BREWING AND MODERN SCIENCE.[1]

THE industry of brewing has earned unenviable notoriety as affording a subject for every possible kind of controversy: it has been also the most favoured field for the application of modern science. The brewer, faced by competition and by repeated increases of taxation, has sought the help of science in order to make the best possible use of his materials; the result has been in every way a complete justification of his action.

The industry has been more than fortunate in the men it attracted in its early days—Griess, O'Sullivan, Horace and Adrian Brown in this country, to name but a few, have been all men of science of the very first rank. Moreover, the problems of brewing have been so fascinating in themselves, and so intimately bound up with the study of vital change, that they have attracted the interest of a host of other workers not connected with the industry.

In consequence, however much brewing may owe to science, it may be claimed that the advance of modern science has received material assistance from investigations connected with brewing. There is probably no other industry which, in this respect, can exhibit as good a record.

The brewer's task—to make a fermented liquor from malt, hops and yeast—does not appear at first sight to present such complications, but on closer examination it will be found that problems, often of the most vexed nature, are experienced both in the choice of the barley, in the manner of malting it, and in the methods of mashing and fermenting the liquor to the best advantage.

Any comprehensive review of the achievements of science in brewing during the last forty years is impossible within reasonable limits: it must suffice to indicate a few instances in which the progress has been most striking. The examples selected by Prof. Brown serve particularly to show how diversified in character are the problems with which the industry, in its successive operations, is faced.

Barley.

It is characteristic of many of our industries, and brewing offers no exception, that there is often a lack of that full sympathy which might be expected to exist between the producer of the raw material and its user. This is so often the case when agricultural interests are concerned, the farmer preferring, for example, to grow weak wheats rather than the stronger wheats in favour with the miller. In the case of brewing, the estrangement is due to a variety of causes, all tending, unfortunately, to diminish the consumption and lower the value of home-grown barley; most of these are beyond the brewers' control.

It is tempting to digress from the subject covered by the title of this article and reflect on the advantages of beer made entirely from malt and hops. There is a widespread opinion that the quality of English beer is not what it was, though it is equally true that the present article is in every way wholesome and suited to the public taste; indeed, if this were not the case, its production would soon cease to be possible commercially.

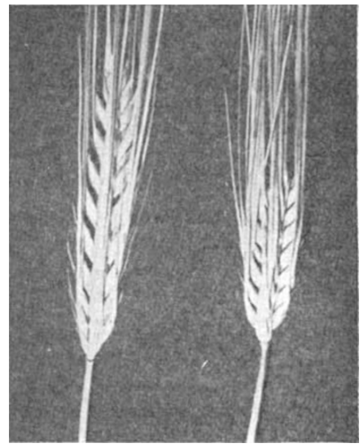
Before the abolition of the malt tax in 1880 the number of varieties of barley which the brewer could use with advantage was comparatively small. Since this date any suitable barley can be malted, and much has been done to put the knowledge of the subject on a scientific basis by the work of Beavan, first published so recently as 1900.

All barleys may be classified into two broad groups from the position and character of the flowers: these are six-rowed barleys and two-rowed. In addition, each group may have short and broad or narrow and long heads, making in all four distinct classes. These are well shown in Figs. 1 and 2.

In this country two-rowed barleys are the special consideration of the farmer. "Chevalier" barley represents the long, narrow-eared type, and "Goldthorpe" the short, wide-eared kind. The widest difference of opinion exists about their respective merits for malting and brewing. At present the evidence is in favour of Chevalier for the production of the higher qualities of ale, in spite of which, in many parts of the country, the culture of Goldthorpe barley is displacing that of Chevalier.

[1] Royal Society of Arts Cantor Lectures by Prof. Adrian J. Brown, F.R.S.

An altogether model series of investigations to determine the yield and money value of different varieties of barley has been carried on for six years by the Irish Department of Agriculture, assisted by Messrs. Guinness. The yield of the crop per acre for each of the varieties tested was determined under strictly practical conditions, and its commercial value ascertained on the market. From these data the value per acre was determined for each variety. Archer, a type of Chevalier, proved to be the best barley, being superior and more profitable to grow in every case. Goldthorpe was the best of the wide-eared barleys, but from the farmer's point of view it always gave poorer results than Archer. This conclusion applies primarily to Ireland, but probably it is equally true of English conditions. Another point brought out by the experiments was the importance of using pure seed; indeed, it is claimed that an increase of yield of six bushels per acre, and an increase in value of 200,000*l.*, would be effected in Ireland if pure selected Archer were substituted for the present varieties of barley sown.

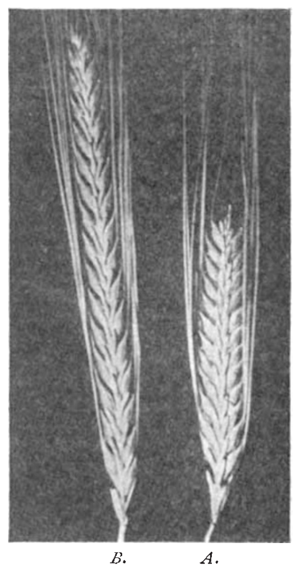


B. A.

FIG. 1.—Six-rowed Barley. *A*, Wide-eared, with short joints (*H. hexastichum*). *B*, Narrow-eared, with long joints (*H. vulgare*).

The market values barley by empirical methods, based on such characteristics as the character of the skin of the grain, its size and shape, colour and relative hardness, together with other factors comprehended under the term "maturation." It is of interest that the scientific investigations of Beavan entirely uphold these methods of valuation, and enable them to be controlled more exactly in the laboratory.

The six-rowed barleys are obtained from countries possessing a warmer and more sunny climate than our own. Many of them are very heavy croppers, and possess valuable characteristics; there is obviously a considerable field open for the scientific plant-breeder to adapt them to English conditions.



B. A.

FIG. 2.—Two-rowed Barley. *A*, Wide-eared, with short joints (*H. zeocriton*, Goldthorpe). *B*, Narrow-eared, with long joints (*H. distichum*, Chevalier).

Malting.

The process of malting involves the germination of the barley grain up to the stage when the starch begins to be attacked; further action is then stopped by drying the malt. Although probably the germination changes of the barley corn have been studied more thoroughly than those of any other seed, our understanding of them is but of the slightest, and much requires to be done before malting is placed on a scientific basis.

The food reserve of most seeds is directly associated with the germ, but in cereal seeds this is not the case, the food reserve being utilised through the agency of special physiological processes. The young plant may be dissected out from the endosperm without injury; a portion of it, called the scutellum, lies in contact with the endosperm, and feeds the germ from it (Fig. 3). As Fig. 4 shows, the endosperm is composed of two very different types of cells. The inner larger portion consists of thin-walled starch cells surrounded by the thick-walled aleurone cells without starch granules. When moistened, the dry barley corn absorbs water, swelling to the extent of 50 per cent. The characteristic re-entering ventral furrow (Fig. 5) allows of expansion, and so prevents rupture of the seed coverings. Internally, the cell walls nearest to the scutellum swell and disintegrate, and this action slowly spreads through the endosperm. Within about ten days the cell walls throughout the whole length of the corn are modified. The endosperm, in consequence, becomes soft and mealy instead of hard, and it can be broken and rubbed between the fingers. This stage of mealiness is that desired by the maltster. At the same time, the starch granules within the cells begin to be attacked; but this action is at first very slow, and only very little has been acted on when change is arrested by drying the malt.

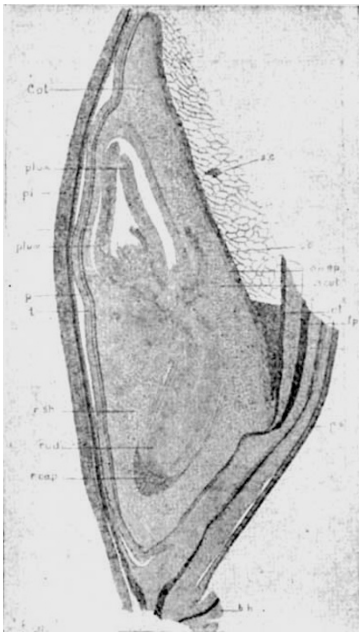


FIG. 3.—Longitudinal Section of the Germ End of a Barley Corn (Highly Magnified). "Plum," plumule; "rad," radicle; "scut," scutellum; "ab ep," absorptive epithelial layer. (After Holzner.)

Brown and Morris found that the scutellum of the growing embryo secretes two enzymes, cytase and diastase, which bring about the changes described, whereas the endosperm is inert and without life. Later experiments by Brown and Escombe confirmed the contention of Haberlandt that the cells of the aleurone layer also secrete the same enzymes.

At various stages of the malting process the nitrogenous compounds originally present in the endosperm migrate to the embryo. These changes are due to the action of two other enzymes, a peptase and a tryptase. Probably these originate in the same parts of the corn as cytase, but direct evidence on this point is still wanting.

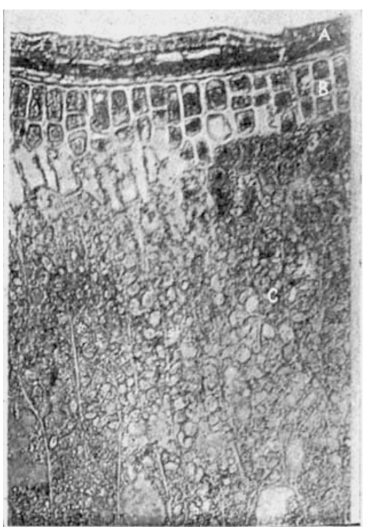


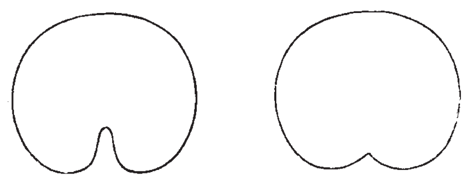
FIG. 4.—Section of Portion of Endosperm of a Barley Corn (Highly Magnified). *A*, Coverings of the corn. *B*, Aleurone cells containing no starch. *C*, Thin-walled starch-containing cells comprising the greater part of the endosperm. The starch granules are visible lying embedded in the remains of the cell proto plasms.

Barley and indeed all other seeds are specially protected by their coverings to prevent loss of the stored-up food material by diffusion. The testa, or inner thin skin of barley, constitutes a very remarkable semi-permeable membrane, allowing water to pass through, but preventing the passage out of the cell of the soluble carbohydrates and nitrogenous materials, or into the cell of such substances as mineral acids and salts. Still more remarkable is the power of selective permeability displayed by the skin: it allows such substances as mercuric chloride, acetic acid, acetone, ethyl acetate, and a few others to pass through, whilst keeping all other materials out. The elucidation of this peculiar behaviour is leading to results of most fundamental significance in connection with plant chemistry.

Mashing.

Having transformed the barley corn into a material full of diastase and other enzymes, it is the brewer's next care to cause further digestion to take place inside his vessels, his object being to transform the starch into soluble constituents. Much depends in practice on the way in which this operation is effected; the composition of the water, the state of division of the ground malt, and the temperature and duration of the process are all factors of prime importance. For the moment, however, we are only concerned with the nature of the transformations.

It is not yet forty years since O'Sullivan rediscovered maltose, and showed that this sugar, and not glucose, is formed from starch by the action of diastase. The new field opened up by this discovery attracted numerous investigators, but, notwithstanding their labours, the essential points are still in dispute: the constitution of the starch molecule and the manner of its breakdown are still far from being settled. The question is too complicated for discussion here other than from its more technical aspect.



A. *B.*

FIG. 5.—Diagram of Transverse Sections of Dry and Steeped Barley Corns. *A*, Dry corn. *B*, Steeped corn.

Brown and Morris have shown that among the products of a starch conversion performed at temperatures much the same as the brewer chooses in practice, are certain unfermentable maltodextrins. If the products from the starch consisted of maltose and stable dextrins only, the maltose would be entirely fermented in the brewery, and the beer obtained would be highly alcoholic and very thin in palate flavour. More important still, it would contain no carbohydrate material suitable for undergoing the secondary fermentation changes in the cask or bottle. Such material is supplied by the maltodextrins, which, though not fermentable during the primary fermentation, are slowly fermented by the secondary yeast forms which develop in beer when in cask or bottle, and give to good beer its characteristic qualities.

Fermentation.

Science has undoubtedly made very great strides in the elucidation of the fermentation process. Pasteur's famous investigations, in which he demonstrated the existence of anærobic life, led him to regard yeast as an organism endowed with two modes of life. When air was present it lived the life of an ordinary fungus and exhibited the usual actions of cell life; in the absence of air it took on the new properties of a ferment, and attacked sugar. This view persisted for many years, until Adrian Brown showed that, in malt wort, yeast cells increase until a definite number are present in a given volume; they then cease reproducing. This property of yeast is independent of the food supply, and makes it possible to work with a constant number of yeast cells. Under these conditions, it was found that oxygen, far from arresting the fermentative power of yeast, as Pasteur supposed, actually tended to stimulate it.

Undoubtedly the most striking advance in connection with fermentation is Buchner's famous discovery that the direct cause of the fermentative power of yeast is an enzyme present in the cell. This at once destroyed all theories connecting fermentative power with the vital activity of the cell. The enzyme has been termed zymase, and its behaviour, which in many respects differs from that of other enzymes, has been studied very fully both by Buchner himself and also by Harden, whose results are of a very remarkable character.

When yeast juice, which contains active zymase, is filtered through a Chamberland gelatine filter, it is separated into two portions, one of which remains on the filter, whilst the other passes through. Apart, neither portion has any fermentative power; when united they ferment sugar. The filtrate still retains the power of activating the residue after it has been boiled; it has been named the co-enzyme. The part retained on the filter is destroyed by boiling; it is considered to be the enzyme.

Further experiments showed that dilute solutions of sodium or potassium phosphate have a marked stimulating effect on the activity of zymase, and proof has been afforded that a compound of sugar and phosphoric acid is formed when such addition is made. At the same time, a part of the sugar is decomposed to alcohol and carbon dioxide. An enzyme, appropriately named hexosephosphatase, is present in yeast juice, and serves to break down the compound of sugar and phosphate into its components. Such facts as these have introduced altogether new conceptions into the knowledge of enzymes.

Without going into greater detail in so complex a subject, Dr. Harden's explanation of the fermentation process may be summed up somewhat as follows.

Enzyme and co-enzyme act in unison on a mixture of hexose sugar and phosphate; one half of the sugar is decomposed into alcohol and carbon dioxide, and the other half combines with the phosphate, forming hexosephosphate. The phosphate is thus for the time being put out of action, but the hexosephosphatase enzyme comes into work and resolves it into free phosphate and free sugar, when the cycle of changes begins anew. The speed of fermentation is regulated by the activity of the hexosephosphatase. Dr. Harden has calculated that with ordinary brewer's yeast at 25° C. the whole of the phosphorus of its cell goes through this cycle twice in every five minutes!

It is well known that, besides ordinary ethyl alcohol, small quantities of other higher alcohols are formed during fermentation, particularly under the working conditions of a distillery. The explanation of the formation of these "fusel oil" constituents has been long outstanding, but quite recently Ehrlich has proved beyond doubt that they arise from the action of yeast on the amino-acids ordinarily present in fermentable liquors. These alcohols are physiologically of great importance as stimulants and excitants of protoplasmic activity. Their presence, even in the minutest quantity, has considerable bearing on questions of flavour, so that technically the proper understanding of their mode of formation is a matter of great importance. Ehrlich's researches have gone far in this direction, and their application in practice is bound to lead to valuable results. It is not improbable that many of the subtle flavouring materials met with in plants may originate from amino-acids in the same manner.

Much has been done in studying the influence of traces of other substances on yeast, since the final character of the beer depends to a large extent on the fermentation being normal. As showing how sensitive the living cell is to stimulus, the effect of zinc on the growth of the mould fungus, *Aspergillus niger*, may be cited. Almost inconceivably small amounts of this element—a dilution of 1 part in 50 millions—are capable of exercising a noticeable effect in favouring growth. Copper in like dilution is known to have a poisonous effect on bacteria, and it is evident that the brewer must use the greatest care in the selection of his vessels.

In addition to the thirteen elements which are generally stated to be essential to plant life, many others are found in plants in very small quantities. The tendency has been, for the most part, to regard these as accidentally acquired, and not essential. Latterly the point of view is changing, and there is evidence that some at least of the elements present in minimal quantities play a very important part.

Sufficient has been said to indicate how closely science and brewing are connected, and how many problems still await solution.

EDUCATIONAL CONFERENCES CONSIDERED IN RELATION TO SCIENCE IN PUBLIC SCHOOLS.

I.

THE end of the second week in January marks the close of a series of conferences which are annually attended by teachers. The majority of these conferences are concerned, in the main, with topics which have only a remote connection with the subjects usually connoted by "science." An exception to this statement must, of course, be made in the case of the proceedings of the Association of Science Masters in Public Schools, which have a strong and beneficial influence on the early training of men who may be expected to take leading positions, not only in the university, but in the country generally. It is owing in part to the realisation of this influence, in part to the sensitiveness and ready response to stimuli of the audience, in part to good management of the society, that the association has been able to secure, year by year, an address from a man of real eminence, and this time special importance was given to the meeting by the fact that Sir Joseph Thomson had accepted the office of president. His address is reproduced elsewhere in this journal; we may here testify to the obvious enjoyment which its delivery gave to the audience, and ask the serious attention of headmasters to the weighty remarks concerning neglect of the German language.

The first paper was contributed by Mr. M. D. Hill (Eton), who has been led by his own experience to doubt the necessity, or even the wisdom, of previous training in chemistry and physics for young biologists. In the discussion the weight of opinion was clearly in favour of insistence on such training. Mr. E. I. Lewis (Oundle), in the next paper, argued that plant biology should be taught in every secondary school. It was a subject the interest and value of which increased throughout life. For junior pupils the subject of plant life affords a preparatory study full of suggestion for the after-study of chemistry, and it does not demand a special technical knowledge on the part of the teacher. The work can consist almost entirely of observation and experiment in the class-room and out of doors; it abounds in examples of comparative method. Another paper dealing with the sequence of subjects was read by Mr. C. E. Ashford (Royal Naval College, Dartmouth), who discussed the place of electrostatics in a school course of electricity. Mr. Ashford began by excluding from the discussion the case of those students of eighteen years and above who are studying as "science specialists" with good mathematical equipment, and invited consideration of the average boys about fifteen years old. He supported the theory which deprecates teaching subjects for their artificial "discipline," and attaches importance to the value of the "content" or subject-matter. On these grounds, and by reason of the great interest evoked in the inquiring mind of boyhood by the everyday phenomena of current electricity witnessed in modern life, it seemed good to begin with the effects of the current, and to postpone electrostatics until some idea of Ohm's law had been obtained. One unfortunate result of insistence on preliminary electrostatics had been unduly to postpone the study of electricity in those practical applications which appeal to the ordinary boy.

Mr. Ashford had been convinced by his experience at Harrow of the soundness of these propositions, and he proceeded to sketch a plan of teaching in accordance therewith. He showed by demonstrations with the current from the lighting supply, and with commercial instruments, how readily electrostatics could be made to follow the current work, and directed attention to the fact that success did not depend on the weather. Prof. Worthington criticised the details of Mr. Ashford's scheme, and advocated the older plan of taking electrostatics first. Mr. Sanderson, on the contrary, regarded the teaching of electrostatics to