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ON HOME-BREWING AND THE THEORY OF FERMENTATION.

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We are not advocates of the use of malt liquors, much less of the abuse of them; on the contrary, should be happy to believe that nine-tenths of the barley now employed in the breweries—private and public—were consumed as food, solid aliment, by man or animals. Excitement then would be exchanged for strength, and true economy would thus be consulted, and go hand in hand with improved morality.

But as malt liquors *are* consumed, and will continue so to be till man become more alive to his real interests, it is quite certain that a good and well manufactured beverage is to be preferred to one of doubtful purity and indifferent quality, in every sense of the word. Having had opportunities to investigate the process of one of the best private brewers of England, and practised brewing at home during a very long period, we are perhaps qualified to describe the operation with some degree of confidence.

It is usual to consider the condition of the malt as of primary importance; and assuredly, if this chief constituent be defective, it ought to be rejected as worthless. But it is to the water we must look, in all cases, as the extracting agent; for, be the quality of the malt what it may in point of excellence, if the water be deficient in extractive power, or otherwise chemically unavailable, good sweet wort, rich in flavour, capable of undergoing a sound and complete fermentation, cannot be obtained. This we have proved, and the fact is borne out by the very different characters which distinguish the ales of various localities.

The water employed by the friend whose process we above alluded to, was that of a running brook which terminated in a mill-stream. It was dammed up near the mill to give it bulk and power, and there formed a sort of head, or small quiet pond, which abounded with duck-weed (*Lemna*). So particular were the parties, that water-casks were sent from the distance of a mile or more to bring in a supply previous to the brewing. Of its chemical properties we can say nothing; but of its extractive power there could be no doubt, because the results were superior and of uniform character. The stream was pure and undisturbed; it was never interfered with by any species of manufacture, and therefore could always be relied on. There are, doubtless, wells of a similar character everywhere, and these should be carefully resorted to; for it may be assumed as certain, that the water of wells, of rain-tanks, or of stagnant ponds, are never to be relied on, and, in general, will disappoint the expectation of the brewer.

Malt.—Of the three varieties of this article, that which contains the greatest proportion of pure saccharine matter, and well adapted to the purposes of the domestic brewer, is the one termed Pale Malt. If properly prepared, each grain is tender and sweet throughout its entire length, and it yields its soluble portion with the greatest facility to good river water at a proper temperature. The density, or specific gravity, of a wort produced from the best pale malt is higher than that obtained from the other varieties; but by publicans and other venders of ale, the sort termed Amber malt is usually preferred: The wort yielded by that is of a rich amber colour, but is neither so saccharine on the palate as that of the pale malt, nor of so pure and fragrant an odour. 3. High-dried and *porter* malts are unfit for family brewing, and require extreme caution in mashing. We have witnessed the loss of an entire brewing by the setting of the mash, though the temperature of the water did not exceed that which is usually employed for ale. A person, therefore, who attempts to brew porter from high-dried malt must reduce the heat of his liquid at least 10 to 15 degrees; and, after all, he will fail to obtain porter. Whatever be the quality of the malt chosen, economy requires that the brewer grind it at home; for it acquires bulk in passing through the mill. All our calculations are founded on malt in the grain; therefore, when we direct any given number of bushels for a gyle or brewing, if the brewer purchase that quantity of ground malt, he will be a loser of at least one-sixth in the strength of his wort. The best pale malt we ever saw used was prepared at Newcastle in Staffordshire. It was then sold at the enormous price of 16s. per Winchester bushel; but so excellent was its quality, that we preferred it to the malt of Ware or Cambridge, though the cost of carriage to London was very considerable. Malt can be ground either by a crushing or a cutting mill, like that used for grinding coffee, but on a larger scale, and furnished with a fly-wheel, and an extra hopper that will contain a bushel, and which is adapted to, and drops into, the iron hopper of the mill. In Staffordshire, it was crushed by a pair of rollers set in the manner of a cider-press, so regulated that each grain was bruised without detaching the fine flour of the malt. This is of some consequence, as it facilitates the processes of mashing and drawing off. Malt, after being ground, is called "*grist.*"

Hops.—In England these are grown abundantly in Kent, Surrey, and Worcestershire. The Kent hops are employed by all the great brewers of London; and they are in general use throughout the east of the kingdom. Farnham hops are esteemed very highly for their brightness of colour, and for the fine flavour which they impart to the beer; they are used throughout the counties west and south-west of Surrey. But, in our judgment, the hops of Worcestershire are far preferable for the domestic brewer. They impart a mild and extremely pleasant aromatic bitter to table ale and beer; and experience has proved that the ales of the south-west are some of the best in the kingdom.

Nottinghamshire produces what are called the "North-clays," a species of hop little known elsewhere, but highly spoken off in the districts where they are grown.

The quality of hops may be estimated by their colour, fragrance, and weight; but brilliancy of colour is too often dependent upon "sulphuring," and may therefore deceive; fragrance is produced by a substance called "*condition*," which, according to Planché, "is the unappropriated farina or pollen-dust, which has alighted on the scales of the females." This "condition" is a yellow waxy powder, discernible to the eye: it is that substance which causes the adhesive gumminess that is felt in rubbing a small quantity between the hands. Where this abounds, the weight is comparatively great: it is lost by long keeping and age; and, according to Mr Lance, author of the *Golden Farmer*, depends, in a great degree, upon the presence of the male fructifying hop in the hop plantations. Hops should not be above two years old at the utmost.

Brewing-Vessels and Utensils.—In describing these, in order to avoid any omission, we extract a paragraph from the article *Brewing* of the Penny Cyclopædia, premising that, though we retain therein the technical terms of the brewer, we shall entirely avoid them in our remarks. The first process of brewing is "mashing."—"The mash-tun or vessel in which this operation is carried on is usually of wood, varying in size according to the quantity of malt to be wetted, and having two or more holes, called taps, in the bottom." This is the common mash-tub; the hole or holes having a cock or tap of some sort, while on the inside a wicker-basket, or even a mere wad of straw, is applied to prevent the egress of the grains, and to act as a strainer. But there are improvements of this simple machinery. "From one to two inches above the bottom is a false bottom or diaphragm, pierced full of small holes, on which the ground malt is placed; the hot water is then admitted, either above, or between the true and false bottom of the mash-tun, and the 'grist' is now to be intimately mixed with the water."

In family brewings this mixing is effected by a mash-oar, an instrument consisting of a long pole, at the lower end of which there is a triangular rack, made of cross-bars running through the central pole, and fixed into two side pieces, the rack being about nine inches long. A simple pole, with a broad flat end like an oar, is occasionally substituted, and answers very well. Whatever is used as a strainer, the grist and the "liquor" (hot water) must be agitated till "the whole assume a perfect homogeneous consistence. This being completed, the mash is allowed to stand at rest for a certain time, and the taps are then opened, or set, as it is termed, at the bottom of the mash-tun, the infusion of sweet wort is allowed to run off into a vessel called the under-back, from whence it is pumped, or otherwise conveyed into the copper for boiling."

The copper ought to be large enough to boil a hogshead of wort—allowing for waste, and to admit of the swelling of the head of hops:—thus, six inches of spare room above the liquor will not be too much to insure safety. Two coppers are better than one, the subsidiary copper being employed to heat a supply of water during the brewing. It need not be so large by one-third as the main copper; but each ought to be furnished with a large cock, fixed close to the bottom of the vessel, which should incline a little so as to permit the liquors to pass off to the last drop.

"*Coolers* are large shallow vessels placed in a part of the brewery, so as to command a free current of air over the whole of their surface: they may be constructed of either wood or iron. The latter possesses many advantages from its cleanliness, and the exposure of a large radiating surface to assist the cooling."

This passage indicates the construction and office of coolers, of which there should be a sufficient number to contain all the boiled wort. Some of our readers may know or recollect an apparatus, for which a patent was taken out above twenty years since by Needham and Rawlings, under the title of a "brewing machine." It consisted of a mash-tun, interior-strainer, furnace, chimney,—all in one piece, made of sheet-iron, or copper tinned; and of two shallow oblong coolers of the same materials, fitting one into the other, varying in depth from seven to nine inches. Two of these coolers, of capacity to contain between them forty gallons of liquor, we still possess, and can correctly add our testimony to that of the Cyclopædia in favour of the convenience and lightness of such vessels. The whole machine was a model of compactness itself; but the mash-tun soon became rusty, the fire-place decayed, and the first cost was heavy; the coolers and inner-straining cylinder are, however, serviceable and durable utensils.

A vessel called a *gyle* or *fermenting-tun* is of a round or square figure,—the former is preferable; and some persons are content to employ the mash-tub for the process of fermentation; but it is injudicious to do so, because time is lost, in the first instance, and cleanliness, as respects so important an agent as yeast, is made to yield to false economy: this vessel should also be more deep and narrow than the mash-tub.

Bowls—of sheet-iron, tinned; a pail of the same material, painted; two or three hair-sieves, and a light stand to lie across a cooler, constitute the remainder of the essential utensils. A good brewing thermometer graduated to 212°, or boiling heat, will be required; and if great precision of strength be an object, a correct saccharometer must be consulted. Having thus taken a general view of the materials and apparatus, we shall describe the process of our late friend. It will not be approved by the moderns, but as it always produced a most perfect beverage, which a numerous acquaintance never failed to acknowledge, we offer it in proof of one of those "stubborn facts"—which, at times, strangely perplex the theorist. Our own observations thereon extended from 1801 to 1809.

Malt, pale and of excellent quality, when properly crushed or cut, absorbs and *retains* about 3 gallons of water at the first mashing; this quantity must be allowed for second and third additions of hot water, by dissolving saccharine matter, and thus alternating the worts, bring off a portion of this retained fluid, therefore more will be obtained than is poured on at these additions.

Our calculations, founded upon observation in 1809, confirmed by varied experiments carried on for many years, will be the following:—The quantities to be produced are 3 kilderkins (18 gallons each) of stout keeping mild ale (not strong beer), and a fourth kilderkin of table beer. The malt will be estimated at its measure before grinding, as otherwise irregularity will occur, that is, at 6½ imperial bushels. The hops at little more than ¾ lb. per bushel, or in round numbers, 5 lb. Two mashings are supposed to extract the saccharine quality sufficiently for the ale wort; a third will bring away the wort retained by the grains, and leave them exhausted of sweet wort, but yet good enough to prove excellent nutritive food for the cow or the pig.

Mashing.—Fill the larger of two coppers with soft river or brook water, and bring it to a boil,—the malt being ready in a tub or cooler close at hand,—pour 6 gallons of the boiling-water into the mash-tun, and to it add malt, bowl by bowl, scattering it over the surface of the liquors, while an assistant stirs, and intimately blends the materials till they become a thick mass, then add 3 gallons of the boiling-water and more malt; thus alternating, and always stirring, observing the required consistence, till half a bushel only of the dry malt remain. With that dry malt cover the mash; it will gradually absorb water, and prevent evaporation and radiation of heat.

This first mash should contain fluid sufficient to produce nearly half the sweet wort required for the ale: Thus, at least, 10 gallons in excess should be provided (64 gallons); and as the malt will retain 20 gallons, 50 gallons should be the first quantity allowed. The tun is to be covered with sacks, or a lid adapted to it, and the mash should remain undisturbed two hours.

Theorists will exclaim against our directions, and even practical men will deprecate the use of boiling water. Be this as it may, the results were and will be undeniable; we have proved the fact in experiments varied to meet every theory from the year 1805 to 1822, and our journal of operations is now before us. But, though the water boil in the copper, be it remembered that the cold mash-tub, in the first instance, and subsequently every addition of malt, must reduce the temperature to the ordinary standard of 175° or 180°. For porter malt, the process would, indeed, be unsuitable; but with really good *pale* malt we have never observed any other that could surpass it.

For the second mashing, the smaller copper should be filled and brought to boil, and, in the mean time, the hops being rubbed and broken up, are to be mashed in a separate small tub, with as much boiling water as will soak them thoroughly; they are then to be covered to retain the steam. This process prepares them for the copper, and provides against the loss of sweet wort by absorption during the first boiling.

It may here be proper to notice an improvement in the apparatus, which also will meet the views of those who might disapprove of our mode of mashing. It combines the advantages of the old wooden mash-tub with those of the brewing machine. To an oak-tub, capable of containing 7 bushels of malt and 60 gallons of water, is adapted an inner cylindrical vessel of sheet-iron tinned, which fits it almost exactly. Its bottom is slightly convex; but at the lower rim falls into the angle of the tub and rests upon it. A central tube of the same material, four inches in diameter, passes to the bottom of the vessel and is soldered to it, thus forming a complete channel, open to the wooden bottom of the outer tub. This inner vessel is very light, and is lifted in and out of the mash-tub by two movable ring handles; it possesses all the advantages of the false bottom, combining those of a complete strainer, being pierced with small holes in every part, to within two inches of the upper rim, where the tin plate is folded over a strong iron wire, which supports the handles. In fig. 1 *a* is the mash-tub, with the inner strainer fitted into it. It may stand upon a horse or settle of any kind that will permit a tub or cooler to stand under it to receive the wort. In fig. 2 *b* is the inner vessel alluded to, with its handles, and the rows of holes to shew their arrangement. *c* is the inner cylinder, through which the water is poured, and passes from the bottom upwards, and through the perforations into the malt in every direction. When this method of mashing is adopted, the malt ought to be previously moistened with a little cold water to facilitate conduction, and slightly reduce the temperature of the liquid.

Fig. 1.

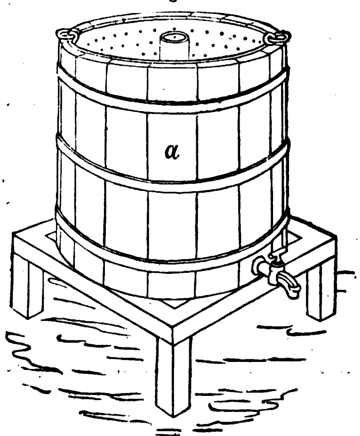
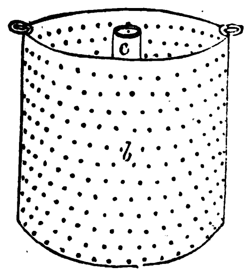


Fig. 2.



By whatever mode the mashing is effected, this first liquor must remain on the malt, as we have stated, at least two hours; but prior to drawing it off, the wort must be cleared by drawing two or three bowlfuls, which are to be returned over the malt till it pass bright and free from grains. This clearing should be finished a few minutes before the expiration of the two hours, when the top should be opened to permit the wort to run off, first in a small stream, then more freely, till the entire quantity be drained away. It should be accurately measured while it is transferred to the larger copper, and with it the soaked hops and a hand or two of common salt. As 64 gallons will be required at the least, 40 ought to be obtained from this first mash; and, to secure this, we have frequently poured a few bowls of hot water from time to time over the grains while the wort has been running. A little practice will soon instruct the observant brewer when it will be needful to make these additions, if at all; and when the 40 gallons are in the copper, the top should be stopped, and 24 gallons of boiling water poured over the grain. His *second mashing* will require one hour and a half.

Being then drawn off, the quantity in the copper will be made up 64 gallons, which should be brought speedily, though with great caution, to a boil. A brewing of this description requires so much time, that every process must be conducted with precision and despatch. Still in bringing this first glutinous wort to boiling by a quick fire, the hops are liable to swell up into a compact head, which, if not frequently broken by the mash stick, may rise suddenly, and produce a wave that will cause the loss of several gallons of the best liquor. When the boiling is once established, the hops move rapidly in the copper, and this action should be steadily maintained during an hour and a half.

The *water for* the table-beer will be poured over the mash, and remain in the tub during the boiling of the ale-wort; the quantity required will be 12 gallons for 9 gallons of beer.

Rapid and brisk boiling of every kind of wort is beneficial; it decomposes it partially, effecting the separation of the substance termed vegetable *albumen*, which, after an hour, or sometimes less time, coagulates, and floats in small masses through the clear wort. A bowlful of the liquor, taken up now and then, will exhibit this breaking, which should be perfected before the boiling be permitted to cease. That the hops of the ale-wort are sufficient for the beer (that is, to be boiled with it), and they may be readily obtained by straining some of the boiling wort through a sieve placed over the copper; and if there be two coppers, a saving of time may be made, for the beer-mash may be drawn off after an hour, and both coppers can thus be at work together. Thus, if half of the hops be boiled with the beer, as above suggested, the other half, after the ale-wort is strained, should remain in the sieve; and the beer-wort, after boiling one hour, may be passed through them, by which every particle of the strong wort will be extracted to the great improvement of the table-beer. We impress these minutiæ, knowing the value of economy in every item of the domestic homestead.

Straining is best performed by passing the boiled worts through hair sieves into large shallow coolers, so that a considerable surface of the worts may be exposed to the air, for cooling cannot now be too speedily accomplished.

Fermentation.—Upon this all-important process depends the success of the brewing. We shall not in this place go into the theory of fermentation, of which much will be said hereafter. It must, however, be observed, that a certain degree of heat is indispensable in all brewings, but that a higher degree of heat is required for small quantities, than for the large gyles of the publican or great brewer for sale. In our batch the highest temperature for the *ale* will be 78°, descending to 65°, for the *table-beer* 72° to 75°; but even these degrees are dependent upon the condition of the atmosphere. A mild temperature of about 50° to 55°, wind at S. or SW., lively, with the usual concomitants of moisture, and a falling barometer, promote and sustain fermentation; while the contrary conditions of cold, acidity, high pressure, and northerly winds, are adverse to it.

Many are the directions which we meet with for adding the yeast (*barm* or ferment) to the cooled wort. Some persons cool the ale-wort as rapidly as possible, and in the evening stir in fresh yeast to the whole quantity of wort at once, in the proportion of three pints of the former to one hogshead of the latter. We prefer the practice of our friend, which we never knew to fail. The quantity was distributed among four coolers previously placed on the floor of a cellar, the temperature of which (as the walls were thick and the roof brick-arched) varied little from 55° either in winter or summer; and when 8 or 10 gallons were cooled to 84°, the yeast was stirred into the wort, and suffered to act upon it for several hours. Thus supposing this batch was "set" at 6 P.M., by 9 a vigorous fermentation was established, and then the contents were poured into the deep gyle-tun, adding another quantity of 10 gallons which had cooled to about 74°. After a second similar interval, a third quantity was added before retiring for the night. Next morning a strong and deep head of frothy yeast was formed, the temperature of the fermenting work being about 72°. The liquor in the fourth cooler was found as low as 60°. Too much caution cannot be inculcated at this stage of the process. If October be mild, the external temperature 50° to 55°, wind at SW., and the cellar close, worts may not cool rapidly. Thus in 1809 (cellar 55°, external air nearly 60°) a process, of which we took the notes, was conducted as follows:—Set 6 gallons at 84°, with two quarts of ale-yeast at 6 o'clock P.M. added, at 10 P.M. 12 gallons at 69°, next morning 10 more at 70°, the third quantity at noon 64°, and the remainder at 7 P.M., then cooled to 60°.

When strong, full-bodied wort has been stimulated by a lively ferment to full activity, it acquires several degrees of temperature above 70°, even if it have cooled to that degree before the yeast shall have acted upon it. 84° is much too hot for a body of wort to be "barmed," but it is not so for a small quantity; and when once the fermentation is established, an addition of ten or twelve gallons of cool wort will not check the process. In March, with a drying wind at east, however warm the wort or cellar, the fermentation will be languid; but in February, with an electrical, vaporous atmosphere, it proceeds rapidly. At no season, however, should the fermenting body be permitted to rise above 77° without tempering it, either by the addition of cold wort, or by barrelling without loss of time. The heat of the gyle rose in the above instance to 78°, when a handful of flour was mixed up with a bowl of raw cool wort, and poured equally into two barrels; and upon this the wort with its yeast was tunned immediately.

Here we may notice a very neat and cleanly practice adopted in Leicestershire. Each barrel is pierced with a vent or cork-hole half an inch below the upper stave, if the barrel lie on its side, or below the head, if it be upright; and into this hole a tin curved scoop and pipe, called a "spurger," is fitted. In filling the barrels, the wort is passed through a funnel till it rises to this hole, and fairly flows through the scoop. The bung is then put into its place, and the frothy barm passes through the vent into a small receiving-tub, leaving the barrel clean, and free from yeast. As the working abates, wort is added repeatedly, till no more yeast can be obtained through the medium of the spurger. That being withdrawn, the hole is corked, and the barrel is filled with clear fermented wort, a vent-hole being only left at top. In a few days, when the liquor appears tranquil, this vent is stopped with a peg, and the bung-hole is secured with double strong brown paper, cemented over the orifice with thick yeast; the paper also is covered over, and between the folds, with thick yeast, which forms a very firm cement, but yet capable of being detached if the working be suddenly renewed. If a barrel be tightly bunged so soon as the liquor appears tranquil, a disturbance is frequently occasioned by atmospheric changes, which endangers the vessel; whereas, if air be cautiously excluded by a medium that will yield to strong internal pressure, a safety-valve for the newly generated carbonic acid is provided. The covering should be inspected from time to time; and in about a fortnight from the cessation of active fermentation, a mass of wet adhesive sand may be piled over the bung-hole, whether the paper be retained or replaced by a bung or plug. Some persons put a double handful of warmish spent hops from the following brewing into the bung-hole, and stir them among the ale, in the idea that they excite a degree of fresh activity, which liberates a little more yeast, and with the floating hops forms a firm head over the liquor. If the materials have been good, and the processes skilfully conducted, whether it be thus hopped or not, fine ale perfectly bright and mellow will be ready for the table in three or four months.

The *table-beer* may be worked *in the barrel* with a pint of yeast, the wort being cooled to 75° before it is tunned. It may be "cleansed" at the spurge-hole, in the same manner as the ale.

A mild table-beer can be readily prepared in one process from malt and hops, without any ale, by reducing the quantity of materials. One bushel of malt (we always calculate *before* grinding) and half a pound of the finest hops, are sufficient for 12 gallons of beer; the domestic brewer must, however, take into the account, that the greater the brewing the stronger is the beer, and the more certain the regularity of the fermentation. If there be a known consumption of malt liquor in a family, sound economy requires that it be brewed in the bulk, and not in small detached quantities. Three brewings in October, and two in February, each of 54 gallons, will insure good ale and mild table-beer; the same quantities, if distributed among twelve petty brewings, would, on the contrary, produce a much poorer liquor, to say nothing of the almost certain loss of two-thirds of the whole during the warm spring and summer months. A good under-ground cellar, brick-built in every part, must always be considered as indispensable; and persons should never become brewers if they possess no adequate cellarage to secure their stock.

Racking.—Brewers for sale rack the beers and small ales from small working barrels into great store casks, whence they are drawn off as required, into firkins, kelderkins, and barrels, for their customers; but unless beer be very new when used, private brewers seldom rack. Ales, if they cleanse themselves quietly in the barrels, require neither racking nor fining with isinglass; and as we have seen no example of the kind in the practice of the establishment to which we refer, it is reasonable to conclude that a well conducted fermentation is all that is essential. The ale was always bright as wine, and remained perfectly mild.

We have thus described the process of fermentation as generally conducted by the best English family brewers; and now are prepared to compare it with the one described by Dr Justus Liebig, which produces the celebrated *Bavarian* beer.

He observes, and correctly, as every one has experienced to his cost, that "*Beers are converted into vinegar when exposed to air.*" "But this property is not possessed by Bavarian beer, which may be kept in vessels only half-filled, without acidifying or experiencing any change. The perfection of experimental knowledge has here led to the solution of one of the most beautiful problems of the theory of fermentation." "Wort is proportionally richer in gluten than in sugar, so that during the fermentation in the common way a great quantity of yeast is formed as a thick scum. The carbonic acid evolved during the process attaches itself to the particles of the yeast, by which they become specifically lighter than the liquid in which they are formed, and rise to its surface. Gluten, in the act of oxidation, comes in contact with the particles of the decomposing sugar in the interior of the liquid. The carbonic acid from the sugar, and the insoluble ferment from the gluten, are disengaged simultaneously and cohere together. A great quantity of gluten remains dissolved in the fermented liquid even after the transformation of the sugar is completed, and this gluten causes the conversion of the alcohol into acid on account of its strong disposition to attract oxygen and to undergo decay. Now, it is plain, that with its separation, and that of all substances capable of attracting oxygen, the beer would lose the property of becoming acid. This end is completely attained in the process of fermentation adopted in Bavaria."*

There are some terms in the foregoing and following extracts which are strictly chemical, and therefore require elucidation. This will be attempted when we arrive at the theory of fermentation. The act of fermentation depends in a great degree upon the presence of gluten, a substance which contains about fifteen per cent. of the azotic principle of the air, which is now called *nitrogen;* this air or gas is one of the constituents of ammonia, and this will account for the ammoniacal odour given out by fermenting bodies in a state of decay. With these observations we recur to the process of brewing Bavarian beer.

"The wort, after having been treated with hops in the usual manner, is thrown into very wide flat vessels, in which a large surface of the liquid is exposed to the air. The fermentation is then allowed to proceed, while the temperature of the chambers in which the vessels are placed is never allowed to rise above from 45° to 50° F.

"The fermentation lasts from three to six weeks, and the carbonic acid

* Liebig's Organic Chemistry, p. 295.

evolved during its continuance is not in large bubbles which burst upon the surface of the liquid, but in small bubbles like those which escape from a liquid saturated by high pressure. The surface of the wort is scarcely covered with a scum, and all the yeast is deposited in the bottom of the vessel in the form of a viscous sediment," p. 296.

We know not what our readers may think of a fermentation conducted without yeast or ferment. True it is that wort *will* ferment alone, because it contains abundance of gluten; but whenever we have tried the process, a dull and even viscous-tasted liquor has been the result. It underwent, however, the process of spontaneous fermentation in barrels, not in coolers, therefore the cases are not parallel; and no doubt can be entertained of the facts described by Liebig: hence they ought to be brought to the test in our climate, were it only to obviate the pernicious effects of a secondary fermentation.

"In order to obtain a clear conception of the great difference between the two kinds of fermentation, it may perhaps be sufficient to recal to mind the fact, that the transformation of gluten or other azotised matters is a process consisting of several stages. The first stage is the conversion of the gluten into insoluble ferment in the interior of the liquid; and as the transformation of the sugar goes on at the same time, carbonic acid and yeast are simultaneously disengaged. It is known with certainty that this formation of yeast depends upon oxygen being appropriated by the gluten in the act of decomposition; but it has not been sufficiently shewn, whether this oxygen is derived from the water, sugar, or from the gluten itself; whether it combines directly with the gluten, or merely with its hydrogen so as to form water. For the purpose of obtaining a definite idea of the process, we may designate the first change as the stage of oxydation. This oxydation of the gluten then, and the transposition of the atoms of sugar into alcohol and carbonic acid, are necessarily attendant on each other, so that if the one is arrested the other must also cease.

"Now the yeast which rises to the surface of the liquid is not the product of a complete decomposition, but is oxydised gluten still capable of undergoing a new transformation by the transposition of its constituent elements. By virtue of this condition it has the power to excite fermentation in a solution of sugar; and if gluten be also present, the decomposing sugar induces its conversion into fresh yeast, so that in a certain sense the yeast appears to reproduce itself. Yeast of this kind is oxydised gluten in a state of putrefaction, and by virtue of this state it induces a similar transformation in the elements of sugar," p. 297.

Before we proceed further, it will be needful to refer to the opinion of our author, of the difference which he conceives to exist between fermentation and putrefaction. "The first kind of transformation is the transposition of the elements of one complex compound, by which new compounds are produced with or without the assistance of the elements of water. In the products newly formed in this manner, either the same proportions of those component parts which were contained in the matter before transformation are found, or with them, an excess consisting of the constituents of water which had assisted in promoting the disunion of the elements." This is termed *fermentation.* The second kind of transformation, termed *putrefaction,* "consists of the transposition of the atoms of two or more complex compounds, by which the elements of both arrange themselves mutually into new products with or without the co-operation of the elements of water. In this kind of transformations, the new products contain the sum of the constituents of all the compounds which had taken a part in the decompositions." p. 247.

"The transformations of these matters which evolve gaseous products without odour, are now, by pretty general consent, designated by the term fermentation; while to the spontaneous decomposition of bodies which emit gases of a disagreeable smell, the term putrefaction is applied. But the smell is of course no distinctive character of the nature of the decomposition, for both fermentation and putrefaction are processes of decomposition of a similar kind, the one of substances destitute of nitrogen, the other of substances which contain it."

"The yeast formed during the fermentation of Bavarian beer is oxydised gluten in a state of *decay*" (to which condition our author has given the term *eremacausis,* or slow progressive combustion). "The process of decomposition which its constituents are suffering, gives rise to a very protracted putrefaction *(fermentation)* in the sugar. The intensity of the action is diminished in so great a degree, that the gluten which the fluid still holds in solution takes no part in it; the sugar in fermentation does not excite a similar state in the gluten.

"But the contact of the already decaying and precipitated gluten or yeast, causes the eremacausis of the gluten dissolved in the wort; oxygen gas is absorbed from the air, and all the gluten in solution is deposited as yeast," p. 298.

If ever a process of brewing be attempted in the British dominion to produce beer at the Bavarian quality, the operator must clearly appreciate the difference which exists between the two fermentations; it appears that in some of the German states a considerable premium is offered for the preparation of beer according to the Bavarian method, "to be adjudged to any one who can prove that the beer brewed by him has lain for six months in the store-vats without becoming acid."

Our strongest malt liquors will not keep if exposed to the air: they abound with alcohol, so much so as to blaze if thrown upon the surface of a clear fire; yet the spirit soon disappears, since, by the action of atmospheric oxygen, it is converted into vinegar (acetic acid). This phenomenon ought to instruct the manufacturer of home-made wines, or British sweets, that nothing is really gained by the addition of brandy, rum, or other ardent spirit. If any of the ferment remain undecomposed in the wine, this spirit will only prove a source of useless expense and ultimate loss. The science of brewing and wine-making consists in the adaptation of the quantity of sugar to the power of the ferment or leaven, whether existing native in the fruit or applied by art.

"The ordinary frothy yeast may be removed from fermenting beer by filtration, without the fermentation being thereby arrested; but precipitated yeast of Bavarian beer cannot be removed without the whole process of its fermentation being interrupted. The beer ceases to ferment altogether, or, if the temperature be raised, undergoes the ordinary fermentation."

"The precipitated yeast does not excite ordinary fermentation, and consequently is quite unfitted for the purpose of baking; but the common frothy yeast can cause the kind of fermentation by which the former kind of yeast is produced," p. 298.

In the description given in an early page of this article of the common process of fermentation, it was seen that a certain degree of heat (from 60° to 75°) was deemed essential; and so indeed it is whenever a rapid process is carried on in the gyle-tun: it may also be added, that ale of the strength brewed in the establishment to which we had access, would keep free from any tendency to acetic fermentation for two or three years. But if fermentation be conducted without yeast, or very slowly under any circumstances, Bavarian beer, or something approaching to it, may be produced. Liebig cursorily alludes to a process, which perhaps might be tried in England with success. He says—

"When common yeast is added to wort at a temperature of between 40° and 50° Fahr., a slow tranquil fermentation takes place, and a matter is deposited on the bottom of the vessel, which may be employed to excite new fermentation; and when the same operation is repeated several times in succession, the ordinary fermentation changes into that process by which only precipitated yeast is formed. The yeast now deposited has lost the property of exciting ordinary fermentation, but it produces the other even at a temperature of 50° Fahr.

"The temperature of the fluid during fermentation has a very important influence on the quantity of alcohol generated. It is known that in the fermentation of Bavarian beer, the action of the oxygen of the air, and the low temperature, cause complete transformation of the sugar into alcohol; the cause which would prevent that result, namely, the extraction of the oxygen of part of the sugar by the gluten in its conversion into ferment, being avoided by the introduction of oxygen from without," p. 306.

As the conversion of sugar into alcohol depends upon a slow and protracted disturbance of its element, and the evolvement of carbonic acid, so the retention of that alcohol is effected by the low temperature of the fermenting fluid, and thus we arrive at the final result; for "beer obtained by the mode of fermentation adopted in Bavaria contains more alcohol, and possesses more intoxicating properties than that made by the ordinary method of fermentation when the quantities of malt used are the same."

Whether the British brewer will ever change his present practice, and adopt another, solely with a view to obtain a beverage replete with ardent spirit, is, and ought to be, questionable; and flavour, after all, is a consideration of moment. The aged *strong beers* of great families are reduced by keeping to the condition of Bavarian beer; they are seldom broached till they have attained twenty-one years, and retain little or no flavour of mild table-ale, but possess a most insidious intoxicating quality.

Beer prepared without yeast in Britain has generally been fermented in the casks, the boiled wort being turned at once into them hot from the copper, and closely bunged, air-tight, almost immediately; the result, therefore, could not be supposed to resemble that of the Bavarian process. Some persons, however, have assured us that they have succeeded thereby to their entire satisfaction; with us the operation completely failed; and now, having laid before our readers all the data at command, we will investigate the phenomena of common fermentation.

The theory of fermentation has been the stumbling-block of chemical science. M. Liebig, without entering upon the enquiry of primary causes, has perhaps taken the most luminous view of what we may be permitted to style *casual effects* that we possess. This we find in Part II. of his *Organic Chemistry*, under the head *Chemical Transformations*.

As a leading position, we shall extract the following passage from p. 522 :—" A body in the act of combination or decomposition enables another body with which it is in contact to enter into the same state. It is evident that the active state of the atoms of one body has an influence upon the atoms of a body in contact with it; and if these atoms are capable of the same change as the former, they likewise undergo that change; and combinations and decompositions are the consequence."

We shall omit every passage that does not supply *positive* facts; but the above and what follows, we may remark, will be found to bear equally upon, and interpret, the phenomena of fermentation and contagion, for both imply *induced and communicated motion*.

" The influence exerted by one compound upon the other is exactly similar to that which a body in the act of combustion exercises upon a combustible body in its vicinity, with this difference only, that the causes which determine the participation and duration of these conditions are different. For the cause, in the case of the combustible body, is heat which is generated every moment anew, whilst in the phenomena of decomposition aud combination, the cause is a body in the state of chemical action, which exerts the decomposing influence only so long as this action continues," p. 225-6.

If we rightly understand the learned author, his strong predilection for what he considers abstract chemistry has caused him to overlook the simplicity of his position, and to make a distinction where in reality there is no difference. The fact appears to be this: the *motor* of combustion, and of all chemical action (in which we include the phenomena of decay and fermentation), is simply *one*, or, in plain terms, it is a *disturbance of the electrical condition;* and this disturbance operates precisely in the same manner, though with more visible energy, in the case of combustion, as in that of decomposition. Thus in *fermentation* the commotion proceeds so long as there remain any atoms capable of being brought into the same condition as the *ferment;* and in combustion heat and light cease to be generated the moment that the decomposable particles or atoms of the combustible body have yielded to the energetic action of the supporter.

"Numerous facts show that moisture alone exercises a considerable influence on chemical forces. In the processes of combination and decomposition under consideration, motion, by overcoming the *vis inertiæ*, gives rise immediately to another arrangement of the atoms of a body, that is, to the production of a compound which did not before exist in it. Of course, these atoms must previously possess the power of arranging themselves in a certain order, otherwise both friction and motion would be without the smallest influence, p. 225-7.

"Several bodies appear to enter spontaneously into the states of fermentation and putrefaction, particularly such as contain nitrogen or azotised substances. Now, it is very remarkable, that very small quantities of these substances, in a state of fermentation or putrefaction, possess the power of *causing unlimited quantities of similar matters to pass into the same state.* Thus, a small quantity of the juice of grapes, in the act of fermentation, added to a large quantity of the same fluid which does not ferment, induces the state of fermentation in the whole mass. So, likewise, the most minute portion of milk, paste, juice of the beet-root, flesh or blood, in the state of putrefaction, causes fresh milk, paste, juice of the beet-root, flesh or blood, to pass into the same condition when in contact with them," p. 231.

A number of facts and arguments are adduced to shew the difference which may be traced between the changes which are wrought in the decomposition of *organic* bodies, and those which are effected by chemical affinities in ordinary cases; but they are too complicated for our present purpose; we therefore pass to the consideration of the changes that *sugar* undergoes in the process of *vinous fermentation*, under the stimulus of yeast or barm. "The peculiar decomposition which sugar suffers may be viewed as the type of all the transformations designated fermentation. The analysis of sugar from the cane proves that it contains the elements of carbonic acid and alcohol, *minus* 1 atom of water. The alcohol and carbonic acid produced by the fermentation of a certain quantity of sugar contain together 1 equivalent of oxygen, and 1 equivalent of hydrogen; the elements, therefore, of 1 equivalent of water more than the sugar contained. The excess of weight in the products is thus explained most satisfactorily; it is owing, namely, to the elements of water having taken part in the metamorphosis of the sugar.

"It is known that 1 atom of sugar contains 12 equivalents of carbon, both from the proportions in which it unites with bases, and from the composition of saccharic acid, the product of its oxydation. Now none of these atoms of carbon are contained in the sugar as carbonic acid, because the whole quantity is obtained as oxalic acid, when sugar is treated with hypermangate of potash (*gregory*); and as oxalic acid is a lower degree of the oxydation of sugar than carbonic acid, it is impossible to conceive that the lower degree should be produced from the higher, by means of one of the most powerful agents of oxydation which we possess.

"It can also be proved that the hydrogen of the sugar does not exist in it in the form of alcohol, for it is converted into water and a kind of carbonaceous matter, when treated with acids, particularly with such as contain no oxygen; and this manner of decomposition is never suffered by a compound of alcohol. Sugar contains, therefore, neither alcohol nor carbonic acid, so that these bodies must be produced by a different arrangement of its atoms, and by *their union with the elements of water*," p. 248-50.

This allusion to the elements of water furnishes a key to the phenomena of this mysterious process. By the perspicuous experiments of Dr Faraday of the Royal Institution, it appears to be proved, that the volume of electricity which retains the elements of water (oxygen and hydrogen) in their liquid form, is enormous. Analogy, and even direct experiment, evince that chemical and electrical action are identical or coincident, and lead to the conclusion that there are two distinct electrical conditions, which may be represented by those of acid and alkali, and through which they attract and neutralize each other; this, perhaps, is the most simple elucidation that can be adduced.

Water in a state of electrical disturbance yields up one of its electrized elements in the form of nascent oxygen, which attracts a definite equivalent of electrized carbon (*carbon vapour*), and passes off in the form of carbonic acid gas. This gas we may define as a combination of carbon and oxygen retained in chemical union by the attractive power of their two electric elements thus neutralized, and therefore rendered inappreciable by the senses.

The disturbance, therefore, of the elements of water, and the energy exerted by the electricities of the oxygen and hydrogen so set at liberty, induce the changes which take place in the constituent of sugar, and form a certain definite quantity of alcohol. *Fermentation*, therefore, if this view be correct, is, like every other process of chemical decomposition and combination, a purely voltaic process, which fails to reveal visible electricity, solely because compatible elements at hand which instantly exert mutual, neutralizing attractions, and produce new compounds, wherein the powers of the equivalent constituents balance each other.

As a general principle of fermentation, though at present its applicability may be questioned, we would suggest that, whereever sugar is present, whether in fruits or vegetable extracts, and there exist also a surplus of *water*, or its elements (as in apples and pears during a very wet autumn, and in preserves not effectually boiled), fermentation will be established as a consequence of attractions exerted between the electricities of the redundant water, and some hydro-carbon existing in the pulp or mass; hence fruits of the present season do not keep, but speedily undergo a sort of vinous fermentation; and fruit-jellies become watery, and covered with some cryptogamous plants called "mouldiness." On the contrary, if a balance of the elements exist, fruit keeps and becomes mellow, and preserves remain sound, depositing their surplus sugar in the form of crystals or candy.

Liebig's theory of fermentation of *beer*, as established by the agency of a substance containing *nitrogen*, is condensed in the following paragraphs:—

"*On yeast or ferment.*—When attention is directed to the condition of those substances which induce fermentation or putrefaction in other bodies, evidences are found in their general characters, and in the manner in which they combine, that they all are bodies, the atoms of which are in the act of transposition.

"The characters of the remarkable matter which is deposited in an insoluble state during the fermentation of beer, wine, and vegetable juices, may be first studied. This substance, which has been called *yeast* or *ferment*, from the power which it possesses of causing fermentation in sugar, or saccharine vegetable juices, possesses all the characters of a compound of *nitrogen in a state of putrefaction and eremacausis*," p. 252.

"Yeast produces fermentation in consequence of the progressive decomposition which it suffers from the action of air and water. Now, when yeast is made to act on sugar, it is found that, after the transformation of the substance into carbonic acid and alcohol is completed, part of the yeast itself has disappeared. From 20 parts of fresh yeast from beer, and 100 parts of sugar, Thenard obtained, after the fermentation was completed, 13.7 parts of an insoluble residue, which diminished to 10 parts when employed in the same way with a fresh portion of sugar. These 10 parts were white, possessed of the properties of woody fibre, and had no further action on sugar."

"Now, if we consider the process of the fermentation of pure sugar, in a practical point of view, we meet with two facts of constant occurrence. When the quantity of ferment is too small in proportion to that of the sugar, its putrefaction will be completed before the transformation of all the sugar is effected. Some sugar here remains undecomposed, because the cause of its transformation is absent, viz. contact with a body in a state of decomposition. But when the quantity of ferment predominates, a certain quantity of it remains after all the sugar has fermented, its decomposition proceeding very slowly on account of its insolubility in water. This residue of ferment is still able to induce fermentation, when introduced into a fresh solution of sugar, and retains the same power until it has passed through all the stages of its own transformation.

"Hence, a certain quantity of yeast is necessary in order to effect the transformation of a certain quantity of sugar, not because it acts by its quantity increasing affinity, but because its influence depends solely on its presence, and its presence is necessary until the last atom of sugar is ecomposed," p. 255–6.

Pure sugar will not ferment alone. Syrup clarified will not undergo vinous fermentation; but all the vegetable substances with which we are acquainted that can be employed for the preparation of wines, contain natural leaven, one of the constituents of which is *nitrogen*, that singular element of atmospheric air which constitutes about four-fifths of its entire volume. Nitrogen or azote has a powerful affinity for hydrogen, and this it meets with in a solution of sugar. "Now, since it is found that no body destitute of nitrogen possesses, when pure, the property of decomposing spontaneously whilst in contact with water, we must ascribe this property, which azotised bodies possess in so eminent a degree, to something peculiar in the nature of the compounds of nitrogen, and to their constituting, in a certain measure, more highly organised atoms. Every azotised constituent of the animal or vegetable organism enters spontaneously into putrefaction when exposed to moisture and a high temperature. Azotised matters are accordingly the only causes of fermentation and putrefaction in vegetable substances."

The conclusion we arrive at from this theory, established by experimental facts, is, that all fruits contain an azotised material in their juices, which is the cause that they run into spontaneous fermentation without the introduction of artificial yeast; and that when sugar is added to British fruit in sufficient quantity to bring the sweet "*must*" to a specific gravity of 1.130, taking water as the standard at 1000, a volume of alcohol is formed which will convert the *must* into a strong wine capable of keeping, and improving by age for an almost indefinite period. Flavour or bouquet is the concomitant result of other decompositions with which our present inquiry is not connected.

The *fermentation* of malt liquor might, as has been seen, be produced spontaneously, as by the Bavarian process already alluded to; it only remains to consider the ordinary fermentation of beers by the introduction of yeast.

"From the phenomena which have been observed during the fermentation of wort, it is known with perfect certainty that ferment is formed from gluten at the same time that the transformation of the sugar" (saccharine principle of the malt) "is effected; for the wort contains the azotised matter of the corn, namely *gluten*, in the same condition as it exists in the juice of grapes. The wort ferments by the addition of yeast, but after its decomposition is completed, the quantity of ferment or yeast is found to be thirty times greater than it was originally.

"Yeast from beer, and that from wine, examined under the microscope, present the same form and general appearance. They are both acted on in the same manner by alkalies and acids, and possess the power of inducing fermentation anew in a solution of sugar; in short, they must be considered as identical. The fact that water is decomposed during the putrefaction of gluten has been completely proved. The tendency of the carbon of the gluten to appropriate the oxygen of water must also always be in action, whether the gluten is decomposed in a soluble or insoluble state.

"The fermentation of pure sugar in contact with yeast must evidently be a very different process from the fermentation of wort or *must*. In the former case the yeast disappears during the decomposition of the sugar; but in the latter, a transformation of gluten is effected at the same time, by which ferment is generated. Thus yeast is *destroyed* in the one case, but is *formed* in the other."—P. 283–4.

The difference just described originates in absence of gluten in the one case, and its great abundance in the other. In sugar we detect only carbon, oxygen, and hydrogen; and hence the constituents of a vinous product. In malt we have the same elements combined with the azotised principle called gluten. When yeast is added to a solution of malt and hops, its decomposition by electric disturbance produces a corresponding condition in the gluten, which substance is convertible into yeast, and at the same time induces those chemical attractions which convert the saccharine principle of the malt into alcohol.

Yeast, then, if added in due quantity, brings on a rapid disturbance in the several elements of malt and hops, and produces the separation of a great volume of fresh ferment; and beer of strength varying according to the quantity of the materials employed is the product.

The process of fermentation begins to be appreciated; it is involved in mystery so far only as the *motor cause* is invisible; but as *that* is traceable by analogy, we obtain a clew which promises to lead to true results. In fermentation, and the decomposition of sugar, water is decomposed. Now, according to Faraday, *one grain* of "water will require an electric current to be continued for three minutes and three quarters of time to effect its decomposition, which current must be strong enough to retain a platina wire $\frac{1}{104}$th of an inch in thickness, red hot in the air during the whole time."—"It will not be too much to say that this necessary quantity of electricity is equal to a very powerful flash of lightning."—"If the electrical power which holds the elements of a grain of water in combination, or makes a grain of oxygen and hydrogen unite into water when they are made to combine, could be thrown into the condition of a *current*, it would exactly equal the current required for the separation of that grain of water into its elements again."*

To what train of reasoning do these remarks lead us? Why, evidently this:—If the elements of water be held together by electricity,—and if, when separated, a similar volume of that subtile fluid be evolved,—if, again, chemical and electrical action be identical and simultaneous,—then, be agent of decomposition what it may, the electrical developments will be identical, and the results must be viewed as electrical combinations.

"It is the great beauty of our science, *Chemistry*, that advancement in it, whether in a degree great or small, instead of exhausting the subjects of research, opens the doors to further and more abundant knowledge, overflowing with beauty and utility to those who will be at the easy personal pains of undertaking its experimental investigation."

We cannot conclude more appropriately.

* New Researches, 250. 8vo. edition.