposed, and you have to employ higher temperatures to arrive at same initial heats. Small bulks are in this respect a disadvantage; while, as a general rule, I may say that it is well to so arrange your plant and so heat your mash tuns before use that you are enabled to employ a lesser degree of liquor heat and yet arrive, by the use of this standard quantity of liquor, at the same initial temperature. With such a system of mash—that is, the employment of one single quantity of liquor at a stated temperature—you meet with many disadvantages; you are bound down, as it were, to one fixed temperature to produce a certain heat of mixture, and there is danger lest the temperature of liquor should be a trifle too high, and yet you must perforce adhere to it in order to obtain a good action and a brilliant wort, unless you vary the fluidity, which is a system objected to by most practical men as interfering with the extraction of all available matter.

Now, as starch undergoes change into dextrine under one limit of temperature, and as this dextrine becomes converted into grape sugar under the influence of increased heat and time of standing, it is theoretically correct to use two distinct quantities of liquor for mashing at different temperatures. You first of all use such a degree of heat as is capable of dissolving diastase, enabling it to convert the starch into dextrine; and then you, by a simple addition of a further quantity of liquor at an increased temperature, enable this same diastase to induce a further change—the conversion of dextrine into sugar. You will now see why the old internal rake machinery, enabling you to mix in distinct and separate quantities of liquor, is superior to the outside mixing machine, through which you have to finish your mashing process, for the employment of a fixed quantity and temperature of liquor gives you a wort containing, from the same malt, one fixed proportion of dextrine and sugar, which you are only able to alter afterwards by a delay in the process, which I shall explain hereafter; while by the use of two distinct liquors at different temperatures, you are enabled to avoid the use of too high a temperature of liquor in the primary stage, and afterwards to vary the proportions of wort constituents, not at will, perhaps, but to a much greater extent than is compatible with the more simple mashing system.

Now the importance of all this is, as I said, great. Dextrine does not give so clear a solution, or one so adapted for undergoing fermentation as sugar; and I have often been consulted by brewers as to why such and such a beer undergoes languid fermentation, and why spontaneous clarification fails to take place; while, on the other hand, brewers often complain of thin, fiery heads during fermentation, and a tenuity of finished product distasteful to the consumers. Now these characteristics arise, in most cases, from errors committed in selecting mashing heats and process, and are easily altered by a simple change in the mashing system, or the use of saccharine in fixed proportions. Thus, in viewing the theory of the mashing process, we see what a complex operation it is and how very much depends upon it, while there is no clearer proof of its chemical nature than to notice the rise of heat which takes place during the standing of your mash. Every chemical change liberates heat, and if you observe the initial temperature of the mash at the moment that it falls into the tun, and again after the lapse of an hour, you will find a rise of many degrees has taken place, which would be even more marked if it were not for the outside cooling influence at work tending to counterbalance the rise.

Finally, as regards theory, let us see what the conditions and results are when malt is used containing a little sugar, an excess of modified starchy matter, diastase, and albumen: Liquor at a certain temperature is added, which, dissolving this diastase, enables it to induce conversion of starch into certain proportions of dextrine or gum and sugar, which proportions can be varied by a practical adaptation of theory. Albumen partly soluble, and partly of that variety coagulable by excessive heat, is dissolved; this quantity depending upon the variety of grain employed, the success or failure of the malting process, the peculiarities of the water in respect to saline constituents, and, finally, upon the temperature of the mashing liquor. We coagulate a portion of this extracted albumen, no doubt, by boiling; but in most cases an excessive quantity remains to be eliminated as yeast during the progress of vinous fermentation. The refinement of theory is that we brewers ought to employ such a low degree of heat to begin that, with while avoiding an extreme that would facilitate the formation of lactic acid, our temperature is sufficiently low to allow of the whole of the starch being, first of all, converted into the intermediate dextrine, so that by varying applications of liquor at increased temperatures in the secondary stages we may obtain such different proportions of two distinct substances as will enable us to attain the necessary difference in the characteristic properties of the different beers we attempt to produce. To obtain an unvarying result, you must treat different malts in different ways. The latent heat of malt varies, for instance, according to the degree of heat applied to it when undergoing kiln drying; in other words, some malts, such as brown and black, cool hot liquor less than pale malts; so we mash porter grists at a lower temperature than ale, and yet arrive at the same initial temperature. Again, some malts are steely in nature, their contents have not undergone suitable modification, and you must arrange that either your mash system shall be capable of effecting the whole change necessary, or that your fermentation system shall be capable of overcoming the defects arising from extraction of excess of dextrine.

We must now leave theory for a while and branch a little into the practical part. We arrange our fluidity in accordance with the knowledge that the thicker your mash the higher temperature must you employ to obtain standard initial heat, and the less brilliant wort will you obtain; while a dilute mash enables you to use a lower temperature, but prevents your obtaining a good extract. I am in favour of using two barrels of liquor per quarter when through a mixing machine at about 168°, which gives me an initial temperature of 150°, rising to 156° or 158° before setting tap, and a tap gravity of 35° per barrel. Now such a mash gives you, I believe, dextrine and sugar in equal proportions, with a satisfactory malt. If the malt is imperfectly malted, your dextrine is in greater proportion, since the diastase has had more work to effect, and you must adopt either some special kind of fermentation to allow of this dextrine being decomposed, or you may keep your wort for some time at a temperature of 170° after it runs from mash tun, to allow of the diastase exerting its converting power on the excess of dextrine before the power of this converting agent is destroyed by the boiling temperature in the copper, or you may increase the proportion of sugar in your worts by the addition of saccharine. Again, where you have internal rake machinery you can, with great exactitude, regulate your proportion of constituents, and so give different characteristics to your produce. With rake machinery you mash in with about one and a-half-barrels per quarter at some 162°, and you allow this mixture to stand some three-quarters of an hour; and then a second quantity of liquor, at a much higher temperature than the first, is forced under false bottom and mixed in by machinery. Now we saw theoretically what this second flow of liquor would effect. You may theoretically employ any temperature, *for all the starch has been modified in the primary stage of the mashing process;* but the brewer must determine in his own mind what he wants to effect. If a dextrine beer is required—and I had better remark that it never is wanted in a small brewery—you take a sufficient quantity of second flow liquor at a rate of half a barrel per quarter to bring up the heat of the mash to 156° or 158°, while you stand some hour and a quarter after final mixing in is finished, and then, on setting tap, bring the wort to the boil as soon as possible, to destroy the converting agent, and prevent the proportion of constituents being altered. We will call this the dextrine process. If, on the other hand, a saccharine beer is wanted, your second flow of liquor is taken at such a heat that the initial temperature is raised to 165° or 170°; and I ought incidentally to remark that the mind must be kept quite clear respecting the safety of this high temperature, *so long as starch is modified into dextrine;* and before any addition is made it would, in all cases, be best to test for starch, for so long as that principle is present no high temperature must be employed. Time is another important feature. The longer you allow the mash to stand at this elevated temperature the more sugar will you obtain; but you must, on no account, stand so long as to allow of cooling down taking place. Steam may be used instead of hot liquor if more convenient—in fact, the principle is a very simple one: you first of all make sure of altering starch, and then with safety employ the higher temperature to again modify the dextrine. Thus a "*flow mash*," as it is called, with internal machinery for mixing purposes is most adapted for breweries, but if you only have outside mixing machines, although you cannot obtain so much extract, and stand in danger of extracting a little starch, you can vary your constituents to a certain extent, either by delaying the process after the worts flow from the mash tuns—while you keep them at a medium temperature for a time—or by the addition of saccharine; but whatever process you adopt, be careful of the starch, for it is a most insidious agent in finished beer, and there is really no great fear of obtaining it, even by the employment of a single mash system, so long as you run an even mash with liquor not over 168°, while with the old-fashioned flow mash there is no possibility of extracting it if primary heats be correct. The whole conversion takes place during mashing and standing, so no after agitation is required. The first evidence of the change is that the thick pasty mash begins to liquefy so soon as dextrine and sugar are formed, and the wort percolates through the goods and issues from the mash tuns limpid and bright. There are different views respecting this part of the subject, and I am asked whether it be necessary that worts should be quite bright? Now, brightness is a very essential characteristic, no doubt; but still a good sound wort may often be turbid, without any evil result being feared. It really depends upon what is causing the turbidity. Turbidity, as a rule, is due to one of two causes: the wort is either carrying more soluble matter than can be held in perfect solution at the temperature, or it is carrying matter which is but semi-soluble or insoluble altogether. Now, so long as your mash has been simply too thick, although initial temperature may be correct, your worts will be unable to carry the excessive quantity of extractive matter in perfect solution—they will be turbid, in fact, and yet there will be no danger in this kind of turbidity; but if starch is extracted through error in process, your worts will still be turbid, but grave risk will be run, so it is not actually correct to say that it matters not whether a wort be bright or no. Keep a little solution of iodine at hand, and when your wort is running off test it, and if by the coloration starch is indicated—which, with a proper system, is impossible—keep the wort at an intermediate temperature of 170° for an hour before allowing it to come to the boiling point.

Now let us apply all this theoretical and practical knowledge to individual cases. We want light ales to undergo vigorous fermentation and retain slight palate fulness; we want, in fact, a saccharine beer. I was once told, by a celebrated brewer, that if you want a good bitter beer you must always arrange to get a fiery fermentation, which means you must obtain a wort fully charged with sugar. I do not quite hold with this idea myself, as I shall have to explain in reviewing vinous fermentation, nevertheless it is correct enough for some systems and for some waters. Again, for stouts and heavy stock beers generally, we want a dextrine beer, but unless you have a special means of inducing decomposition of this beer constituent during fermentation, you must not have too great an excess, or your fermentation will be languid and unsatisfactory. Much difficulty is experienced by many brewers in obtaining full tasted stouts, the error in the generality of processes being the excessive employment of saccharines; beyond this, the brown malt of a porter grist, besides having a different latent heat, has had its original starch so modified by the torrefication that it has undergone, that if ordinary heats are employed you are certain to procure from it a large proportion of actual sugar; and thus, from one cause or another, your stouts are highly saccharine and yet very deficient in palate fulness. We may, in fact, safely lay it down as a rule that beers of decided palate fulness contain dextrine in excess. Sugar will give sweetness no doubt, but its decomposition takes place so rapidly that this soon vanishes and our produce is left vapid and unsatisfactory.

So soon as mashing is finished the goods are allowed to stand for a length of time—varying from one and a-quarter to two hours, according to the system in practice—and then comes the operation of sparging after setting taps. This is a simple operation, the whole aim being to dissolve the changed matter and replace the wort which is percolating through the goods and running from the mash tuns. Now a great deal depends on the heat of the sparging liquor; in the case of a flow mash, as I will call it, your whole chemical action has taken place before setting tap, but with other systems the upper portions of the mash are too cold to allow of actual sugar formation, and the effect of the first addition of sparge liquor is to raise the heat of the upper portion of goods, so that you thus get fresh quantities of sugar formed from the dextrine under the influence of the diastase at the increased temperature. It might thus be supposed that the use of very hot liquor would be an advantage, and to a certain limit it is. It will be remembered that in speaking of the different mashing systems I remarked, in reference to the internal machinery double heat system, that no evil would result by the use of boiling hot liquor for sparging purposes or the second flow. Pray do not misunderstand this remark; I made it to express more forcibly what resulted from the employment of a low initial temperature; to begin with, you made certain of altering all the starch, and then the application of high heats could bring about no gelatinous state. My remarks hold good so far, but no one would be wise in using boiling hot liquor, and in point of fact, much nice discrimination is required to fix the heat of the second flow of liquor, to ensure desired proportions of wort constituents being extracted. But with reference to sparging heats, other considerations have weight. We do not wish temperature of mash to fall, for fear of lactic acid formation being possible; while, on the other hand, we do not care to go too high, *more especially with the single mash system*, since the high temperature would cause the solution of any unaltered starch, and much other slightly soluble and yet worthless matter would be extracted. We obtain, of course, the more soluble matters first, and afterwards these that are soluble or semi-soluble at excessive heats, and our wort, from being brilliant, gradually assumes an opaque shade, and you will remember that I pointed out how competition in modern brewing necessitates the extraction of part of this worthless matter. It should be our aim, then, to diminish its quantity by not allowing the goods to get so hot as to allow of excessive solution, and I have myself found 176° a very safe sparging heat—safe in this sense, that if any starch remains unaltered in the upper or surface layers of a mash, made through an outside mixing machine, such a temperature will enable diastase to convert it, and yet not be sufficiently hot to render inactive the converting agent or bring about solution of unaltered matter; but with regard to heats I cannot pretend to lay down fixed rules, since circumstances vary so much, nevertheless I think it best to give some idea of what is considered correct.

Allow no cooling down to take place after wort leaves mash tuns; so, unless it passes direct to copper, the intermediate vessels must be kept warm by steam coils, and you will remember that such an arrangement gives you the power of overcoming the defect of sugar deficiency, for in this "*underback*" you can retain your wort at such a temperature as will allow of increased sugar formation.

The wort should be bright, should cream in glass, and carry a thick white fob in underback, if it runs from outlet taps with any pressure, and this it always does when grist and fluidity are correct. Excess of dextrine gives you viscidity of wort, and consequent thickness of fob, while excess of sugar allows but for the formation of thin and bladdery heads. A good malt and a satisfactory system ensures the whole of the extract being made in the first mash; it is, consequently, a matter of vast importance to understand the theoretical reason for every part of the process. In connection with the sparging operation, we have the question of raw worts; these are generally taken when the brew proper is for strong beer, or where excessive quantities of hops are being used. Now such worts contain, after ordinary strength has been already extracted, but little valuable matter—they may weigh perhaps one or two pounds per barrel—while this extractive matter consists of a little sugar and small quantities of albumen and husk; they aro quite sound if heat has been kept up, and they continue so by keeping them boiling hot, but if cooling is allowed you get formation of acid through the influence of the albuminous matter on the sugar. They are pumped to coppers, boiled, and then passed over spent hops (which is a better plan by far than boiling spent hops in the raw wort), filtered off, and again returned to copper, and retained at a suitable heat for mashing, and are, as a rule, used for that purpose in place of simple liquor. Any starch they contain is converted into dextrine and sugar during mashing and standing, and no danger arises from their use so long as you prevent any kind of decomposition taking place in them; nevertheless these last runnings are always more or less doubtful, without you have a very quick process and perfect system, and it is well to dispense with their use and substitute liquor for them; by passing it, boiling hot, over hops, unless on account of the excessive strength of your brew proper, you are obliged to employ a raw wort to extract the whole of the available matter from your "*grist.*"

I must, with regret, leave this subject as it stands for your consideration; if space would permit I might have explained the details of the process with more minuteness—as it is, I leave it with the hope that some of my readers will gain insight into the complexity of this, the first actual brewing operation. Surely it will be easy to see a little more clearly why some beers possess such peculiar characteristics of fulness, condition, and keeping quality; why others remain vapid and thin, or else undergo violent frets in cask, ending in premature acidity. The system of mash is in direct connection with vinous fermentation, a subject we shall shortly consider, but for the present I shall have failed in my object altogether if I have not made clear the important influence of dextrine as a beer constituent, and how to vary the proportion extracted. We require sugar certainly in large proportion, but it is by regulating this proportion in reference to the dextrine percentage that we are able to arrange for different systems of fermentation, and for the production of beers that shall vary in their more prominent qualities.

## ESSAY VIII.

### Boiling and Cooling.

THE wort on passing from the mash tuns is either pumped, or run direct to coppers, or retained for a time in an intermediate vessel called the underback; which vessel, as I have already said, ought to be fitted with a steam coil in order to prevent any cooling of the wort taking place before the boiling process has given it the stamp of stability. It is well to remark here that sufficient copper-space effects a wonderful saving of time in your process, and tends to prevent injury to the worts arising through needless delays. Thus, while a first wort is boiling a second should be pumping to another copper, while the first copper will again be at liberty for a third or return wort; such a systematic boiling arrangement, if backed up by superior refrigerating power, enables one to push along with rapidity, and this kind of practical convenience is certainly superior to such a system as arranges but for a single copper being employed for the purpose of heating liquor and boiling off all the "*lengths*." Besides this, coppers are best employed for worts alone, for in using them for liquor heating the constant change of temperature, the powerful tarnishing effect of the water heated, and the deposition of saline matter from it, all combine to injure the metal in no small degree. The worts pass to coppers containing variable amounts of sugar, dextrine, albuminous principles, and, may be, a little starch, and we now put in such a proportion of hops as is deemed necessary, while boiling of the wort is continued for a longer or shorter period. Now we effect much by this simple ebullition. We first of all extract the available constituents of the hop-flower, and this solution, as we shall see, is in great measure effected by the intensity of the heat employed. Secondly, we coagulate by the intensity of the temperature a large quantity of those albuminous matters which, like the white of egg, become insoluble when submitted to a temperature even below our ordinary boiling point; and, Thirdly, we evaporate away a certain quantity of water, which enables us to obtain a little more extract by running longer "*lengths*" than we could do if the steam arising from the boiling wort were not allowed freely to escape.

Now this extraction of the available constituents of the hop-flowers is not so easy a matter to explain as some writers imagine. It has long been known that very considerable ebullition is necessary to effect the chemical disintegration of the extractive matter, *while the actual presence of saccharine* is required to enable much of this matter to remain in solution. Now the available constituents of the hop-flower may be taken as narcotic oil, bitter principle, resin, and tannic acid. The first of these is insoluble in water, and yet seems to aid in the solution of the bitter matter, and it seems to be naturally ordained that boiling for a considerable time should be necessary in order to break up the combination of oil, bitter principle, and resin, when once dissolved, for unless this disintegration is effected the oily compound would again most certainly come out of solution so soon as the wort cooled down. Once break up this combination and your bitter and other useful matters become soluble in the extractive matter of the wort. You see this practically in the case of highly hopped beers when care is not taken to employ nearly the whole of the hops in the first wort; the weaker runnings, when boiled, contain no sufficient quantity of saccharine to effect the perfect solution of hop extract, and although your hop oil and its associates are disintegrated they are not dissolved, and float about in mere semi-solution, causing wort to look dull and unsatisfactory even while boiling hot; and although this may be no great disadvantage, since if carried into your fermenting tuns the matters will either be taken up under the influence of the extractive matter of the richer worts, or by the aid, perhaps, of the spirit so soon as actual attenuation commences; it is far better, in my opinion, to ensure boiled worts passing from the hop-backs in a brilliant condition, than to allow of their doing so opaque in look, through a superabundance of hops being used in a weak wort, which contains *no sufficient amount of extractive matter* to enable hop constituents to enter into perfect solution, so soon as their disintegration is effected by the heat intensity of the long continued boiling process.

The greater bulk of the oil seems to be insoluble, once having performed its useful office, and you can see it floating about in the wort, and more especially existing on the surfaco as a thick pellicle, so soon as this wort begins to cool down, losing thereby much of its solvent power. Thus it is actually necessary to boil the hopped worts some considerable time, not merely simmering, but allowing violent ebullition to take place; and I hope some brewers will see the uselessness of merely steeping their hops in wort, or allowing the boiled worts to pass over them, in place of submitting them to the disintegrative agency of intense heat, and also why there is some disadvantage in placing excess of hops in racked beer. In this latter case you have no proper breaking up of the hop extract, and your solvent agency, the saccharine, has mostly been decomposed, while you have in its place the rosulting alcohol, which is not, after all, such a powerful solvent medium for oily compounds, and you, therefore, havo to wait for the attainment of brilliancy till incipient fermentation takes place in cask, generating some slight amount of ether, which then takes up in perfect solution the matters which seemed to resist the solvent power of the mere alcoholic liquid; you see this in a marked manner in such low attenuated stock beers as are heavily hopped in cask; leave out the hops, and thc bcer soon brightens, but put them in and your product long retains the appearance of a liquid containing oil in a state of semi-solution, and it is only when slow, incipicnt fermentation has taken place that an ethereal compound is produced capable of putting an end to thc cause of partial opacity. I have specified low attenuated beers, since if much extractive matter of a saccharine typo remains in them it is capable of aiding solution, or clse of partially hiding turbidity.

Thus we see that the old idea (French in origin), that to obtain all the boiling cffects, it was only necessary to retain the wort at a fixed temperature of 180° or so, for a certain time, cannot be accepted as correct. It seems to have been imagined that by keeping the wort at such a temperature you effected the coagulation of the albumen, without either caramelizing any of the wort constituents or driving off the volatile oil. True it is, that you would effect coagulation of albuminous matter, but you would hardly bring about the necessary breaking up of the extractive matter of the hop, and you would most probably get as much caramelization as if actual boiling was going on, for as a practical matter, more burning takes place when a wort is left quiescent in copper with fire withdrawn than during the time of actual and fast ebullition, this result, of course, arising from the fact that so long as convection is going on each particle of wort is in rapid motion, thus being less liable to burning effects under the influence of the intense heat of the metallic surface. The retention of the oil, so long as it has failed to effect its useful purpose, is of no utility.

As a whole, I think we may say that boiling is actually necessary, not only for getting rid of a portion of the albuminous matters, but for effecting by direct agency of extreme heat the solution of the hop constituents, and beyond this we may take it that the more prolonged and penetrating the heat is, the better disintegration shall we obtain, and thus far the heat derived from actual fire may be considered superior to that from steam.

The coagulation of albumen is a very simple matter; part is induced by the heat and part by the presence of the tannic acid, and the technical expression, "breaking of the worts," only refers to the length of time necessary for effecting perfect coagulation. The length of time for boiling is easily fixed. If continued too short a time you do not effect the desired disintegration; and if carried on for too lengthy a period, you not only allow of excessive caramelization of saccharine matter, but complete disintegration, not only of the extract of hops, but of the actual flower and leaves, the result being that you find it impossible to obtain a bright wort from the mere pulp to which your hops have been reduced. Practically, some hour and a-half seems capable of effecting all good action; while with weaker worts, which suffer less injury through lengthy ebullition, a length of time, extending to two and a-half or three hours, may with advantage be adopted; but in such a case it is well to boil without hops for quite half the time.

I think this sufficiently explains the chemistry of boiling, and now we will turn for a time to a brief consideration of the cooling process, which, of course, is necessary, in order to reduce the wort to such a temperature as is compatible with healthy and sound vinous fermentation. Boiling hot, the albuminous constituents of the wort have no power of effecting change, but at much lower temperatures they have; so our aim ought to be, first of all to free our cooling space from all impurities, and then to so rapidly reduce the temperature of the wort passing over, that no lactic ferment can get to work. When wort passes from hop-back, it soon loses its brilliant look, and becomes dull and heavy; this result, of course, being due to the fact that the watery medium cannot hold as much matter in solution at the lower temperature as it did when boiling hot. Much of the oil comes out of solution, and a good deal also of what we may call extractive matter of low solubility. Some writers advocate that all these gross matters should be swept into the fermenting tun along with the wort, which, to my mind, is anything but correct, for although they probably do no injury to the wort itself, not being taken into solution again, they tend to contaminate the yeasty matter, and render it unfit for store purposes.

Knowing the powerful agency of these wort contaminations when process is so delayed that wort sinks to, and remains at, a dangerous temperature, means were adopted —not so long ago either—for aiding cooling by some mechanical appliances, and, possessed of them, we are certainly better off than brewers in times gone by, who had to expose their worts for very lengthy periods, and even to go so far as exposing them to the atmosphere on clear nights, trusting for actual radiation aiding the cooling influence of the ordinary evaporation.

If we are not benefited by superior produce, we are enabled with an ordinary plant to brew more frequently and save much time and labour; while in spite of the obvious defects of exposing worts so constantly to metallic influences at dangerous temperatures, this defect is, we may take it, more than counterbalanced by the many advantages obtained. These refrigerators are all based on the same principles, but there are very obvious objections to the employment of some of them, which perhaps it would be unfair to specify by name. It is somewhat of a disadvantage, no doubt, to expose the wort in a *thin film* to metallic and atmospheric influences at the same time; but with such refrigerators the cooling is very rapid, while it is certainly unwise to pass worts through closed pipes difficult of access. For such reasons, being free from such defects of construction, the refrigerators of old-fashioned make are preferable; and besides this, they are of stouter build and will bear a greater liquor pressure, a matter of importance where you have to study economy of cooling, since liquor does more in cooling worts the greater the pressure under which it acts. Personally, I am in favour of partial cooling taking place by means of evaporation on coolers, since I do not hold with passing a boiling hot wort over a refrigerator that in almost a second of time reduces its temperature 150°. I do not, in fact, believe that the constituents of the wort can stand such sudden changes of temperature without being affected by them to a greater or less extent; this, however, is a mere passing idea, which may have no foundation in fact. These machines are all constructed of copper, or copper with a coating of tin; and I need not refer again in detail to the necessity of the brewer seeing that no conjunction of metals be employed in the refrigerator arrangements.

It is equally necessary to avoid any possibility of an electrical current being carried, through the inlet and outlet pipes being in direct connection with the ground, while great attention to exterior cleanliness is advisable, not only on account of the easy solubility of the oxides of the metals used in the construction of ordinary refrigerators, but because much organic matter, difficult of removal, is deposited upon the surface of them, more especially on those that effect very rapid cooling. With reference to this exterior cleansing of metallic surface, nothing is so easy of use as iron filings or fine ashes, the friction of which under the brush is enough to remove all metallic oxide; while if there be a deposit of organic matter, I know of nothing so useful as a strong solution of potash, which is a powerful solvent of albuminous substances.

Refrigerators are in use constructed for the passage of wort through the pipes in place of over them, and in this case even greater care is necessary to prevent accumulation of impurities, for no one unacquainted with the subject would believe the rapidity with which matter is deposited, more especially from the weaker runnings. When out of use such pipes ought to be kept full of potash solution, or if strong enough to stand pressure, steam may be passed through them after each day's use.

The other cooling machines are indirect in their action, or are used in an indirect way. They are employed for the purpose of reducing the temperature of air or liquor, which you then apply for the purpose of effecting reduction of the temperature of the wort. These machines, wonderful in their power, are arranged on the principle that before a substance can evaporate it must absorb heat to enable it to exist as a vapour. I need not go deeper in theory than to say that advantage of this fact is taken in all cooling machines. A very volatile liquid is taken, ether or ammonia for instance, and a vacuum is created by means of an air pump. The arrangement of this part of the apparatus is costly and difficult. The ether store, being in connection with this vacuum, the volatile liquid is bound to evaporate, and in so doing absorbs heat from the warm air or liquid that you wish to cool and which you bring into contact with it by a suitable arrangement of pipes. No loss of ether takes place if the apparatus is tight, and these machines are of constant utility where water supply is scarce, or exists at such a temperature as renders it useless for cooling purposes. Thus we have all the necessary means at our command for cooling our worts down to a point suitable for vinous fermentation, according to our knowledge and ideas. These metallic cooling surfaces are no doubt a disadvantage, but we certainly select the lesser evil in adopting a ready means of preventing unduo action of any wort constituent, or atmospheric contamination, by reducing our wort regularly and quickly to such a temperature as is consistent with the addition of yeast for the induction of sound and healthy fermentation. The consideration of what this temperature ought to be belongs to the next Essay; suffice it to say here that 58° is about the average temperature at which the wort leaves the refrigerators. If theoretical considerations were taken more into account, I imagine we should attempt to cool our worts naturally the first 100° from the boiling point, leaving our cooling machines to effect the further reduction necessary as speedily as possible.

## ESSAY IX.

### Vinous Fermentation.

We now come to the consideration of a part of our process that will not bear any hasty explanation, and I therefore propose going moro into detail than I have made the practice of doing in former essays.

When our worts are gathered together in our fermenting tuns at suitable temperatures, and with the addition of requisite quantities of ferment or yeast, we expect vinous fermentation to follow; we depend upon the sugar and dextrine being split up under the influence of our ferment into alcohol, carbonic acid, and other minor products, such as succinic acid and glycerine, which I will not now refer to at greater length, and we hope for the elimination of the greater part of the nitrogenous impurities, as yeast.

Let us examine, before we go more into detail, the different theories which account for the main feature of vinous fermentation, viz., the change of sugar into spirit.

I believe I may say that two rival theories are held even at the present day, for although most chemists no doubt accept the more modern theory as correct, there are many who feel loth to give up the older one, which certainly serves to explain to us, in a simple and beautiful manner, every change that takes place in the complex wort, from the time that the components of this fluid are first formed, to the period when each has been resolved into some fresh combination of elements. The older theory, that of Liebig, the great German chemist, is that all nitrogenous substances—themselves very prone to undergo change by oxidation—have the power, while so altering, of inducing other bodies in contact with them to enter into a like state of change, and thus Liebig's theory of fermentation is that of a physico-chemical action. Now a few words will suffice to explain how wonderfully this simple theory bears out all the manifestations a brewer has to deal with; we extract from our malt a large quantity of nitrogenous matter as albumen, and Liebig's idea was that according to the state in which this substance happened to exist, so would its inducing action vary at different stages of the process. Existing in your original grain in presence of moisture and warmth it induces change of small quantities of sugar into lactic acid; during malting a portion becomes modified into diastase—as it is technically called—possessing under certain circumstances marked power of inducing change of starch into dextrine and sugar, while, if delay or error of judgment occurs in the primary stages of brewing, the remaining unaltered and more simple albumen exerts its power of increasing the normal acidity of your worts.

During the boiling process the diastase is destroyed, and once more you have sugar in presence of simple nitrogenous matter; this matter, ever prone to change, absorbs oxygen from the atmosphere, becomes thereby a ferment (according to Liebig), and induces other matters in contact with it to assume a simpler form; induces, in fact, the decomposition of sugar into spirit and carbonic acid gas. Once existing as a ferment it has power of decomposing water, and so the necessary supply of oxygen, after fermentatiou commences, is of necessity derived from the water of the wort, the atmosphere being cut off by the evolved carbonic acid. We may go a step further than this, and say, that for each pound of sugar decomposed, a fixed quantity of albumen is eliminated as yeast, so long as process is gradual and correct in all its primary stages.

Let us progress and see what takes place, according to Liebig, after the desired attenuation has been arrived at when the beer exists in casks containing, we will suppose, certain quantities of undecomposed sugar and dextrine, aud a quantity of oxidized or unoxidized albuminous matter. This latter existing as a ferment, or becoming one through absorption of oxygen, does not allow of matters remaining quiescent for any length of time; excess of dextrine checks, but does not prevent the incipient action which commences, and now comes the proof of your process so far as its theoretical correctness is concerned.

I have said that for each particle of sugar or dextrine destroyed, a corresponding quantity of albumen is eliminated, and this will now be seen as an important factor. The albumen in solution exerts its influence, sugar is decomposed, and yeasty matter perishes, and so long as the quantity of sugar present is sufficient to last out, as you may term it, the whole albuminous force, your product will be sound and good, if other circumstances are correct; but if excess of nitrogenous matter be present, this matter continues to oxidize, and acts thereby as a ferment, and not finding sugar to work upon, works upon the alcohol existing in its place, and induces the formation of acetic acid, and thus you see that a *balance* of *power*, as you may term it, ought to exist between sugar, dextrine, and albuminous matter; for if excess of the latter be present in a finished beer, no skill can prevent it inducing acetous action after the decomposition of the sugar; when once it becomes a ferment through the absorption of oxygen.

This, then, is a rough outline of Liebig's theory, and if I have now and then overstepped the limits of actual knowledge, I have only done so for the purpose of placing matters in a clearer light, so that those not possessed of scientific insight, may yet understand the secret of successful work.

Now the more modern theory is that of Pasteur, and although its basis is a direct contradiction of Liebig's, in so much as he denies that fermentation is the result of simple physico-chemical action, I think I shall be able to link the two theories together in such a manner that in practice we shall be able to pay attention to the teachings of both without working thereby in a faulty manner. Pasteur, so far as I with my limited knowledge know, does not combat the idea that lactic acid is formed from sugar, sugar from starch, and acetic acid from alcohol, through the agency of albumen in different stages of change. He does not deny this since we have physical and chemical agencies of different types that will effect similar changes; but Pasteur does deny that the mere oxidation of albumen confers upon it the power of inducing the change of sugar into spirit, for we know of no simple chemical or physical agent which has such power. He asserts with much force and clearness that vitality itself is concerned in this change, that actual germs existing in the atmosphere find in wort food most suitable to their wants, and living and reproducing themselves on this sugar, dextrine, cellulose, and albumen, in presence of a supply of oxygen, they give off the carbonic acid gas and spirit which we find as a result of the fermentative action. This low type of vitality imitates in a perfect manner more important agencies: a supply of oxygen is required, as also a store of suitablo food, and then within limits of temperature we obtain distinct and definite results. Cellulose and albumen, no doubt, would be built up into the organism, while sugar and dextrine would undergo decomposition in that system, and then be expelled as new products. This necessity of a supply of oxygen to the germ to enable it to sustain vitality, and of albumen to enable it to grow and reproduce itself, affords, to my mind, a ready link between tho two theories, which is confirmed by the connection that exists after primary fermentation is finished. In this case, when beer is in cask, we saw how it was necessary to avoid excess of albumen according to Liebig's theory, while, with the more modern idea, so long as you avoid excess of albumen, no reproduction of germs can take place, and, consequently, no prolonged action can ensue; the germs, in fact, perish, just tho same as man would if the necessary supply of food for keeping up animal heat and compensating for bodily waste was cut off. I have thought much on this subject, and in my own mind there is no reason why you should not be able to explain the different actions in vinous fermentation by either theory, excepting, perhaps, the one powerful argument employed by others against the correctness of Liebig's, that although chemical and physical means are at hand for imitating lactic acid, sugar, and acetic acid formation, no such means have so far been discovered to imitate the so-called inductive action of albumen, when in a certain condition of change, and under certain conditions of temperature, and that in the absence of this confirmatory chemical or physical change, one must of necessity doubt whether mere albumen actually possesses powers previously ascribed only to vitality. Thus by both theories albumen is a substance of importance—it is the agent of change according to one idea, the support of the active agent in the other. According to one theory we should not expose our worts too long for fear of excessive absorption of oxygen, while, according to the other, excessive exposure allows of such absorption of germs that unhealthy action is induced under the influence of existing temperature. Then, again, limit of heat is another important feature in both theories; according to Liebig's idea, alcohol oxidizes to acetic acid most readily after a limit of 70° is reached, while Pasteur's would explain that above that limit healthy germs became unhealthy, and act as acetic ferments in place of vinous. We shall see more of this connection as we progress with the subject under consideration, so I will now in a theoretical manner explain the reason why the Bavarian system of fermentation is such a success, and why at Burton results are so superior.

Now, according to Liebig, there is a point of temperature below which no oxidation of alcohol can take place, but not so low as to prevent oxidation of albumen. Tho Bavarian brewers took this idea up, and in practice the worts are fermented in shallow tanks, freely exposed to the air, at such a temperature that no danger of spirit oxidation need be apprehended. The albumen of tho wort oxidizes, acts as ferment and induces decomposition of sugar; but since the wort is freely exposed, obtains its supply of oxygen from the atmosphere in placo of from the water of the wort; so, by thcory, no matter what proportion of albumen may exist in the wort originally, you can rid your product of it during such a system of fermentation, by freely exposing it to the air at such a temperature as does not allow of formation of acid from spirit. Then, again, at Burton, thcy have a natural water, containing such an cxcess of a certain lime salt that no superabundant quantity of albumen can bo dissolved, and as a result their *balance* of power is never out of proportion, and it is safe to rack beers at much higher gravities than is possible where circumstances aro so different. Thus, in my original essay on WATER, I was careful to point out what an advantage arises when you are enabled to employ a water which, through its saline constituents, exercises a controlling influence on the quantity of albumen derived from malt; while, in my second paper, I explained how necessary it was to select a cereal for brewers' use, not having too large a percentago of albuminous principles. No matter which theory of fermentation is adopted, we must regard albumen, oxygen, and temperature, as the most important factors; and when one thinks how easy this albumen becomes the agent of change, or by its presence becomes, or rather acts, as the necessary food for Pasteur's germs, no reasonable doubt can exist, that unless we regulate its quantity in wort with care and attention by such knowledge as I am trying to unfold, unless, in fact, we have a perfect *balance of power* between the nitrogenous matter and the tenary compounds in contact with it, beers cannot fail to acidify before the termination of the incipient action which takes place, so soon as they are placed in cask and exposed to atmospheric fluctuations of temperature.

In this brief outline of theory I have mentioned the Burton and Bavarian systems as examples of my meaning, and think that if you have no natural or artificial means of preventing excessive solution of albumen, *you ought, either to purify your worts by the use of specified proportions of pure saccharines, or fall back upon such a system of fermentation as will enable you to eliminate in a natural manner that excess of hurtful matter which has been extracted in the primary stage of your process.* I have said that, according to Liebig's theory, a fixed amount of albumen becomes oxidized for every particle of sugar decomposed; this proportion varying according to variation in such controlling influences as temperature or pressure; while, according to Pasteur's, we must take it, that a certain amount of germ power exerted, necessitates also definite results, not only in regard to the decomposition of sugar, but also in respect to the other characteristic features of vinous fermentation, and in saying this we must believe that a slow and gradual action, a perfect imitation of nature, allows of more complete chemical results than when a violent rearrangement of elements is allowed, or, in other words, it is my firm opinion that by means of a slow and gradual yet regular destruction of sugar at a low temperature, you are enabled to eliminate much more worthless matter than would otherwise be the case; and just as dextrine necessitates more breaking down power to be brought to bear on it than sugar, so will more albumen be driven out of solution during the attenuation of a dextrine beer than would be the case during the chemical modification of a beer excessively saccharine. It is not, however, all brewers who can with safety take worts highly charged with dextrine in place of sugar, since this dextrine is apt to resist too strenuously the decomposing power of germ or yeast, and it is only those who have to deal with large bulks, or who employ some form of mechanical motion for aiding the fermentative action, that can experience with any degree of success the benefits of employing a wort constituted as I have described.

Knowing that the germ or the simple albumen exerts different changes in saccharine solutions, according to the state that the ferments themselves may be in at the time when used, that these changes are regulated in no small degree by temperature, it is evident that great care is necessary in arranging that the right kind of ferment shall alone be employed; and, secondly, in so regulating the temperature that the primary healthy action shall not degenerate into one of different type. The wort constituents, first of all, must be so arranged that while preventing any violent decomposition through excess of sugar being present, you avoid at the same time the danger of excessive dextrine percentage interfering, as this excess would, with the easy conduct of the process. Your temperatures must then be based on the principle that, while we are unable with the English climate to imitate the perfection of the Bavarian theory, we ought, nevertheless, to keep to its teachings as nearly as possible, and, as a matter of no small importance, no delay in commencement of vinous fermentation ought to occur so soon as worts are gathered in the tuns.

All ferments tend to reproduce their characteristic indications—a vinous ferment in a pure wort containing the necessary food for reproduction, giving a fresh supply of vinous ferment, and so it is with the other types; an acetous ferment would of a surety reproduce itself, and so would it be with a ferment of the mucous type, and thus the greatest care is necessary to avoid the use of any agent of fermentation that is not of perfect purity as indicated by its soundness, or of perfect characteristic formation, as proved by microscopic examination. The most striking system is to use as small a quantity of ferment as possible, and rely upon the freshly oxidized natural albuminous matter obtained from the malt; this is somewhat important as we shall see when dealing with practical information, so let me put it before you a little more plainly. With a saccharine wort and excess of yeast you depend upon your added ferment effecting the desired action; the attenuation is so quick that little oxidized albumen seems to be eliminated until after the beer is cleansed, but with a slow fermentation with deficiency of added yeast the case is different; slow fermentations are generally caused (so long as ferment is vigorous and healthy) by excess of dextrine being present in place of sugar, or by extreme lowness of temperature, the attenuation is very gradual, and the elimination of albumen is proportional and regular. This kind of fermentation, where temperature cannot be kept as in the Bavarian system at a safe limit, necessitates the employment of mechanical motion, in order to keep this freshly eliminated albumen in contact with the dextrine and sugar. With this slow and gradual attenuation, brought about by the employment, first of all, of a dextrine wort; secondly, a deficiency of ferment; thirdly, mechanical motion, to enable you to prevent fermentation becoming actually sluggish; and, fourthly, as low a temperature as is consistent with regularity of process, a brewer has the means of eliminating in a perfect manner the excess of nitrogenous matter extracted from malt either through the employment of a grain in the first instance excessively rich in such matter, or the use of a very soft water for the purpose of extraction; and whether we consider that oxidized albumen is the active agent of change, or only the necessary food for a vital germ, we find no difference in results: albumen is eliminated in the insoluble form and your beer is rid of the direct or indirect agent of future deterioration. Thus, in my explanation of theory, I have tried to link the rival ideas so as to cause no confusion in the minds of those who are only anxious to learn the mere outlines of theoretical knowledge, and, speaking from experience, I do not see one single part of the vinous or acetous change that cannot be as simply explained in a theoretical manner by the teaching of Pasteur, as by that of Liebig, or *vice versa*. Let us see if we can trace some of this knowledge by glancing for a few moments at practical rules.

We are all aware that under the influence of ferment, whether it be a germ or mere albuminous matter in a state of change, our wort commences to attenuate, becomes thinner in fact, through the conversion of part of the solid constituents into products of less specific gravity, that is through the conversion of sugar and dextrine into alcohol and carbonic acid, and more than this, through the elimination of much albuminous matter as yeast, which, supported in great measure by the evolved carbonic acid, rises to the surface of our fermenting and attenuating wort. Now, as a result of this wonderful and complex chemical action, much heat is generated, and since the success of a vinous fermentation depends in part upon the question of the temperature at which it has been conducted, it becomes a matter of importance to so regulate its rise and fall, that while sufficient for successful results, it is not so elevated as to allow of any undue alteration in the wished for products. Thus it is of importance to so regulate the proportion of constituents in worts that healthy action shall take place under the influence of our yeast, and then to so regulate the fermentative process that no excessive rise of temperature occurs; while bearing in mind that before you allow the decomposition of the spirit-yielding constituents to cease, a certain balance shall be brought about between the proportion of sugar and crude ferment left present in the beer. With the English climate-temperature, and its atmosphere charged with impurities peculiar to that temperature, it is not wise to allow worts charged with unstable constituents to remain quiescent for any lengthy period, and since a moderate temperature is necessary to the early commencement of fermentation, it is seldom that worts in English breweries are gathered at a lower temperature than 57°. To prevent the external heat influences, the rise of temperature is regulated by means of attemperators, suitably fixed; but since this checking of the natural rise of heat has a deteriorating effect upon some descriptions of ferment, brewers have frequently to put up with the lesser of two evils, and in order to obtain a complete decomposition of sugar and elimination of nitrogenous impurities, to allow temperature to advance beyond the theoretical limits of safety.

The vigour of vinous change depends in great measure on the proportion of constituents in the wort to which ferment is added. If rich in sugar, decomposition is very rapid, and difficulty is experienced in restraining the violent action and the consequent rise of temperature; but in this case, you may safely restrain the heat more than is possible when your wort is surcharged with dextrine, which is not so prone to undergo fermentative change. Bulk, again, has much to do with the vigour of vinous action, small quantities being so easily affected by external cooling influences, that in small plants, where cooling of the mash induces excessive dextrine extraction, and where small bulk in the fermenting tun allows of but slight rise of temperature, it is difficult in the colder months to get vigorous decomposition, and, as a result, your worts are apt to taste mawkish, yeast bitten, and frequently exhibit the appearance of ropiness. Now this languor of action may frequently be overcome by increasing the proportion of sugar in your worts, either by altering the mash system, or by actually adding *saccharine* to the copper, or in a state of pure solution to the fermenting wort.

We next come to the point as to what quantity of ferment or yeast it is necessary to use in order to induce healthy action. In the first place, I need hardly say that store yeast should be of stability: that is, it should be taken from a wort when near the limit of final attenuation, as very much depends on this point, for in fast fermentations especially, much of the first yeasty matter thrown off, even when attenuation has well advanced, is of no service as a healthy and vigorous yeast, is not capable of inducing well sustained decomposition in worts to which it is added, is not capable of effecting perfect blending of resulting principles, and certainly has no tendency to aid by its action the early spontaneous clarification of the finished beer. So many governing factors exist, as to the quantity requisite, that it is difficult to lay down any fixed rule; but we must bear in mind that all ferments tend to reproduce similar results to those apparent in their own formation, and that the use of a small quantity of yeast is only compatible with a highly saccharine wort and unchecked temperature, or what allows of these two conditions being neglected, the employment of some mechanical motion system of fermentation. Thus some brewers employ but half a pound to the barrel, others as much as three or four; but we may lay it down as a rule that those who use the smaller quantity, either submit to its action the most suitable food, as sugar, allow a rapid advance of temperature, or adopt some method of agitation.

Let us next consider what our limit of attenuation should be. Now on this point wo have a vast number of controlling influences, such as character of brewing water, constitution of the grain employed, system of mash, requirements of trade, &c., and these are considerations which cannot be overlooked.

We have seen that the idea of fermentation is, in the first place, to generate an intoxicating principle in a saccharine wort by means of the induced decomposition of sugar; now, a secondary, and yet highly important object is to eliminate from the wort all undue excess of principles, the presence of which is not consistent with lengthy soundness of the finished beer. It is my firm opinion, as before insisted on, that just as in a *slow and gradual decomposition of sugar* you get a certain fixed quantity of heat set free, so do you as a result of that decomposition and consequent rise of temperaturo, eliminate one certain and directly proportional quantity of albumen. This state of affairs holds good simply so long as the action is natural and gradual; once let it get violent and beyond control and you fail to see this proportional elimination that I am speaking of. Now the limit of our required attenuation depends upon the character of brewing water, grain, and mash system employed to this extent, that if as a result we obtain worts containing excessive quantities of albuminous impurities, we must carry our attenuation sufficiently far to allow of the elimination of the superabundance; while, on the other hand, if the water employed is naturally consistent with pure worts, or if we employ chemicals or saccharines to practically lessen the percentage of nitrogenous principles present, our attenuation need not be carried so far in order to arrive at the proper balance of power between the spirit yielding constituents and their agent of change. And, again, we must remember that if our beers are for export purposes, it is of the utmost necessity to arrive at perfect elimination of hurtful matters; while, if for present use and early condition in cask, it is not only usual, but correct, to leave a larger proportion of unattenuated and uneliminated matter present. Thus, theoretically speaking, we must carry our attenuation to such a point as is consistent with perfect *balance of power*, subject, in practice, to the controlling influences of trade requirements.

Public taste, for instance, stipulates for palate fulness as a first characteristic of certain beers; but brewers are not all ablo to arrange for a mash to give thom a large proportion of dextrine, and, consequently, in small breweries where you are always suffering from the external cooling influences on small bulks, and where you have not the necessary machinery or appliances for aiding your ordinary ferment in its decomposing action upon the wort constituents, you must give up the idea of having what I will call a dextrine wort, and fall back upon sugar and albuminous principles combined for the purpose of affording the basis of palate fulness; in other words, you must leave much more matter unattenuated than you would have to do if dextrine in excess had been originally present. This, in most cases, is a great disadvantage, for we are not all so fortunate as the Burton brewers, who can safely leave much matter unattenuated, since they are aware that, thanks to the saline contents of their brewing water, they extract no excess of hurtful principles from their malt, and that before their very moderate attenuation limit has been reached, the larger proportion of it has been removed. From all this we may learn, that if beers are for stock purposes, the attenuation must of necessity be excessive, unless the brewing water or system of brewing performs naturally a portion of that elimination work that otherwise it is the duty of your attenuation to effect; while, if a full tasted product is required, you must be guided by circumstances in deciding whether the fulness on palate shall be the result of having present a small proportion of dextrine undecomposed, or large portion of unaltered sugar. The former you dare not have in excess in the primary worts, unless you have means for effecting its decomposition in your fermenting tuns; while with the latter present, as it would needs be, in excess in your finished beer, to give apparent palate fulness you would, with an ordinary water and absence of chemical knowledge, leave far too much albuminous impurity uneliminated from your produce. With an ordinary wort containing, as we will suppose it does, sugar and dextrine in the proportion of two to one, combined with excess of albuminous matter, an attenuation to one fourth of original gravity may suffice for ordinary running beers, but such moderate attenuation is not compatible with lengthy soundness of product, unless the primary worts are of comparative purity and free from excess of ferment basis. Thus, to obtain similar results, we must adopt different systems, and not run away with the idea that because certain heats, gravities, before and after fermentation, answer in one district or brewery, that they will, as a natural consequence, equally answer in another. Nothing, indeed, can be more remote from the facts of the case, and it is in the consideration of such matters that we find the untold advantages of theoretical knowledge, for it is by the aid of theory that we can work out the proper system for a certain district, more especially by bearing in mind the influences of hard and soft water, the character of malts, and the requirements of different tastes. Finally, let me repeat, that to eliminate excessive quantities of albumen you want large proportions of dextrine present as a spirit-forming principle, since a larger proportion of albumen will be removed during the breaking up of a certain quantity of dextrine, than as a necessary consequence of sugar destruction, while in reference to this we have seen how having excess of dextrine present necessitates the adoption of some system of rousing for bringing about its perfect decomposition under the direct influence of the ferment, and that the advantages of such a system are very marked; you are enabled, in fact, to use a small quantity of yeast with low temperature of action, and yet as a result you have gradual and yet perfectly regular attenuation, while excess of albumen is as a consequence eliminated and thrown to the surface as yeast, your wort ferments without exposure to the atmosphere under a greater pressure, you retain thereby much gas in semi-solution, and in place of racking beers at one third of original gravity, in order to retain palate fulness, you are enabled to attenuate even as far as one seventh without losing the characteristic of original strength that the direct influences of a slow and gradual change afford. Thus, practically, as well as theoretically, fermentation is a most complex subject, very much depending on its successful issue, while if a correct system has been adopted, you can tone down in great measure, if not entirely annul, many minor defects of a brewing water or of a malt.

It was my wish to say a few words upon the practical subject of head changes, the beautiful appearances that our first frothy heads assume during the primary stages of vinous fermentation. The presence of these changes may, to a certain extent, be the index of successful work, but their absence by no means proves the reverse, but I must leave the consideration of this part of the subject to some future time, and for a few moments again devote myself to more practical information.

Great attention must be paid to absolute cleanliness of the fermenting vessels, for it is wonderful how readily beer takes up different tastes and smells, during the vinous change, and beyond this do not allow of any formation of surface acidity on the materials of which your tuns are constructed.

Many brewers, no doubt, experience great difficulty in preventing this formation, and in such cases I know of no better plan than to keep surfaces coated with a film of monosulphite of lime. There is an objection to the use of ordinary lime, but this salt of lime has striking advantages, has no unpleasant smell, consists of a powerful neutralizing agent in combination with a weak acid easily displaced by those ordinarily existing in beer, while it tends to prevent formation of further acidity through the affinity of its sulphurous acid for oxygen.

I would adviso all brewers to give up those *hissing* and violent fermentations one sees so often—some of them being due to the presence of excessive quantities of sugar, others to the employment of unhealthy ferment—and in their place adopt some slow yet regular action at a low temperature, in order to arrive at that proportion of constituents which is alone consistent with soundness of beer. Be careful to allow no sinking in of denso yeasty matter, especially at a high temperature, and if attenuation becomes sluggish, flour should be added in order to generate a supply of gas or as the natural food of organic germs, while rousing must be resorted to in order to stimulate the drooping energy of the yeast. So soon as fermentation has arrived at the limit decided upon, from a due consideration of the chemical and theoretical principles, the next effort is to free the beer from insoluble floating impurities, while the temperature must be gradually roduced, since it is a general rule that so soon as one chango ceases another of a different type will spring into life, unless you so alter the conditions of temperature as to render further change impossible. This reduction of temperature, however, must not be too rapid, or spontaneous clarification will be hindered.

No fixed rules as to temperature, quantity of store required, or attenuation, can be given; in each case we must be guided by surrounding circumstances, but I cannot too often impress upon all that one of the main features is to eliminate all excess of that agent which has the direct or indirect power of either inducing healthy decomposition of the sugar and dextrine, or when that has gone the oxidation of the spirit formed. If excess be left in solution, you soon have formation of acidity, and although we have now some knowledge of chemical agents, such as calcic monosulphite, calcic bisulphite, and ordinary sulphurous acid, which prevent the formation of ferment in the finished beer (for you will remember that before albumen becomes an active agent of change it must of necessity absorb oxygen, and Pasteur's germs are alike situate, and although some advantage may be derived from their skilful use, on account of their marked affinity for oxygen), it is far better to arrive at correct results by a well-considered and carefully carried out system of brewing, than to correct mistakes by the employment of powerful chemical agents, unless you have an intimate knowledge of their probable effects.

The unattenuated matter left in beer consists, in great measure, of dextrine, sugar, and a substance called caramel, which is derived from the saccharine matter, and is incapable of undergoing change, while with this saccharine and extractive matter you have albumen combined, which brings about incipient change in cask, in vigour and result depending on the final point of attenuation you have decided upon. This slow decomposition affords a supply of gas to give your beers condition, and it is during this gradual change at a low store-room temperature that we obtain peculiar products of after fermentation which tend so to improve the distinctive properties of finished beers.

Each step of the process should be carefully noted. Naturally, the rise of temperature and fall of gravity should be in perfect accordance, but if artificial means of restraining temperature are employed, exert this influence with care, in order that attenuation may continue regular.

I have no greater space at my command for entering into a more lengthy description of this most interesting subject; nevertheless I have made clear, I trust, some of the considerations which ought to guide us, and although it may not concern practical men, perhaps, to know all the details of the different theories respecting vinous fermentation, it is certainly most essential that all who have to conduct brewing operations should have a complete knowledge of the influence of albumen when existing in a finished beer, and it has been my great object in these papers to explain that influence, while giving just sufficient practical information to enable brewers to follow out the teachings of theory in their daily practice. The remaining portion of practical information, in reference to vinous fermentation, will be given in my next essay, which in reality is simply a continuation of the subject matter of my present paper.

## ESSAY X.

### Cleansing and Yeast Storage.

THE point at which we start to cleanse the beer, that is to free it from suspended impurities either by skimming them off, or else by allowing them to be naturally thrown out from unions, pontoes, or the old-fashioned working casks, depends not only on the kind or quality of beer we are dealing with, but also upon the kind of fermentation we are conducting.

As a general rule you may take it that if during vinous fermentation you have much yeasty matter eliminated, and thrown to the surface as yeast during the early stages of the attenuation, the decomposition of saccharine matter will get slowor and slower as you progress, and will cease altogether when you commence to skim off the floating head and allow natural cooling down to take place. On the other hand, in many breweries where the worts are, from the kind of malt employed or the system in practice, rich in sugar, a fast fermentation is naturally the result, and great difficulty is experienced in checking the attenuation in the final stage; and this is not strange when we consider how little matter is eliminated during the fast and fiery decomposition that has been taking place, and that it is only when temperature is lowered and action thereby checked that the nitrogenous matter becomes oxidized, insoluble, and eliminated as yeast, while it is hardly possiblo to conceive this oxidation and elimination progressing without corresponding docomposition of saccharine matter. Thus in breweries where the constitution of the wort, or the system of fermentation, allows of a gradual decomposition of extractive matter at a low temperature, the necessary oxidation and elimination of albumen proceeds in the primary stages, and as a result, we do not find it necessary to start skimming or otherwise cleansing our beer till we nearly reach the limit of final attenuation; while, as an extreme example with rousing fermentations, where the attenuation seems to depend in great measure upon the mechanical motion communicated to the fluid, all decomposition seems to cease so soon as this inciting cause is put an end to. Thus the necessity arises for some brewers to start the cleansing process at a gravity of 10 in order to rack at 5, and yet in this case they often find it difficult to restrain the attenuation progressing to a much lower limit; while others actually start the cleansing process at the racking gravity, since they are sure that but slight attenuation will result during this process, and that the lowering of temperature will in great measure compensate for it.

During this process of attenuation a great loss in bulk occurs, amounting to as much as 7 per cent. in the best managed breweries, and surely it will not be difficult to account for this loss in quantity, when we consider what attenuation means. Our sugar and dextrine are decomposed into a most volatile liquid of great tenuity, and a gas of overpowering smell, while a large proportion of the albuminous matter becomes oxidized and thrown out of solution as yeast.

Take for instance the case of a 23 lb. beer attenuated to 4. The apparent saccharometer indication after fermentation is 4 lbs. per barrel, but if you drive off the spirit which by its presence and low specific gravity hides a portion of the real saccharometer weight, you will find, I think, that the real gravity is, about 7—that is, 16 lbs. of solid matter per barrel, as indicated by the saccharometer, have been decomposed and eliminated during the progress of our vinous change. This 16 lbs. of comparative weight indicates some 42·6 lbs. of real matter, which in bulk would practically, I think, be represented by 2·6 gallons, which is theoretically a loss of some 7 per cent., to which our practical results very closely approximate. Thus we see another reason why the mere elimination of yeasty matter causes decrease in gravity; so long as it is in solution it affects the saccharometer—not so, when it is eliminated, and thus when beers are in tanks in a perfectly quiescent state at a low temperature, you will still find a slight daily decrease in gravity on account of the beer becoming brighter and brighter through the mere elimination of matter previously held in semi or complete solution.

I do not think sufficient attention has been paid to the question of this decrease in bulk during fermentation Brewers are apt to regard it as a positive loss, but from a theoretical point of view it is rather the index of successful action; and if the elimination of nitrogenous matter is considered advantageous, this decrease in bulk, indicating, as it does, partially the decomposition of sugar and partially the elimination of hurtful matter, means actual gain in quality of produce. In the case of the beer I have placed before you as an example, for every 100 barrels in fermenting tun, nearly two tons of solid matter would have vanished during the progress of fermentation, some in the form of yeast thrown out, and some in the form of spirit and gas retained in the liquid, while with beers of very high original gravity carried to a low attenuation point, the loss in bulk from these chemical changes is much more astonishing and marked.

In smaller breweries, where no modern appliances exist for the prevention of what we will call unnecessary losses, this 7 per cent. increases, till with some systems I imagine a percentage of 15 or 16 would hardly represent the decreased bulk, and this is one of the many reasons why small brewers find it so difficult to compete with the larger houses.

The great aim during the cleansing process is to rid your beer of suspended impurities with as much celerity as possible, while at the same time you reduce the temperature to what we will call safe limits. Now I suppose we may say that with few exceptions the great bulk of English brewed beer attains a temperature of 70° before the cleansing point is reached; and while I am not so strictly theoretical in my views as to regard this as a fatal temperature so long as vinous change is in full swing, I must say it is a dangerous temperature to allow beer to remain at, when vinous change is falling off and ceasing altogether.

We have seen that there is a point of temperature at which sugar can be decomposed into spirit and gas, albuminous impurity oxidized and eliminated, and yet at which no oxidation of alcohol can result. This is the temperature at which Bavarian brewers conduct their fermentations, and the nearer we can approach to the general idea of that system, the better results we shall attain. As we allow higher and higher temperatures to prevail, we soon arrive at a point when vinous formation of alcohol and acetous oxidation of that spirit can proceed together, and to this extent a temperature of 70° is more dangerous than one of 60°, the more especially when the vinous change is naturally falling off in vigour. Thus the practical plan, based on theoretical teaching, is to start reducing the temperature of the fluid, *to bring the heat within safe limits, and diminish at the same time the affinity of fluid for suspended solid matter, at the very time that the cleansing process is commenced*, and all we wish to avoid in this case is any sudden reduction of temperature.

Fermentation, we must remember, is a complex chemical action, and during its progress we must avoid any sudden alteration in circumstances, for as regards temperature there is no doubt that sudden change does affect in marked manner the progressing rearrangement of particles, and as a practical fact we must bear in mind that sudden reduction of temperature does interfere with spontaneous clarification, through much matter being brought into a state of semi-solution that would otherwise have remained dissolved or have been completely eliminated if a more gradual fall of heat had been arranged for.

It is for this reason that slate is found to be unsuitable as a material used in the construction of cleansing vessels, although most useful for other purposes in a brewery, and why, in speaking of refrigerators, I gave it as my opinion that such intense rapidity of cooling could not be considered as altogether an advantage.

The skimming system of cleansing is theoretically and practically the best, unnecessary losses are prevented, the beers remain more or less under complete control, and you are enabled to free them with great rapidity from suspended impurities. In practice, the saving of time, labour, space, and hot liquor for cleansing purposes, without taking into consideration the disadvantage of increase in temperature of brewery buildings through the employment of this hot liquor, in the purifying of a multitude of small cleansing vessels, are points worthy of consideration; but where the plant is differently arranged it is perfectly possible to adopt some system of fermentation, which is adapted to the use of unions or pontoes, and yet arrive at a regular and satisfactory result. Tho defect of these small cleansing vessels is, that when in use with the ordinary fast fermentation systems, you lose to a certain extent control over the fermentative action, and beyond this your beer picks up a variety of flavours from the contact during fermentation with the constructing material of a large number of small casks; and consequently, in order to employ such vessels with advantage, a slow system of fermentation is preferable, while to attain this slow system we must arrange our mashing system in conformity with the rules that I have laid down.

We must not overlook the question of *depth*, for this has much to do with speedy clarification, and we may sum up the result in the expression that tho greater the depth of fluid, the longer the timo necessary for spontanoous brightening. It is wonderful to see the difference in time necessary for the clarification of a beer when contained in a fermenting round some ten or eleven feet deep, and when started to a tank of shallow dimensions; and from a consideration of this fact we may see why in pontoes, which are as a rule six or seven feet deep, some considerable time elapses before the contents will brighten spontaneously, and also why brewers with a skimming system of cleansing and the employment of shallow tanks are enabled to turn out finished beers, not only in a remarkably short timc, but more than this in very superior condition.

Of course in the use of shallow settling tanks you have greater exposuro, which might be considered a disadvantage, as allowing of atmospheric oxidation effects and an excessive escape of gas with consequent flatness of produce, but in great measure all results of a disadvantageous nature may be avoided by taking your beer to tanks while there is yet sufficient eliminated matter and gas present to quickly form a protecting cover of yeast upon the surface. Nevertheless you cannot pay too much attention to the necessity of preventing undue exposure of finished beers to atmospheric influences, either direct or indirect, through allowing the formation of froth upon the surface when starting beers from fermenting or cleansing vessels to tanks or casks, and this is one reason why we should arrange, if possible, for racking cleansing vessels—such as unions or pontoes—direct, in place of running them to intermediate racking tanks. Although we have to prevent all undue exposure of the cleansed beer to atmospheric influences, we must at the same time skim off the yeasty matter thrown up at frequent intervals, and in the case of cleansing casks, arrange for their being kept quite full to allow of natural expulsion of yeasty matter, while on the supply of evolved gas falling off, it is well to remove swan-necks from union casks and work them till fit for racking in the same manner as ordinary cleansing vessels. Speaking of "unions" leads me to mention a slight practical indication, which may prove of service to some of my readers, by which we know when such casks have a proper supply of beer, that is, when they are quite full. The slight indication is that when full, and with a steady supply of beer from the supply box, a single drop of liquid will hang from each head of froth or yeast as it issues and drops from the metallic outlet.

This necessity for frequent skimming, and also for keeping cleansing vessels full to bung, hinges upon the fact that if yeasty matter be not removed, it gradually gets more and more dense, while your evolved gas is getting less and less in quantity, and consequently, less able to support it, for we must remember that these impure matters are not naturally specifically lighter than water, but simply float so long as they are blown out and supported by the gas constantly rising to the surface. When the supply falls off and your heads get dense and specifically heavier than the fluid on which they float, partial sinking in takes place, allowing of minute solution, and consequently a very objectionable yeast-bitten flavour. Thus, in striving to prevent undue exposure of beer, we must still skim as frequently, without actually clearing off the entire head, as is requisite to prevent any danger of yeasty matter sinking in, and then in the final stage of the skimming process it is well to leave but a thin film upon the surface of the quiescent beer, while it is worthy of note that if this film is intact, spreading over the whole surface, it will be partially supported by its adherence to the sides of the fermenting or settling vessel.

There is one chemical, the bisulphite of lime, which may be used in settling tanks with very considerable advantage. Whatever the objections may be to its use in mash tun, copper, or cask, they do not apply to its use in the vessels we are now speaking of. Its presence in the quiescent beer prevents any fret taking place, and counteracts any atmospheric influence if beer remains exposed for a lengthy period; and, as I have more than once pointed out, so sure as it exerts a protective power, so sure will its unpleasant characteristic smell disappear. Some quarter-pint per barrel is quite sufficient—indeed, to derive all the benefit of its protective power while avoiding the unpleasant smell effects, no excessive quantities must be used—and it should not be added unless beer is free from excess of yeasty impurities.

Now, with respect to the management of yeast, its selection for pitching purposes; there is no part, perhaps, of the brewing process which requires more careful attention or a greater knowledge of theoretical principles.

Yeast, as I have said, tends to reproduce itself, to recreate its distinctive character, and we brewers ought to see that its distinctive character is such that as a result of its action we may obtain a produce of stability. Nothing is so necessary to the success of a brewery as regularity in characteristics of produce; nothing militates against regularity so much as constant changes of store, which are in nowise necessary in a well-conducted brewery.

The best yeast for store purposes is that derived from a beer when nearing its final attenuation point, yeast which has not been exposed to atmospheric influences for any length of time, through forming the upper surface of the floating head, and as a rule the best pitching store for distinctive beers is that taken from brews of like quality, or from a beer of medium gravity. The acidity of yeast should be very low, but I hope I shall not frighten any brewers by saying that the soundest yeasts are distinctly acid; I do not mean to say that oxidized albumen is acid, but it is always combined with much fluid beer, containing, as we have seen, free acid, constituting normal acidity, and thus our yeast itself is by no means neutral. On the palate there ought to be no trace of sharpness, while with chemical tests its acidity should never exceed some ·05 per cent., for any greater acidity would be a simple proof that your acetous ferment was at work, inducing formation of acetic acid from alcohol.

I find it very useful in practice to rinse my clean yeast storage vessels with a fluid mixture of mono-sulphite of lime, a most useful chemical agent of neutralization and preventative of oxidation, without the unpleasant smell of the stronger sulphurous acid compound of lime. This salt neutralizes any little free acid in yeast, and tends to prevent any incipient or fretful change in the store.

When "store" is taken off tuns, it should not be exposed either to light or heat influences or to currents of air, but should, if possible, remain undisturbed till required for use, the fluid beer which settles from the solid matter being drawn off. Yeast has a natural tendency to work itself, especially when fluid beer is present, or when two distinct qualities of ferment are mixed; thus, it is necessary to prevent intermixture of yeasts of different age or quality, and to wash out all saccharine matter, if store has to be kept for any length of time. I may as well say at once that it is impossible to retain yeast in a sound state for any considerable period if in a liquid form and exposed to the atmosphere, but we may preserve it to a certain extent even in warm weather by washing from it all saccharine matter, by allowing a stream of pure cold water to flow over it. It unfortunately happens that the mechanical pressing of yeast seems to injure its vitality, and this is not to be wondered at when we think that the structure of yeast is globular, and thus easily affected by heavy pressure; besides this, the pressed material has a tendency to heat very rapidly in bulk and so decompose, and for these two reasons we are unable to utilize the pressing method as a directly preservative influence; nevertheless with the modern systems of cleansing, yeast pressing is an absolute necessity. In carrying it out we depend upon the principle that a mere mechanical connection exists between solid and fluid, which we are able to overcome by means of mechanical pressure; once let the connection between solid and fluid become chemical in nature, as you do, in fact, when you allow yeasty matter to become stale, and it then becomes impossible to separate them by mechanical means. Not only for this reason should yeasty matters be pressed while quite fresh, but also because you naturally desire to employ the resulting fluid in a paying manner; and, as a matter of fact, the "drawings" from a good press, if yeast itself is in good order, may be used with perfect safety for blending with racking beers, but to allow of this being done, they must of necessity be bright, sound, and free from any unpleasant flavour.

The pressed yeast, perfectly solid and dry, will not long remain so if retained in bulk. If of good quality it is easily saleable, either to distillers direct, or to intermediate yeast merchants, who ship it away to Germany and France. Their process for preserving it is to allow the escape of gas by spreading it out on cold floors, and then after mixing it with water repressing it to rid it of all saccharine matter before packing it in bags for shipment.

The preservation of yeast is no easy task. We can but fall back upon the one simple system of keeping it undisturbed, and unexposed to influences that can affect its quality; and from what I have said, it is evident that great care and circumspection is necessary in selecting a store for pitching purposes, while any overplus should be at once got rid of, by means of sale in a pressed or natural condition, before actual decomposition sets in.

Whatever yeast may be, whether it contains a vital germ or no, the same influences affect the mere chemical agent as well as vitality itself, and brewers would do well to give the most anxious attention to the proper management and preservation of ferment which is to be used for the purpose of inducing vinous changes in fresh worts.

## ESSAY XI.

### Racking, Fining, and the Storage of Beer.

THE racking process itself is a simple one, but a brewer has to arrange that his produce shall be fit for being run into the shipping away casks in a reasonable time. In this respect we find great differences, but the average time of racking would be, I imagine, one week after the brew is taken. Chemically speaking, the beer should, at the time of racking, simply contain tho final constituents in proper proportion, and, practically, it should exist at a low temperature, and be free from suspended impurities. No advantage is gained in cooling the racking beers below the average temperature of the atmosphere, for the resulting rise of heat in cask soon takes place and nothing so soon causes a fret, often ending in premature acidity, as this unsteadiness of temperature in cask.

The vessels into which the beer is racked should be cold, dry, and free from acidity. This latter condition is no easy matter to arrange for, but in any case, if the bulk of shipping away casks are in any degree sharp, some such neutralizing and preservative agent as mono-sulphite of lime ought to be placed in them along with the beer, to counteract the acidity of the wood and prevent it having any injurious effect upon your finished produce.

It is usual to place a certain weighed proportion of hops in finished beers, which tend by their presence to aid coagulation of fining material and to form, by floating on the surface, a kind of covering for the beer itself, besides giving a fresh and decided bitter flavour on palate.

Many publicans, however, object to the employment of hops for this purpose, and unless the sample in use happens to be superior in point of size, some annoyance is experienced on account of minute fragments of leaves, flowers, or seeds floating about after the usual fining action has taken place. In such cases, I imagine, a really good hop substitute might be used with advantage, especially if it contained the necessary constituent for enabling artificial fining to be carried on with success.

I cannot say that I am in favour of adding any excessive quantity of hops at this stage, although their tendency is so preservative in many ways, since in adding excess there is chance of getting more oil of hops present than is capable of being taken into perfect solution, necessitating lengthy storage for spontaneous clarification, unaided by any artificial fining agent, to take place, and, as a matter of fact, some quarter-pound per barrel ought to suffice for most beers, with a larger proportion for such as are intended for stock purposes.

In this latter case early brilliancy in cask is not necessary, and the excess of hop oil present will be taken into solution during the frets, which the soundest brewed beer has to withstand. If hops are put in casks dry—and it is best to do so, in order that distinct weights may be added—considerable absorption of fluid takes place, necessitating a second filling up after the lapse of an hour or so, before the casks are finally "bunged up" or "shived off."

We naturally come now to a consideration of the fining process, and, as briefly as possible, it will be necessary to see what turbidity means, what means we have at our command for overcoming it, and by what methods we prepare our artificial materials for use as fining agents.

Turbidity means that there is a certain equilibrium between the solvent and matter floating about therein, *affinity is at a stand in fact.* It is not sufficiently strong to induce solution of the matter causing turbidity, and yet it is enough to keep that matter in a state of equilibrium, neither sinking to the bottom nor rising to the surface. In order to induce the fining action we must either increase the affinity of the liquid for the solid, or diminish and overcome it by adding some artificial material that will eliminate all suspended impurity. Thus we can increase the affinity of the solvent for suspended matter by raising its temperature, or adding some chemical which exerts a powerful solvent influence; but it will be evident to you why we cannot adopt such a method in a brewery. We have the other characteristics of a good beer to study besides mere brilliancy, and accordingly we have to fall back upon a substance capable, under certain circumstances, of being affected chemically in the first instance by one of our beer constituents, and then of so acting mechanically as to filter off the impurities, without, by its presence, injuring the beer itself.

There are mere mechanical agents, such as sand, which would no doubt tend to fine beer by sinking slowly through it in a cloud-like state, but such agents are not sufficient for a brewer's purpose, and consequently we have adopted animal gelatine in the form of isinglass to induce artificial fining, where spontaneous clarification cannot be expected or cannot be waited for. This isinglass has to be brought into a convenient condition for use by causing it to assume a gelatinous state, by means of steeping it in some sort of acid, usually an organic one. I suppose that in most cases old beer or "*returns*" is employed, and in many instances, this apparently profitable practice is a fruitful source of early acidity in such beers as are retained in stock or on ullage for any considerable time. It is far better to employ such an agent as sulphurous acid, the advantages of which I have pointed out before, and thus obtain finings, which practically are non-acid, while the liquid portion acts as a preservative agent in your beers.

I cannot go more into the practical part of the manufacture of these non-acid finings than to say that if you take 56 lbs. of ordinary isinglass (leaf is the best, perhaps, at 4s. or 5s. per lb.), cover it with water, and then add eight gallons of sulphurous acid solution—1032 gravity—you will obtain a pure gelatinous mass, which may in the course of two or three days be diluted with water and rubbed through sieves, in order to be ready for immediate use. Such finings should always smell of sulphureus acid, which being present in a free and unaltered state, prevents any kind of decomposition setting in.

No actual solution of gelatine takes place in any case, unless the solvent agent exist at a high temperature, and indeed, if solution were effected, no fining action by the use of it would result. The object of this steeping is to so soften the material as to enable you to bring it into a state of proper gelatinous fluidity. When once sufficiently softened the next operation is to rub it through hair sieves with a considerable amount of pressure and friction to bring about a condition of equal consistency, as also to separate all matter not sufficiently acted upon or otherwise worthless as a fining agent.

Not only do you do this by the "rubbing through" process, but you mix a large quantity of air with the fining material. The finings, in fact, are fresh and frothy, and in this state they seem to act much more quickly, through being specifically lighter, than if used after being in stock for a considerable time.

This is no simple idea, but a most important practical fact, and explains in great measure why fresh home made qualities are superior in action to patent non-acid finings, made by outsiders, consisting of a pure gelatinous mass in a quiescent and flat condition.

If we remember that animal gelatine is at all times prone to decompose, and that acetic and lactic acid ferment is present in all sour beer, it is evident to us why we should use in place of sour returns some harmless acid such as I have named, capable of inducing very speedy softening of the isinglass, and, at the same time, by its presence, not only preventing any organic change in the material itself, but actually tending to prevent oxidation of the alcohol in the beer, to which your fining material is added.

The action of finings may be thus explained :—When added to beer in proper quantity, the beer itself being quiescent and without indication of any incipient fret, the active principle of your finings, gelatine, becomes coagulated by the tannin of your hops existing in the fluid, and being specifically lighter than the beer in which they float in this coagulated cloudy form, they rise to the surface and carry with them all suspended impurity. We must, however, bear in mind that they will not separate *matter held in semi-solution*, and consequently, if, through errors in our process, we have brought some extractive matter into such a state, although our finings may appear to "cut," as it is technically called, perfect brilliancy of product will not always result. It is asserted by some writers that the gelatine sinks instead of rising, but this is not so, however, in the primary action according to my experience, if excess of finings be employed, and if the beer be in a proper state for fining to take place. Nevertheless, if beer be in a very turbid condition the separated matter in cohering to the flocculent gelatine may render it specifically heavier than the watery medium, and consequently it will subside instead of rising.

This is actually what takes place in all cases in cask after the *first* action of the fining material. In that first action they rise, if beer be in proper condition, and then quickly losing their flocculent form and cohering together with greater tenacity, combined with the organic impurities filtered, as it may be expressed, from the turbid beer, their superior specific lightness no longer exists, and in secondary actions they sink in place of rising. The whole subject of fining of beer is very interesting. It is, as we see, partly a chemical action, where we employ gelatine as the active principle, and partly mechanical—chemical, so far as coagulation of the fining material by tannic acid is concerned; and merely mechanical so far as rising to the surface afterwards.

This chemical fact of coagulation explains why I insisted so much on the necessary presence of tannic acid in all hop substitutes, and why you cannot adopt gelatine as a fining agent unless you have the coagulating agency present in your beer. You cannot fine unboiled wort with ordinary finings, but you can bring about the clarification of wort that has been boiled with hops, although, on account of the quantity of gross matter present in such a heavy unattenuated fluid the action of tho "finings" is slower and not so characteristic, as in the case of finished beer; and, consequently, when beer is stubborn, we may take it that an excessive quantity of gross matter is present, or that there is a deficiency of tannin in the beer, and, I must confess, that it is far easier to prevent such a state of things by due care during the brewing process, than to overcome the evil when it exists. Tannic acid is such a powerful agent that I dare not advocate its use by unskilled hands; but when employed properly it tends in marked manner to remove the defects of a stubborn beer.

There is one more important point connected with the action of finings, and that is as regards necessary temperature of beer. The action takes place, perhaps, quicker at a high temperature of 60° than at one of 50°, but you can get equal brilliancy in either case so long as no chilling occurs during the fining action.

This is a very important matter, and I may as well enter into a short explanation. A beer or any liquid is capable of holding different quantities of matter in absolute solution at different temperatures. We all know how brilliant a wort is when running from hop back at a temperature of 180°, and yet how thick and opaque it is at 60°. This is simply on account of the watery medium being unable to hold in perfect solution at the lower temperature as much solid matter as it did at the higher.

Now, I have just said that finings will fine beer even to brilliancy at any temperature between 50° and 60°, or even at lower or higher temperatures, so long as no cooling down be allowed, and I mean by this that if, when finings are added, the temperature of the beer itself falls but a single degree, a dulness will result, although the finings themselves may have been coagulated and carried to the surface by their superior specific lightness in the ordinary manner. Thus in very cold weather it is clearly a mistake to rack beers at high temperatures, such as 58° or 60°, when the atmosphere of the consumer's cellar may be but 50° or even below, and in many cases it would be better to adopt some sort of modified idea from the Bavarian and American plan of keeping beers in small casks in a store at a very low temperature, say 35° Fahr. Much carbonic acid gas is thus retained in solution that would otherwise have escaped, and perfect quiescence and soundness during the period of storage result—while as a consequence, when such casks of beer are sent from the brewery into cellars that can but exist at a higher temperature, the gas in solution is set free and gives an appearance of condition to the beers not resulting, as you will see, from any frot or incipient fermentation, but as an effect of the change from the low temperature at which the beer has been kept to the higher temperature of the consumer's cellar. The beer has by storage attained besides a certain stage of brilliancy at this low temperature. *How much superior will the brilliancy be at the higher temperature the beer will attain in the consumer's cellars.* I must remark, however, that although this spurious condition is pleasant in appearance, it is very evanescent, and this fact explains why the beer preserved by this plan is put into such small vessels, the contents of which are sufficient but for a day's consumption.

I have spoken of an excess of fining material, as being necessary to perfect action, and mean by that some one and a half pint of finings of ordinary consistency per barrel. It is really curious to observe how the mere method of admixture aids or retards the result. Some brewers place the finings in beer before racking, others place them in the cask before bunging up, while a large number of the more extensive brewers train up the publicans to fine the different beers some few hours before being required for use. Not only do finings act better when stirred in by means of a stick in the manner adopted by publicans, but you derive two other benefits which are of some importance, especially where you use your stale beer for the purpose of softening your isinglass. These sour finings are not placed in the beer until just before it is actually required for consumption, and secondly if the stock of beer is kept up you are enabled to allow of its attaining the cellar temperature before the addition of finings, and, consequently, as no after chilling is likely to take place in a cellar of standard temperature, the beers so treated attain great brilliancy of appearance.

A few words must suffice to explain what I consider necessary respecting the storage of beer.

The cellars should be of equal temperature and that temperature sufficiently low, not too cold if but a small stock is kept, or if from the nature of the water excessive attenuation has been necessary to eliminate impurities, but still sufficiently cold in the warmer months to prevent constant frets, while sufficiently warm in the colder months to prevent unpleasant flatness and vapidity of beer. But whatever the temperature may be, whether

50° or 60°, it must be an unvarying one, in order to prevent constant alterations in condition of beers.

Now the frets that take place in beer when in store have very important influences. If the beer has been properly brewed, if the balance of power really exists in it, then these frets are actually necessary before you can expect to arrive at perfect spontaneous clarification and solution of hop oil. In the case of proper proportion of constituents being left in finished beers, these frets are not only necessary, but safe; but if, as frequently happens, the nitrogenous matter in proportion exceeds the fermentable, a fret, if not put a stop to in time, ends in acidity.

Theoretically, you can feed the fermentation (for a fret is simply a resetting up of vinous change) and so prevent acidity setting in by keeping fermentable matter in excess by means of the addition of pure saccharine solution, or you can check or put an end to it altogether by the addition of some such chemical as sulphurous acid or calcic bisulphite, either of which tends to stop fermentation by absorbing oxygen, thus either preventing oxidation of albumen to ferment or the reproduction of Pasteur's germs.

These cures, however, for evil of great moment are not easy to carry out in practice, and if my essays on mashing and vinous fermentation are studied carefully, I think, some of my readers may learn from them how to attain such a "*balance of power*" in finished beers, as will enable them to regard these fretful changes in cask as necessary to prime condition of their produce. If it be necessary to fine beer in cask before shipment, it is far better to leave it on bung till required, and then add finings before shiving off. No stock beers ought to require artificial fining, while all beers ought to undergo spontaneous clarification, differences in constitution of malt or saline constituents of water employed only affecting the length of time requisite.

I must now leave these combined subjects to your consideration: they certainly are of sufficient importance to justify much study and attention.

I have not devoted much space to the consideration of beer storage, since the changes that take place therein are simply continuations of vinous fermentation governed by the same rules and affected by the same influences, so that if we understand the principles of vinous changes, we shall find no difficulty in explaining to ourselves the reason of certain characteristics which appear in stored beers.

## ESSAY XII.

### General Recapitulation.

In coming to the last essay of a series, one is wishful to explain, in an interesting form, some of the salient features of the course, some of the important facts to be deduced from the general remarks, and to bring out in relief, as it were, some of those imperative rules which we fairly expect will steer us through the difficulties of a manufacture, which, to say the least of it, is complex both in theory and practice.

Strictly speaking, brewing is a chemical process, which can be carried on no doubt in a manner by uneducated men, but which nevertheless requires for its successful management a complete theoretical knowledge of the constituents which it is possible to employ for the production of this fluid, and beyond this we must not only know how to regulate the proportions of original constituents extracted from the grain employed, but be qualified to decide as to final qualities and quantities of matter to be left undecomposed in our finished produce. To this extent a complete theoretical knowledge is of eminent service, and although a mere theorist may not be a successful brewer, it is none the less true that before you can arrange a successful practice you must turn to theoretical knowledge as affording a groundwork for the arrangement of your process.

It is important to remark how little account has been taken by most writers of albumen and dextrine, although, I imagine, my readers will by this time have come to understand that on these two factors very much depends; to such an extent, indeed, that unless we know how to regulate the proportion of these two constituents in a finished beer, we can have but little hope of success. Beer may be a saccharine fluid, but we ought to bear in mind that as a fluid suitable for the purposes it is generally expected to fulfil, it must contain many other constituents which are capable of directly or indirectly bringing about the necessary changes in the saccharine, and others capable of communicating such an essential characteristic as fulness, and of resisting to a greater extent than saccharine the breaking-down effect of the ferment. This view of the subject has within the last few days received striking confirmation in a paper read by Mr. Valentin on Dextrine-Maltose before the Society of Arts Chemical Section.

What else can brewing be but a grand imitation of Nature by chemical agencies? And is it not matter for wonder that the process, as a whole, was originally built up by men having no knowledge of this fact, and that yet the arrangement of the processes was not so faulty even when looked at from a theoretical point of view?

Brewing has become year by year far more complex than was originally the case, and this principally results from the daily increase in competition, necessitating, as it does, the extraction of increased quantities of matter from the grain employed, this excessive extraction process tending at all times to make successful brewing more and more difficult, on account of much more injurious matter being taken into solution than would otherwise have been the case.

Thus it has come about that brewers are expected to have not only a deep theoretical knowledge of the process they have to arrange and conduct, but also of chemistry, electricity, and the allied sciences; and this is justly so, if we think what a complex subject brewing is at the present, and how much more complex it will become under a liberal alteration of the excise laws—such, for instance, as the abolition of the excise malt duty, which would practically allow of a brewer using any grain that he thought proper, either in a raw or malted state.

Thus, in my last essay, it is my wish to enter briefly into a summary of the most important and striking facts that we have noted in previous papers, and to impress upon the minds of my readers that no crude knowledge can be accepted as of service, while, in accepting theories, to accept them in a liberal way, not as facts so much as a primary means of ascertaining a correct system, and of avoiding some of the difficulties and dangers that constantly beset us.

We know first of all how important it is to select a good site for a brewery, a site where good water supply can be depended on, and where pure air in abundance is not always an absentee. We have seen the meaning of a gravitation brewery, with its avoidance of all expense in pumping. We have seen the advantages of steam breweries, where fire is employed to produce steam, which thus becomes the active agent of change; and then I had to mention the disadvantages of steam, as not giving so penetrating a heat as flame, which disadvantage, perhaps, has been over-estimated through the well-known custom of brewers to refer difficulties and defects of produce to the plant used in the production of it; but we may take it that the many advantages of steam do not outweigh that one disadvantage of small penetrating power as a heat, and that if we can reduce pressure so as to prevent coloration or caramelization of our saccharine by the intensity of flame-heat, it is well to adopt a safe medium in preference to a somewhat doubtful one.

Then we come to the question of water supply, and although we saw that defects as to its temperature or quantity might be overcome by the use of expensive machinery, such as the ether refrigerators, or cooling machines of Siddely or Siebe, we could not be too careful in ascertaining its freedom from certain impurities, its wealth in certain salts.

We saw how, in times gone by, "soft waters" were simply considered pure and suitable for use, and in London at the present day we know what wonderful effects a soft water has upon the produce of the brewery in colour and taste; but, now, brewers do not look for a pure water theoretically, that is, one free from salts and organic matter, but for one free, certainly, from organic substances, but rich in salts, which they know exert a very marked influence on the character of their beers. Why else have we sulphate of lime and chloride of sodium urged upon us as a cure for evils, which with an absence of them in our brewing water we cannot avoid, or how else is it that Burton brewers excel in pale beers, and London houses in soft palated stouts?

Thus, chemically a pure water is equivalent to aqua distil, while, from a brewing point of view, a pure water is one free from organisms, but rich in salts of lime and soda; but saying this we must remember the different effects produced by such salts as chloride of sodium, carbonate of soda, carbonate of lime, and sulphate of lime, and one cannot help saying at this point, how different in effect are the various compounds of a chemical base. Finally, with reference to the water question, we may say that for stouts we should look for a soft water; for ales, a pure hard water; and this word pure must refer simply to purity in respect to freedom from organisms.

Next, we naturally come to the actual materials used for beer, and we have studied how the old idea of barley being the only corn possible of being used in a brewery for malt production has exploded, and how many other grains could be quite as usefully employed in conjunction with sugar in certain proportions. In fact, in a great measure, the possible economy and utility of a grain depends on its proportion of husk to available constituents, for various differences in respect to proportion of albumen to sugar can be balanced by a definite use of saccharine. It is well to remember the effects of heavy soils in giving highly albuminous barley and rank hops, and since we are unable to practise the Bavarian method of fermentation in England, this point is very important, for if excess of albumen is obtained from a malt through neglect respecting the use of sugar, or carelessness as regards temperature of mashing liquor, we are not able to overcome the disadvantages of this excess, and it remains ever afterwards as a powerful agent of change. It is hardly necessary to enter into the details of malting to point out how the albumen of the seed is modified, how lactic acid is formed by non-attention to heats and working, and what effect inequality of growth and excess of rootlet has upon the malt as a producing material.

Before leaving this subject it is well to bear in mind the effects of high temperature in producing lactic acid during the early stages of drying, and since its formation requires the presence of moisture, it is evident that while moisture exists we ought to beware of excessive heats as tending to facilitate the alteration of sugar.

The growth of the malted corn once sufficient, every effort ought to be made to keep this malt in a perfect state of dryness—the effects of slack malt being well known—and it is well to remember here that if the use of raw grain is ever permitted in breweries, our care ought to be directed to expelling moisture from it at a gentle heat, for slackness in reality means moisture, and one and the other have but one baneful influence, namely, the certain and sure production of excessive acidity.

Thus, I think, we may justly say that malting is no vulgar art, but a poor imitation of Nature itself, and beyond this that the Excise laws tend to prevent, in great measure, the imitation from being carried out in greater perfection.

In considering sugar as a substitute for malt, we must always be careful to remember that sugar is but a substitute for sugar, and that if we attempt to substitute it for dextrine we shall, without a doubt, make a grand mistake. Then, again, sugar cannot be used in excess with barley malt, this latter being very deficient in yeast-forming matter, as compared with best oats and wheat, and we must give a passing remark on the difference, chemically speaking, between dextro glucose made from starch, and inverted sugar, this latter being much richer in sweetening properties than glucose from starch. This manufacture of sugar from starch, under the influence of some strong acid, is one of the wonders of chemistry, and explains, in great measure, why we must doubt the views of Liebig on vinous fermentation. If it is true that sulphuric acid can take the part of albumen in primary changes, surely we ought to be able to discover some chemical agent capable of imitating its theoretical fermentative action, and, failing this, we must doubt whether albumen or gluten is capable of being the sole agent in vinous changes.

In coming to hops, we must remember that they really do deteriorate by lengthy keeping, principally through oxidation of essential oil, and also on account of its escape in a crude condition, being, as we all know, very volatile.

The oil, as we have seen, performs a most useful office during ebullition, and till this stage of the brewing operation has been completed care should be taken to employ hops rich in this active principle. Thus "olds" are of little value, and in practice many brewers have found this out, and if you inquire into the reason, chemically speaking, you will find that it is on account of deficiency in oily constituent.

In connection with hops let us briefly refer to hop substitution. We must not be prejudiced by the one-sided cry raised against their use by interested hop growers, while on the other hand we must not forget what must of necessity be the characteristics of a truthful substitute.

Thus far we have glanced briefly at the materials, let us now glance for a moment at the means employed for effecting a solution of useful constituents, and the methods adopted for correcting undue solution of baneful agents, and alteration of other constituents of primary solution.

Mashing really stamps itself as one of the most important and weighty operations in the brewery. No mistake in the heats can well be made good, and no character stamped on the beer by the system of mash can well alter in the after processes. We have seen how the heat of liquor and fluidity ought to vary under different circumstances, of place, time of year, and requirements of trade, and how correct initial heat may be arrived at by a variety of ways of procedure, and the use of a variety of machines.

Now we may accept, as a first important principle, that in beer we require certain fixed proportions of various material matters, and that, in great measure, the success of a brewery depends upon the correctness of the brewer's system, and the proportion of constituents in his worts. We have seen how low first heats and high final heats tend to produce large extracts and sugar beers, and how high temperatures and short process work together in lowering extract and proportion of valuable constituents, and it is only by a correct knowledge of these heats as applicable to different requirements of trade and taste that we can hope to please a very exacting public.

As important features, one must bear in mind that small breweries and quick sales require a beer highly charged with saccharine matter, to give, in the first place, a vigorous fermentation and quick condition in cask; while in dealing with large bulks or with beers for stock purposes we may safely arrange for larger proportions of dextrine being present. Then, again, an English brewer must avoid excessive solution of albumen, for, although part of any excess is coagulated in the boiling down process, all does not, by any means, become precipitated, but exists in the fermenting wort, and works with characteristic energy for good or evil. We know the necessity of a quick process of solution and no delays, for albumen under certain conditions and heats is ever an active agent of lactic acid, and in passing quickly to the boiling process, it is well to say that a brewer is fortunate if he obtains a perfect wort in his coppers, for otherwise his boiling will not mend matters. Liquor will certainly be evaporated, the oil compound of resin and bitter principle will be extracted and disintegrated, but no lactic acid formed in the mash tun will pass away, no excess of sugar or dextrine will be altered, and no excessive quantity of albuminous matter deposited, but semi-soluble starch will be taken into solution, and the wort will pass on to the coolers with the stamp of good or evil qualities that it received in the mash tun.

Boiling is extractive; by means of it we expel air and precipitate by coagulation some of the albumen, which then acts as a fining medium, and, as a matter of fact, were it not for the disintegration required, we might with safety coagulate the albumen, and evaporate excess of moisture at a lower temperature, and so avoid some of the evils of pressure heats. The necessary care in cooling is to avoid, as we have seen, the excessive exposure of the wort at dangerous temperatures, to the energetic influence of the air, acting either as an agent of oxidation or a carrier of germs of life. We have noted with some care the evils of various refrigerators, and seen that, however well constructed, they are all open to some objections, of more or less importanco. Contact of metals, filtration of air, thin film of wort, exposure, suddon cooling, are certainly imperfections; but, on the other hand, celerity of process is of immense advantage, and perhaps far overbalances theoretical defects of machinery employed.

And now, in coming to vinous fermentation, and knowing that only a few yoars back the production of spirit was said to be the sole result of distillation, one must confess that a very difficult organic process must have made rapid strides to have come to its present advanced stage of theoretical porfection. What would beer be without its alcohol, ethers, and pleasant acids? and if a study of chemistry can explain a production of them, should we not turn to such works for information? It was not long ago that Liebig explained his theory of catalysis, how one nitrogenous substance, ever prone to oxidizo and alter in presence of air and moisture, seemed to have some influence in communicating a like state of change to more stationary bodies, such as sugar and dextrine; and when people begin to understand such a wonderful influence, while viewing the effects of acids on starch or platinum black, on alcohol, another theorist steps in, and with very beautiful simplicity explains that he cannot understand simple albumen possessing such powers, such microscopic character, and pins his faith to the belief, not that the air contains simply oxygen to work the change in albumen, thus enabling it to induce a decomposition of sugar, but that our atmosphere contains the very germs of animal life, which find in wort the very nourishment they require, and, in growing themselves, cause the destruction of glucose, and a removal of albuminous matter. The coincidence that in both theories oxygen and albumen are important factors links these theories together, and makes our knowledge of fermentation much more simple. Liebig asserts that albumen causes the change, and in causing the change disappears. Pasteur asserts, with much force, that actual germs of life are absorbed, and tend to break up the starch and sugar, taking for their own structure much albumen and dextrine. In Liebig's theory we find no fermentation taking place in the absence of oxygen, and the same applies to the theory of Pasteur. Both are linked together, and we can easily ground our faith on a careful study of a medium truth. There is much simplicity in Liebig's idea, but Pasteur has a host of believers, and, to me, it seems difficult to believe that albumen should possess powers and properties of conversion which previously had only been ascribed to vitality, although we are at the same time able to understand that it should be possible for nitrogenous matter to convert starch to sugar, and alcohol to aldehyde and acetic acid, for we have before us the power of sulphuric acid in bringing about the former change, and platinum black in inducing the latter. Let us remember carefully that whatever be the agent of change, whether germs of life or nitrogenous matter, no difference can be detected in the results. We have sugar and dextrine split up, carbonic acid and hydrogen given off, in varying proportions, according to the system in practice, and as a result of this wonderful process we find impurities eliminated and heat generated in fixed proportions so long as the process is conducted in a scientific manner. We have alcohol formed, giving to our beer its warmth and intoxicating character, ethers, which communicate their pleasant bouquet, and a variety of pleasant acids if we are successful, but an excess of one, which obliterates all other good qualities, if we fail in our conception of theoretical law, and simply study the conveniences of practice.

I tried to explain how the Bavarian brewers had worked out in practice the knowledge that alcohol cannot be changed to aldehyde under a certain fixed temperature, while decomposition of sugar and oxidation of albumen may still go on together; aud in thus plodding through the different systems, we came to understand how very complicated they might appear, and yet on what very simple chemical laws these intricate changes were based. Finally, in noting the expression "balance of power," it is necessary to understand that, in order for beer to remain sound, no excess of albumen must exist in the finished fluid, and in saying this we can easily understand how no excess of germ-power can be present, in the absence of nitrogenous matter, for the life of the germ depends on the presence of albumen, and when this has vanished the torulæ dies. Then, again, we do not want excess of sugar or dextrine, but only such a balance of power that while avoidiug thin beer of excessive teuuity, or a heavy mawkish fluid, we may yet have sufficient saccharine matter to afford the condition so essential to a keeping characteristic. To sum up a process like this is a difficult matter; but we ought to keep in view soundness of store; lowness of temperature; excess of gas; pressure; and balance of power in final fluid.

We naturally come next to systems of cleansing, and little need be said on this point after my recent lengthy remarks, except to impress upon my readers once moro the importance of so regulating a cleansing process that the floating impurities may be quickly removed, when the vigour of vinous fermentation begins to flag, and the heat be *gradually* reduced to safe limits.

Speedy cooling is a disadvantage, while quick skimming is almost a necessity.

We have seen the different effects of unions, pontoes, skimming rounds, and Yorkshire stone squares, in these two respects, and are obliged to confess that a skimming system, so long as no excessive exposure of beer to atmospheric influences takes place, is about the most perfect.

Unions are noted for the clean tasted beers they give; pontoes are more fitted for porter and stouts, while a skimming system is specially adapted for stock beers. All turn on the principle that oxidized or unoxidized organic matter containing nitrogen is a very evil thing to have in beer, and every effort should be made to rid our produce of it, so soon as we have worked essential changes by its aid. We must here refer to two subjects respecting fermentation, which are of considerable importance. The one is whether acetic acid has the power of inducing alcohol to change into aldehyde and acetic acid. The second refers to the question of ropy beer.

Now in reference to the first, so far as I know, acetic acid has no such power, but acetic germs have; and as we hardly ever see the acid free of these germs—the vinegar-mother of Liebig, and the mycoderma aceti of Pasteur—it is not hard to understand why sour beer should be such a very active agent in the production of acidity. Then, again, we have what is called "mucous fermentation," and I believe no one has ever yet explained what it arises from, or by what mistake in our system it is brought about. One theory, and a pretty correct one concerning ropy beer, is that the appearance is produced by the interlacing of minute filaments of organic impurities, which does not, however, go far to explain in what manner or way these filaments are created. Now, if I take chemical knowledge as my guide, I find mucous fermentation can be produced in saccharine fluid by excess of boiled gluten or albumen being added, and the fluid kept at a high temperature. Keeping this fact in mind, I must ask you to believe that if mash heats are so carelessly fixed as to induce or aid the solution of yeast-forming matter, together with excess of dextrine in place of sugar, we have the very factors present for the production of a mucous change, when the wort becomes exposed to a high fermenting temperature, and this, surely, is one aid that chemical knowledge can give to us, enabling us to solve difficult problems and escape from many dangers. Yeast is ever prone to change; great care therefore is, as we saw, necessary in order to prevent its alteration before being used as the active agent in fresh changes, while we must never forget that wort would ferment without this aid of foreign matter under proper conditions of temperature, for this point you would allow me to say has a great bearing on slow fermentations where we rely more upon the *native albuminous ferment*, as we term it, effecting directly or indirectly the greater part of the necessary decomposition of the saccharine matter. We cannot pass from the subject of fermentation without briefly considering the effects of electricity. The contact of metals produces actual currents which have, without a doubt, the power of decomposing beers, while a high state of frictional electricity in the air tends to produce polarization in the particles of all matter, and this change in matter can be so intense that cessation of fermentation often takes place, while its course may be so changed under its influence, that the results are often very dubious. We may laugh at thunder, but we must not treat the cause of thunder with levity, for it is a subject which most writers speak little of, being very difficult to understand in all its refined actions. Let us remember, at any rate, to avoid contact of metals, to prevent draughts or currents of air, let our tuns be insulated in their supports, and our attemperators cut off from our mains. This, I am afraid, is all I can teach you to do, except to watch carefully the differences in attenuation and rise of temperatures when electrical tension increases to such a degree as to be visible to our senses. It certainly at all times affects the many changes, and the subject shall be one for a future paper.

Much has been written about the influences of weather, and I am quite ready to allow that in summer months we have many unhealthy germs floating in the atmosphere; we have electrical tension at its highest pitch, and this may explain why beers brewed in such weather fail to possess correct characteristics, or bear the test of age. This has been at all times a very difficult subject with practical men, for they were under the idea that if a tun of beer could be retained at correct temperatures, a sound beer could be obtained at any time; but, alas! it is not so, and I am afraid Pasteur's unhealthy germs frequently become absorbed and produce changes, either in the yeasty head, or even in the fermenting beer or wort below.

This leads me to refer to a subject which has well nigh escaped my memory. "Is it wise to keep to the system of closed tuns?" a question, surely, which will not long perplex us.

If air really contain germs of animal life—and we know it now for a fact, for tho knowledgo comes before us day by day in one form or another ;—if the kind of life varies according to temperature and character of medium in which it finds itself, surely it would be well to prevent, as far as possible, undue absorption of these germs by the fermenting worts, or else retain the yeasty head, which is most exposed, at such a temperature that no evil kind of action can occur.

A good many brewers have adopted some means or other for the purpose of keeping yeast at a moderate temperature; for, as a practical fact, you know that yeasty heads, as a rule, are much warmer than the beer below. One and all have adopted the principle, without any knowledge of the theory that in great measure explains why unhealthy seasons militate against the production of sound stores, and consequently of sound beers. Probably they know a little of the Bavarian system of low heats, and wish to imitato it in some respects, for we find them not only keeping yeasty heads at a low temperature by means of cold liquor or ice, but actually forcing into the wort itself currents of cold air, trusting that this air will be sufficiently warm to oxidize albumen without at the same time bringing about a change in the alcohol.

This, surely, is a curious and interesting proof of my remark that men may work out theoretical laws and facts while yet knowing but little of them, for this forcing in of cold air would be a great hypothetical advantage if we could retain the whole bulk of fermenting wort at a safe temperature, but if meant only to take the place of attemperators, one would think it a somewhat dangerous expedient.

Keeping a head cool is more correct in theory, for we are preventing the growth of active germs even if not preventing their absorption from the atmosphere, and it would be well if these requirements of system could be carried on a little more generally, and crude ideas come to bear a little less on the method of procedure in our fermenting rounds.

And now it is time to leave the subject of fermentation and cleansing, and it has struck you, no doubt, that no part of the brewing process requires more forethought on the part of the operator, more skill and watchfulness, or a greater knowledge of the principles of organic chemistry. We have noted that the stamp given to worts in the mash tun can never be altered, or at any rate overcome in the after-processes, and no less certain is it that the effects of good or bad working in the fermenting tun are sure to be noted, so long as the beer itself remains as such. Once eradicate the nitrogenous compounds, themselves the agents of change, or otherwise the necessary food of active vital germs, and our produce is safe; once allow the balance of power to be disturbed, or regulated on wrong ideas, once allow the creation and growth of acetic torulæ, and no art or skill can overcome the evil.

We must now briefly glance at the materials used for the construction of plant in breweries, and the various processes for keeping them in a state of cleanliness, and, finally, consider what chemical agents are advisable, and how the Excise laws at present in force tend to hamper the brewer's skill.

We have seen how impossible it is for brewers to use conjunctions of metals in brewing vessels; we have noted the effects of iron, its wonderful properties of oxidation, acting, as it may be expressed, like nitric-oxide in the manufacture of $SO_3$; we have considered how necessary it is to keep copper vessels ever free from a coating of oxide, which is soluble, the more especially in a saccharine solution slightly acid, like wort; and how lead cannot be used in any shape or form; then we have noted how glass has been proposed for use in certain departments, as being a perfect electrical insulator; how slate is found in most breweries, as being wonderfully clean and lasting, but very chilling as well, on account of its powers of heat conduction and radiation. This as we have seen unfits it for use in some parts of the process, and, practically, we know it is not suited for cleansing vessels, in which you wish the temperature of the fluid to sink slowly. And, in coming to wood, which is perhaps the most universal material, we must remember that wood decays, through the presence of albuminous matter in the pores, which acts as a ferment in destroying the cellular and woody fibre. We must not forget how potash acts in dissolving this albuminous matter, thus fitting itself as a preparatory cleansing agent in the case of stinking casks. Then we have seen how chemical knowledge has stepped in, and advised that the nitrogenous matter should be pressed or drawn out, and paraffin, a substance hardly acted upon by any known agent, substituted for it in the pores. We have seen how tar or enamel is applied in a somewhat different manner, and for a different purpose—it may be for the same purpose by indirect means for preventing moisture coming in contact with the woody fibre, and more especially with the albuminous matter in the pores of the wood itself. We have seen how chloride of lime acts as a perfect cleansing agent, in affording a supply of nascent oxygen for the destruction of adhering impurities, and how bisulphite of lime removes all excess of chlorine by forming two harmless insoluble salts—Ca,Cl,

$Ca\ O\ SO_3$. We were careful to note the effects of excessive steaming, in causing the wood to perish and in closing the pores, thus allowing a fresh film of moisture to escape so soon as the wood cooled down.

Then, in order to neutralize the surface acidity of vessels formed of wood, I pointed out how ordinary lime may be used as a cleansing agent in a double sense: it is a scouring material, and one capable of neutralizing any existing acidity; and then I explained how a lime salt, the calcic mono-sulphite, might be employed, as not only a neutralizing agent, but as a preventative of further acidity formation.

This mono-sulphite of lime, a very cheap bye product in chemical works, is insoluble, and may be used with great advantage for coating such woody surfaces as are apt to become acid, and with which your beers come in contact. It is nearly insoluble in water, but you can easily make a mechanical mixture and use it in your fermenting rounds, wooden settling tanks, mash tuns, or shipment casks as a kind of whitewash.

There is no necessity for its use *where no liability to surface acidity exists*, but I know that many brewers suffer in no small degree from this surface acidity of woody material, and if they will be guided by me they will keep all such surfaces coated with a film of this valuable salt. As the beer or yeasty head rises in the vessel, this salt easily dissolves in the natural acid of your worts, and thus tends to neutralize any excess of normal acidity.

It has no smell, but a strong alkaline reaction, and from its low price—some 30s. per cwt.—cannot be called a very expensive safeguard.

I refer to it more in detail, as I have had many inquiries on the subject from a variety of quarters, and may as well say that it can be obtained from Messrs. Kendall & Co., of Stratford-upon-Avon, or Messrs. Gillman & Spencer, of London, who do not perhaps go so far in praising its useful characteristics as I am always inclined to do, for actual chemists would naturally be more in favour of the calcic bisulphite, but many practical men will agree with me that certain circumstances constantly arise in a brewery requiring the actual use of some alkaline agent. Now, certain disadvantages apply to the use of ordinary lime, while the bisulphite cannot well be called a powerful alkaline agent, and with some beers tends to communicate unpleasant smell and taste, and for this reason I am myself content to rely more upon the useful mono salt I have spoken upon so fully.

Then we must not forget the sulphurous acid, so useful in preparation of finings, or the many ingenious preparations of chemists and brewers for counterbalancing, if possible, the injurious effects likely to arise from the excessive presence in our beers of albuminous principles when in contact with air.

One and all are prepared on most scientific principles, and where necessary may be used with great advantage, but I must add a remark to the effect that it would be well if we could always select such a water and such materials for the production of our produce as would render the employment of any chemical agent superfluous.

So much for chemicals, and so deep an interest do I take in this subject that I fear I must have tired many of my readers who do not happen to be fond of chemical knowledge.

In considering finings, one must confess that brewers without them would find great difficulty in effecting quick returns by getting such speedy brilliancy. We know how finings are prepared by semi-solution, or softening of gelatine, in sulphurous or acetic acids, how their efficacy is destroyed by heat, how no real solution is effected, as proved by their saccharometer weight, and how they certainly contain in a fresh state much air condensed on their surface. We glanced at the different theories respecting the action of finings, their chemical action in coagulating under influence of tannic acid, their mechanical action in rising to the top of wort on account of specific lightness; and we must not forget how this is increased by the air condensed, as it appears on the surface of the fining material, and what a very important feature this is in the action. We considered how they were effected by change of temperature through chilling of beer, and were bound to allow that the very preparation of them must be based on true chemical reasons, and their use carried out by skilled hands.

If, in conclusion, I refer to the Excise laws, it is simply to point out how harsh they are—as, for instance, in insisting that no saccharine shall be supplied in a liquid state—what efforts of memory on the part of the brewer are insisted upon, and how free and scientific we should become if they were removed. So far, we cannot use raw grain in any shape or form, unless we place ourselves on the footing of saccharine makers and adopt their method of conversion, and sugar only under restrictions of Excise duty as place it at a disadvantage, economically speaking, when compared with malt, and these rules, of course, necessitate sharp and sometimes unpleasant supervision on the part of the Excise officers.

My readers will, I am sure, agree with me that the art of brewing is a most interesting subject for study; complicated as all the details are, we have yet power to master the difficulties which constantly appear.

If we learn a little more of chemical laws, if we pay attention to the teachings of Nature, we shall see more in what direction we must look for improvements in our process, and fear less the ideas of crude knowledge and the timidity generated by excessive anxiety.

Now I have finished, and will but observe in conclusion that if there are many shortcomings, my time has been short; yet if I can know that in these papers I have satisfied a want, by opening up some of the so-called secrets of brewing and by placing the various theories before you, both in an easy and yet satisfactory manner, I shall be the more encouraged to enlarge upon them at some future time.

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# APPENDIX.

LONDON, *September*, 1878.

WHEN first I sat down, more than two years ago, to write a series of simple essays on the art of brewing, I never for one moment thought that I should ever be called upon to add a few words as a kind of introduction for a second edition of the papers which, at the request of a great number of the readers of *The Brewers' Journal*, were bound up in one slight volume under the title of "The Art of Brewing."

If I had thought of this happy eventuality of my work, I might, perchance, have spent more anxious consideration and more earnest labour on its subject matter, although I should, even then, have kept firm to the object I had in view, by putting in every-day language and perfectly simple form some of the main theories which should certainly be known by every person who has charge of actual brewing operations. I might have put these theories before my readers in much more complex shape; I might have described them in much more flowing language; have neglected, in fact, mere practical knowledge by making too much of theory, and to myself, no doubt, would have been the greater gain. My scientific reputation, whatever it may be, would have been increased; but would my readers have been benefited in like degree? I fear not; for the truth is that the vast majority of readers who so honoured my essays as to desire their reproduction in complete form, had, previous to the publication of the essays, but scanty knowledge of the theories upon which the art of brewing is really based. This conviction was so firm in my mind that I decided, rightly as I believe, to make my essays a bridge over which my readers might pass from practical to theoretical knowledge. I determined to abolish mystery, expose the so-called secrets, and endeavour to make brewing what it really is—a most wonderfully interesting process, depending for successful accomplishment on factors which may be counted upon the fingers of the hand. To the scientific theorist these factors are as clear as earnest study can make them; but it requires a practical construction of these theories before we can expect to carry them out successfully. On the other hand, the mere practical brewer experiences, in many cases, the influences of these factors to a good result without really knowing what they are, is, in short, accidentally successful, and so becomes the critic who denounces the most eminent savants as quacks, empirics, and so forth; while in hundreds of other cases the work of the mere practical man becomes the practical exemplification of that result we may expect when we ignore altogether the teaching of Nature, run counter to her laws, and laugh theory to scorn, because we are too idle or too prejudiced to learn what theory really means. Placed in a locality where freshness of air and purity of water are two of the unknown factors, dealing as we may be with malt which is free from germs of unsoundness, or the type of food essential to their existence, with hops free from mould, and with yeast which, as a consequence of all these influences, is pure also, the practical brewer sails along in a simple and easy manner, and looks with something between amusement and scorn upon the experiments of the laboratory, the study of the microscope; speaks in many cases of Pasteur as a quack, and of his teachings as worthless visions. Alter one of these factors and the whole fabric of success falls to the ground, even as life itself would fail if we cut off a single necessary element of its continuation. Let water become contaminated with organic impurities, let malt, hops, or yeast employed become in any way unsound—what results do we see? Little by little the products become more and more unsatisfactory; every suggestion of practical and lengthy experience is tried as a remedy, but still no improvement is effected. Anxiety and nervousness follow the old scorn and the old confidence, and the practical brewer at last takes refuge in consulting every possible authority, catching, as it may be expressed, at every straw of theory, till by some happy stroke of fortune he comes into connection with some theorist who can explain, not only theoretically, but exemplify practically, how the simple fact even of impurity of yeast—an impurity caused, in many cases, by the absence of one or more of the factors of success I have previously made mention of —can upset all prior calculations, make satisfactory results impossible, and confer fresh lustre on those who are never weary of preaching how theory and practice should run hand in hand if constant success is to be relied upon or arrived at. Thus we can understand how it is that in England we see at the present time very many brewers most eminently successful who could lay no claim to a knowledge of theoretical principles, who require no "Essays on Brewing," and who follow out the system of previous years almost letter for letter; we can understand also how it is that hundreds of other men who, practically speaking, are quite as skilful, are eminently unsuccessful, while in reading the present Appendix my readers will, I hope, also come to see why the students of Pasteur's brilliant works regard success as within the reach of all who read as they run, and who lay to heart the readings that are so essentially important.

With thoughts such as these in my mind, I was originally careful, or, more strictly speaking, wishful, to create a connecting link between theory and practice, a link that could be readily understood and enlarged upon by the people who were most likely to read my papers, while, with these same thoughts intensified a hundred fold by the results of recent experimental research, I feel glad that I am now asked to fill up the gaps that I left in my preliminary attempt to interest the readers of *The Brewers' Journal*, since I am enabled to strengthen my bridge—my link, as I have expressed it—by building in what I have come, with many others, to regard as the secret of all success in brewing. What this new store of knowledge is will rapidly explain itself.

It is easy to see, I think, that since writing my original essays much has occurred to render this filling-in process wonderfully interesting and simple. It is not I alone that regard "Études sur la Bière" as a work containing the secret, the very essence of successful work—the microscope as the instrument which must eventually become the brewer's guide and safeguard.

It is not I alone that believe that, to be successful as a brewer in all districts, under different conditions, and in view of different trade requirements, one must know how to cultivate a healthy yeast cell, and stamp out a ferment of disease. Others, far more skilful in this work than I can claim to be, far more advanced in scientific knowledge, would speak of this as a mere outline of the truth, and would be the first to acknowledge that their own success had resulted from following the path in their practical manipulation which the microscope pointed to as being not only necessary, but, at the same time, easy and sure.

Let me not, however, anticipate too much, but take my stand to make brief reference to each section of my preliminary work, correcting errors where they exist, and pointing ont, as I may express it, the crude ideas which at the time I thought suitable for attaining the object I then had in view, but which I now regard as somewhat too elementary for the requirements of modern students of theoretical brewing.

I cannot add very much to my views in reference to water. Every one connected with brewing knows, I presume, how essential it is to have a water supply of a certain standard of purity, and that if brewing operations previously successful degenerate in result, the first and most sensible step to take is to ascertain by analytical means whether the supply has in any way become contaminated. It is a very old idea, but, nevertheless, a very true one, that waters of decidedly saline character produce in some way beers that are of superior flavour and stability; but few even at the present day know exactly the means by which this stability is assured. To microscopical workers the immense influence of certain types of nitrogenous matter on the stability of a beer has long been known; in short, every good quality of a beer hangs, as it may be expressed, upon the state or condition in which we keep the aliment of our yeast, which aliment is extracted naturally from malt, in varying quantity, corresponding to differences in character of water. This being so, it is easy to conceive how the difficulties of a brewer increase when, by the peculiar softness of water in use, its extractive power in regard to special types of proteine matter becomes excessive. We may no doubt benefit by obtaining a larger quantity of extract, but the long storage of the resulting beer becomes a dangerous experiment; in fact, while many a practical operator can succeed with a saline water, it requires a very skilful brewer indeed to attain a like success with water of peculiar softness, since, with excess of all type of nitrogenous matter present in his worts, how can he expect to stave off for long the life of false ferments, unless these albuminoid bodies can be retained in a condition of perfect unalterability? In this fact we see at once the wide difference between a hard and a soft water, and from it can account for the wonderful trade that is done in soluble sulphates and the other nostrums which are said to render a soft water readily saline when used in due proportions.

If I am asked whether this system of hardening is a wise step for all to adopt, I should most certainly reply, not in all cases. There can be no two opinions respecting the superiority in flavour of a beer produced by means of a distinctly saline water as compared with one produced by the use of soft, insomuch as the saline water extracts only the finer flavours of our malt and hops; but in many cases the public taste is not so much for superiority of flavour as for a certain fulness and "body" on palate, and since such qualities are only attainable in cases where a soft water is in use, or when much extractive matter is left unattenuated; it follows that, in using such water, the greatest care must be taken in arranging our practical manipulation, if we wish to obtain characteristic stability of produce.

If the saline character of a water is important, how far more important is its condition in respect to organic impurities! It is simply impossible to brew successfully with a water overladen with animal refuse. Our yeast at once falls away in point of purity, reproduces itself in more evil state time after time, so long as we employ it for store purposes, till the diseased ferments flourish almost as rapidly as those of healthy type. Our wheat and our tares grow together, and disaster follows disaster so quickly, yet in so mysterious a manner, that unless some vigorous steps be taken to determine the evil and effect its speedy removal, complete ruin of the trade is sure to result. To my mind, every brewer should be capable of conducting and carrying out a water analysis for himself; but few, I regret to say, seem to be aware how much the process has been simplified by Professor Wanklyn and others, while many who know the importance of the subject are hopelessly at sea respecting the meaning of the analytical reports sent in to them.

Free and albuminoid ammonia proportions, "chlorine," "nitrates," and "nitrites," expressing, no doubt, much to a chemist, are but confusing when glanced at by men who have little or no knowledge of chemical terms; and yet it is important that they should know something of this subject of "terms" meaning, even if they remain ignorant of the analytical method by which they are arrived at. The "terms" are simple indices. Much free ammonia, in ninety-nine cases out of a hundred, means sewage contamination, while much albuminoid ammonia and little "free" is the index of vegetable impurity.

The latter is not so fatal in its influences as we find animal refuse to be; but both descriptions of organic contamination interfere with purity of yeast, although in varying degree, and both should be altogether absent, or present only in minute quantity, in any water suitable for brewing purposes. In my more recent papers in *The Brewers' Journal*—papers which at some future time I hope to revise and reprint—I pointed out pretty fully the importance of these index numbers, so it remains for me here to explain the actual proportions that are within reason. If the free or, as it is sometimes called, saline ammonia amounts to over ·03 parts per million, a further and more minute examination of the water should be made, especially if the chlorine proportion is also high. Now, the average grains of chlorine in an inland town water is about 1·7 or 2 grains per gallon; but if this is far exceeded, and the free ammonia proportion rises to tenths per million parts, then sewage is most certainly contaminating the supply, and immediate steps must be taken to obtain a fresh one. Under the circumstances of high chlorine and excessive free ammonia proportions the albuminoid ammonia is likewise in excess, certainly more than one-tenth part per million; but, on the other hand, in the absence of much free ammonia chlorine is no longer a sign of contamination, and the presence of such a proportion of albuminoid ammonia as I have referred to is not in itself alarming.

My readers must remember these terms as simple index numbers, as I may express it. *The free or saline ammonia* being that quantity which a water contains, arising from the decomposition of urea, or, under certain special circumstances, of strata formation, by the reduction of the nitrates—an important statement which I must qualify by the remark, that if this strata formation accounts for quantities of free ammonia, which at first sight appears to be conclusive evidence of contamination, then the albuminoid ammonia would invariably be low, certainly not more than ·05 parts per million. *The albuminoid ammonia*, on the other hand, is representative only of the nitrogenous organic matter existing in solution, matter which becomes converted by oxidation into ammonia during the analytical process, while both varieties for the sake of unison of arrangement and convenience are expressed as such in so many parts per million, in grains per gallon, or some other easily convertible proportion.

There is, to my mind, no satisfactory or effectual way of staving off the influence of a water actually contaminated with *sewage* matter; but in many cases where vegetable impurity *alone* exists (as represented by a somewhat high "albuminoid" and minute "free" ammonia proportion), we can by filtration, boiling, increased care during our practical manipulation, and a skilful application of calcic bisulphite and salicylic acid, tone down, if not entirely prevent, the slower influence and action of this type of organic impurity.

The subject, indeed, is a wide one, a subject of immense importance not only with reference to the organic contamination of a water, but with regard also to its saline character, and I have no hesitation in saying that in the majority of cases unsatisfactory results can be traced directly or indirectly to some peculiarity of the water supply; and saying this, one is tempted to add the remark, when will brewers be wise enough to become their own analysts, so as to determine for themselves the possible variations in quality and purity of their brewing waters?

What must be my brief reference to the increase of knowledge respecting malt and its substitutes since my essays were written? I was only able in my final recapitulation, as will be remembered, to refer to the wonderful discovery of Mr. Cornelius O'Sullivan, who placed just then before the scientific world in the clearest possible manner the whole change undergone by the constituents of a malt during the process of mashing. He has since that time pointed out in detail how under the influence of our catalytic agent of change—if it really is "catalytic" in action—the starch of the original barley, partly modified as it is, no doubt, during the process of malting, becomes completely changed during a successful mashing process, not simply into sugar and dextrine, but into a combination of a peculiar and typical sugar, "maltose," or the sugar of malt, and a variety of carbohydrate matters, and thus explained how impossible it was to imitate this wonderful yet complex reaction in any artificial manner.

This knowledge has, perhaps, more practical reference to mashing; so before I enlarge upon it further, let me ask my readers whether malting operations have nothing to do with success in brewing? Maltsters seem to think that evil-smelling steep water, mould during germination, and general decay during early drying off, are of slight moment, as in their view the defects of such evils can be hidden or obliterated by a strong application of temperature during kiln-drying. What shall I say to such ideas? Simply that they are utterly absurd; simply that in deceiving themselves they deceive the unfortunate brewers who have to brew such defective malts. This kiln-drying does not kill the germ of disease, bring back the decaying nitrogenous constituents to a state of stability, or counterbalance in any single point the defects of their process, which seems based upon mere economical expediency. Every reader of this statement can test the truth of it for himself by means that will be fully explained before I close. I am taunted in a new and valuable work—if cost demonstrates worth—with condemning slack malt, and for asserting that the re-drying of such malt fails to bring it back to its primary state, or remove the defect which condemns it; but let me ask my critic if he for one moment believes that the re-drying can remove the excess of acidity, destroy the factor that has produced it, or diminish for a day the tendency such a malt has to promote a lactic acid change in wort and beer? Does he, in short, hold and believe that such a malt will yield a wort that will reproduce, or allow of the reproduction of a yeast free from lactic and putrefactive ferments? If so, the very foundations of his belief are of doubtful stability; he has failed to study "Études sur la Bière," and has attempted to score a point by an assertion that will not bear for a moment the most simple scientific investigation.

I am sorry to make such a sweeping statement, but I believe, with many others, that the existing methods of malting make successful brewing, in many districts and with many descriptions of water, more and more difficult year by year, since everything is sacrificed, as

I have said, to mere economy of working and increase of profits. The constant change of steep liquor, swarming as it does with organic impurities, is even considered a wasteful refinement, leading only to a visionary benefit, and as a result the unfortunate brewer, unable to distinguish defects by the eyes—since kiln-drying and a little sulphur give a wonderful polish to a malt, and more or less hide its defects—uncultured in methods for determining them by the microscope, fancies that his malt is sound and good, although I shall prove to him, if I find space at command, and if the knowledge as I progress does not seem to me a little too advanced for my present Appendix, that means exist, suggested by our eminent teacher Pasteur, for demonstrating in no incomplete manner the correctness or error of any mere eye judgment that we may form. But even here I would ask him to believe that a malt possesses in itself—possesses *in the condition of its constituents*—an influence for good or for evil that we should be mad to disregard; and thus our brewing water and the malt we use constitute factors of no mean importance—factors upon which depend the purity, the vigour, and the whole typical character of the ferment we eventually employ to produce an alcoholic, brilliant, and stable fluid.

The discoveries of Mr. C. O'Sullivan gave, as it may be said, a new turn to the thoughts of scientific brewers. So wedded had they become to the idea that malt yielded simply sugar and dextrine, that they viewed all substitutes for malt as deficient in not containing the requisite amount of dextrine to ensure fulness of flavour in produce; while I, no doubt like others, advocated that saccharines should be prepared to resemble our actual malt extract, composed, as one then imagined, of simple grape sugar and dextrine. This idea was caught at by more than one firm, and "saccharines" containing certain percentages of dextrine were duly thrown upon the market, while Mr. O'Sullivan himself suggested the preparation of "dextrine maltose" by a most refined and scientific limitation of the catalytic agency of the acid employed in the inversion or converting process. Useful as all such matters are in their proper place, superior as they may be to the unrefined and uninverted sugar, may be chemically and optically the same as extract of malt, they yet fail to take the place of such malt extract successfully. Our palate taste discourages their excessive use, while the ferment—the wonderful cell life we have to think of, tempt, and cultivate, if we wish to be successful in our work—refuses to assimilate them, and produce the same result as is seen when assimilating malt extract alone.

Malt extract, as Mr. O'Sullivan proves so clearly, is very complex in composition, and even now we do not know or fully understand the influence of many of its constituents. Containing as it does maltose—a distinct type of sugar—dextrine, and a variety of carbohydrate matters, some resembling very closely the sugars that are fermentable, others incapable of undergoing fermentation—various types of nitrogenous bodies, or albuminoids as they are generally called—it yet contains them so perfectly blended together, if our mashing operations have been successful, that when dissolved it not only yields the very flavour we desire to obtain, but seems, as it may be said, naturally fitted to allow of the healthy *reproduction* of a special type of yeast. Thus in using the substitutes for malt we not only alter the flavour of our produce, but also, and this is by far the most important point, the whole character of our yeast. It is here that the microscope becomes so wonderfully serviceable, for we can by its aid determine when our yeast is languishing for want of its natural aliment, and thus know when to restrict the use of such substitutes for malt as fail to supply it, and the excessive employment of which facilitates the injurious influences arising from the employment of a weak and unhealthy store. But if care is required in using these artificial saccharines, which at any rate are free from actual organized impurities, how much greater care is necessary when we use raw unrefined sugars, which contain so many germs of disease and so many types of changeful nitrogenous matter! The use of these sugars thoughtlessly constitutes the rock upon which the previous success of many brewers is wrecked. The low prices, and the many other advertised advantages are too tempting to withstand, and the fatal step is taken of attempting to substitute for the extract of malt—complex as we have seen it to be—a sugar which teems with impurities, and the actual germs of diseased ferment life. The natural result is soon seen. Rapid deterioration of yeast takes place; and what this means is only too well known to such firms as persist in the use of these substitutes for malt, *when their trade is unsuited* to such economies of production, and when their scientific knowledge is not sufficient to allow of their so regulating their employment, that the necessary purity of yeast supply is not unduly interfered with.

My remarks, so far, are, as will be observed, gradually yet steadily drifting to the announcement and support of one important conclusion; in short, that success in brewing depends in the main upon our selecting a solvent and materials which, under careful manipulation, will yield worts capable of supporting healthy, as opposed to diseased, cell life, and beers incapable of supporting to any excess the life of either. This is strictly true, so far as stability of produce is concerned; but in the primary stages of brewing we have to pay some attention to flavour and other palate requirements, and in this respect the paper of Mr. O'Sullivan, read before the Chemical Society, on the "Action of Malt Extract on Starch," and the paper of Mr. Valentine on "Dextrine-Maltose," read before the Society of Arts, contain statements and suggestions of the highest importance. If artificially we are able to limit the catalytic agency of sulphuric acid, we can also naturally limit the action of the soluble albuminoids grouped under the term "diastase"; and thus in mashing, as I before explained, fluidity, time, and temperature, or range of temperature, are all important factors, since it can be easily proved that, by a skilful arrangement of factors named, a variety of flavours can be obtained through alterations in proportion of wort constituents, since such variation, most probably, allows of certain modification in the changes that the yeast cell actually induces; in fact, there is little doubt that all our efforts in practical brewing to be successful must, openly or insensibly, tend to a healthy culture of the cell life that we rely upon for effecting so much. The subject of mashing was explained so very fully in my original papers, that the only other reference I need make to it here is to repeat once more, that according to Mr. O'Sullivan's discoveries we are not varying simply the proportion of dextrine and sugar by variations in our mash system, but many of the carbohydrate and nitrogenous matters also, these being the very bodies which influence in no small degree the after character of the beer.

The preparation of hop substitutes languishes, for the very reason, we may suppose, that demonstrates the inferiority of a simple saccharine. They are real substitutes only in name, for it is simply impossible to imitate artificially the complex extract we obtain from the hop flowers. We can use some bitter principle, no doubt, in combination with tannin and other matters, but these no more compensate for the actual extract of hops that we dispense with, than does a saccharine when we attempt to substitute it for the complex extract of malt, although it must be understood that hop substitutes have no evil influence in regard to ferments, a direction in which the influence of sugar or saccharine, as we have seen, is very potent. All such substances are very useful in their way—useful when employed with judgment and skill; but they all fail in coming up to the standard of excellence represented by the extract obtained from malt and hops of good quality.

It is in coming to a consideration of the fermentation stage that I must make my appendix of value in its added information. How many clouds have lifted, how much the theory of our process has been simplified, since Pasteur wrote his grand work on beer, few will be prepared to dispute; but it is those who have read between the lines of the studies, who have carried out his experiments, followed his teaching, and finally accepted his doctrines in their entirety, that speak and think of him as the one man who has solved the only real secret in brewing—a secret, the bare outline of which is seen at a glance when looking through a microscope at the deposit of a finished beer, or at a yeast in an active state of fermentation. It is such men, more especially, that regard "Études sur la Bière" as containing a series of principles most brilliantly argued out, until they seem to be incontestable facts; the work as one that will confer on its author a fame that will never perish, and a work which certainly ought to gain for him the lasting gratitude of every student of the art of brewing.

What, then, is the idea of Pasteur, the outcrop of years of silent study? I think I can state it very simply.

1st. That fermentation is due to the action of organized cell life.

2nd. That there are many types of ferment life.

3rd. That the germs of each one exist in the atmosphere floating around us. And

4th. That deterioration in the character of a wort or beer corresponds with, and is due to, the presence therein of diseased ferments.

The primary statement is, of course, by no means strictly modern; but it is modern in its ramifications, as I may call them, while it is only quite recently that brewers, inspired, as I may express it, by Pasteur's researches, have seemed to grasp the facts as stated above, and taken steps for bringing their practical processes into some sort of unison with their teaching.

The knowledge *that is* essentially modern, remarkable, and deeply interesting, is comprised in the statement that *the deterioration of a wort or beer corresponds with the existence in it, not of ordinary ferments, but ferments of diseased type;* while the special way in which our savant benefits brewers, and indeed humanity at large, is by unravelling the mystery of ferment life in general, illustrating the appearance and size of each type or class of ferment under the searching light of the microscope, explaining the conditions necessary to their existence, the means we may adopt to avoid their germs becoming actual cells, and describing, in short, in the most brilliant manner, every detail connected with ferment life in reference to its influence in regard to practical brewing.

Once having grasped the fact that fermentation is due to organized life, that deterioration of produce corresponds with the action or influence of diseased ferments, that the germs of all ferments, good and bad alike, exist in the air we breathe, the water we drink, and the materials we employ, it will appear plain to all that, *since* we have types of cell life to contend with, the chief aim of a brewer must be to afford the necessary conditions for the reproduction of that form of cell life that is alone capable of inducing the vinous change. In short, as I have over and over again explained, our chief aim in brewing, from the preliminary stage to the final step, must be to so arrange our conditions of life that no opening exists for disease.

It is curious to observe that the conditions in reference to cell life are much the same as in regard to higher forms. A cell for its reproduction, for instance, requires food or aliment that can be readily assimilated, and a certain temperature, according to the character of the alimentary matter; while this character or condition of alimentary matter, and the temperature we adopt, decides in great measure the type of ferment that will appear to flourish.

No one could over-estimate, I suppose, the importance of such statements, for so long as we can ward off the conditions necessary to enable a diseased ferment to assert its influence, so long can we ensure the stability of our produce; and herein is seen one of the special values of Pasteur's work, for no statement is made without being followed by a series of experimental proofs and suggestions; proofs which claim our admiration for their point and conclusiveness, and suggestions which have been enlarged upon and practically applied by many eminent and scientific workers in the vast field of industry that we are connected with.

In my original essays I tried hard to point out how important the nitrogenous bodies as constituents of a wort really were; but at the time of writing I had not grasped their full influence, or their full bearing under varying conditions; for, just as Liebig stated that the kind of action set up by albuminoid bodies depended upon the state of change in which they existed, so do I now believe that the type of cell nourished by these bodies varies with the peculiar condition in which they exist.

There is no doubt, of course, that one of the essential conditions for the reproduction of cell life, in any shape or form, is the presence of albuminous matter, and my readers will remember how Liebig, in the days of the physico-chemical theory of fermentation, demonstrated that there was no reproduction of yeast when nitrogenous matters were absent. On this one fact, slight as it may appear to some, we find the intimate connection that must exist between our practical operations and this one secret of success that I have been speaking of.

Ferments, of course—or, as we practically call them, yeast—assimilate, and, indeed, require other kinds of alimentary matters—maltose and fermentable carbohydrates, for instance—for, as a matter of fact, it is by balancing in a scientific manner the proportions of these various constituents that we can cultivate an improved yeast, but while saying this I shall carry my readers with me better if I confine my remarks more especially to the influence of the one of nitrogenous type.

This subject, as my readers will grant, was by no means overlooked in my original papers, for I was constantly insisting upon the importance of these substances, while on page 90 will be found this passage:—"Thus, under both theories, albuminous matters are substances of importance, they are the agent of change according to one, the support of the active agent in the other." But, while justifying myself so far, I must confess that at that time I had no idea how such a statement might be enlarged upon. If quantity is an important factor, if excess of albuminous bodies is of moment (and who can doubt it?), the existing state or condition of these bodies is a thousand times more important; and no shadow of doubt exists in my mind that, while in one condition albumen may act as a perfectly natural aliment for healthy yeast cells, the very same matter, in a different condition, may, and does, act as the support of a ferment of disease. It may be asked, Is there any direct proof of this? I can but reply that any one acquainted with microscopical work can test this subject for himself. Two malts are taken, mashed with hot distilled water, and the resulting wort allowed to ferment spontaneously under certain and similar conditions. We observe this wort under the microscope; that from one sample of malt teems with the diseased ferments, while the other exhibits no such sign. What are we to conclude? May we not say that in one case the alimentary food of the ferment is unsuited to its healthy reproduction? and, since the most essential food is of nitrogenous type, may we not say that there is some difference in its condition? The actual proof of this statement is difficult; but I feel more than hopeful that the solution of this wonderful problem will be arrived at, while for the time it must be accepted as a statement of the most extreme importance. Once having mastered my argument so far, we may well turn to a brief review of the influences, practical in origin, which bear upon the purity and healthy character of yeast, not perhaps, directly, but indirectly, in preventing the appearance of, or the reproduction, when already existing, of unsound types of yeast.

It will be understood, I think, now, why we must blame maltsters for many of the misfortunes brewers are subject to from their faulty work. What care they about the conditions of the albuminoids? If they exercise care at all, it is in limiting the quantity, and not the quality of these nitrogenous bodies, by selecting special types of barley, and vegetating freely; and thus, in spite of their care, many malts give worts having a decided tendency to undergo unsound changes, containing as they do the very constituents in a condition prone to facilitate such changes. This is seen in the case of slack malts. The condition of slackness has allowed a lactic acid change to result, and the malt in consequence never fails to exhibit the tendency that this presence of moisture has endowed it with. Re-dry it as you like, and yet the worts obtained will show a marked capability of supporting the reproduction of the lactic acid cell. Look, again, at the influence of waters. See, first of all, the wonderful property of the sulphates and certain chlorides in limiting the quantity, and, may be, influencing the condition or variety of the albuminoid food of ferment that is extracted. This influence of saline matter has long been known, but it is only quite recently that, by means of microscopical examination, the direct bearing of this influence has been accurately ascertained. And what does this bearing amount to? The beers produced with these special waters, saline in character, show a remarkable tendency to stability, coinciding with the non-appearance of certain diseased ferments—such as acid and putrefactive filamentary rods—in the cask deposit of a finished beer; while beers, on the other hand, produced with soft waters exhibit a tendency exactly the reverse of this, especially if the limit of attenuation is not based specially in reference to the necessity of eliminating, prior to racking, all excess of hurtful types of albumen which have been dissolved so copiously by the very extractive water in use. There is sufficient evidence in such facts as these to connect the life of the ferment with the quantity and type of food we submit to it, and it is in reference to this influence of quantity and condition of nitrogenous aliment extracted that the saline character of a water is chiefly important; for, although this saline character is sufficiently influential in its agency as regards flavour and spontaneous classification of produce, such points are as nothing compared with the bearing of a water upon the propagation of healthy cell life; and in this fact is seen, as I have previously pointed out, the reason why many practical men succeed sufficiently well so long as they have a characteristic saline water, while they are hopelessly at sea if such a supply fails, and the necessity arises for using one of no marked saline property. Turning, again, to the organic impurities of a water, we may say at once that here the nitrogenous matter is in a decomposing condition to begin with, and entirely unfitted for assimilation by healthy cells, exactly in the same way that diseased food would be unsuited to the healthy life of human beings, while the nitrates and nitrites, the very indices of organic defilement at a certain stage, encourage the growth of bacterial life in general, by affording, no doubt, that supply of oxygen which these ferments of disease actually require; or by fulfilling, on the other hand, the part of a saline necessity, since it is well known that ferments in general do actually require saline food, for if we attempt the preservation of yeast by washing, we find that its vigour and power of reproduction is sensibly diminished, on account of much of the saline matter—principally phosphates—being dissolved away. We might wade through a consideration of the influences of the other materials employed in brewing in connection with the required purity of yeast, but I could but urge the same fact over and over again—that, in our practical manipulations, in our selection of malt, hops, saccharine, and sugar, or in the standard of dry extract constituents we attempt to attain, we must keep the requirements of the yeast cell firmly fixed upon the mind. Many brewers wonder that the use of sugar should be so dangerous, and yet there is nothing to surprise one in the least, for all raw sugars contain but a small percentage of desirable alimentary matters or food of ferment, alongside with many types of actual disease already in active existence; again, actual *inversion* is necessary before such sugar is capable of being assimilated, and so yielding, by fermentation, alcohol and carbonic acid; while lastly, all sugars, of whatever type, especially in cases where hard saline water is in use at the same time, so upset the proportions of dry extract constituents which are alone suited to the vigorous growth and healthy reproduction of yeast, so tend in this way to complicate and render uncertain the results obtained during the various stages of our brewing operations, that the substitution of such matters for a really good sound malt constitutes a system of doubtful utility.

In spite of this, what do we find the majority of brewers doing—endeavouring to stamp out the diseased ferments from the yeast they derive from these sugar brewings? *Nothing of the kind.* We find them using this impure store again and again for pitching purposes, reproducing each time the evil in greater degree, till the yeast becomes not only the agent of vinous, but also of acid and putrefactive changes. If we are to improve practical brewing in England—and in many districts there is much scope for improvement—we must all give up the idea that yeast is a mere bye-product, by the use of which we induce the necessary vinous fermentation, and remember, once for all, that mere whiteness, vinosity, sweetness, vigour, and low acidity are no real tests of microscopic purity, and that to keep our processes practically perfect we must continually strive to retain the standard of microscopic purity, upon which so very much depends. I put in this way a most essential requirement, since this microscopical purity of yeast can never be attained in its entirety; *it is a question simply of degree.* At one end of the scale we see the purity of a Burton yeast, where the greatest care is taken to cultivate and purify the store by a process of selection; at the other we see the types of yeast that are produced where soft water is the solvent, and a raw unrefined sugar, used in excess, one of the materials. If stability of produce is not an essential requirement, then, so far as mere business expediency is concerned, purity of yeast becomes a matter of secondary importance, although both the colour and flavour of a beer depend upon it, but in cases where produce is expected to retain its characteristic soundness for months, to undergo a series of frets, and yet improve in flavour and character, what but disaster can result from ignoring such facts as I am trying to set before my readers—disasters that find the unfortunate manipulator utterly at a loss to solve their cause or to remove the evil, even if it were apparent to the eye?

This subject might be enlarged upon at much greater length; but it would be impossible to put it in more complete form, unless I could make detailed reference to the different types of disease as they are portrayed in the diagram reproduced from "Études sur la Bière." To do so I should have to use microscopic terms, and dip somewhat too deep into the subject for the patience of my present readers, although I shall refer to it again before I bring my Appendix to a close. Those who view in my statements the outlines of a subject they would desire to master as a whole, will in Pasteur's work find all the knowledge that they require; and this will be possible, since I myself hope shortly to have the honour of publishing an English version.

It now remains for me to draw attention for a moment to influences that arise during the progress of fermentation itself, and to point out, step by step, the methods a brewer has at command for staving off the evil which may arise from oauses beyond his control. We can see, I think, why oleanliness becomes of so much importance, sinoe dirt in any state or form means either one of two things—a oonglomeration of germs of disease or else the aliment of diseased ferments. In removing dirt there is nothing so efficient, perhaps, as the application of *scalding* liquor, but for wooden vessels a mixture of lime and chloride of lime acts as a very efficient scouring material, the chloride of lime also burning up any impurities it comes in contact with; although, while speaking of this agent, I must remark that care must be exercised respecting the use of lime, as it most certainly has an injurious influence on the character of yeast which comes in contact with it. It will thus be seen that I have modified my original view respecting the use of lime in the crude state; the microscope, in short, has taught me much, and I see that, by its strong alkaline quality, it tends to encourage the growth of unhealthy cells, *though effecting the semi or complete neutralization of the normal acidity of a wort or beer*, so in this Appendix I simply suggest its limited use as a scouring agent, while I shall refer to substitutes for it in a later passage.

What is the influence of temperature, and how is it modified and counterbalanced? is the next question that suggests itself.

The influence of a high temperature is to encourage the growth of false ferments; in other words, the diseased ferments are actually inactive and torpid at a temperature of 50°, whilst at 70° and over they become more and more vigorous.

We remember, I suppose, Liebig's idea of Bavarian bottom fermentation—how during its progress at temperatures below 50° the albuminous matter might undergo oxidation and become eliminated as yeast, without any danger being experienced through a possible oxidation of alcohol to aldehyde and acetic acid. But now, I fear, we have to view this matter somewhat differently, for we know that at the low temperature named our produce is safe, since no ferment capable of producing any action of deterioration can at such a temperature exert its influence. If this is so, how is it that at certain centres of successful brewing, where temperatures during fermentation exceed even 80° Fah., the results are yet most satisfactory? This, again, is a point sufficiently easy to explain, *for we have, fortunately, more than one method of controlling the ferments of disease.* They are naturally rendered torpid by lowness of temperature; while their rapid reproduction can, at any rate, be rendered improbable if we cut off one of the essential matters that constitute this possibility of reproduction. I have explained more than once that this matter is nitrogenous food, in a condition, of which we absolutely know nothing; and how certain saline bodies act, as we may express it, as purifiers of our worts by limiting the quantity or influencing the quality of such alimentary matters as are naturally extracted from malt, and thus you will, I think, invariably find that in centres where these high temperatures are in use, and where the produce is uniformly stable, there also will the water be characteristically pure and typically saline. Sodium chloride, or common salt, is, in short, almost as powerful in this respect as calcic and magnesic sulphate; and yet brewers are unable to profit from this preservative action, on account of the absurd idea prevalent among the ignorant that a few grains of salt per gallon is injurious to health; while the brewer who tries honestly to improve his produce by the addition of minute quantities of salt, in view of the active influence of such matters as cause deterioration in yeast, and the unfortunate deficiency of saline matter in the brewing water, is regarded by the public as a man carrying on a system of fraudulent adulteration!

But, if we cannot procure special waters, and are obliged to carry on our attenuation at a high limit of temperature, in order to attain a certain flavour, have we no means at command capable of aiding us in preserving the purity of yeast? To a certain extent no doubt we can keep clear of danger by striving to diminish the quantity of albuminoids in our finished beer; by carrying on such a system of fermentation as will allow of the nitrogenous matter being removed, among it we may hope, indeed, that portion of albuminous matter most capable of supporting the type of ferment life we desire to see absent from our deposit in cask; while, as a further step, we may adopt the use of certain preservative agents, the two most important of which are salicylic acid and the calcic bisulphite—at least these are the two most important in view of the remarks I shall make in the final section of my Appendix—but even then the difficulties experienced in keeping up standard purity of yeast where pale malt alone is in use—under the solvent influence of a soft water—are very marked.

In my original essays I broached the idea that preservatives, to be powerful in preventing unsoundness, must in themselves have a strong affinity for oxygen; and this, no doubt, held perfectly true so long as Liebig's view of fermentation held good, while even now I do not imagine that such an idea could be easily upset, for there is no doubt that oxidizing agents are fatal to the soundness of a beer, *not* by causing the oxidation of the alcohol so much as by affording the necessary supply of oxygen for the support of diseased ferments; and we may justly argue from this that, if we place in beer such an agent as calcic bisulphite, we stamp out disease by cutting off the ready supply of free oxygen. It is more difficult to explain the action of salicylic acid, which probably exerts the same preserving influence in a different way, both agents, in short, acting as absolute poison to acid and putrefactive bacterial life. From this point of view it is difficult to understand how "sanitas" can act as a beer preservative, when we know that its chief active principle is peroxide of hydrogen, a very powerful oxidizing agent; in short, an agent, as it seems to me, quite capable of inducing the speedy formation of aldehyde and acetic acid, even if it does not facilitate the life of diseased ferments. But this is a matter that each brewer can settle for himself on the lines that I am at once coming to.

In the same way that the last act of a drama is supposed to contain the climax of the plot, so I am wishful that the last section of my Appendix should contain the most interesting and valuable addition to the information that was contained in my original papers, and I intend that it shall be in the form of a brief description of the method that is employed by scientific brewers for proving to their own satisfaction that the statements of M. Pasteur—statements which I have tried to put before you in simple manner—are in reality all they claim to be—that the causes which produce deterioration in beer are to be found in the deposit that settles from it. The outline of this method is shadowed forth in "Études sur la Bière," while much of the practical manipulation that I must explain has been worked out by my friend Mr. Clifton, who was one of the first, if not the very first, to recognize the great value of Pasteur's work, and to carry out many of its suggestions in a practical and yet scientific manner. The principle of this forcing test, as it is styled, is to submit, under certain conditions of time and temperature out of direct contact with the atmosphere, wort, beer, or yeast that we wish to experiment upon, finally solving the problem of stability, healthiness, and purity by a careful examination of the deposit by the aid of the microscope. If this beautiful process is conducted with due care we can tell at a glance *the tendency* of the matter under examination, and predict with the greatest certainty the future of fluid, and of the dry extract contained therein, that we are critically examining.

I purpose first of all entering into a brief description of Pasteur's statements and the diagrams that I have reproduced from his most recent work for the purpose of illustrating these statements or rather the truth of them, in such a way that my after description of methods of manipulation suggested by the same savant may the more likely prove of greater interest and far greater practical utility to students of modern brewing. The chief statement I wish to impress most earnestly upon the attention of my readers is, that deterioration in wort and beer coincides with the presence in the deposit therein, and is due to the action, of diseased ferments. This seems sufficiently important, but Pasteur by no means stops here, but follows this statement up by actually determining *the variety of ferment* that corresponds with each kind of deterioration. It would have been sufficiently easy to make a theoretical statement of the kind sketched above, but few could over-estimate the brilliancy of experimental research, the patient labour, the true confidence overcoming apparent contradictory results, that must have been expended in determining the different varieties of ferments, their size, or rather relative size, their distinctive character, their mode of actual life, as I may express it, and the essential conditions of their development, while few of my readers will deny that something more than thanks is due to the author of that wonderful work on beer, that contains as a storehouse the vast scientific question of the day, mainly in reference to its bearing upon practical brewing.

The chief charm of the work, to my view, seems to concentrate itself in the beauty and artistic merit of plates illustrating the statements and arguments of the writer of "Études sur la Bière," since these illustrations have of a certainty enabled each tyro in microscopical work not only to detect the evil ferments, but to go a step beyond and work out the cause of disease.

The truthfulness of these microscopical fields will be apparent to each manipulator who, after reading my Appendix, puts its communicated knowledge to a practical proof. It is no easy matter to picture a ferment of disease with all its original distinctiveness of character; few could picture them as we find them in the "Études" that I am speaking of, and hence it is—in view of the importance of such illustrations—that I reproduce in this enlargement of my little work such, as I know will prove of the greatest service to those who, being wise in time, accept the microscope as a practical working instrument.

What nonsense it is to hear men speak of the microscope as too refined and delicate an instrument for ordinary brewers' use; for, in truth, if such men could only look at the scientific aspect of practical brewing they would willingly allow that the investigating lens stood as a gauge of quality in one direction, even as the saccharometer is the measurer of it in another, and I do not go too far in saying that in a brief space of time—a year or so, perhaps, will suffice—

the microscope will be as universally in use as the saccharometer is at the present time, for the only barrier to its employment now is the very one that I hope to myself remove—the ignorance existing as to the source of the necessary information for not only working with it, but for making its indications of true practical utility.

My object just now, however, is not to explain the manipulative detail of the microscope, so I pass at once to a simple description, in the words of Pasteur, of the different ferments that we may come across in our microscopical working, so that when viewing our pitching yeast, our worts, or the deposit from our finished or stored beers, we may refer to our representative plates, and determine at a glance the character of our microscopical field.

I reproduce, as I have said, three plates:—

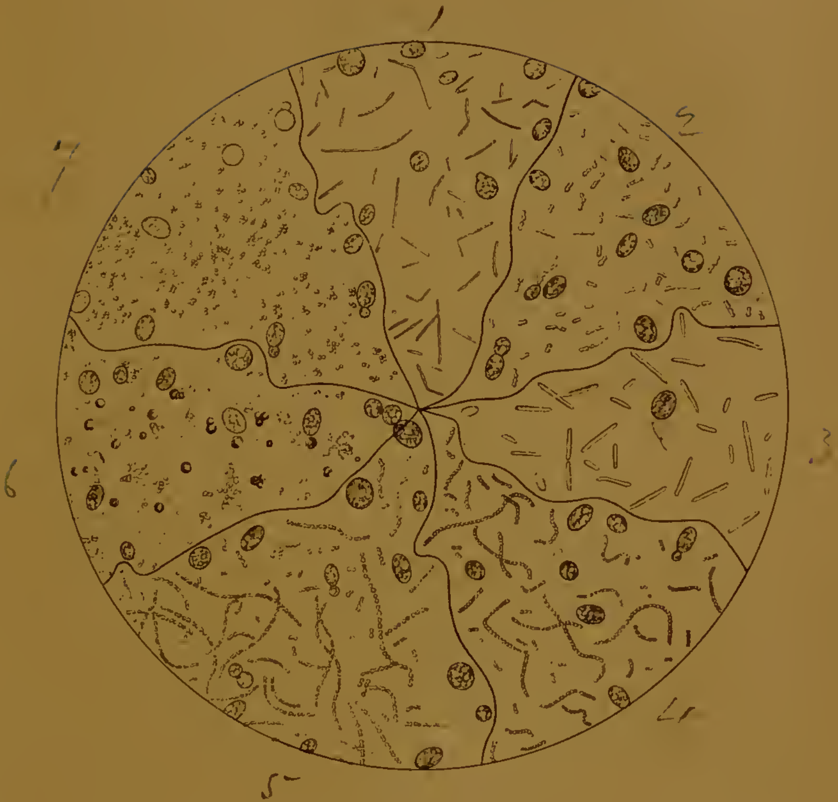
Plate No. I. represents the diseased ferments peculiar to wort and beer in seven sections.

No. 1. The diseased ferments of "turned" beer, as it is called. These being filaments, simple or articulated, forming chains of different size, and having a diameter of about $\frac{1}{1000}$ part of a millimetre. When observed through a glass of great magnifying power, they seem broken up into many series of shorter filaments, immovable in their articulations, which are scarcely visible.

No. 2. The lactic ferments of wort and beer. These are small, slightly made, and narrow, or pinched in the middle. They are generally detached, but sometimes occur in chains of two or three, while their diameter is greater than that of No. 1.

No. 3. The putrid ferments. These are vibrating filaments, whose motions are more or less rapid, according

PLATE 1.




THE PRINCIPAL DISEASED FERMENTS OF WORT AND BEER.

to the temperature. Their diameter varies, but it is for the most part greater than that of the filaments of Nos. 1 and 2. They only appear in the wake of very defective working.

No. 4. The ferments of viscous wort and beer which the French call *filante*. They form chaplets of nearly spherical grains. Such ferments rarely appear in wort, and still less frequently in beer.

No. 5. The ferments of pungent sour beer which possess an acetic odour. These ferments occur in the shape of chaplets, and consist of mycoderma aceti, which bears a close resemblance to lactic ferments (No. 2), especially in the early stages of development. But, in spite of this similarity, their functions, physiologically speaking, are widely different.

No. 6. The deposit of a wort, which must not be confounded with the deposits of diseased ferments. The latter are always visibly organized, whilst the former is shapeless, although it would not always be easy to decide between the two characters if several samples of both descriptions were not present. This shapeless deposit interferes with wort during its cooling. It is generally absent from beer, because it remains in the hop backs or on the coolers, or combines perchance with the yeast and disappears with it. Among the shapeless granulations of No. 6 may be discerned little balls of resinous or colouring matter that are frequently found in old beer, in either cask or bottle.

Finally, No. 7. The ferments present in beer of very peculiar acidity, which reminds one of unripe acid fruit, with an odour *sui generis*. These ferments occur in the form of grains, which resemble little spherical points, placed two together, or forming squares. They are generally found with the filaments of No. 1, and are more to be feared than the latter, which cause no very great deterioration in beer *when alone.* When No. 7 is present by itself or with No. 1, the beer acquires a sour taste and smell that render it detestable. It is, without doubt, a most fatal ferment of disease.

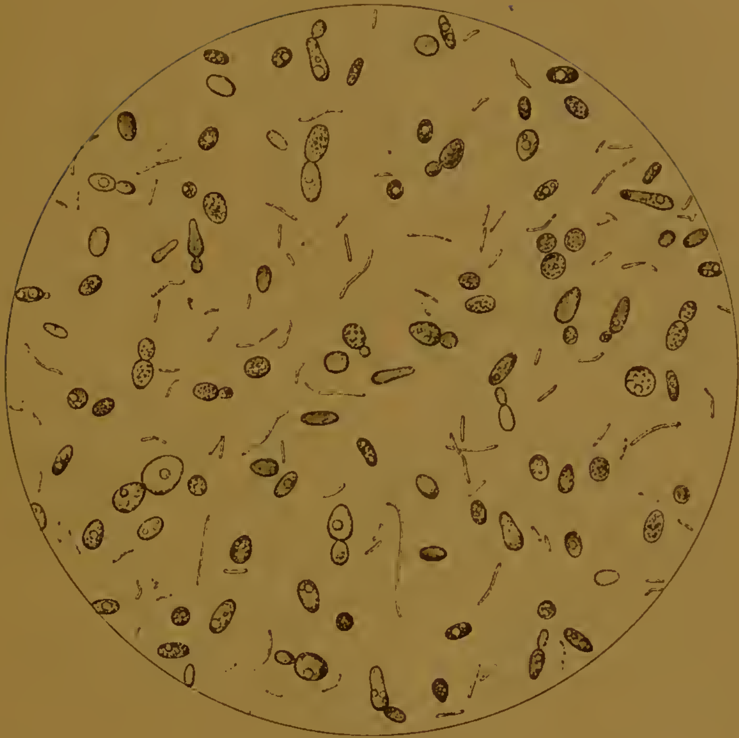
Plate No. II. represents the deposit of a "turned" beer—the deposit of a beer that is going off.

Plate No. III. represents the gradual growth of perfectly healthy torulæ—I say perfectly healthy, since it is seldom or never that such a "field" is seen in the examination of ordinary brewery yeast, such store being only comparatively pure.

It ought to be mentioned that the sectional divisions of Plate I. contain cells of alcoholic yeast, in order to indicate comparative size.

Now, we require to know, say, the daily character of our yeast, or we desire to select portions of our supply as are most suited for pitching purposes; but, before advancing, I must qualify the word "select," as in breweries where slow fermentations are in progress there is some little difficulty in making any selection, since the whole of the yeast and impurities are intermingled and exist in combination on the surface of fermenting wort till the skimming point is reached, when all is taken off together, little, indeed, being left for the succeeding skimmings. This is the qualification, and it means a great deal. But let me turn for a moment to the more satisfactory picture, and explain how the *selection* is accomplished in breweries where ordinary fast fermentations are conducted. It is, I presume, a well-known fact that little or no yeast is eliminated during these fermentations prior to the skimming point which, on

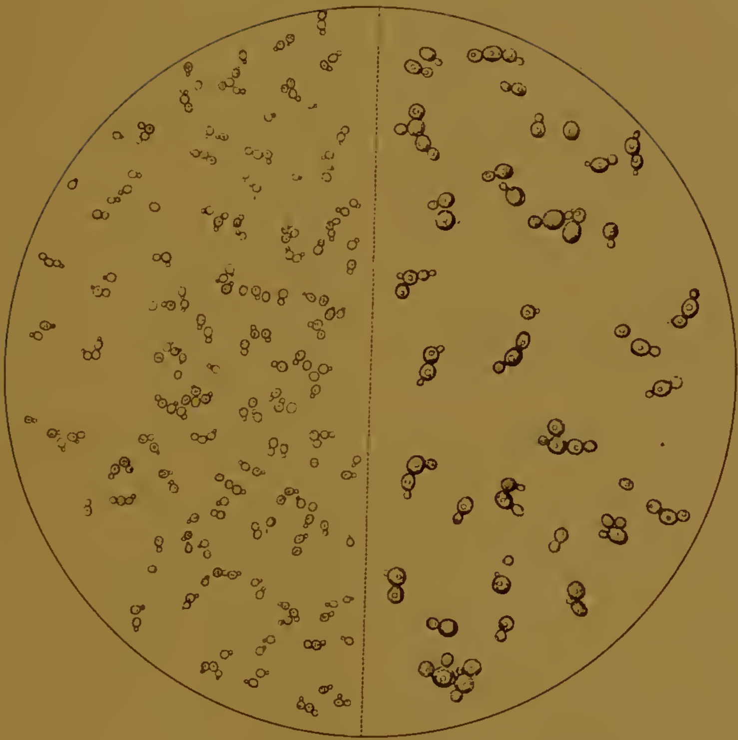
PLATE [illegible]



THE MICROSCOPICAL ASPECT

OF THE DEPOSIT OF A "TURNED" BEER

PLATE 3.



YEAST CELLS OR TORULÆ
IN PROCESS OF DEVELOPMENT

account of the rapid attenuation, is fixed very high; so that, as the gross matters held in suspension are thrown off with the first and second skimmings of frothy yeast, each succeeding crop must not only increase in thickness and quantity, but also to a remarkable extent in character and microscopical purity; so that it becomes easy for a careful manipulator to determine when the individual skimmings have arrived at that standard of purity that he accepts as his working standard.

Now, if we study Plate I. we shall soon be able to make ourselves familiar with such types of disease as are usually met with in beers when undergoing any action of deterioration; and thus, if we detect such ferments as are there so graphically sketched, among our pitching yeast, or detect them in any excess, it is time, surely, to commence an attempt at purification, or change our store from some source that we can depend upon. Let us ponder for a moment to examine such microscopical signs as are of importance when examining the character of a yeast, so that we may the better judge of the immense value of these reproduced plates from "Études sur la Bière." The yeast, mixed to a state of great dilution with very pure distilled water, to which a little glycerine is added, is dropped upon the object-glass, and carefully covered with circular covering slip, so as to expel all the air, any excess of fluid being removed by the skilful application of a slip of blotting paper. Placing our specimen on stage, and bringing our field into perfect focus, we examine carefully and intently the field that we see by revolving our supporting stage, so as to determine with certainty the general character of cell life; while, to do this effectually, the number of cells per field should not average more than twenty or thirty. We glance first at the general character of our yeast. The cells, round or oval according to character of water supply, should be clear, of even size, and, according to age, contain plasmatic "bags," or developed nuclei. Unevenness in size is always a sign of what I will call a weak yeast, a yeast that feeds unequally, while any granulated appearance means either a very old yeast or a ferment that has been living on itself, which is one and the same thing almost, or one that, by careless work, we are gradually starving out. You cannot feed a human being upon sawdust, and, in the same way, it is simply impossible for a yeast cell to flourish upon much of the food that brewers, in their perversity, insist upon submitting to it. This done, we search carefully for impurities, more especially for those that are typified in Sections i., ii., iii., Plate I. Lactic ferments we are sure to find; but, if in excess, they are the signs of most careless malting or faulty mashing if the parent store was free from such germs of unhealthy ferment life. But these are as nothing compared with the dire influence of ferments of Sections i., iii., and vii. In Section i. we see the acid and angular filamentary rods slight and sharply defined, energetic in the extreme when developed, and fatal in their significance when in such a state. In Section iii. are sketched the bolder, non-angular rods of putrefactive change, the evidence of actual decay in the materials we employ, in the wood of which our fermenting vessels are built, or of actual deterioration in character of yeast supply.

It would be an insult to brewers to suppose, for one moment, that they would knowingly employ yeast which contained developed ferments of other types, as portrayed in Section iv., v., and vii. No doubt the germs may be there, but to have these germs actually developed would mean, I think, somewhat more than careless heats, unbalanced dry extract proportions, and general faulty work. Our practical aim, therefore, must be to keep our yeast free from types i., ii., iii., and I can assure my readers that the employment of good malt, pure saline water, and careful manipulation, combined with perfect cleanliness, will ensure such a result being arrived at, so long as the practical operations are skilfully conducted. Let any one examine a good Burton yeast, and they will see at once the truth of this last statement; but in many districts it is quite impossible to arrive at such purity, and the question therefore arises—What amount of impurity can be allowed, and what means have we for improving matters when improvement becomes a necessity?

I personally regard the presence of developed diseased ferments as a sign that ought to generate extreme anxiety. I detest the sight of an angular filamentary rod, and I get frightened when I see *not* dormant but active living cells. It is useless to employ such yeast with the vain idea that it will naturally improve; certainly it might do so in a perfectly pure wort by perfect culture, but practically such improvement is rarely effected, since an ordinary wort contains the food of all types of ferment life, and it is difficult, indeed, to stamp out these active agents of deterioration when once they have secured foothold in our "store;" and under such circumstances it becomes necessary to adopt some extreme measures in order to avoid the train of evils that are sure to spring from the employment of pitching yeast of doubtful quality, especially so if the water supply to the brewery is of that deficient saline character that ensures the production of worts overladen with nitrogenous constituents.

What better step can we take than to cease all brewing operations until every trace of store in use can be got rid of, and until every vessel in the fermenting and cleansing department can be effectually freed from germs of disease by a course of cleansing with chloride of lime, followed by fumigation with sulphur or treatment with calcic bisulphite. This done, a successful result again becomes possible if a start is made with a parent store that can be depended upon, so long as this does not become immediately contaminated by grave imperfections in character of water supply or the malt in use.

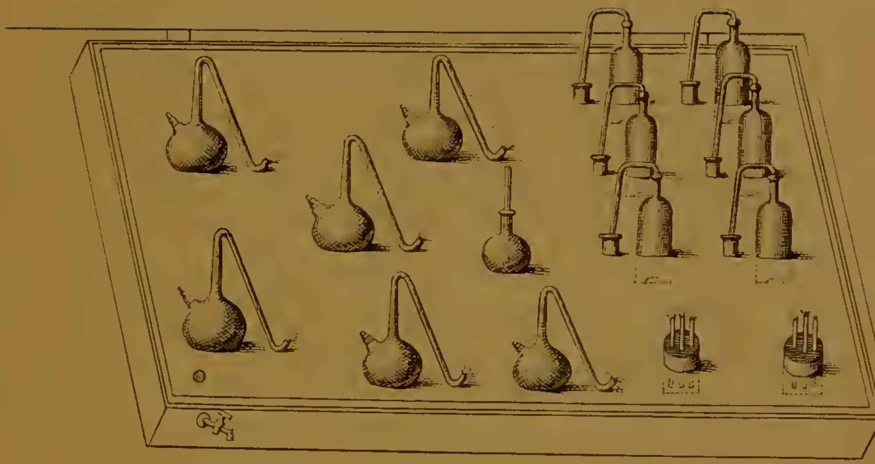
This view of the case is perhaps too serious, and we will suppose that our yeast supply is only slightly contaminated. Under these circumstances the careful, yet *intermittent* use of salicylic acid during fermentation often works a wonderful purifying action; for to give this antiseptic agent its due, it is, perhaps, the most powerful material that I know of—excepting, perhaps, carbolic acid—for effecting the practical purification of yeast. Its influence is apparent to any ordinary observer; no filamentary or lactic ferment can flourish in its presence, and if not overdone, I am confident that its use will prove beneficial; but in saying this I must add, that on no account must its use be continuous, unless we can microscopically determine when its influence on the vinous or alcoholic cells is also getting too potent.

As for the weak, granulated, or emasculated yeast, this may be improved and cultivated by submitting food that the yeast can easily assimilate—not cane sugar, for instance, which has a fatal influence when used in excess, but maltose and healthy albuminoids—under the influence of a moderate and suitable temperature. This surely is information that is practical enough, but still I will go a step deeper and raise the interest of my readers sufficiently to induce them to work out the knowledge that will enable each to conduct personally these refined, important, practical, yet highly scientific experiments.

If it is important to know the real character of a yeast, surely also it is important to know the tendency of a malt, and to gauge the future stability of a beer. If this be acknowledged, I think that I can easily explain the means of determining such complex problems in a way quite distinct from any process previously explained in print; while if I am asked from whence I derived the inspiration for this scientific work, I frankly reply from Pasteur's "Études sur la Bière," although I fear that alone I should have fallen far short of successful results if it had not been for the cordial co-operation of my friend Mr. Clifton, who has ever been devoted to the study of scientific questions connected with practical brewing. The suggestion that set me working at the question was simply the statement that the deterioration of a wort or beer coincided with the appearance in its deposit of certain diseased ferments, *these ferments being in themselves the absolute cause of the deterioration*, and not, as *some* writers suggest, simply the index of the change. Hence, if we can submit our beers under certain conditions to a *forcing* temperature, we can determine *its tendency*—the tendency of its nitrogenous constituents—with the greatest ease and certainty, and thus determine in a few days the result that will arise from lengthy storage at home or shipment abroad, for we can *see this tendency* of life and the food of life in the deposit which subsides, and thus write *the future* history of any beer submitted to this test. In the same way also we can determine the stability of a malt—its tendency, as I prefer to express it—and it needs but a thought to understand after this the means at hand for determining for ourselves the practical value of the many antiseptic agents that are so boastfully advertised for the use of brewers.

Let me carefully explain this subject in detail, in order that each reader of my little work may see for himself the value of these beautiful experimental researches that are the practical outcrop of Pasteur's brilliant work. If we turn to our illustrations we shall see an arrangement of trays—forcing trays as they are called—each tray constructed of tin, being properly supported, and containing water, which is retained at any desired temperature by a single gas jet, as shown in sketch. On the top tray, A, we see: (1) growing flasks, as they are called, the outlet end of long bent neck being closed with a plug of cotton wool; (2) ordinary beer bottles standing in "pockets," and connected with bent glass tubes with the mercurial trough, or dipping simply into a small beaker of mercury; while (3) at the right-hand corner of tray we see another "pocket" arrangement tenanted by test tubes, each tube being plugged with cotton wool.

On the lower tray, B, we see the ordinary "forcing flasks," ranged in series round a central reservoir of mercury, the outlet pipe of each flask being connected to angular tube dipping into mercury, while the next

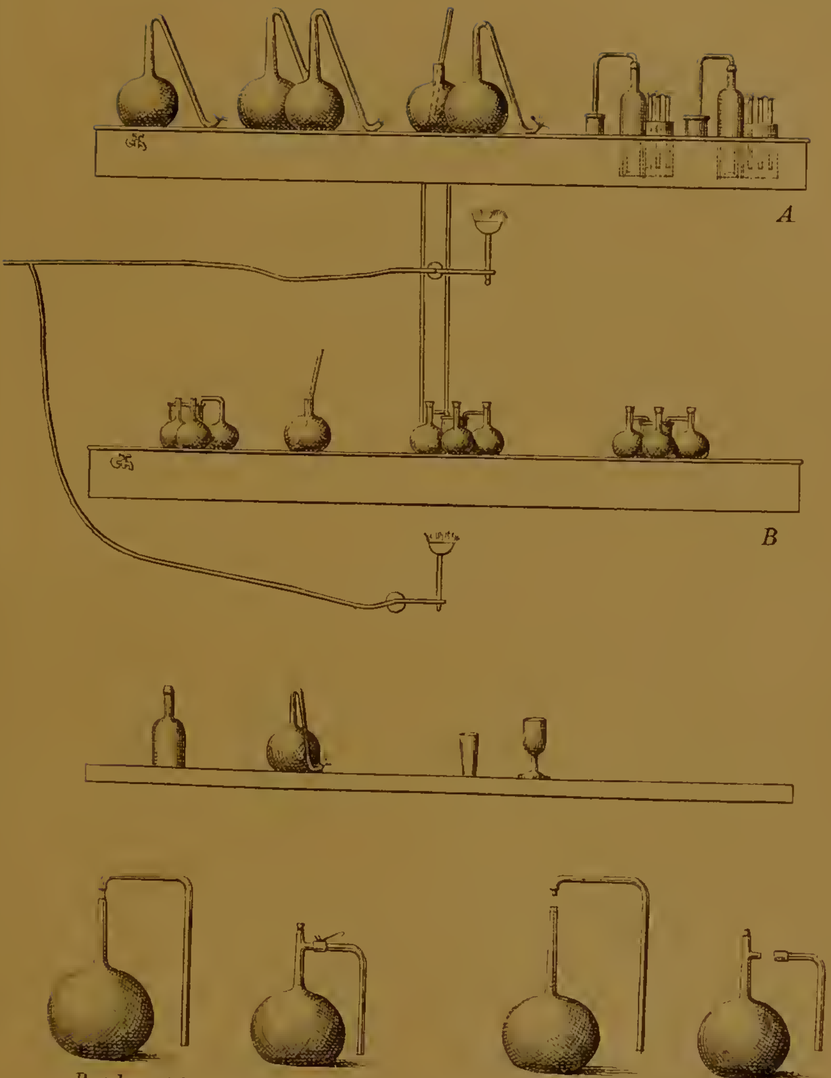


*Top Tray A*

*Bottom Tray B*

"FORCING TRAY" ARRANGEMENT

FRONT VIEW.




*Bottles with Tubes attached* *Bottles with Tubes separated*

"FORCING TRAY" ARRANGEMENT

(DETAILS)

illustration shows us a front view of the same trays, A and B, with gas arrangement below; and following this we have an enlarged representation of the forcing flasks, showing the way in which the bent tube is attached, while on each tray, to be precise, is seen a a small thermometer standing in a flask of water, so that temperature of beer in forcing flasks of similar size may be regulated with certainty. Filling our trays with water, we bring the temperature to the standard required—generally 75° Fah.—and allow it to steady for a few hours (since no irregularity should be permitted even when the experiments are continuous), and we then proceed to ask ourselves what the problem is that we wish to determine?

We desire, say, to ascertain the truth of Pasteur's theory. It is proved, I think, in the most simple manner. We take a "growing flask," perfectly clean, sterilize it by boiling a little distilled water therein, and then half fill the flask with filtered first wort from hop back. Again applying heat, we cause rapid ebullition to result for a few moments, and, as the steam is blowing from end of bent outlet-pipe, we quickly withdraw the flame, and at the same moment plug up the two outlets, the one on left hand side of bottle with a sterilized glass stopper with india-rubber connecting-joint, and the bent end of outlet-tube with a slight plug of cotton wool which has also been previously sterilized by exposure to steam heat, the plug of wool not being so tightly inserted as to stop the ingress or exit of air, *but only to filter it.* The forcing flask is now placed on our tray, and may remain there for ages without any sort of change resulting, and yet every one must know how prone such a wort with its saccharine and nitrogenous constituents must be to undergo rapid deterioration and decomposition if left exposed at the temperature of our water tray to the ordinary atmosphere. How is this? Listen for a single moment. The wort boiled in forcing flask is sterilized, all germs of ferment life it may contain being destroyed by the temperature of ebullition, but "Liebig's ferments," the oxidizing albuminous bodies, are still there, and air is present as an agent of oxidation. Yet no change results. Can any one doubt for a single moment that oxidizing albuminoid bodies are quite incapable of directly, by means of a catalytic influence, causing fermentation of alcoholic type? but, on the other hand, can they doubt that the quiescence is due simply to the fact that the air, in filtering through the cotton wool, becomes deprived of its capability of inducing vinous change? If any lingering doubt remains, the confirmation of the theoretical statement is practically easy. Let the plug be withdrawn from the outlet-pipe, and we shall see that a scum that has remained quiescent for months will appear on the surface of the wort in the course of a few hours; while, if this same plug of cotton wool be dropped into another of the forcing flasks containing a sterile wort, the inlet into flask being immediately closed again, fermentation will set in in a very few hours. Facts such as these surely prove the statement that fermentation is due to ferments, that these ferments, or their germs, are ever present in the atmosphere, and that, if the atmosphere be filtered, it is no longer capable of causing fermentation to result in any organic fluid submitted to its influence. Such facts are quite beyond dispute—they are incontestable and yet grave in their significance.

We want, again, to determine the true character of a yeast even more accurately than a mere mieroscopical examination can do.

We take one of the "growing flasks," the eontents of whieh have remained unaltered for months, dip a fragment of sterilized platinum wire in the specimen of yeast we wish to experiment upon, and, withdrawing the plug from inlet-tube of flask *for a single moment*, we slip in our fragment of wire with its adhering film of yeast, and immediately replug the opening. It would be unfair to expose the yeast to sueh a temperaturc as 75° Fah., so the glass is removed from the tray and plaeed in a eool atmosphere, so that fermcntation may gradually result. The wort in whieh the yeast has been plaeed was itself pure and free from ferment life of all kinds; and so in the yeasty deposit whieh subsides we see the direet and unmistakable evidenee of the eharacter of the yeast added. We examine the deposit side by side with Plate I., " Études sur la Bière," Figure I. of our illustrations. We seareh for the evidence of disease, and, failing to find them, we demonstrate the absolute purity of the yeast, or otherwise, the *tendency* of its aetions.

Again, we desire to determine the general character of a malt. Let us take some large test tubes of 200 c.e. eapaeity, boil in them a little distilled water, allowing the steam to foree its way out through the eotton plugs that have been lightly inserted. Emptying away the water, we introduce a spoonful of crushed malt, fill tubes to two-thirds their full content with distilled water, re-insert the cotton plug, and immerse the tubes in a water bath standing at a temperature of 155° Fah. for three-quarters of an hour. This is, in fact, a miniature mash, and, when complete, the tubes are placed in the pockets of trays, as shown in the illustration of top tray arrangement. The wort is microscopically examined in 48 hours, and the comparative condition of that wort is a sure index of the tendency of the sample of malt that we are experimenting upon. It is, of course, sufficiently easy to make a standard of purity for ourselves by testing a malt of the finest make, as suggested above, accepting the microscopical character of its wort as the basis of decision in succeeding experiments. So far, surely, there is nothing to bewilder the ordinary reader, and I trust that all that follows will prove as easy to grasp as it will be interesting to read, for it is a description of a process very intimately connected with practical operations.

We desire to determine the *future* character of our beer and the value of the various preservative agents, the two determinations being jointly considered, as they run together almost hand in hand.

The first step in the actual manipulation is as follows: —We sterilize in the way before described the flasks that we are going to collect the beer in we are wishful to experiment upon, care, of course, being taken that the beer is bright and drawn from cask through a freshly-bored peg hole instead of through a tap with its adhering mould, the flask being immediately closed by an india-rubber stopper. It is thus seen that everything used, beaker, measure glasses, bent glass tubes, and more especially, perhaps, the forcing flasks themselves, must all be sterilized, either by boiling water in them or holding them (such as can be so treated without breaking) in a strong Bunsen flame for a few moments. The samples being duly collected, all is now ready for the operation of filling the flasks themselves, and in this operation extreme care and nicety must be observed.

The little flask is taken and half filled with distilled water, an india-rubber cork being inserted in upper outlet and the side outlet connected to a shortened 50 or 75 c.c. pipette by means of an india-rubber tube.

This arrangement complete, the flask, clipped by a proper holder, is held over a Bunsen flame; ebullition quickly results, the steam rushes out of flask through side outlet down india-rubber connecting link, and makes its exit through the attached measuring tube. Everything is thus quickly sterilized, and then, by a sudden twist of the hand, the flask is inverted so that the whole of the fluid contents are ejected, this being partly effected, of course, by the steam pressure. Immediately clipping the india-rubber connection between the thumb and first finger, we plunge the free end of the measuring tube well below the surface of the beer we are experimenting upon. Instantaneous condensation of steam in flask results, and the tube becomes filled with beer, and, by gradually manipulating the fingers which clip the india-rubber connecting pipe, we allow the beer to be sucked into the flask itself. If manipulation is successful, the flask will fill, but not so if the beer is very gaseous and frothy. Under these circumstances, when suction ceases, the supply tube may be withdrawn from beer, turned up so as to become a supply fountain, while the india-rubber cork of flask is loosened for a moment. Beer flows in to fill the bottle within a short distance of side outlet; and, if this little manipulation is carefully conducted, no injury to experiment, or rather to its accuracy, results; since, while outward pressure from the flask is in force, no entry of ferments can take place. When forcing flask is properly filled, the india-rubber cork is again tightened, the india-rubber connecting pipe again clipped while we disconnect measure tube and substitute for it the bent tube, the outlet end of which dips into the mercurial trough, no relaxation of clip on pipe being allowed until the bent tube is duly connected with flask and immersed in the mercury. With a little practice, this filling process becomes very easy; but it will be evident that everything really depends upon the skill expended in filling these bottles so quickly and accurately that no entry of germs with fluid can take place. The arrangement of forcing flask, connecting pipe, and beaker of mercury is now placed on the trays, and the result is as follows:—The beer contained in these sterilized flasks, out of contact with the atmosphere, undergoes fermentation, the gas evolved escaping through the mercurial fluid, which allows no entry of air; and thus, in a period of either fourteen or twenty-one days, according to the character of the brewing water—beers produced with soft water being, as a rule, of inferior stability—we may carefully examine the deposit from each forcing flask, and determine with the most complete accuracy the tendency of the beer in question.

Plate III. shows us the aspect of the deposit of a "turned beer;" our deposit, therefore, in our forcing flasks should be free from these filamentary rods—entirely free, if the beer is to withstand export influences—although I cannot pretend to lay down any hard and fast line upon this part of the question. It is, however, in the power of each manipulator to fix upon a standard for himself, determining, in fact, the microscopical appearances which coincide with the practical results of lengthy storage. The forcing experiments mean this: The germs of all ferment life are present—nitrogenous food also of variable type—the temperature of incubation facilitates the reproduction of ferment life, while the quantity and condition of the albuminoids determine the type; and thus, by carefully examining each field, and comparing the appearances with the sectional divisions of Fig. I., we demonstrate most successfully the future tendency of the beer as sketched in its existing deposit.

In determining the value of preservative agents we proceed in the same way, putting on our trays a series from each gyle of beer we are testing; and in point of fact it is usual at all times to put a *series* of samples down in our forcing flasks, as a single specimen of deposit would not be a very reliable index, or, at least, not a result to be considered as final, since some accidental contamination, through faulty manipulation, might lead us to doubt the stability of a beer experimented upon if only one sample of that beer is treated; but if we put down a series of four or six, there is, of course, far less chance of a faulty judgment being arrived at, for if the first sample of deposit we examine is either exceptionally good or bad, we confirm this result by a further examination of the other deposits of the series. Now, the various preservatives may be thus added:—Half a litre or 500 c.c. of beer contained in a sterilized beaker is treated with 1 c.c. sanitas, another half litre with 1 c.c. calcic bisulphite, a third with ·05 gramme dry salicylic acid, and a fourth with 1 c.c. Gillman & Spencer's preservative, and we duly fill four forcing flasks from each half litre so treated in the way previously described, while for comparison a series of flasks are filled with the same beer untreated in any way. Exposing these on our trays for fourteen or twenty-one days, we microscopically examine the deposit in each, and learn at a glance the power that each preservative exercises over ferment life.

Such, then, are some of the interesting studies that Pasteur submits; deep as they are in their theoretical significance, they are equally potent in practical use. Chemically, no doubt, we can discover the extract constituents of a beer, we can analytically determine the variety and quantity of acid contained therein, and by the eye and palate we can form a judgment as to the existing flavours and condition. But what of the future? Can we, by any one of the chemical agencies named, predict with absolute certainty the future of a beer uuder the variable conditions of temperature and the trying influences of export shipment? So far we certainly cannot, but years hence the secret may be mastered; but even now we have this wonderful forcing system ready to hand; we have all the boundless knowledge contained in "Études sur la Bière" to guide us in our researches, and we have the never-failing microscope to show the peculiar and ever-potent agency of albuminoids in their influence on ferment life, or to bring in view the results of that influence in the deposit of a beer. It was Liebig that first taught us the influence and high importance of albumen as a beer constituent, and Pasteur has but deepened this importance by explaining how the whole character of ferment life depends upon the condition in which this albuminoid aliment exists. If all my readers will bear in mind that fermentation is due to vital action, if they will remember that there are phases of health and disease in the lowest type of cell, which we can moderate, encourage, or stamp out almost at will, then they will see how much the practical operations in brewing depend, in reference to success, on the influential bearing that they are likely to have upon the life of the future ferments. Those who have read the primary essays in this little book will see that I am no visionary or theorist, that practical knowledge is to me of great and ever increasing worth; but in spite of this it is impossible to work with a microscope, cultivate a yeast in a growing solution, or examine the deposit of a beer, without acknowledging that if there be any secret or mystery in brewing it is to be seen therein—a secret that can become the property of every student of brewing who will make "Études sur la Bière" his text-book, and who will carry out in all their integrity and refinement the experiments that I have so fully sketched.

One word respecting the illustrations that I have reproduced from Pasteur's work. These are, perhaps, not all that could be desired, but no method beside actual steel engraving could give the clear and beautiful outline of originals, and the price of this little volume would not allow of so expensive a process being resorted to.

I trust, however, that they will suffice for the purpose that I have in view, while I would ask those who take deep interest in this subject either to refer to the original work, or rest content until I can publish an English version of these "Études."

This, then, is the apology of my Appendix for the incomplete character of my essays. "Études sur la Bière" became my teacher and my guide in reference to the influence of albuminous bodies. My views on this subject became modified to the extent that in place of being the agents of change, they became transformed into the necessary aliment of cell life; in one state or condition the support of healthy ferments, in another the essential food of disease. For many months past, in "Occasional Notes" and papers on a variety of subjects, I have been trying to interest my readers in the theories that are so novel in the intensity of their influence. I shall continue to adopt this course; while in being asked to write an appendix of correction to my old essays—if there was any room for correction—what system of correction could I better adopt than by filling in a gap that existed, urging the vast importance of the germ theory, or by endeavouring to link our conduct of practical operations with the theoretical doctrines that ought at all times to be the foundation of them? It is a difficult matter to accomplish all this when space is limited, and when the majority of my readers care little for theoretical teaching; but as I have endeavoured to put this matter in a practical and interesting shape, let me hope that the success which attended the first edition of my essays, crude and unsatisfactory as they were, will no less accompany the second, for which this Appendix is written. Pasteur remarks that, "The greatest aberration of the mind is to believe a thing because we desire it to be." It is certainly not possible to read through his work and not believe the teaching so connected with Pasteur's name. We may be sceptics, quacks, and empirics, but no practical manipulator can in reality upset a single theory that Pasteur explains in "Études sur la Bière," a work which, unfortunately, is almost unknown to the majority of brewers. If it is the object of some men to ignore scientific knowledge, thinking mere practical experience is the only essential point, then I can understand the sneers of the many; but knowing what I do, I think that brewers should have the issue put fairly before them, for I have no shadow of a doubt that practical brewing operations will benefit so long as they are carried out in reference to the essential requirements of healthy cell life. There is no single practical operation not in direct connection with such life, and if my essays and appendix are read together I think no little advantage will accrue to the readers of the compilation.

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