| | Barley. | Malt. |
|---|---|---|
| Gluten soluble in Alcohol | 0·28 | 0·34 |
| Albuminous substances coagulable | 0·28 | 0·45 |
| Albuminous substances not coagulable by heat | 1·55 | 2·08 |
| Insoluble Albumen | 7·59 | 6·23 |
| | 9·70 | 9·10 |

There are three kinds of kiln-dried malt—pale, amber, and brown, and one of roasted, called black or patent malt. We have already seen how pale East India malt is made; also that the ordinary pale malt is dried off at a higher temperature by 30° or 40°.

*Amber malt*, when ground, is of a rich amber colour, hence its name. This is dried off at a heat of 180°. The fuel used during drying is different. For pale malt, coke or anthracite coal is used, but the colour and flavour of amber malt are produced by burning oak or other hard-wood faggots,—the flavour being caused by the pyroligneous acid thrown off during burning. High-coloured malts have advantages over pale; more dextrin is produced and more albuminous matter is rendered insoluble; it is, therefore, easier to brew good beer from them.

*Brown or porter malt* is dried in yet another way. The floors of malt-kilns used for drying it must be made of thin sheet-iron or stout wire, as the heat must be raised in a few minutes from 100° to a heat nearly approaching combustion, and lowered as rapidly. The process requires great attention, or the malt would take fire. The grain is spread thin, not exceeding 1½ inches in depth; and the whole process is completed in less than two hours. The fuel used consists of faggots of beech, elm, or oak; at first the fire is kept down by being sprinkled with water, but the last half-hour it is allowed to increase, and an intense heat is obtained. This kind of malt weighs about 32 lb per bushel. It is sometimes called "blown malt," from its distended appearance. By this process the gum, sugar, and starch are converted into a kind of caramel, which gives the flavour so much prized in porter. It makes the malt, however, deficient in extractive matter, to the extent of from 20 to 30 per cent.

*Patent malt*, which is the legal colouring-matter in porter, is made and charged with duty in the same way as other malt, and then removed to the roasting premises, where it is treated like coffee, being roasted over a fire in cylinders of perforated iron. The law requires that 95 per cent. of this malt shall have the "spire" extend to one-half the length of the grain in order to prevent the introduction of raw grain. It is generally made from injured or inferior malt, as the high temperature in drying quite restores the appearance. There is, of course, no saccharine extract from it, that having been converted into caramel or burnt-sugar; it is only wanted to supply colour and flavour. Good malt of this kind should have each grain distinct, of its own original size and shape, not adhering to each other; and when it is bitten the inside should be of a rich chocolate colour.

Pale malt differs in appearance from barley; the grains are plump and generally free from wrinkles, and paler than barley. Instead of the tightly-closed end, the opening through which the rootlets have passed is visible at the base of each grain; when broken the starch should be loose, friable, and cretaceous, and should leave a white mark as of chalk when drawn along a black surface. It should be crisp to the teeth, and have a sweet and empyreumatic flavour, free from the least mould or mustiness of smell or taste. Malt should weigh from 39 lb to 43 lb per bushel. There should be no vitrified appearance when broken; that would be due to an excess of heat at the beginning of the drying process, or to the barley having been grown in too rich a soil, or to mixed seed being used which did not work regularly. A good test is to take 100 seeds and throw them into water, stirring them well up; good malt, being specifically lighter than water, should float on the surface; if more than 5 per cent. sink it is bad malt. Another test is to take 100 grains of malt and carefully examine the regularity of their acrospire, which should extend ⅘ths of the length of the grain for large and ⅔ths for small brewers. If more than 5 per cent. have projected it shows a waste of material, whereas if more than 5 per cent. have the acrospire less than half way up, it is a sign of insufficient germination.

Dr Ure's analysis goes to show the amount of solid extract obtainable by the brewer. He takes 100 grains of malt by weight, which are powdered and dried half-an-hour by the heat from boiling water; they are then weighed, and the loss shows the quantity of moisture in the malt. This powder is then mixed with cold water, and the vessel containing it is heated in the steam-bath half an hour, the contents being occasionally stirred. The husk and insoluble matters are then drained off, washed with boiled water, and then dried and weighed,—their weight giving the insoluble matter in the malt, and the residue the soluble extract available to the brewer. Dr Ure found in several experiments the average in 100 parts by weight, to be—

| | |
|---|---|
| Moisture | 6·5 |
| Insoluble matter | 26·7 |
| Soluble extract | 66·8 |
| | 100·0 |

According to this, if we assume that a quarter of malt weighs 324 lb, the total soluble extract will be 216·4 lb avoirdupois; but as the gum and sugar in assuming the fluid form combine with the elements of water, if the extract were dried it would weigh 23 lb; and being reduced to the basis of the barrel of 36 gallons would become, in the language of brewers, 87 lb extract per barrel, which means that, if the wort from a quarter of malt were evaporated down to the bulk of a barrel of 36 gallons, it would weigh 87 lb more than a barrel of pure water. Practice shows these experiments to be correct, the extract per quarter varying, according to the sample of malt, from 80 lb to 90 lb.

Malt is made duty-free for distillery purposes and exportation; in both cases the maltster has to enter into a bond with two sureties for £1000 that the malt goes to its declared destination. It may also be made free of duty for cattle feeding, an Act giving great facilities being passed in 1864; it was, however, found to be useless, except in small quantities, as a condiment, and the practice of giving it is entirely discontinued. In 1870 there was not a single bushel made, as there was no demand for it. In the case of malt damaged by fire or water, an allowance equal to the whole of the duty, if totally destroyed, or part if the damaged malt be sold on salvage, is granted by 7 and 8 Geo. IV. c. 52, § 76. The duty on malt is payable at the end of every six weeks, but upon entering into a bond with sureties for payment, a maltster is allowed six weeks' credit. Also by 26 Vict. c. 6, § 1, he may defer payment of half the duty on malt made between 1st January and 1st April, and the whole of the duty on malt made between the latter date and 16th May, for three months, on giving notice of his intention to the proper collector before 1st April, paying interest at the rate of 3½ per cent. per annum for the accommodation, and giving bond for security.

By 7 and 8 Geo. IV. c. 52, § 46, it is provided that, if any workman, maliciously or otherwise, commits an act by which his employers are liable to a penalty, he shall be imprisoned with hard labour for not less than three or more than twelve months. The master is liable for these penalties incurred by the workman unless he prosecute his servant within a month of the offence, and show the Commissioners a certificate of such conviction. Some maltsters have a notice put up in their maltings to the effect that their men will be prosecuted if they commit the offences mentioned in the Act.



In America there are no internal taxes on materials used in brewing as such, but there is an import duty on hops and barley,—five cents per lb on the former, and 15 cents on the latter per bushel. The barley mostly used comes from Canada, the import duty being equal to about 1s. 4d. on an American barrel of beer. The duty is levied in the form of a stamp-tax on the beer fermented, completed, and in barrel, at the rate of $1 per barrel of 31 gallons, and $2 per barrel of not less than 63 gallons. No restrictions are imposed as to the materials of which it shall be made.

In Bavaria the duty is raised on malt, but not assessed till the malt is brought to the mill to be crushed. It is made without licence or permission, and may be sold without restriction; but traffic in ground malt is strictly forbidden. The case is the same whether the malt is used by brewers or distillers. The consumption of beer and spirits is untaxed, except through the impost on malt. The means adopted for preventing fraud consist exclusively in the control exercised in the public mills by the Government inspectors. Private mills for crushing malt are only allowed when the proprietors have their mills furnished with the regulation self-acting measuring apparatus, together with the Government automatical counter. This apparatus is sealed officially, and thus it is impossible for an ounce of malt to be crushed which has not first been measured and checked. Besides these means for preventing fraud, there exists a regulation that no malt, whether tax-free or not, may be brought to any mill, or be found there, for which a certificate (polette) has not been given specifying the date, the quality, and the mill.

Americans are now making beer largely from maize meal and maize malt. The experience the writer has had of the use of the latter leads him to doubt its economy; the extract is small, and the fine flavour of the ale impaired. However, a small quantity can be used with advantage where the fermentations are sluggish or inactive,—maize being the most powerful stimulant of this process that we possess. Barley has always been considered, and with good reason, a better, and in favourable seasons a cheaper, grain than any other for malting. The reasons for this are, first, that whilst the husk permits the steep-water to pass through to the starch it effectually precludes the escape of the starch; secondly, the acrospire grows under the husk in barley, and so is protected from injury during malting, whereas in wheat, maize, &c., the acrospire forces its way out with and at the same end as the rootlets, and therefore runs the risk of being damaged by turning on the floors; these damaged grains become mouldy, and mould being propagated by means of spores, one mouldy grain may send out thousands of these spores among the good grain, and infect the previously healthy ones; and thirdly, barley contains a large ready-made proportion of grape-sugar and starch. It is, therefore, only in bad barley seasons that there will be much demand for malt made from other grain. The average price of barley from 1872 to 1875 has been 43s., and in 1874 the average was as high as 49s. This high price, which means a material increase in the cost of manufacture, has naturally made a great inquiry for a cheaper sugar-forming product; and there is no doubt that if the duty on malt were either taken off or laid on the manufactured article, beer, large quantities of other grain dried on a kiln at from 230° to 240° would be used in bad barley seasons. In Germany the grain is steeped before kiln-drying for three or four hours, to remove from the husk the unpleasant flavour it sometimes imparts to ales; the materials used to a considerable extent there are wheat, oats, rice, maize, and even potato starch. Beer made from rice is of a very clear pale colour, of an extremely pleasant, mild taste, foaming strongly, and yet retaining its carbonic acid. Dr Graham, in his instructive lectures on the chemistry of brewing, at the Society of Arts in 1874, explained how raw grain might be used to obtain a beer either alcoholic in its nature, as brewed in England, or dextrinous, like the Bavarian beer. Mr John Prior, of the firm of Truman and Hanbury, in his examination before a committee of the House of Commons, says, "If the malt Acts were not in the way, numerous substitutes for malt might be employed," and that, amongst these, mangel-wurzel might be used to any extent; and he goes on to say, "I have tasted as good beer brewed from that alone as any home-brewed beer I have ever tasted in my life."

The only substitute for malt allowed in Great Britain is sugar. Of this, in its different forms, there was used in the year ending September 30, 1874—

| | | Cwts. |
|---|---|---|
| In England | London | 283,736 |
| | Provinces | 422,136 |
| | | 705,872 |
| In Scotland | | 7,323 |
| In Ireland | | 54,825 |
| | | 768,020 |

being an increase over 1873 of 204,528 cwt. Sugar may be used in brewing to the extent of one-third,—two cwt. being equal to a quarter of malt; the duty is 11s. 6d. per cwt. It is either boiled with the wort, or dissolved in the underback. Ordinary cane-sugar contains a large amount of dangerous putrefying albuminous matter. It may also be said to cause two distinct fermentations, having to be converted, by the action of the ferment, into glucose before it is broken up into alcohol; it is, therefore, only good for ales of quick consumption. For store ales it is as well to destroy one of these fermentations, and at the same time convert the cane into grape-sugar or glucose. This is done by treating it with dilute sulphuric acid, the acid being afterwards got rid of by means of chalk or lime, which combines with and carries it down. This is effected very rapidly if the temperature be increased by pressure to 250° or 300°, 1 lb of acid mixed with 600 lb of water converting 100 lb of starch or cane-sugar into glucose in three hours. This action of acids upon cane-sugar has formed the subject of a patent (Garton's), which is being worked on a large scale at Southampton, and the product is sold under the name of saccharine; it has found great favour with brewers, as it gives a rounder flavour, and more permanent character, to the beers than when brewed from malt alone, and at the same time masks the acidity where any exists, better than starch or cane-sugar. Saccharine has been carefully analysed, and the analysis shows the whole of the raw sugar to have been converted into glucose with a certain percentage of water. The best mode of distinguishing grape from cane-sugar is by adding to the solution to be tested, in a flask, a few drops of an alkaline solution of tartrate of copper, and then gently boiling it. If any grape-sugar is present a bright red metallic-looking precipitate of suboxide of copper is shortly thrown down; if no grape-sugar is present the solution remains clear, with a slight blue tinge, from the addition of the copper solution.

It does not appear that the best judge can, from the taste alone, distinguish between a beer made from malt and one brewed from a mixture of malt and sugar. This is not surprising, when it is borne in mind that brewing from malt consists in subjecting the malt to those condi-

tions which are most favourable to the conversion of the *maximum* quantity of the starch it contains into grape-sugar, by the action of the diastase produced in the grain by the process of malting.

*Hops* are the catkins or flowers of the *Humulus Lupulus*, a dicœcious plant belonging to the natural order *Urticaceæ*, or the nettle family, and the Linnæan *Diœcia pentandria*. It is the female flowers (which grow on different plants from the male flowers) that yield the hop known to commerce. The plant is mentioned by Pliny under the name of *lupus salictarius* (*N. H.*, xxi. 50). It was cultivated in the 9th century, for we find that in 822 the millers of Corbey were freed by the abbot from all labours relating to hops; and hop-gardens are mentioned by Ludovicus Germanicus, a few years later. Hops were introduced into England from Flanders about the time of Henry IV There is a curious edict of Henry VIII., forbidding the mixture of either hops or sulphur with beer; but little attention seems to have been paid to it, for in 1552 hop-plantations were formed. In 1649 the city of London petitioned Parliament against "hoppes" being used, urging that "this wicked weed would spoil the drink, and endanger the lives of the people." It came into common use in Queen Elizabeth's reign.

The hop-clusters are ovoid cones, consisting of scales which are the enlarged persistent bracts enclosing the fruit. They are covered with a tenacious yellow, waxy substance, like powder, called lupulin, and technically "condition." Under the microscope this is seen to consist of minute semi-transparent granules, round in shape; it is the most valuable part of the hop, containing most of its active properties. The amount of powder compared with the total weight of the hop varies from 10 to 15 or even 20 per cent. Amongst the leaves and powder of the hop, we find essential oils, resin with associated bitter principles, and tannin. When distilled with water, the powder gives 2 per cent. of its weight in essential oils (there is none in the leaves); one of these distils at 212 Fahr., but the other requires a much higher temperature for its volatilization. Other products are formed from the lupulin—among them valerianic acid, which is the disagreeable characteristic of old hops. The essential oils not only give the aroma, but are of importance, as through their combination the resins and bitter substances become soluble in water. The resin constitutes 50 per cent. of the powder, and is soluble in alcohol. The importance of tannin consists in its power to precipitate albuminous matter; of tannin there is only about 2 per cent. It has been suggested to increase this by using the tannic acid of commerce as a partial substitute for hops; and experiments have been made in Dresden by Dr Fleck for this purpose. This must, however, be used with caution, as an excess of it would be prejudicial to a successful clarification of the beer.

The most delicate hops are Goldings, grown in East Kent, —Farnham and Worcester districts being next best, while good, strong, serviceable hops are grown in the Weald of Kent, Sussex, &c. Large quantities are imported from Germany, Belgium, America, &c., the best being Bohemian, grown near Saaz, which are very excellent in delicacy of flavour and aroma; Bavarians grown in the district round Spalt are valuable for their cleansing and beer-keeping qualities.

The acreage under hops in England is 65,000,—40,000 being in Kent. This is an increase of more than 15,000 acres since the commutation of the duty in 1862. In that year the duty was taken off hops, and a charge made on brewers of 1s. per quarter, being at the rate of 3d. per barrel, on the supposition that four barrels of beer were drawn from every quarter mashed. The old duty was 2d. per lb and 5 per cent. additional. A hop-garden costs from £70 to £100 to start, and from £27 to £30 to farm per annum. A rich, deep soil, rather inclined to moisture, is, on the whole, the best adapted for the crop; but any soil (stiff clay only excepted) will suit, when properly prepared. It should be enriched with the kind of manure best suited to the land the hops are to be grown on; stable and cowhouse dung, old rags, shoddy, guano, sprats, and other decomposed matter are used freely; while on some land peat and lime are required. The land is first rendered fine and mellow by being ploughed and harrowed several times; then, in the spring, a large hole is made and filled with rich mellow earth; into this "sets" or small pieces of the roots of the kind of hop intended to be grown are planted with the buds uppermost and the earth pressed close about them. These sets take three years to come to perfection. Two or three sets to a pole, three poles to a hill, 1050 hills to an acre, is the usual calculation. The hills should be 6 or 8 feet apart, the latter being best on rich land, as there the bine runs the most. The poles are from 12 to 18 feet high, according to the adaptability of the ground for vigorous growth, with the ends that go into the earth charred to preserve them. In America the hop is trained on wires; this has also been introduced into England.—Mr Farmer, of Worcester, having taken out a patent. It is very successful, but the first cost, £75 per acre, has prevented its being used extensively. The hop crop is a most precarious one, and may be said to vary from nothing up to a ton or even 25 cwt. per acre, and in price from £3 to £25 per cwt. In proof of this, at the annual Worcester Fair in 1874, only 74 pockets were on sale, whereas the year before 1000 pockets were in the market, and 2000 more were offered for sale by sample.

The plant is very dependent on the season, and has many enemies in the insect world, in particular, the fly or aphis, which infests the crop early in its growth, feeding upon its juices and leaves, giving the latter the appearance of having been riddled with swan shot. The flies come originally from the sloe bushes, and are produced from eggs deposited in the previous autumn. These, as well as fleas, red spiders, lice, &c., may be destroyed by syringing the plants well with soft soap and water. The mould first betrays itself in yellow and drooping leaves, finally in the hop itself, eating it up with mildew,—the presence of a few half-eaten leaves spoiling a sample. The blight coats the leaves with a thick sooty substance; and when this appears the hop dwindles away. The fire-blast, as its name implies, sears and scorches the foliage, and withers it up. All these may be seen working mischief at once in the same hop garden.

The catkins of the hop ripen early in September; they are picked from the bine by thousands of people from London, &c., whose welfare and accommodation have been much neglected; but great changes in this respect are made by sanitary regulations which come into force this season (1875). Besides these strangers, every man, woman, and child of the resident population is made available for the season, which generally lasts three weeks. The pay is about 2d. per bushel; and in a good season a family can make 2s. 6d. a day per head.

After picking, the hops are dried on a kiln (oast-house, as its called),—the heat never being allowed to rise above 90°, lest the aroma and volatile oil should be thrown off. A small portion of sulphur is sometimes added to the fire, the appearance of the sample being improved by the sulphurous acid thus formed. This has been generally considered by brewers injurious to the hop, and also to fermentation; but a commission appointed by the Bavarian Government in 1855 (the late Professor Liebig being one of its members), after two years of experiments, arrived at the conclusion that the use of sulphur was beneficial to the hop, and not injurious to fermentation. It is frequently used while the plant is growing to cure the various diseases to which the hop, like the vine, is liable. The last process before the hops are brought to market is "bagging." This used to be done by "footing," that is, letting the empty bag drop through a hole in the floor, and having the hops stamped down by one man, whilst two others filled; after which they were pressed by hydraulic power. Under a new process the whole operation is effected by machinery in about eight minutes. Hop-growers, as a rule, have no stores or convenience for warehousing hops for more than a month or two; the consequence is the whole growth, whether large or small, gets into the hands of a few great hop merchants, who command the market.

The best hops have a yellow, golden colour, and an agreeable smell; when rubbed between the hands they leave a yellow, odoriferous, sticky powder on them, without any broken parts of the leaves, and yield to boiling alcohol from 12 to 15 per cent. of soluble yellow matter. A very pale green colour indicates that the hops have been gathered before they are fit; whilst a deep brown shade would show they were allowed to hang too long before being gathered, or that they have been over dried on the oast-house floor. A fair test in choosing hops for India pale ale is to make a strong decoction of them with boiling water, putting it into a white bottle, corked and exposed to the sun; if in twenty-four hours the colour has become dark they are not fit for the purpose.

During the year 1852 only 34,622 lb of foreign hops were imported; in 1853 this increased to 4,739,307 lb, and in 1871 to 24,685,808. Before the hop-duty was taken off there was a great deal of betting on the crop, which was computed as equal to so much duty; and the appearance in the Borough of a hop leaf covered with fly from one of the most favoured districts used to cause much consternation. Since the repeal of the duty brewers have been allowed to use any bitter instead of hop, provided such bitter does not give a factitious strength to beer, and thus become a substitute for malt. Many preparations are, in consequence, offered for sale as partial substitutes for hops; but in these none of the noxious, forbidden articles, such as *Cocculus indicus*, &c., &c., are found, for we learn from the laboratory returns of the Inland Revenue that, in the year 1872, only six samples of beer tested were found to be adulterated. Considering the enormous extent of our brewing industry (it is calculated that 900,000,000 gallons of beer are brewed annually), such testimony to the purity of the beer is highly creditable to those engaged in the trade. From the same source, we learn that in every instance where an adulterant of a dangerous nature was used, the offending parties have been those who brewed and retailed their own beer on a very small scale.

Age alters and deteriorates the character of hops in a marked and distinct degree, much more so than in most aromatic substances; indeed, it changes them to such an extent that, at the end of two years (when they are called "old olds"), they retain little but the bitter, the aroma being gone.

In the year ending 30th September 1874, the hops imported into Great Britain were—

| | Cwt. |
|---|---|
| From Belgium | 60,338 |
| ,, Germany | 39,459 |
| ,, Holland | 16,035 |
| ,, United States | 2,809 |
| ,, Other countries | 4,875 |
| | 123,516 |

being a decrease on 1873 of 11,626 cwt.

Hops are grown with success in Tasmania, upwards of 450 acres being under cultivation. The Australian market, it is supposed, will be eventually supplied from thence. At present between 600 and 700 tons of hops are exported from England yearly.

*Water.*—Pure water, protoxide of hydrogen, is obtainable only by art; it is therefore impossible, even were it desirable, to use that in brewing. But good water is an indispensable element in the manufacture of good beer. It should be hard and free from organic matter; this last point cannot be urged too strongly, as this alone frequently causes failure in brewing operations. From Cohn's investigations we find that the germs of putrefaction are so small that no filter of charcoal or other material removes them. It is also doubtful if ordinary boiling destroys these organisms. Pasteur asserts they are not killed below a temperature of 100° C. (= 212° Fahr.); and Lex found them alive after heating to 260° Fahr. Water charged with them is a decided loss to the brewer, as the organic matter is decomposed during brewing and carries off some portion of the strength of the worts, besides making the beer liable to spoil. Soft water, or water that has flowed through moorland, and is free from saline matter, is bad for the brewer's purpose. When this has to be used for want of a better it should be impregnated at second hand with chloride of sodium (common salt) and gypsum (sulphate of lime). To allow for the deficiency of salt in some water the Excise allow brewers to add sufficient salt to make up, with that naturally in the water, 50 grains per imperial gallon. Soft water gives greater extracts, as it dissolves the albuminous matter in the malt more effectually than hard. With the use of very soft water as much as 100 lb of extract per quarter has been obtained; but here the goodness of the extract was the chief proof of the badness of the water; for it is dangerous to have too much albuminous matter in solution, except in the case of porter or ale that is quickly consumed, albuminous bodies being such powerful agents of change. Hence the Burton brewers, whose beers have to stand a long time, and in all climates, are perfectly right in praising their water, which contains a large proportion of these mineral salts. The supposed superiority of the Burton ales is due to the water, which is supplied, not from the River Trent, but from wells 20 to 120 feet deep. These wells are supplied from springs rising in the Outwood hills that form the western side of the valley. The springs take up lime in their passage through the gypseous deposits contained in the keuper marls of the district. The presence of sulphates and carbonates of lime and the absence of organic matter make the water of that district so advantageous for brewing. The following is an analysis of the water used in one of the largest breweries in Burton, showing the amount of ingredients in the imperial gallon, represented in grains:—

| | |
|---|---|
| Chloride of Sodium | 10·12 |
| Sulphate of Potash | 7·65 |
| ,, Lime | 18·96 |
| ,, Magnesia | 9·95 |
| Carbonate of Lime | 15·51 |
| ,, Magnesia | 1·70 |
| ,, Iron | 0·60 |
| Silicic acid | 0·79 |
| | 65·28 |

The water of another large firm in the same town gives by analysis 54·5 grains of sulphate, and 9·93 of carbonate of lime. The temperature of water used to be a great consideration for refrigerating the worts; but this is now of little consequence, as in most large breweries the water used for that purpose is first brought to a point just above freezing, by means of ether spray.

We now come to the actual process of brewing, or the

art of making the materials we have described into beer. While brewing cannot be considered a difficult or a mysterious art,—good materials, a good method, and strict attention being the secrets of success—there is no process in which rules are of less avail. To obtain complete success, it is necessary that the brewer shall have formed an opinion of his materials from personal observation, and that he should be thoroughly acquainted with the brewery in which they are to be used. It is not too much to say, that the same heats and quantities cannot properly be used in any two breweries. Bearing this difficulty in mind, we shall endeavour to point out where instructions may be safely followed, and where the circumstances of locality, &c., will subject them to certain modifications which cannot be strictly defined in an article like the present.

Brewing consists of eight distinct processes, which may be classed as follows :—

1. Grinding.
2. Mashing.
3. Sparging.
4. Boiling.
5. Cooling.
6. Fermenting.
7. Cleansing.
8. Racking and storing.

*Grinding.*—This is a very important operation; for, if imperfectly performed, some of the "goodness," or "extract" as it is called, will be left in the grains after mashing, thus entailing a heavy pecuniary loss on the brewer. The malt is crushed rather than ground between plain metal rollers; this is enforced by law, for the purpose of facilitating the examination of the grain as to whether it has been malted or not. Previous to the passing of the Act fraudulent brewers mixed raw grain with their malt, grinding it all up fine, to prevent identification. Each corn should be well broken, that the mashing water may have free access to every particle; on the other hand, if the malt be ground too fine, it is liable to "set," that is, form a paste in the mash tun. When this happens it will be difficult to draw the wort off, and when off it will contain so much of the coarser portion of the grain that the flavour and keeping qualities of the beer will be impaired. If possible the crushed malt should stand about twenty-four hours before being mashed, care being taken to protect it from air or damp,—the object being to allow the heat generated by passing through the rollers to escape.

*Mashing* is the process of infusion, or mixing the malt with water at such a temperature as shall not only extract the saccharine matter existing in the malt, but shall also change the still unconverted starch into grape-sugar. This is accomplished by the principle called diastase, the power of which we have shown under the head of malting. Many mashing-machines have been invented, and many are in use. In some the malt and the water are simply brought into conjunction, and then mix themselves as they fall into the mash-tun; others, driven by steam, perform the operation of mixing more leisurely, and, in some cases, more effectually. The old-fashioned method of mashing is by means of iron rakes. These rakes are fixed on arms extending from the centre of the tun, and are so constructed that when set in motion, no portion of the mash escapes them. When rakes are used a portion of the mashing water is first run into the tun, and part of the malt; the machinery is then started, and, whilst the rakes revolve round the tun, the remainder of the malt and water are added. The heat of the mashing water is a very important point; the particular temperature must depend upon the quantity and quality of the malt, and the situation of and amount of radiation from the mash-tun. Not less than two or more than three barrels of water should be run on to every quarter of malt, and the heat of the water should be such, that, when all has run on, that is, when the malt has combined with the water, the temperature of the mash shall not be lower than 148° or higher than 152°. In some breweries this result will be obtained by mashing at 168°; in others it will be necessary to go as high as 180°. Neither of these heats will do any harm so long as the heat of the mash does not exceed 152°. Most brewers and chemists think that, to ensure the best results, it is necessary for the mash to stand at least two hours. It would appear, however, that this belief has no solid foundation. Recent observations have convinced the present writer that an extract as good, and perhaps sounder, is drawn from a five minutes' mash as from one that has stood two hours,—a fact which any brewer can test for himself. The wort should be drawn off by means of several pipes running from different parts of the mash-tun. It must be run off slowly at first, or the malt in the tun ("goods," as it is now called) will be drawn down so tightly that it will be difficult for the sparging water to run through it. It is a good plan to probe the mash now and then with a thin stick; if the "goods" feel tight, and difficult to penetrate, the wort is being run off too quickly.

*Sparging.*—When about half the wort has run off the mash, the operation of sparging should be commenced,—the object of that process being to wash out the goodness left in the malt after mashing. The sparging-machine is made and fixed as follows:—A bar of iron having an upright pin in the centre is fixed across the mash-tun; on this pin is placed a copper bowl or pan; into this pan are screwed two or three arms, extending to the sides of the tun. These arms are about an inch and a half in diameter and are perforated their whole length with small holes on their reverse side. The hot water being conveyed into the pan fills the arms, and, running out through the perforated holes, causes the arms to revolve round the tun. By this means an equal and continuous shower of hot water is rained upon every portion of the goods. The heat of the sparging water, like that of the mashing liquor, must be modified by circumstances. In brews of less than 10 quarters, 200° will be found to be a good heat; where larger quantities are mashed 185° may be recommended as a safe temperature.

*Boiling.*—When the wort runs off the mash no time should be lost in getting it into the copper or boiling back. In many modern breweries the mash-tun is placed immediately over the copper, so that the wort runs direct from the former utensil into the latter. Some coppers are built with an ordinary furnace, others are furnished with a coil; in the latter case the worts are boiled by steam passing through the coil from the boiler. Many brewers prefer to boil by steam, as it is a cleaner method, and they are able to regulate the operation to a nicety. Where the steam coil is used the boiling back is generally made of wood. While the wort is running or being pumped into the copper, the hops must be added. Here, again, no positive instructions as to quantity can be given. On this point the brewer must be guided by his customers' tastes, the season of the year, the length of time the beer has to be kept, and the quality of the hop used. For strong store ales, from 10 lb to 13 lb of good hops to every quarter of malt is not too much; whilst for ordinary beers, to be drunk within two months, from 6 lb to 9 lb per quarter should suffice. India pale ale and bitter beer require from 18 lb to 25 lb per quarter. Various kinds of English and foreign hops can be used in the same brewing with advantage; the proportions of each kind must be left to the judgment of the operator. Of course, the ranker Bavarian and American hops must not be so freely used as the more delicate English growths. There is a wide difference of opinion as to the length of time beer should be boiled. For beers of quick draught an hour and a half is long enough; stock ales should have half an hour or an hour extra. The finest pale ale is never boiled longer than one hour. Where it is necessary to have two boilings in one brewing, the second copper should boil rather longer than the first. The boiling during the first twenty minutes should be brisk, in order to break the wort.



*Cooling.*—When the wort has boiled the necessary time, it is turned into the hop-back to settle. The hop-back is a utensil made of wood or iron, and fitted with a false bottom of perforated plates; these plates retain the hops in the back, whilst the wort is drawn off into the coolers. The wort should be allowed fifteen or twenty minutes to settle in the back, and when run on to the coolers should be thoroughly bright. In many breweries coolers are not used, the wort running direct from the hop-back through the refrigerator into the fermenting tun. When practicable this is an excellent plan, for worts often take harm whilst lying exposed on the coolers. In every brewery of any note the worts are cooled artificially by means of a refrigerator. Of these there are several kinds, but all are constructed upon the same principle, which is that of allowing a thin stream of wort to trickle over pipes containing a running stream of water. The water is either run direct from the mains or is pumped by an engine from a well. In every instance it is necessary that the water shall be several degrees colder than the heat the wort is to be "pitched" at, as brewers call it, in other words, the heat at which the wort is let down into the fermenting tun. This "pitching heat" varies very much. Beers pitched at high heats, say from 62° to 66°, come soonest into condition, but do not keep so well. Under ordinary circumstances 60° appears to be the best heat at which to start fermentation, or, in the case of strong ale, 58°.

*Fermentation.*—The fermenting tun may be round or square, open or closed, and made of wood or stone. Stone squares are universal in the northern counties of England, but are rarely met with in the southern and midland counties. When beer is fermented in a stone or slate square, it should never be pitched at a lower heat than 66° or 68°; for these utensils are very cold, and therefore liable to check or stop the fermentation. Every fermenting tun should be fitted with an attemperator. The attemperator consists of a series of pipes fixed within the tun, and having its inlet and outlet on the outside. It should be possible to run hot or cold water through these pipes at any hour, so that the temperature of the gyle can be raised or lowered at pleasure. The work performed by that natural process which we call fermentation is the conversion of saccharine matter into alcohol. It plays a most important part in the brewer's art, and deserves his most careful attention. In order to obtain a quick and regular fermentation, the brewer employs yeast, or barm, as it is called in some parts of the country. Great care must be taken that the yeast used shall be perfectly fresh and healthy, for it must never be forgotten, that it is impossible to obtain a good fermentation from bad yeast. Yeast that comes from porter should never be used in pale or delicately flavoured ales, as it is apt to impart a burnt taste and high colour. The quantity of yeast required depends upon the strength of the wort and the quality of the water. Strong worts require more yeast than weak ones; and the same rule applies to hard waters as compared with soft. Worts of about 20 lb gravity should do well with 1 lb of yeast per barrel, whilst stronger worts require twice that quantity. As we have said, 60° seems to be the best heat at which to pitch wort, unless it is of a high gravity, or the fermenting tun be built in a very warm place, in which case the temperature of 58° will not be too low.

The appearance of a gyle of beer during the earlier stages of a good fermentation is very beautiful. At first the whole surface is covered with a thick white foam, which, within a few hours, curls itself into every imaginable shape and form. This increases in height, until it presents the appearance of a number of jagged rocks of snowy whiteness. With these the artistic beauties of the fermentation disappear, although the fine thick head of yeast which follows delights the eye of the practised brewer, for it tells him that his fermentation is drawing towards a successful end. But the progress of the fermentation must not be judged by appearances alone. Samples should be taken from the tun at least twice a day, and weighed with the saccharometer. By this means the brewer tells at what speed the sugar is being converted into alcohol; and when he considers the process has gone far enough, he stops it by taking away the yeast, which operation is termed cleansing. At the end of the first twenty-four hours, the gyle should attenuate 1 lb in every three or four hours, whilst the temperature should rise from 1° to 2° during the same space of time. The fermentation may proceed quicker than this without any harm ensuing; but if it does not reach the *minimum* speed of 1 lb in four hours, it may be said to be sluggish, and requires assisting. This is done by "rousing" the gyle every two hours with a utensil made for the purpose. Wort fermented in stone or slate squares must be roused every hour and a half, without exception. If unchecked the temperature of the gyle will rise to 76° or even 80°. Any heat above 72° is likely to affect the beer injuriously, for at that temperature the acetous fermentation commences. At the same time, beers for quick consumption may be allowed to rise a few degrees higher, and will perhaps be improved by the increase of temperature. The attemperator must be used to prevent the gyle reaching too high a heat.

*Cleansing* is the act of removing the yeast from the beer, in order to stop the fermentation. There are three modes of cleansing—1*st*, by simply skimming the yeast off as it rises to the surface; 2*d*, by running the beer into casks, and then allowing the yeast to work out through the bung holes; and 3*d*, on what is called the Union, or Burton system, which is the second plan with some improvements. When beer is cleansed in the second or third mode, it is necessary to keep the casks or Unions full to the bung. They must, therefore, be refilled every two hours, either by hand or by a self-acting apparatus invented for the purpose. Brewers differ as to the time when the operation of cleansing should commence; and, indeed, it is difficult to fix any limit, as much depends upon the character of the ale and the appearance of the fermentation. In the writer's opinion strong ales, worked in casks or on the Burton system, should be cleansed when they have attenuated down to 12 or 14 lb; weaker beers and pale ales should be allowed to go quite 2 lb lower before being cleansed. Stout and porter should be cleansed rather earlier than any kind of ale, in order that they may drink full in the month. When all the yeast has worked out of the beer, it is ready for the last process.

*Racking and Storing.*—Ales intended for quick consumption should be racked so soon as clean, or they will be found flat and out of condition. A few of the finest hops should be put into the cask; and in the case of pale ale the quantity should not be less than 1 lb to the barrel. The finest strong and India pale ale should be stored between two and three months before being tapped, and even at that age, must be considered young. Ales intended to be stored some months should have a porous vent peg placed in the shive to keep the ale from fretting, and save the head of the cask from being blown out. (S. A. W.)